1.List of data, formulae and relationships

Data

Gravitational constant	$G = 6.67 \times 10^{-11}\ Nm^2 kg^{-2}$	
Acceleration of free fall	$g = 9.81\ m\,s^{-2}$	(close to the Earth)
Gravitational field strength	$g - 9.81\ N\ kg^{-1}$	(close to the Earth)
Electronic charge	$e = -1.60 \times 10^{-19}\ C$	
Electronic mass	$m_e = 9.11 \times 10^{-31}\ kg$	
Unified mass unit	$u = 1.66 \times 10^{-27}\ kg$	
Planck constant	$h = 6.63 \times 10^{-34}\ J\ s$	
Speed of light in vacuum	$c = 3.00 \times 10^{8}\ m\,s^{-1}$	
Molar gas constant	$R = 8.31\ J\ K^{-1}\ mol^{-1}$	
Boltzmann constant	$k = 1.38 \times 10^{-23}\ J\ K^{-1}$	
Avogadro constant	$N_a = 6.02 \times 10^{23}\ mol^{-1}$	
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ Fm^{-1}$	
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\ N\ A^{-2}$	

Experimental physics

Percentage uncertainty $= \dfrac{\text{Estimated uncertainty}}{\text{Average value}} \times 100\%$

Mechanics

Force $F = \dfrac{\Delta p}{\Delta t}$

For uniformly accelerated motion:

$v = u + at$

$x = ut + ½ at^2$

$v^2 = + 2ax$

Work done or energy transferred $\Delta W = \Delta E = p\Delta V$ (Presssure p; Volume V)

Power P = Fv

Angular speed $\omega = \dfrac{\Delta\theta}{\Delta t} = \dfrac{v}{r}$ (Radius of circular path r)

Period $T = \dfrac{1}{f} = \dfrac{2\pi}{\omega}$ (Frequency f)

Radial acceleration $a = r\omega^2 = \dfrac{v^2}{r}$

Couple (due to a pair of forces F and $-F$)

$= F \times$ (Perpendicular distance from F to $-F$)

Electricity

Electric current	$I = nAQv$(Number of charge carriers per unit volume n)
Electric power	$P = I^2R$
Resistors in series	$R = R_1 + R_2 + R_3$
Resistors in parallel	$R_\theta = R_0(1+\alpha\theta)$ (Temperature coefficient α)
Resistance at temperature θ	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
Capacitance of parallel plates	$C = \frac{\varepsilon_0 \varepsilon_1 A}{d}$
Capacitors in parallel	$C = C_1 + C_2 + C_3$
Capacitors in series	$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$
Energy stored	$W = \frac{1}{2}CV^2$

Nuclear physics

Mass-energy	$\Delta E = c^2 \Delta m$
Radioactive decay rate	$\frac{dN}{dt} = -\lambda N$ (Decay constant λ)
	$N = N_0 e^{-\lambda t}$
Half-life	$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$
Photon model	$E = hf$
Energy levels	$hf = E_1 - E_2$
de Broglie wavelength	$\lambda = \frac{h}{p}$

Matter and materials

Density	$\rho = \frac{m}{V}$
Hooke's law	$F = k\Delta x$
Stress	$\sigma = \frac{F}{A}$
Strain	$\varepsilon = \frac{\Delta l}{l}$
Young modules	$E = \frac{Stress}{Strain}$
Work done in stretching	$\Delta W = \frac{1}{2}F\Delta x$ (provided Hooke's law holds)

Oscillations and waves

For a simple pendulum $T = 2\pi\sqrt{\frac{l}{g}}$

For a mass on a spring $T = 2\pi\sqrt{\frac{m}{k}}$

At distance *r* from a point source of power *P*, intensity $I = \frac{P}{4\pi r^2}$

For Young's slits, of slit seperation *s*, wavelength $\lambda = \frac{xs}{D}$

(Fringe width *x*; slits to screen distance *D*)

Refraction $\frac{\sin\theta_1}{\sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{c_1}{c_2} = \frac{n_2}{n_1}$ (Refractive index *n*)

$\sin\theta_c = \frac{c_1}{c_2}$ (Critical angle θ_c)

$n_1 = \frac{c}{c_1}$

Quantum phenomena

Maximum energy temperature $= hf - \varphi$ (Work function φ)

Thermal physics

Celcius temperature $\theta/^\circ C = T/K - 273.15$

Practical Celsius scale $\theta = \frac{X_\theta - X_0}{X_{100} - X_0} \times 100\,^\circ C$

Thermal energy transfer $\Delta Q = mc\Delta T$ (Specific heat capacity *c*; temperature change ΔT)

Change of internal energy $\Delta U = \Delta Q + \Delta W$ (Work done on body ΔW)

Thermal energy transferred on change of state $= l\Delta m$

(Specific latent heat or specific enthalpy change *l*)

Rate of thermal energy transfer by conduction $= kA\dfrac{\Delta T}{\Delta x}$

(Thermal conductivity k; temperature gradient $\dfrac{\Delta T}{\Delta x}$)

Kinetic theory $pV = \frac{1}{3} Nm\langle c^2 \rangle$

$T \propto$ *Average kinetic energy of molecules*

Mean kinetic energy of molecules $= 3/2\, kT$ (Boltzmann constant k)

Molar gas constant $R = kN_A$ (Avogadro constant N_A)

Upthrust U = Weight of displaced fluid

Pressure difference in fluid $\Delta p = \rho g \Delta h$

Fields

Electric field strength

uniform field $E = F/Q = V/d$

radial field $E = kQ/r^2$ (Where for free space or air $k = 1/4\pi\varepsilon_0$)

Electric potential

radial field $V = kQ/r$

For an electron in a vacuum tube $e\Delta V = \Delta(1/2\, mv^2)$

Gravitational field strength

radial field $g = GM/r^2$

Gravitational potential

radial field $V = -GM/r$, numerically

Time constant for capacitor charge or discharge = RC

Force on a wire $F = BIl$

Force on a moving charge $F = BQv$

Field inside a long solenoid $= \mu_0 nI$ (Number of turns per metre n)

Field near a long straight wire $= \dfrac{\mu_0 I}{2\pi r}$

E.m.f. induced in a moving conductor $= Blv$

Flux $\Phi = BA$

E.m.f. induced in a coil $= \dfrac{Nd\Phi}{dt}$ (Number of turns N)

For $I = I_0 \sin 2\pi ft$ *and* $V = V_0 \sin 2\pi ft$:

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}} \text{ and } V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$$

$$\text{Mean power} = I_{\text{rms}} \times V_{\text{rms}} = \frac{I_0 V_0}{2}$$

Mathematics

$\sin(90° - \theta) = \cos\theta$

$\ln(x^n) = n \ln x$

$\ln(e^{kx}) = kx$

Equation of a straight line $y = mx + c$

Surface area cylinder $= 2\pi rh + 2\pi r^2$
sphere $= 4\pi r^2$

Volume cylinder $= \pi r^2 h$
sphere $= \frac{4}{3}\pi r^3$

For small angles: $\sin\theta \approx \tan\theta \approx \theta$ (in radians)
$\cos\theta \approx 1$

2. The list gives some quantities and units. *Underline* those which are base quantities of the International (SI) System of units.

coulomb force length mole newton temperature interval

(2)

Define the volt.

....

....

(2)

Use your definition to express the volt in terms of base units.

....

....

....

(3)

Explain the difference between scalar and vector quantities.

....

....

....

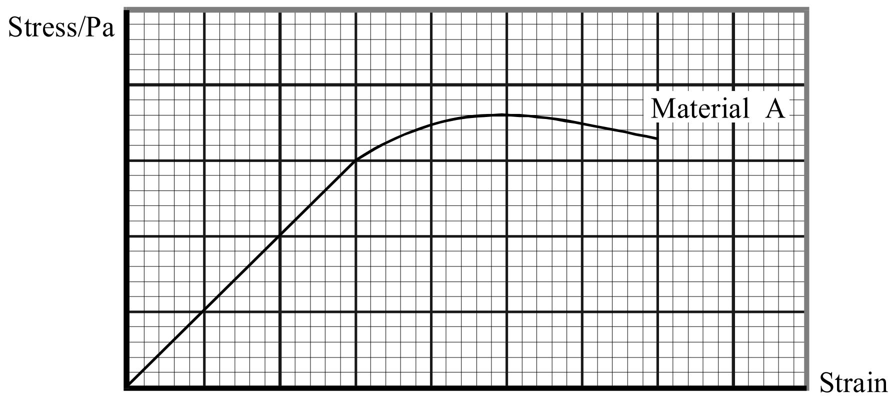
(2)

Is potential difference a scalar or vector quantity?

....

(1)
(Total 10 marks)

3. The graph below shows the behaviour of a material A subjected to a tensile stress.



How would you obtain the Young modulus of material A from the graph?

....

....

....

(2)

What is the unit of the Young modulus?

....

(1)

On the same graph, draw a second line to show the behaviour of a material B which has a *greater* Young modulus and is brittle.

Draw a third line to show the behaviour of a material C which has a *lower* value of Young modulus and whose behaviour becomes plastic at a lower strain.

(3)
(Total 6 marks)

4. Rubber is commonly described as being more elastic than steel but steel has a greater modulus of elasticity than rubber. On the axes below, sketch two graphs which illustrate the difference in behaviour of rubber and steel when subjected to stress.

(4)

Describe with the aid of diagrams the difference in molecular structure of rubber and steel.

....

....

....

....

(4)
(Total 8 marks)

5. With the aid of an example, explain the statement "The magnitude of a physical quantity is written as the product of a number and a unit".

....

....

....

....

(2)

Explain why an equation must be homogeneous with respect to the units if it is to be correct.

....

....

....

....

....

(1)

Write down an equation which is homogeneous, but still incorrect.

....

....

(2)

6. Draw a labelled diagram of the apparatus you would use to find the Young modulus of copper wire.

(2)

State the measurements you would take.

....

....

(1)

How would you use your measurements to obtain a value for the Young modulus?

....

....

....

....

....

(3)

Explain why the copper is used in the form of a long thin wire.

....

....

(2)

Two wires, X and Y, are made from the same material. Wire X is three times as long as Y and has twice the diameter of Y. When a load is suspended from X the wire extends by 8 mm. How much will wire Y extend with the same load?

....

....

....

....

....

Extension of wire Y = ...

(3)
(Total 11 marks)

7. For each of the four concepts listed in the left hand column, place a tick by the correct example of that concept in the appropriate box.

A base quantity	mole	☐	length	☐	kilogram	☐
A base unit	coulomb	☐	ampere	☐	volt	☐
A scalar quantity	torque	☐	velocity	☐	kinetic energy	☐
A vector quantity	mass	☐	weight	☐	density	☐

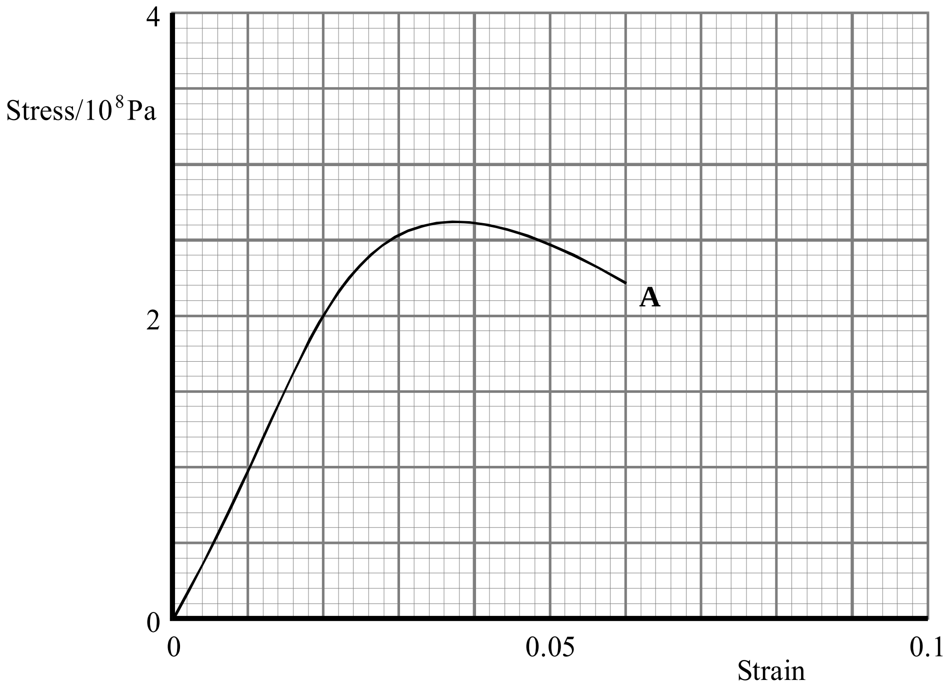
(Total 4 marks)

8. The table and graph show the properties of TWO materials A and B.

Material	**Young modulus/ 10^{10} Pa**	**Ultimate tensile stress/10^8 Pa**	**Nature**
A			
B	0.34	3.2	brittle

Use the graph to complete the table for material A.

(3)



Use the table to draw a graph on the grid below showing the behaviour of material B.

(2)
(Total 5 marks)

9. Classify each of the terms in the left-hand column by placing a tick in the relevant box.

	Base unit	**Derived unit**	**Base quantity**	**Derived quantity**
Length				
Kilogram				
Current				
Power				
Coulomb				
Joule				

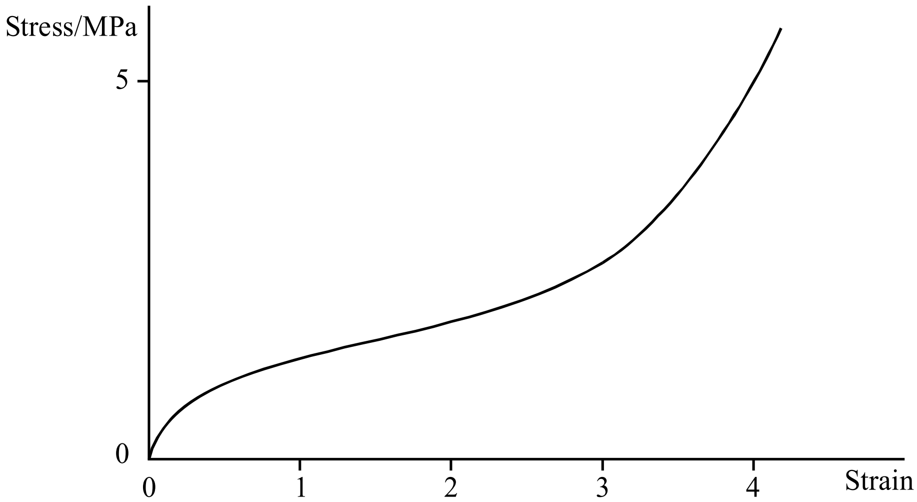
(Total 6 marks)

10. Each row in the following table starts with a term in the left hand column. Indicate with a tick which of the three expressions in the same row relates to the first term.

Joule	kg m s^{-2}		kg m s^{-2}		kg $m^2 s^{-3}$	
Coulomb	Base Unit		Derived unit		Base quantity	
Time	Scalar quantity		Vector quantity		Neither vector nor scalar	
Volt	A × W		A × W^{-1}	×	W × A^{-1}	

(Total 4 marks)

11. The graph shows the behaviour of a material when subjected to stress.



Give an example of a material which behaves in this way when put under stress.

..............................……………………………………………………………………………………

Add to the graph a second line which shows the behaviour of a brittle material with a Young modulus of approximately 10 MPa.

(3)

Describe with the aid of diagrams the difference in structure between a crystalline solid and a polymeric one.

....

....

....

....

....

(4)
(Total 7 marks)

12. Describe with the help of a diagram the structure of a polycrystalline material.

....

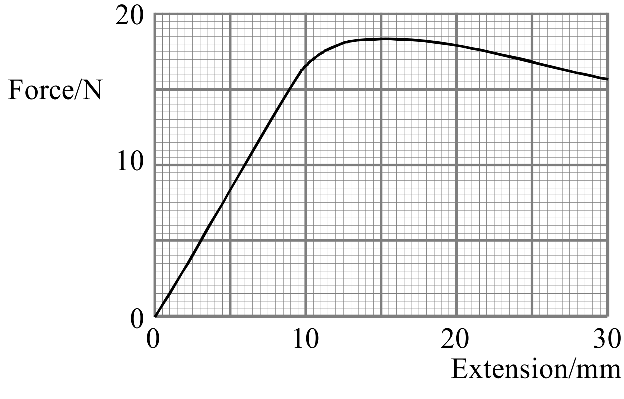
....

....

....

(2)

A force-extension graph for a long thin copper wire is drawn below.



Show clearly on the graph the region where the copper wire obeys Hooke's law.

What additional information would be needed in order to calculate the Young modulus for copper from this graph?

....

Estimate the energy stored in the wire when it has been extended by 20 mm.

Energy stored = ……………………………...

(5)
(Total 7 marks)

13. State what is meant by "an equation is homogeneous with respect to its units".

....

....

(1)

Show that the equation $x = ut + 1/2at^2$ is homogeneous with respect to its units.

....

....

....

....

....

(3)

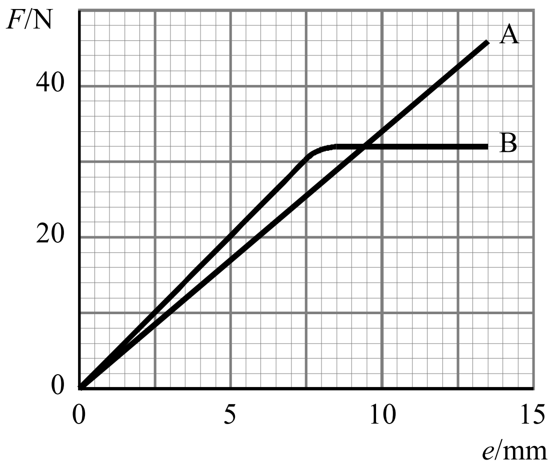
Explain why an equation may be homogeneous with respect to its units but still be incorrect.

....

....

(1)
(Total 5 marks)

14. Two wires A and B are of the same length and cross-section but are made from different materials. The graph shows how the wires extend when subjected to a tensile force.



State how the graph is used to determine which material is

stronger ....

....

brittle ....

....

(4)

Which wire requires the most work to stretch it by 11 mm? Show how you obtained your answer.

....

....

....

....

(2)
(Total 6 marks)

15. The joule is the SI unit of energy. Express the joule in the base units of the SI system.

....

....

(1)

A candidate in a physics examination has worked out a formula for the kinetic energy E of a solid sphere spinning about its axis. His formula is

$$E = \tfrac{1}{2}\rho r^5 f^2,$$

where ρ is the density of the sphere, r is its radius and f is the rotation frequency. Show that this formula is homogeneous with respect to base units.

....

....

....

....

....

....

(3)

Why might the formula still be incorrect?

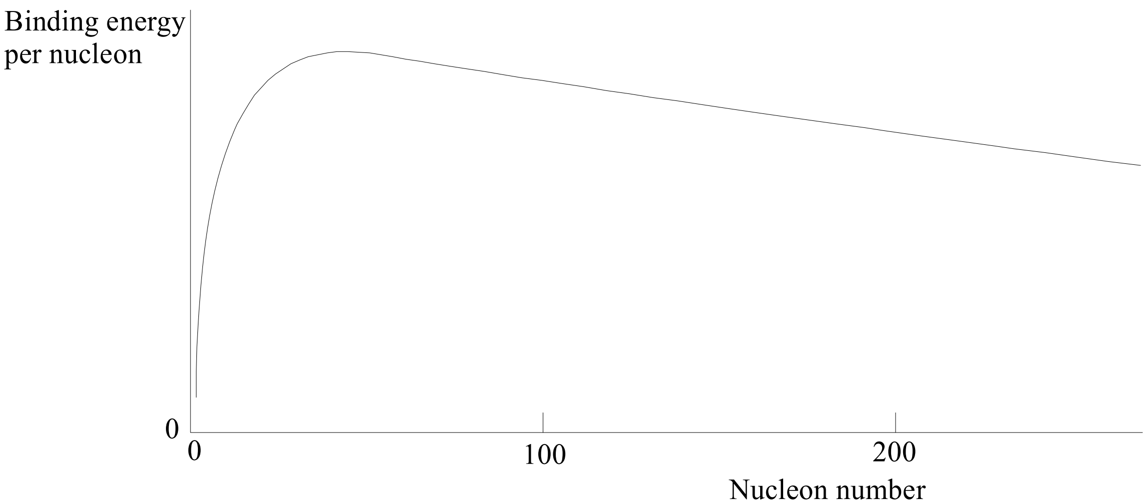
....

....

(1)
(Total 5 marks)

16. A graph of binding energy per nucleon against nucleon (mass) number is shown.

Label the approximate positions of the elements, deuterium D (an isotope of hydrogen), uranium U and iron Fe.



(2)

What is meant by the term *binding energy?*

....

....

....

With reference to the graph, state and explain which of the elements mentioned above would be likely to undergo nuclear fission.

....

....

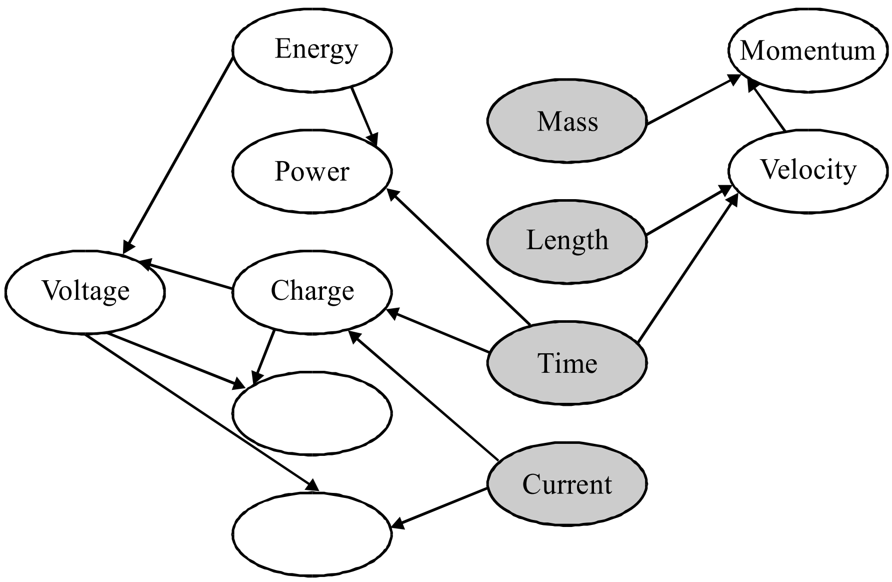
....

(5)
(Total 7 marks)

17. Many physical quantities are defined from two other physical quantities.

The diagram shows how a number of different quantities are defined by either multiplying or dividing two other quantities.

Write correct quantities in the two blank ellipses below.



(2)

Explain what is special about the physical quantities in the shaded ellipses.

....

....

....

(2)
(Total 4 marks)

18. Phosphorus $^{32}_{15}P$ is unstable and decays by β^- emission to sulphur, S. Write a nuclear equation for this decay.

....

(1)

Describe how, using a Geiger counter and suitable absorbers, you could show that an unstable nuclide of long half-life emitted *only* β^- radiation.

....

....

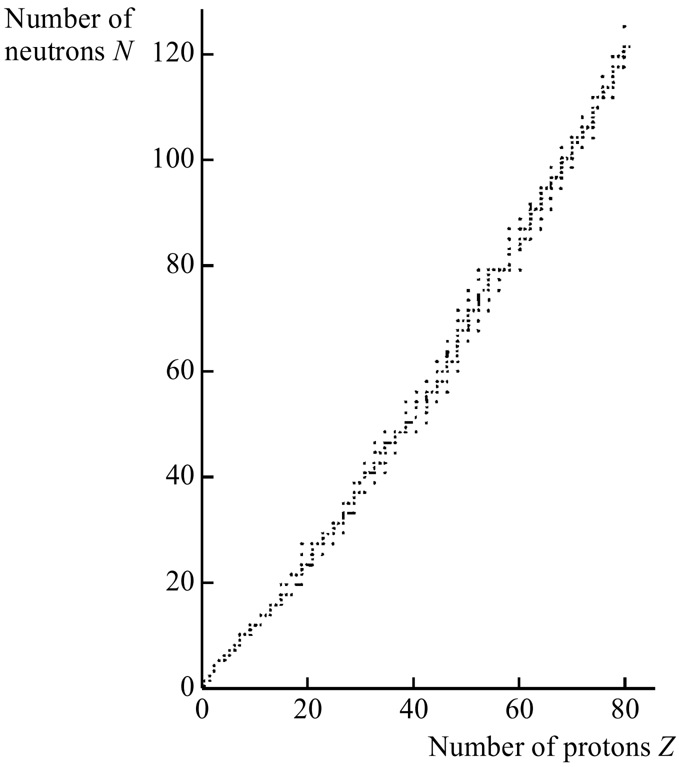
....

....

....

(4)

The scatter diagram shows the relationship between the number of neutrons and the number of protons for stable nuclides.



Show on the diagram the region where nuclides which decay by β^- emission would be found.

Use the diagram to help you explain your answer.

....

....

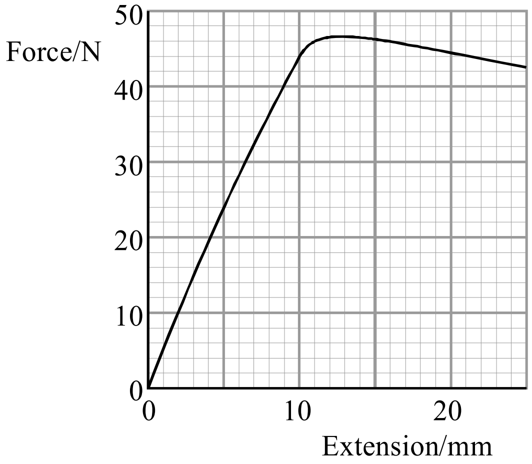
....

....

....

(3)
(Total 9 marks)

19. A force-extension graph for a brass wire of length 3.44 m and cross-sectional area 1.3×10^{-7} m^2 is shown below.

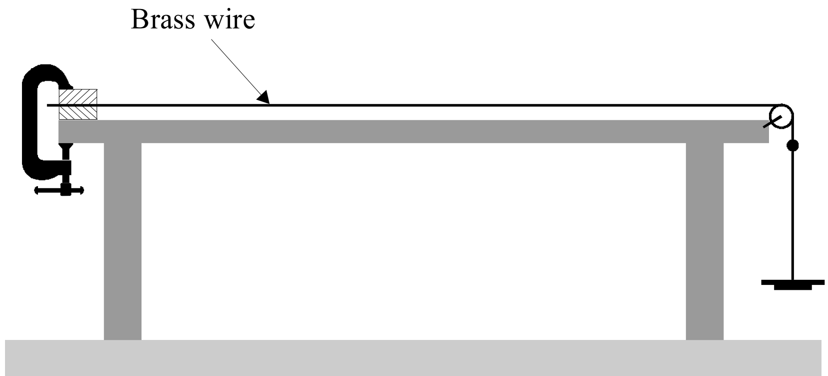


For what range of extensions is Hooke's law obeyed by this wire?

....

(1)

The diagram shows an arrangement for investigating this relationship between force and extension for the brass wire.



Add to the diagram suitable apparatus for measuring the extension of the wire as further masses are added to the slotted hanger.

Show on the diagram the length that would be measured in order to calculate the strain in the wire once the extension has been found.

(2)

Calculate the Young modulus for brass.

....

....

....

....

Young modulus =...

(3)

How much energy is stored in the wire when it has extended by 7.0 mm?

....

....

....

....

....

Energy stored =..

(2)

State one energy transformation that occurs as the wire extends.

....

....

(1)

Use the graph to calculate the tensile strength of brass.

....

....

....

Tensile strength =...

(3)
(Total 12 marks)

20. Define power.

....

....

(1)

State an appropriate unit for power.

....

(1)

Express this unit in terms of base units.

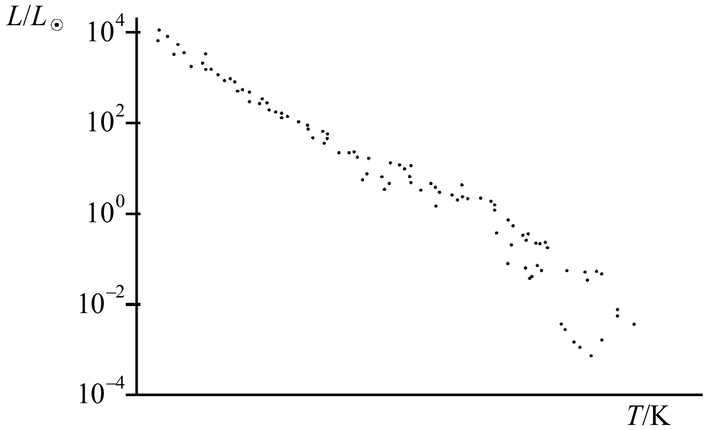
....

....

....

(2)
(Total 4 marks)

21. A Hertzsprung-Russell diagram showing the main sequence is drawn below. Luminosity of the Sun = $L_\odot$.



Draw a circle on the diagram showing the region where the Sun is located. Label this circle S. Draw another circle showing the region where the most massive main sequence stars are located. Label this circle M.

(2)

Indicate on the temperature axis the approximate temperatures of the coolest and of the hottest stars.

(2)

Explain why large mass stars spend less time than the Sun on the main sequence.

....

....

....

(2)

The luminosity of the Sun is 3.9×10^{26} W. Calculate the rate at which mass is being converted to energy in the Sun.

....

....

....

Rate = ...

(3)
(Total 9 marks)

22. Charge coupled devices can have an efficiency as great as 70% compared with photographic film which has an efficiency of less than 5%. State two advantages of this greater efficiency.

Advantage 1 ....

....

Advantage 2 ....

....

(2)

Explain why astronomical telescopes are sometimes launched into space.

....

....

....

....

(2)
(Total 4 marks)

23. Observations with a radio telescope in 1967 detected signals from a mysterious source which was called a pulsar.

What type of star is a pulsar?

....

(1)

What was unusual about the signals?

....

....

....

(2)

Pulsars emit radio waves continuously. Explain why the signals detected on Earth are not continuous. You may be awarded a mark for the clarity of your answer.

....

....

....

....

(3)
(Total 6 marks)

24. Read the short passage below and answer the questions about it.

> Cepheid variables are faint red giants whose brightness changes periodically. Their periodic changes in luminosity are the result of periodic pulsations of their giant bodies. A simple relationship exists between the periods of these pulsations and the luminosities of the stars. The greater the luminosity, the longer the period of pulsation. This relationship has proved very useful for measuring the distances of stars which are too far away to show a parallax displacement. By measuring the pulsation period of a star its luminosity can he determined. This, combined with a measurement of the intensity at the Earth's surface, enables the distance to the star to he calculated.
>
> [Adapted from *The Creation of the Universe* by George Gamow]

What is meant by the following terms used in the passage?

Red giants:...

....

....

....

Parallax displacement:...

....

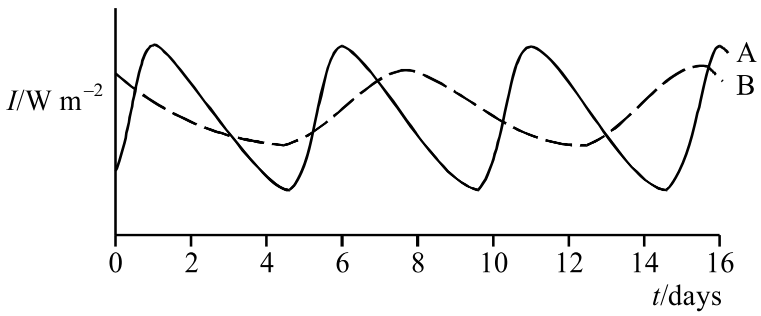
....

....

....

(3)

The curves below are plots of intensity against time for two Cepheid variable stars, A and B. These are known as light curves,



–

Estimate the period of the pulsations of star A.

....

(1)

What can he deduced about the luminosity of star B?

....

(1)

Since the average intensities of stars A and B are similar, what can be deduced about the distances of the two stars from the Earth? Give the reasoning which led to your answer.

....

....

....

....

(2)

Name the two forces, one which causes a star to contract and one which causes it to expand, which must be repeatedly out of balance in a Cepheid variable.

....

....

....

....

(2)
(Total 9 marks)

25. (a) Define work.

....

....

(1)

State an appropriate unit for work.

....

....

(1)

Express this unit in terms of base units.

....

....

(2)

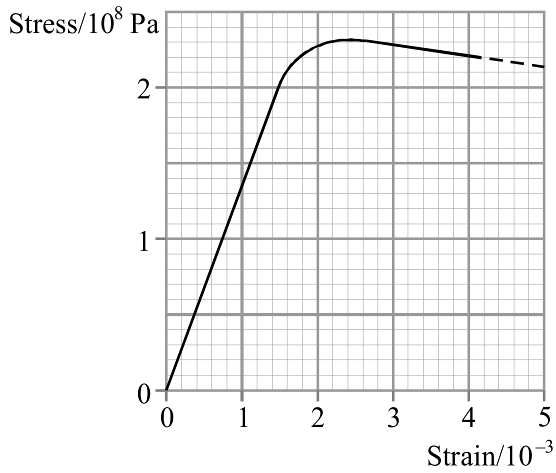
(b) State Hooke's law.

....

....

(2)

The graph shows the stress-strain relationship for a copper wire under tension.



Use the graph to determine:

the ultimate tensile stress for copper ....

the Young modulus of copper ....

....

....

....

....

(3)

A copper wire of cross-sectional area 1.7×10^{-6} m^2 and length 3.0 m is stretched by a force of 250 N

Will the behaviour of the wire at this point be elastic or plastic? Justify your answer.

....

....

....

(2)

Show this point on the stress-strain graph above. Label it P.

(1)

Calculate the extension of the wire.

....

....

Extension = ...

(2)

(c) Explain with the aid of a diagram what is meant by an edge dislocation.

....

....

....

(2)

Describe how the presence of dislocations can reduce the risk of metals failing by cracking. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

(3)

(d) Sketch a force-extension graph for natural rubber showing its behaviour for both increasing and decreasing force.

(2)

Use your graph to explain why a rubber band which is repeatedly stretched and relaxed becomes noticeably warmer.

....

....

....

....

(2)

(e) Read the short passage below and answer the questions about it.

> The outer layer of a human tooth is made of enamel and is the hardest tissue in the body. It is a typical ceramic with a high compressive strength, low tensile strength and a high Young modulus. It is brittle and consists of long crystals of calcium phosphate set vertically on the surface of the underlying dentine. Dentine is the main structural material of a tooth. It is a composite material consisting of needle shaped crystals in a collagen fibre matrix. Dentine has a much lower Young modulus than enamel and is tough. False teeth (dentures) are made from PMMA (polymethyl methacrylate), an amorphous polymer with a glass transition temperature of 110°C.

What is meant by the following term used in the passage?

Composite material ....

....

....

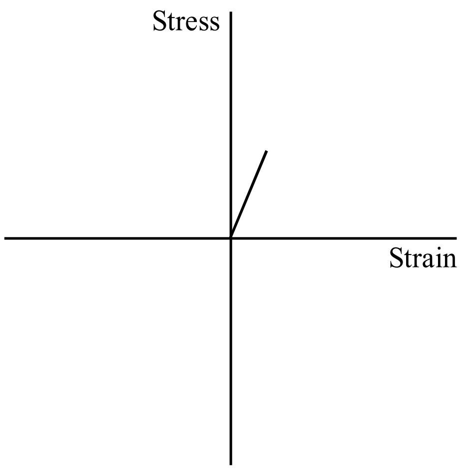
....

(2)

Draw labelled diagrams to show the difference in molecular structure of a crystalline material and an amorphous polymer.

(3)

The graph shows the behaviour of enamel under tension.



Add to the graph:

(i) a line labelled E to show the behaviour of enamel under compression,

(ii) a line labelled D to show the behaviour of dentine under tension.

(4)
(Total 32 marks)

26. Define work.

....

....

(1)

State an appropriate unit for work.

....

....

(1)

Express this unit in terms of base units.

....

....

(2)
(Total 4 marks)

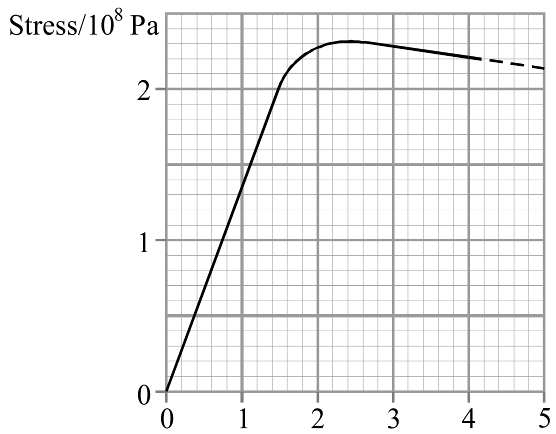
27. State Hooke's law.

....

....

(2)

The graph shows the stress-strain relationship for a copper wire under tension.



Use the graph to determine:

the ultimate tensile stress for copper ....

the Young modulus of copper ....

....

....

....

....

(3)

A copper wire of cross-sectional area 1.7×10^{-6} m^2 and length 3.0 m is stretched by a force of 250 N

Will the behaviour of the wire at this point be elastic or plastic? Justify your answer.

....

....

....

(2)

Show this point on the stress-strain graph above. Label it P.

(1)

Calculate the extension of the wire.

....

....

Extension = ...

(2)
(Total 10 marks)

28. Explain with the aid of a diagram what is meant by an edge dislocation.

....

....

....

(2)

Describe how the presence of dislocations can reduce the risk of metals failing by cracking. You may be awarded a mark for the clarity of your answer.

....

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....

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(3)
(Total 5 marks)

29. Sketch a force-extension graph for natural rubber showing its behaviour for both increasing and decreasing force.

(2)

Use your graph to explain why a rubber band which is repeatedly stretched and relaxed becomes noticeably warmer.

....

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....

....

(2)
(Total 4 marks)

30. Read the short passage below and answer the questions about it.

> The outer layer of a human tooth is made of enamel and is the hardest tissue in the body. It is a typical ceramic with a high compressive strength, low tensile strength and a high Young modulus. It is brittle and consists of long crystals of calcium phosphate set vertically on the surface of the underlying dentine. Dentine is the main structural material of a tooth. It is a composite material consisting of needle shaped crystals in a collagen fibre matrix. Dentine has a much lower Young modulus than enamel and is tough. False teeth (dentures) are made from PMMA (polymethyl methacrylate), an amorphous polymer with a glass transition temperature of 110°C.

What is meant by the following term used in the passage?

Composite material ....

....

....

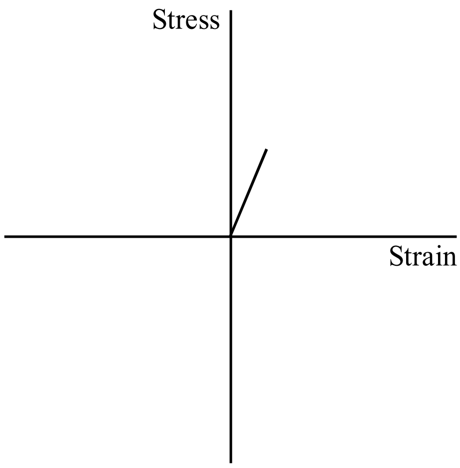
....

(2)

Draw labelled diagrams to show the difference in molecular structure of a crystalline material and an amorphous polymer.

(3)

The graph shows the behaviour of enamel under tension.



Add to the graph:

(i) a line labelled E to show the behaviour of enamel under compression,

(ii) a line labelled D to show the behaviour of dentine under tension.

(4)
(Total 9 marks)

31. (a) Define density.

....

....

....

(1)

Radius of a gold atom $\approx 10^{-10}$ m
Radius of a gold nucleus $\approx 10^{-15}$ m

Show that the $\dfrac{\text{volume of a gold atom}}{\text{volume of a gold nucleus}} \approx 10^{15}$

....

....

....

The density of gold is 19 000kg m^{-3}.

Estimate the density of a gold nucleus.

....

....

....

What assumption have you made in obtaining your answer?

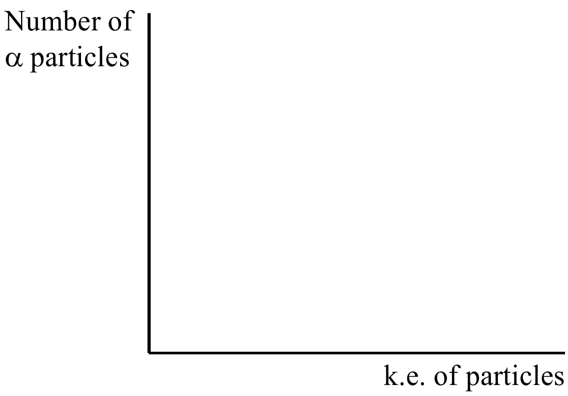
....

(3)

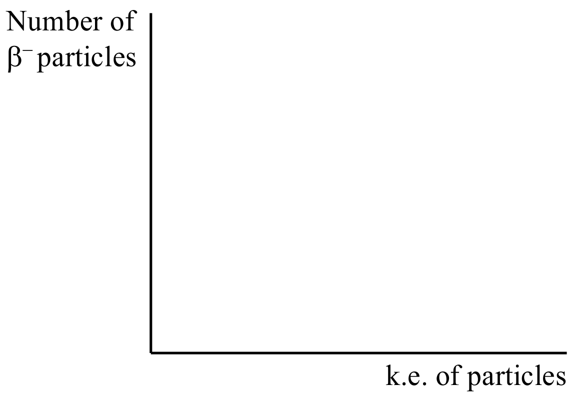
(b) On the axes below sketch graphs showing the energy spectra for

(i) a typical α particle decay,

(ii) a typical β^- decay.



(i)



(ii)

(3)

Complete the equation below showing the decay of a neutron to a proton

$$n \rightarrow p +$$

(2)

State the quark compositions of the neutron and the proton. Use these to explain why only the weak interaction can be responsible for this decay. You may be awarded a mark for the clarity of your answer.

....

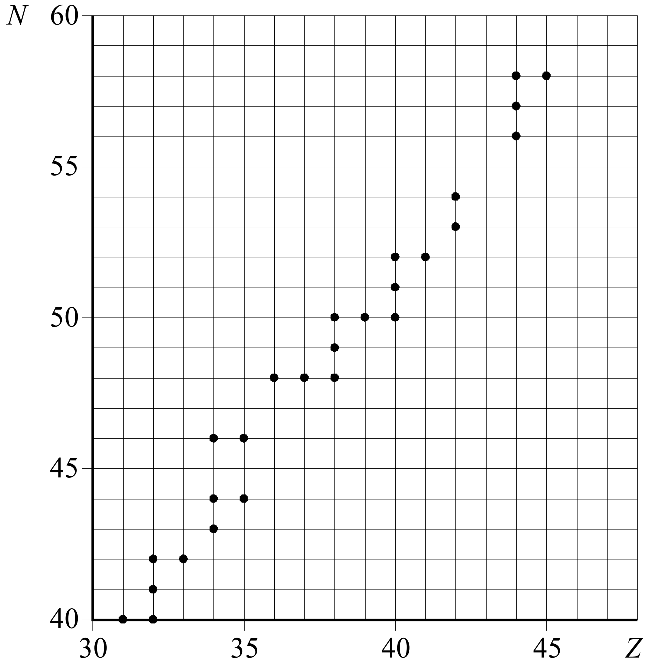
....

....

....

(3)

(c) The grid shows the relationship between number of neutrons *N* and number of protons *Z* for some of the **stable** nuclides in the region *Z* = 31 to Z = *45*.



Strontium-90, $^{90}_{38}$Sr, is an unstable nuclide. It decays by β^- emission to an unstable isotope of yttrium. On the graph mark the position of $^{90}_{38}$Sr and this isotope of yttrium.

(2)

$^{82}_{37}$Rb is another unstable nuclide. Mark the position of $^{82}_{37}$Rb on the graph.

By what means would you expect $^{82}_{37}$Rb to decay?

....

(2)

(d) The following strong interaction has been observed.

$$K^- + p \rightarrow n + X$$

The K^- is a strange meson of quark composition $\bar{u}s$.
The u quark has a charge of +2/3.
The d quark has a charge of –1/3.

Deduce the charge of the strange quark.

....

(1)

Use the appropriate conservation law to decide whether particle X is positive, negative or neutral.

....

.... **(2)**

Is particle X a baryon or a meson? Show how you obtained your answer.

....

.... **(2)**

State the quark composition of X. Justify your answer.

....

....

....

....

....

.... **(3)**

(e) Read the short passage below and answer tbe questions about it.

> In 1974 electron-positron collisions led to the discovery of the psi particle (Ψ). The Ψ is a meson of composition $c\bar{c}$, that is it contains a charmed quark and a charmed antiquark. The c and $\bar{c}$ move around one another, rather like the electron and proton in a hydrogen atom. A variety of orbitals of different energy are possible. If the c and $\bar{u}$ orbit with high energy, they form a relatively heavy particle. A heavier version of the Ψ meson was soon discovered. It is written Ψ′. The Ψ′ rapidly loses energy and decays to a Ψ and two pi mesons, π^+ and π^-. This is followed by the decay of the Ψ′ as its c and $\bar{c}$ annihilate, their energy appearing as a positron and an electron.
>
> [Adapted from *The Particle Explosion* by Close, Marten and Suttoni]

List all the antiparticles mentioned in the passage

.... **(2)**

Although the ψ contains charmed quarks, it has zero charm itself Explain how this can be so.

....

....

....
(1)

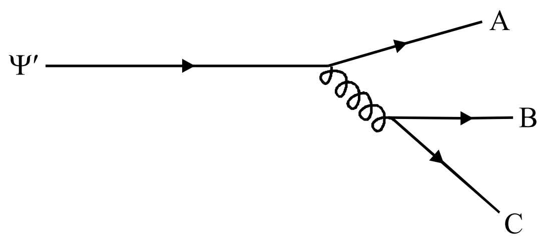
Describe how a charmed quark and a charmed antiquark can create a heavier version of the Ψ.

....

....

....
(1)

The Feynman diagram below shows the decay of the . Ψ



Complete the diagram by identifying the particles A, B and C.
(2)

What fundamental interaction is responsible for this decay?

....
(1)

Identify the exchange particle involved.

....
(1)
(Total 32 marks)

32. Define density.

....

....

....

(1)

Radius of a gold atom $\approx 10^{-10}$ m

Radius of a gold nucleus $\approx 10^{-15}$ m

Show that the $\dfrac{\text{volume of a gold atom}}{\text{volume of a gold nucleus}} \approx 10^{15}$

....

....

....

The density of gold is 19 000kg m^{-3}.

Estimate the density of a gold nucleus.

....

....

....

What assumption have you made in obtaining your answer?

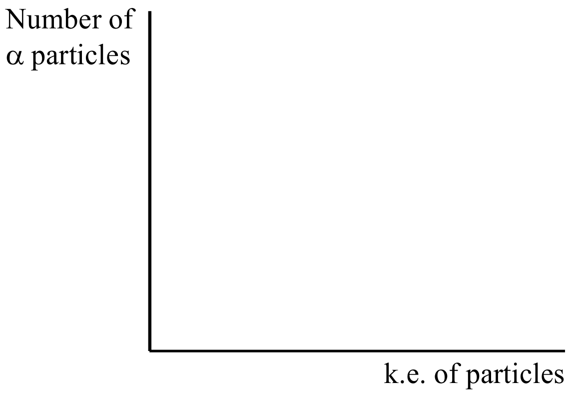
....

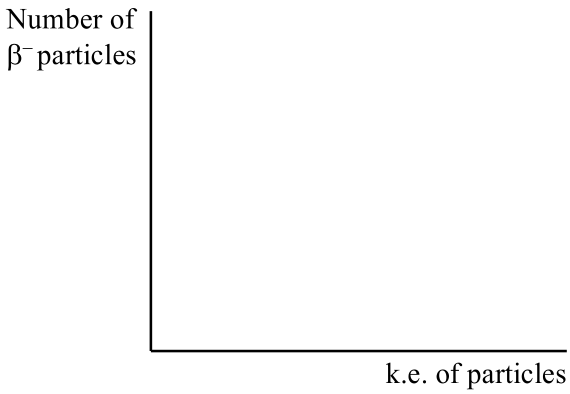
(3)
(Total 4 marks)

33. On the axes below sketch graphs showing the energy spectra for

(i) a typical α particle decay,

(ii) a typical β^- decay.





(3)

Complete the equation below showing the decay of a neutron to a proton

$$n \rightarrow p +$$

(2)

State the quark compositions of the neutron and the proton. Use these to explain why only the weak interaction can be responsible for this decay. You may be awarded a mark for the clarity of your answer.

....

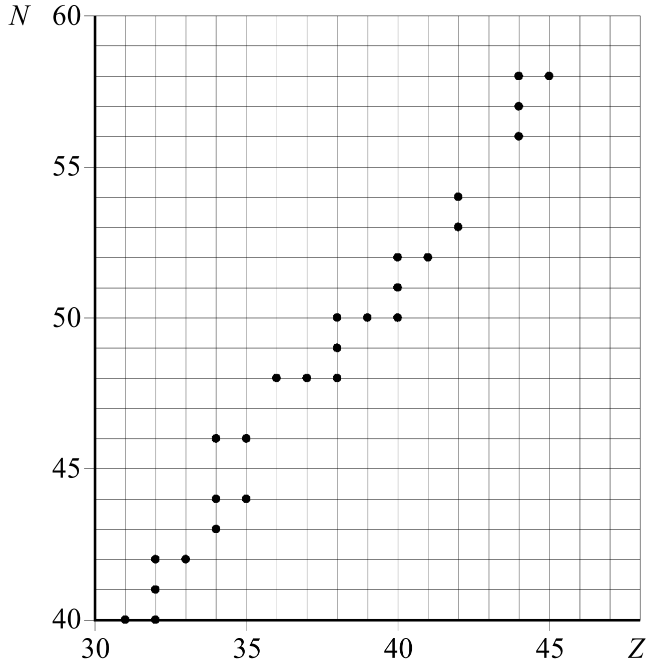
....

....

....

(3)
(Total 8 marks

34. The grid shows the relationship between number of neutrons N and number of protons Z for some of the **stable** nuclides in the region $Z = 31$ to $Z = 45$.



Strontium-90, $^{90}_{38}Sr$, is an unstable nuclide. It decays by β^- emission to an unstable isotope of yttrium. On the graph mark the position of $^{90}_{38}Sr$ and this isotope of yttrium.

(2)

$^{82}_{37}Rb$ is another unstable nuclide. Mark the position of $^{82}_{37}Rb$ on the graph.

By what means would you expect $^{82}_{37}Rb$ to decay?

....

(2)
(Total 4 marks)

35. The following strong interaction has been observed.

$$K^- + p \rightarrow n + X$$

The K^- is a strange meson of quark composition $\bar{u}s$.

The u quark has a charge of +2/3.

The d quark has a charge of –1/3.

Deduce the charge of the strange quark.

....

(1)

Use the appropriate conservation law to decide whether particle X is positive, negative or neutral.

....

....

(2)

Is particle X a baryon or a meson? Show how you obtained your answer.

....

....

(2)

State the quark composition of X. Justify your answer.

....

....

....

....

....

(3)
(Total 8 marks)

36. Read the short passage below and answer tbe questions about it.

> In 1974 electron-positron collisions led to the discovery of the psi particle (Ψ). The Ψ is a meson of composition $c\bar{c}$, that is it contains a charmed quark and a charmed antiquark. The c and $\bar{c}$ move around one another, rather like the electron and proton in a hydrogen atom. A variety of orbitals of different energy are possible. If the c and $\bar{u}$ orbit with high energy, they form a relatively heavy particle. A heavier version of the Ψ meson was soon discovered. It is written Ψ′. The Ψ′ rapidly loses energy and decays to a Ψ and two pi mesons, π^+ and π^-. This is followed by the decay of the Ψ′ as its c and $\bar{c}$ annihilate, their energy appearing as a positron and an electron.
>
> [Adapted from *The Particle Explosion* by Close, Marten and Suttoni]

List all the antiparticles mentioned in the passage

....

(2)

Although the W contains charmed quarks, it has zero charm itself Explain how this can be so.

....

....

....

....

(1)

Describe how a charmed quark and a charmed antiquark can create a heavier version of the Ψ.

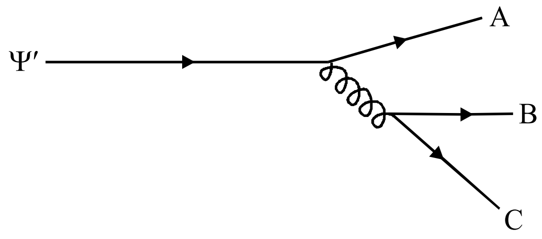
....

....

....

(1)

The Feynman diagram below shows the decay of the . Ψ



Complete the diagram by identifying the particles A, B and C.

(2)

What fundamental interaction is responsible for this decay?

....

(1)

Identify the exchange particle involved.

....

(1)
(Total 8 marks)

37. (a) Define electrical potential difference.

....

.... **(1)**

State an appropriate unit for potential difference.

.... **(1)**

Express this unit in terms of base units.

....

....

.... **(2)**

(b) Explain why the effective half-life of a radioisotope administered to a patient is less than the half-life due to radioactive decay.

....

.... **(1)**

^{31}I has a radioactive half-life of 8 days and a biological half-life of 21 days. Calculate the effective half-life of ^{131}I.

....

....

....

Half-life = ... **(2)**

After how many days will the fraction of a sample of ^{131}I remaining in the body be 1/8 of the administered dose?

....

.... **(2)**

Give one reason why gamma-emitting radionuclides are preferred for tracer studies.

....

.... **(1)**

State another property (other than half-life) that is important when selecting an appropriate gamma-emitting radionuclide for diagnostic purposes.

....

....

(1)

(c) Explain why a coupling medium between the transducer and the body surface is necessary when carrying out an ultrasound scan. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

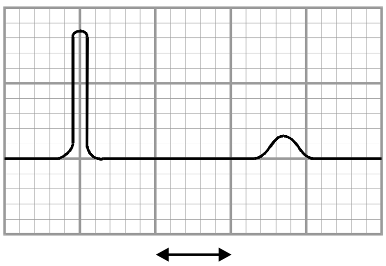
(3)

Suggest an appropriate substance for use as a coupling medium.

....

(1)

The diagram shows an A-scan trace on an oscilloscope. The pulses represent reflections from opposite sides of the head of a fetus.



The time base of the oscilloscope is set at 50μs div^{-1}. The speed of sound in the fetal head is 1.5×10^3 ms^{-1}

Calculate the size of the head of the fetus.

....

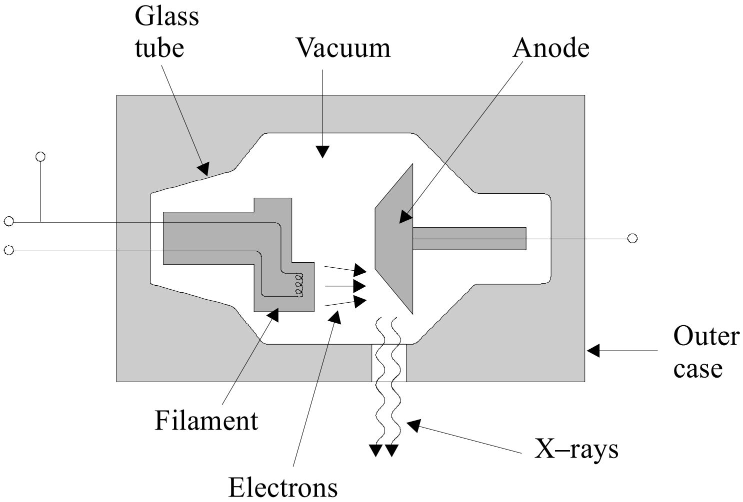
....

....

Size of head = ...

(4)

(d) The diagram shows part of a diagnostic X-ray tube.



Suggest an appropriate operating voltage for this tube.

.... **(1)**

Why is the anode rotated?

.... **(1)**

Why is the X-ray tube evacuated?

.... **(1)**

Suggest an appropriate material for the outer case.

.... **(1)**

(e) Read the short passage below and answer the questions about it.

> Attenuation is the reduction in intensity of a beam as it travels. X-ray beams are usually heterogeneous, that is they contain X-rays of many different wavelengths. In passing through a medium the different wavelengths are attenuated by different amounts. Longer wavelength (lower energy) X-rays are attenuated more than shorter wavelength ones. After passing through a filter the remaining X-rays therefore have a higher average energy and are relatively more penetrating. A more penetrating beam is said to be of better quality. As a heterogeneous beam passes through a medium its quality gradually increases. This process is described as hardening. The quality of an X-ray beam may be improved by either increasing the tube voltage or using a filter.
>
> [Adapted from *Medical Physics Imaging* by J. Pope]

State the meaning of the following terms used in the passage

Heterogeneous: ....

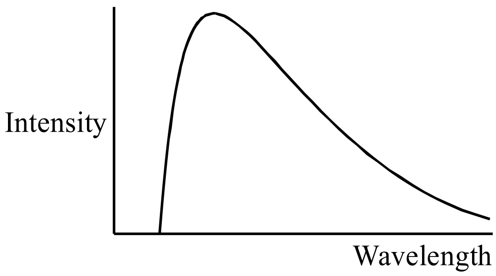
....

Hardening: ....

....

(2)

The graph shows the distribution of different wavelength X-rays in a typical X-ray beam.



Add to the graph to show the possible distribution of X-rays after passing this beam through a filter.

(3)

Why is the X-ray beam relatively more penetrating after it has been filtered?

....

....

....

(2)

Suggest why it is beneficial to the patient to filter the beam.

....

....

....

....

....

(2)
(Total 32 marks)

38. Define electrical potential difference.

....

.... **(1)**

State an appropriate unit for potential difference.

.... **(1)**

Express this unit in terms of base units.

....

....

.... **(2)**

(Total 4 marks)

39. Explain why the effective half-life of a radioisotope administered to a patient is less than the half-life due to radioactive decay.

....

.... **(1)**

^{31}I has a radioactive half-life of 8 days and a biological half-life of 21 days. Calculate the effective half-life of ^{131}I.

....

....

....

Half-life = ... **(2)**

After how many days will the fraction of a sample of ^{131}I remaining in the body be 1/8 of the administered dose?

....

.... **(2)**

Give one reason why gamma-emitting radionuclides are preferred for tracer studies.

....

....

(1)

State another property (other than half-life) that is important when selecting an appropriate gamma-emitting radionuclide for diagnostic purposes.

....

....

(1)
(Total 7 marks)

40. Explain why a coupling medium between the transducer and the body surface is necessary when carrying out an ultrasound scan. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

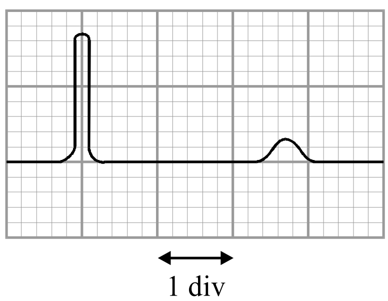
(3)

Suggest an appropriate substance for use as a coupling medium.

....

(1)

The diagram shows an A-scan trace on an oscilloscope. The pulses represent reflections from opposite sides of the head of a fetus.



The time base of the oscilloscope is set at 50μs div^{-1}. The speed of sound in the fetal head is 1.5 $\times 10^3$ ms^{-1}

Calculate the size of the head of the fetus.

....

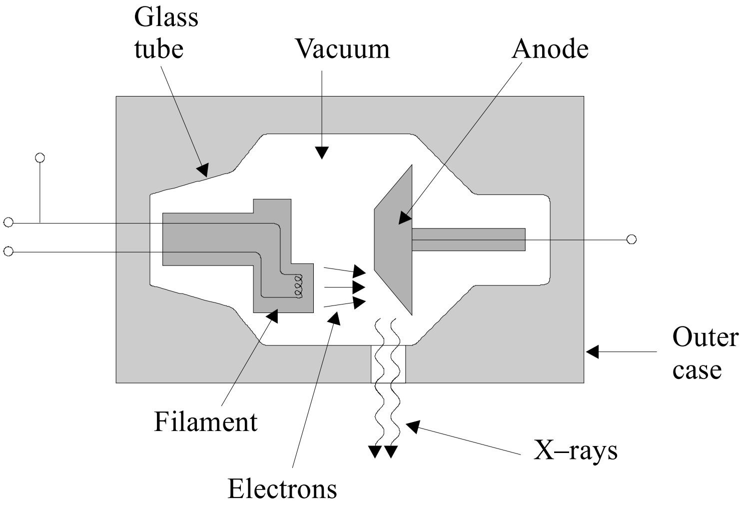
....

....

Size of head = ...

(4)
(Total 8 marks)

41. The diagram shows part of a diagnostic X-ray tube.



Suggest an appropriate operating voltage for this tube.

....

(1)

Why is the anode rotated?

....

(1)

Why is the X-ray tube evacuated?

....

(1)

Suggest an appropriate material for the outer case.

....

(1)
(Total 4 marks)

42. Read the short passage below and answer the questions about it.

> Attenuation is the reduction in intensity of a beam as it travels. X-ray beams areusually heterogeneous, that is they contain X-rays of many different wavelengths. In passing through a medium the different wavelengths are attenuated by different amounts. Longer wavelength (lower energy) X-rays are attenuated more than shorter wavelength ones. After passing through a filter the remaining X-rays therefore have a higher average energy and are relatively more penetrating. A more penetrating beam is said to be of better quality. As a heterogeneous beam passes through a medium its quality gradually increases. This process is described as hardening. The quality of an X-ray beam may be improved by either increasing the tube voltage or using a filter.
>
> [Adapted from *Medical Physics Imaging* by J. Pope]

State the meaning of the following terms used in the passage

Heterogeneous:..

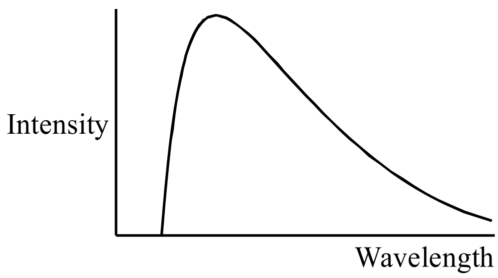
....

Hardening:...

....

(2)

The graph shows the distribution of different wavelength X-rays in a typical X-ray beam.



Add to the graph to show the possible distribution of X-rays after passing this beam through a filter.

(3)

Why is the X-ray beam relatively more penetrating after it has been filtered?

....

....

....

(2)

Suggest why it is beneficial to the patient to filter the beam.

....

....

....

....

....

(2)
(Total 9 marks)

43. (a) (i) Count the number of turns *N* of the spring.

....

Remove the spring from the nails. Measure the diameter *D* of the coiled part of the unstretched spring. Draw a sketch to explain how you did this.

....

With the coils touching, measure the length *1* of the coiled part of the spring.

....

(6)

(ii) Calculate an approximate value for *L,* the length of wire forming the spring, given that L = (N + 4)πD.

....

....

L = ...

Calculate a value for the diameter *d l/N* of the wire from which the spring is made.

....

....

d = ...

Hence calculate the volume of wire $V = \pi d^2 l/4$.

....

....

V = ...

(3)

(iii) Use the balance provided to find the mass *m* of the spring.

....

Use your values of *m* and *V* to find a value for the density of the material of the spring.

....

....

(3)

(b) (i) Stretch the spring between the two nails. Use the meter and leads provided to find the resistance *R* of the **coiled** part of the spring. State any precautions that you took in making your measurement.

....

....

....

....

(3)

(ii) Use your values of *N, D* and *d* from part (a) to determine a value for the resistivity *p* of the material of the wire given that

$$p = \frac{Rd^2}{4ND}$$

....

....

....

....

(3)

(c) The energy stored in a stretched spring is $\frac{1}{2} Fx$ where x is the extension produced when a force F is applied to the spring, Use the apparatus provided to determine a value for the energy stored in the spring when it is stretched between the two nails. Describe with the aid of a diagram how you did this and show all your measurements and calculations in the space below.

....

....

....

....

....

....

(6)
(Total 24 marks)

44. (a) (i) Pour hot water into the glass beaker up to the 200 ml (cm^3) mark. Record the temperature *0* of this water at regular intervals until the temperature falls below 70 °C. Your starting temperature should be above 80 °C.

....

....

....

....

....

....

(4)

(ii) Plot a graph of temperature θ against time t on the grid opposite.

(4)

(iii) Use your graph to determine the rate at which the temperature is falling, $\Delta\theta/\Delta t$, when θ *75°C*.

....

....

....

....

Assuming that it takes 900 J of energy to raise the temperature of the beaker and water by 1 K (1 °C), estimate the power *P* of the heater that would be required to maintain the temperature of the water at a steady 75 °C.

(4)

(b) (i) A student performs a similar experiment using a datalogger to capture the data and a computer to determine $\Delta\theta/\Delta t$. She finds that the required power is 30 W.

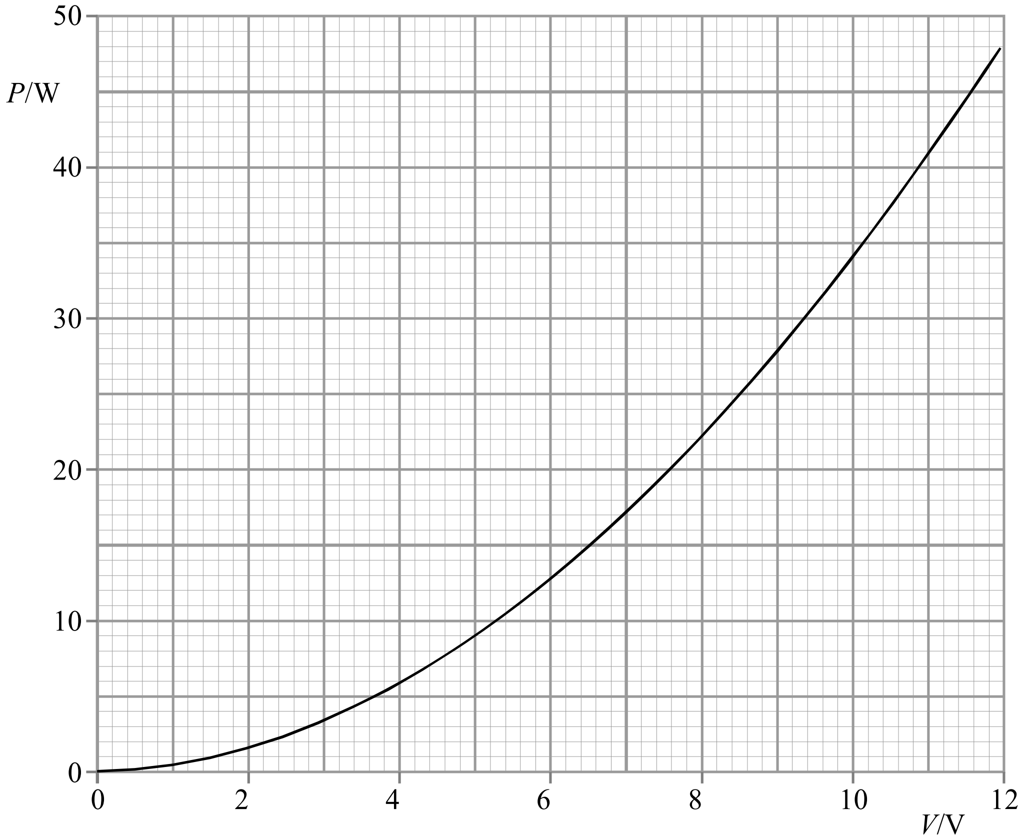
Draw a schematic (block) diagram to show the experimental arrangement and suggest a suitable sampling rate for the datalogger.

....

....

(4)

(ii) In a catalogue she finds a heater rated at 12 V, 48 W. Its power *P* varies with the applied potential difference *V* according to the following curve.



What potential difference would be required to provide a power of 30 W?

....

Describe, with the aid of a diagram, the circuit she could use to set the potential difference across the heater at the required value. You may assume that normal laboratory equipment is available.

....

....

(4)

(iii) After immersing the heater in 200 ml of water and setting the power to 30 W she wants to monitor the temperature of the water in this arrangement overnight and analyse the results next morning.

Explain how she could do this.

....

....

....

....

Suggest two reasons why she might find that the temperature had not remained at 75 °C.

....

....

....

....

(4)
(Total 24 marks)

45. (a) (i) Taking care not to damage the card supplied, determine average values for the length *1,* the width w and the thickness t.

....

....

....

....

....

....

....

Explain why it is necessary to take a number of values in order to determine accurate values for the above quantities.

....

....

(6)

(ii) Using the top pan balance, measure the mass of the card and hence find a value for the density of the material of the card.

....

....

....

....

....

The value you have obtained for the average thickness of the card is not necessarily the best average value. Explain how you could obtain a better average value for the thickness. You may assume that additional apparatus is available.

....

....

....

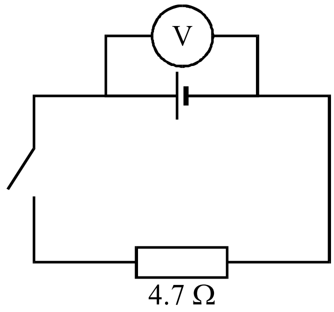
....

....

....

(4)

(b) (i) Set up the circuit as shown below. Before you close the switch, have your circuit checked by the Supervisor. You will be allowed a short time to correct any faults, but if you are unable to set up the circuit the Supervisor will set it up for you. You will only lose 2 marks for this.



(2)

(ii) You may assume that the voltmeter is an ideal voltmeter which takes no current. Use your circuit to determine the e.m.f. *8* of the cell and the potential difference *V* across the 4.7 Ω 2 resistor.

ε = ...

V = ...

Leave the switch **open** after you have completed your readings.

(2)

(iii) Calculate the current *I* through the resistor.

....

....

Hence calculate the internal resistance *r* of the cell.

....

....

....

....

....

(3)

(c) (i) Place 50 cm^3 of water at room temperature in the polystyrene cup. Record the temperature θ_1 of the water.

θ_1 = ...

The Supervisor has placed 10 washers tied together with string in a beaker of boiling water. Using the string, remove the washers from the beaker and transfer them to the polystyrene cup. Record the highest steady temperature θ_2 reached by the water.

θ_2 = ...

Calculate the specific heat capacity c_s of mild steel given that

$$cs = \frac{m_W c_W (\theta_2 - \theta_1)}{m_s (\theta_3 - \theta_2)}$$

where m_W = mass of water 0.050 kg,

c_W = specific heat capacity of water = 4200 J kg^{-1} K^{-1},

m_s = mass of 10 washers, which is given on the card,

θ_3 = initial temperature of washers = 100 °C.

....

....

....

....

....

(5)

(ii) State two sources of error in this experiment.

....

....

....

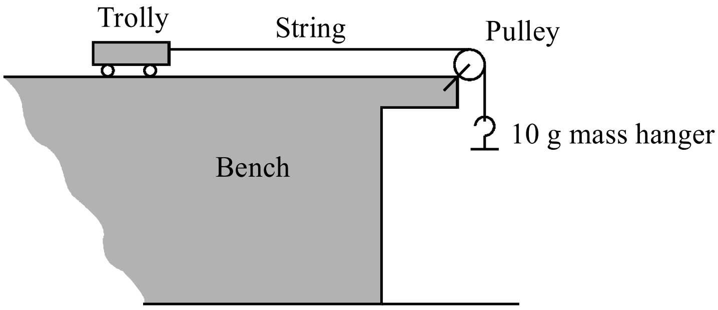
....

....

(2)

(Total 24 marks)

46. (a) The apparatus shown in the diagram below has been set up for you.



Add masses to the mass hanger until it is clear that the trolley accelerates across the table. Record the total mass *m* used to accelerate the trolley in the space below.

m =..

Determine the average time *t* for the trolley to travel a distance *x* 0.500 m from rest when accelerated by this mass.

....

....

Calculate the acceleration of the trolley given that

$$a = \frac{2x}{t^2}$$

....

....

....

....

Acceleration =..

(4)

(b) Explain with the aid of a diagram how you ensured that the trolley travelled a distance of 0.500 m in the measured time.

....

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(3)

(c) Applying Newton's second law to this system gives

$$(M + m)a = mg - F$$

where M = the mass of the trolley and its load, which is given on the card,

F = the frictional force opposing the motion of the system, and

g = the gravitational field strength.

Use your results from part (a) to calculate a value for F.

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(3)

(d) Repeat the experiment with a larger value of m in order to calculate a second value for F

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(4)

(e) Calculate the percentage difference between your two values of *F*. Comment on the extent to which the value of *F* may be regarded as constant if it is assumed that experimental errors are in the region of 10%.

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(2)

(f) The equation in part (c) may be investigated by plotting a graph of $(M + m)a$ against m.

(i) Explain carefully how you would carry out the experiment to plot this graph.

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(3)

(ii) Sketch the graph you would expect to obtain if the force *F* were constant.

(3)

(iii) State the values you would expect to obtain for both the gradient and the intercept on the vertical axis.

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(2)
(Total 24 marks)

47. (a) Name the two main wavelength bands of the electromagnetic spectrum which are used for terrestrial astronomy.

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(2)

State and explain *two* different benefits of observing stars and galaxies from above the Earth's atmosphere.

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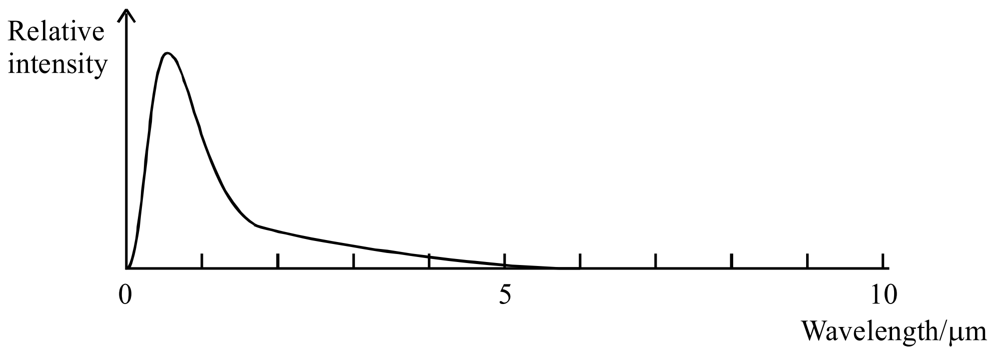
(4)

(b) The graph shows the relative intensity of the energy distribution in the spectrum of a body radiating at a temperature of 6000 K (the approximate temperature of the Sun).



Use Wien's law, $\lambda_{max}T = 3.9 \times 10^{-3}$ m K, to estimate the wavelength at which the intensity of radiation from the Earth is a maximum.

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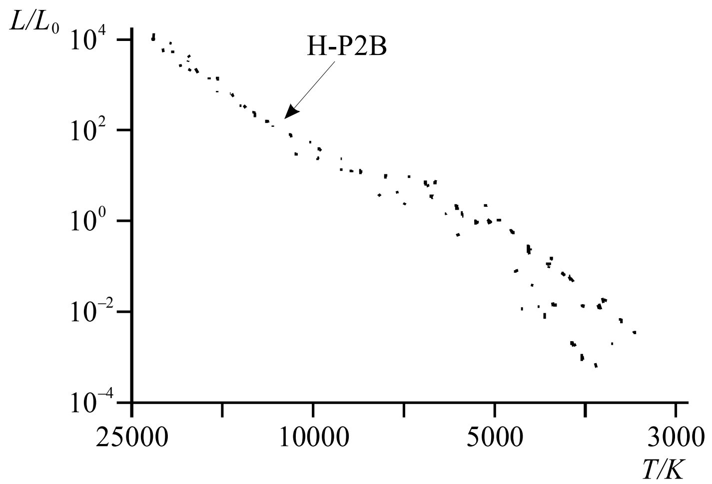
(2)

Add a second curve to the graph to show the approximate energy distribution in the radiation emitted by the Earth in the range 0 – 10 µm.

(2)

(c) Here is a Hertzsprung-Russell diagram showing the main sequence.



Mark regions on the diagram where you would find (i) giant stars (ii) white dwarfs.

(2)

L_0, the luminosity of the Sun, is 3.9×10^{26} W. Estimate the temperature of the Sun.

....

(1)

Use the graph to estimate the luminosity of the star H-P 2B.

....

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(2)

Use the Stefan-Boltzmann law to calculate the surface area, and hence the radius of H-P 2B.

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Surface area =..

Radius =..

(4)

(d) Our Sun is on the main sequence. Outline its past and expected life story, starting from the time it was first on the main sequence. You may be awarded a mark for the clarity of your answer.

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(Total 4 marks)

(e) After thousands and thousands of measurements, first with photographic plates and then with charged-coupled devices, we find a major key to stellar astrophysics, a strict relation between luminosity and mass for main sequence stars. Luminosity *L* climbs roughly as the mass *m* raised to the power 3.5. A star like Sirius A, 2.3 times the solar mass, is some 20 times as bright. The main sequence is really a mass sequence. The Sun is in the middle of the mass range. The observed masses run from a minimum of 8% that of the Sun to over 120 times the solar mass at the top end.

[Adapted from J B Kaler: *Stars*, W H Freeman 1992.]

(i) What, roughly, are the sizes of;

individual grains in a photographic emulsion,
pixels in a CCD?

....

....

State *two* advantages of using CCDs rather than photographic plates in astronomical investigations.

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(4)

(ii) Write an equation linking luminosity and mass for main sequence stars.

....

....

Use your equation to confirm that Sirius A is about 20 times as bright as the Sun.

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(3)

(iii) Explain why there is a minimum to the mass of a star.

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(2)
(Total 32 marks)

48. (a) What is meant by the *strength of a material*?

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(1)

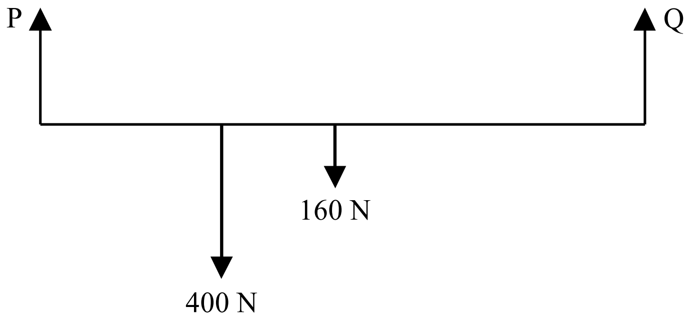
Sketch a stress-strain graph for a copper wire up to its breaking point.

(2)

Label on your graph (i) the yield point, (ii) a region in which the wire's behaviour is elastic, and (iii) a region in which the wire's behaviour is plastic.

(3)

(b) A uniform beam of length 4.0 m and weight 160 N is suspended horizontally by two identical vertical wires attached to its ends. A load of 400 N is placed on the beam 1.2 m from one end. The diagram is a free-body force diagram for the beam.



Calculate the tension in each suspended wire.

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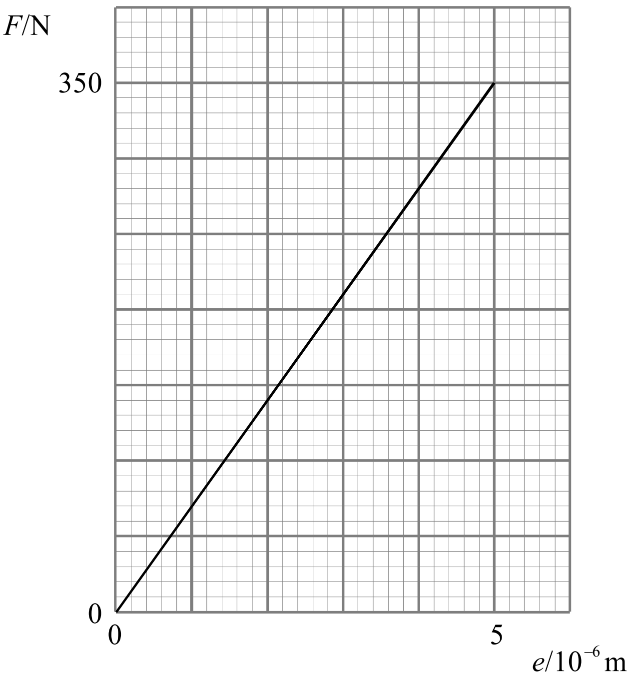
Tension =…………………………………..………

(4)

(c)



The graph shows the extension e produced by a tension F on solid bone. The bone, of circular cross-section, has a diameter of 35 mm and an unstressed length of 390 mm. Calculate the Young modulus of bone.

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Young modulus =…………………………..……………

(3)

Calculate the energy per unit volume required to stretch the bone by 0.0040 mm.

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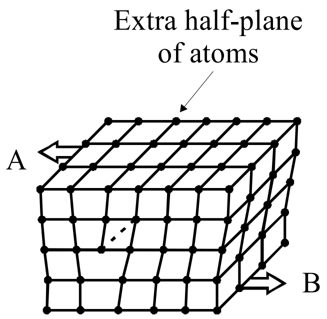
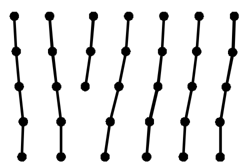
Energy per unit volume =……………………………………………

(4)

(d) The diagram shows the arrangement of the atoms in a crystal in the region of an edge dislocation.



Draw labelled diagrams to show how the dislocation moves when stress is applied as shown by the arrows A, B. You need only draw one plane of atoms. The first diagram is drawn for you.



(4)

Explain why the stress required to deform a perfect crystal is greater than that required to deform one containing dislocations. You may be awarded a mark for the clarity of your answer.

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(3)

(e) Engineers like stiff, strong, light and creep-resistant materials. Plastics are not stiff enough because their working strain is about 1%, whereas that of a typical engineering material is below 0.1%. The combined requirement for stiffness and lightness is equivalent to a high value of the Young modulus E divided by the density ρ. The value for plastics is poor, about one fifth that of metals. The development of composites has already been picked out as a strong growing point. For example, the strength and creep-resistance of glass can be coupled with the toughness of a resin to produce a boat hull.

[Adapted from J Ogborn (ed.): *Materials and Structure*, NAS Physics, Penguin 1971]

(i) Explain what is meant by *creep*.

....

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(3)

(ii) Show that the unit of E/ρ is $m^2\ s^{-2}$.

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For copper $E/\rho = 1.5 \times 10^7\ m^2\ s^{-2}$.

Calculate the Young modulus of a plastic of density $910\ kg\ m^{-3}$.

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Young modulus =…………………………………………………

(4)

(iii) What, in general, is meant by a *composite material*?

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....

What type of composite material is described as being used for a boat hull?

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(2)
(Total 32 marks)

49. (a) The strong force is one of the fundamental interactions. What exchange particle is associated with this force?

....

List the other fundamental interactions. Circle the one for which the photon is the exchange particle.

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(5)

(b) Complete the table below which compares alpha particle scattering with deep inelastic scattering.

	Alpha scattering	Deep inelastic scattering
Target		hydrogen atoms
Incoming particles	alpha particles	
Provided evidence for the existence of		

(4)

(c) The Ω^- (omega minus), a particle with strangeness –3, was identified in 1964 in an experiment involving an interaction between a K^- meson of strangeness –1 and a proton.

$$K^- + p \rightarrow \Omega^- + K^+ + K^0$$

Is the Ω^- particle a baryon or a meson? Give *two* reasons for your answer.

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(2)

Using the information in the table, deduce the quark composition of all particles in the equation.

Quark	Charge	Strangeness
u	+2/3	0
d	–1/3	0
s	–1/3	–1

p ……………………… Ω^- ..……………………….

K^- …………………….. K^+ …………………. K^0 …………………...

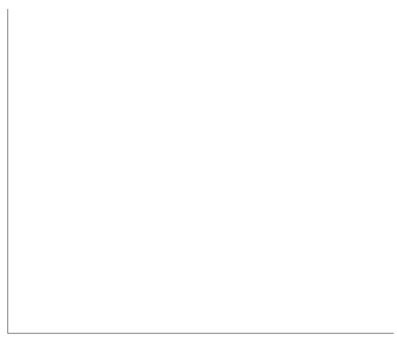
(4)

(d) Complete the following nuclear equation showing the beta-minus decay of an isotope of oxygen.

$${}^{18}_{8}O \quad \rightarrow \quad X$$

(2)

Sketch a graph showing the energy spectrum for a typical beta-minus decay.



(2)

Explain why the shape of this graph is consistent with the decay process involving a further particle, an antineutrino. You may be awarded a mark for the clarity of your answer.

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(4)

(e) The theory of relativity established that all forms of energy possess mass and, conversely, that material particles are a form of energy. If enough energy is concentrated, new particles of matter will appear. Thus, the violent collision of two protons, for example, can produce more protons. Whenever matter is created this way in the laboratory it is always accompanied by an equivalent quantity of antimatter. Each lepton and quark possesses an antiparticle in which all the physical properties except mass are reversed. If an antiparticle encounters its mirror particle they annihilate each other, usually in the form of gamma radiation.

[Adapted from Paul Davies: *The particles and forces of nature*, in Revised NAS Physics, Longman 1986.]

(i) The collision between two protons is described as being a violent collision. Explain why the collision must be a violent one in order to produce more protons.

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(2)

(ii) Whenever matter is created *"it is always accompanied by an equivalent quantity of antimatter"*.

What conservation laws does this statement imply?

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(3)

(iii) An electron encounters a positron. The rest mass of an electron and that of a positron is 0.000 55u.

Describe the outcome of the encounter.

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Support your description with relevant calculations.

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(4)
(Total 32 marks)

50. (a) An X-ray tube operating at 65 kV has a tube current of 120 mA. The tube produces X-rays with an efficiency of 0.8%.

Calculate the rate of heat production in the anode.

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....

Rate = ...

(3)

(b) State what is meant by the terms *radioactive half-life* and *biological half-life*.

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(2)

Why does biological half-life depend on both the organ and the patient?

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(2)

(c) Outline the use of a radioactive tracer in measuring the volume of blood in a person. You may be awarded a mark for the clarity of your answer.

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(4)

Iodine-131 has a half-life of 8 days. Approximately what percentage of a sample of iodine will remain in the body after a period of one month?

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....

....

(2)

Complete the following equation for the decay of iodine-131.

$$^{131}\text{I} \quad \rightarrow \quad _{54}\text{Xe} \quad + \quad \beta^- \quad + \quad \gamma$$

(2)

A second isotope of iodine, iodine-123, is available. It decays by emission of gamma radiation only.

Explain which isotope of iodine you would prefer for treatment of an over-active thyroid gland.

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(3)

(d) The formula for the reflection coefficient for ultrasound is $[(Z_2 - Z_1)(Z_2 + Z_1)]^2$.
What quantity does Z represent?

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(1)

In a pregnant woman, the bladder is between the outside of the body and the baby. A pregnant woman needs to have a bladder full of urine if she wishes to have a successful ultrasound scan of her baby. The principal contents of an "empty" bladder are gaseous..

With reference to the formula for reflection coefficient, explain why an "empty " bladder would make an ultrasound scan unsuccessful.

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(3)

Give one reason why ultrasound might be preferred to a method involving a radioisotope for investigating the size of a body organ.

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(1)

(e) An ultrasonic transducer or probe typically produces pulses of 1 μs duration. The pulses are sent into the medium and the returning echoes are detected by the transducer, amplified and recorded. In general, the higher the frequency the better the resolution gained in diagnostic techniques. You would therefore expect that the highest possible frequencies would be used. Unfortunately, the higher the frequency, the greater the absorption of energy from the beam. Because of this, investigations near the surface all use a high frequency probe operating at 10 MHz, and find detail can be seen. Investigations of deeper tissues use a lower frequency, e.g. 3.6 MHz.

[Adapted from G Hart and F Armes: *Medical Physics for Advanced Level*, Simon and Schuster Education 1992.]

(i) Express 1 μs and 3.5 MHz in standard form, i.e. using powers of ten.

....

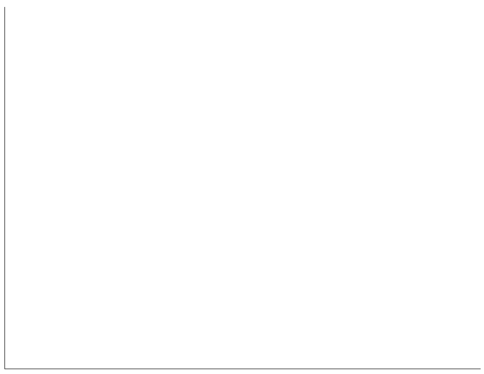
....

Calculate how many times in 1 μs a 3.5 MHz ultrasonic probe moves in and out.

....

No. of times =…………………………………………

Draw a sketch graph of the wave pulse produced in 1 μs. Add a scale to the time axis.



(5)

(ii) How is frequency related to wavelength for ultrasonic waves in one medium?

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Explain the phrase *"the higher the frequency the better the resolution"*.

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(3)

(iii) Give an example of an investigation which would be near the surface of the body.

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(1)
(Total 32 marks)

51. Name the two main wavelength bands of the electromagnetic spectrum which are used for terrestrial astronomy.

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(2)

State and explain *two* different benefits of observing stars and galaxies from above the Earth's atmosphere.

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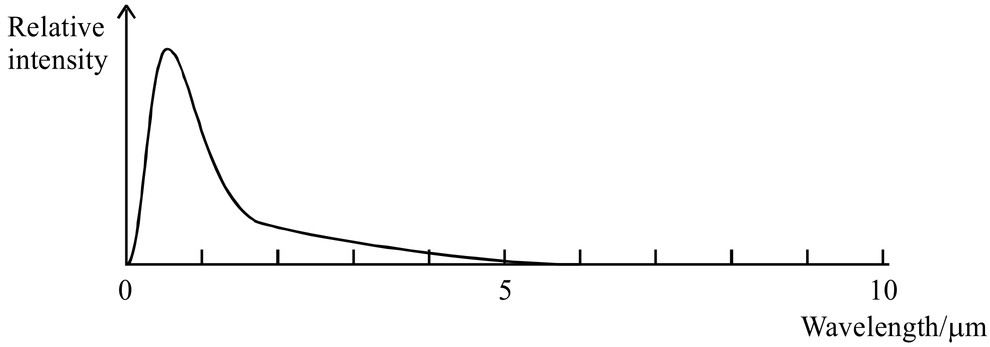
(4)
(Total 6 marks)

52. The graph shows the relative intensity of the energy distribution in the spectrum of a body radiating at a temperature of 6000 K (the approximate temperature of the Sun).



Use Wien's law, $\lambda_{max}T = 3.9 \times 10^{-3}$ m K, to estimate the wavelength at which the intensity of radiation from the Earth is a maximum.

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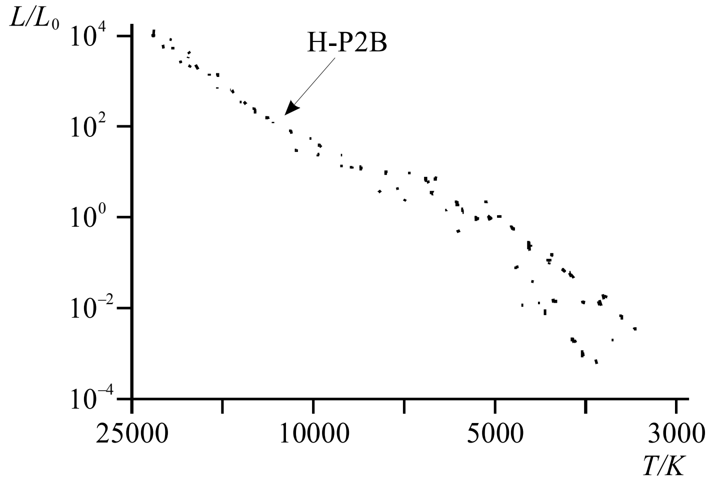
(2)

Add a second curve to the graph to show the approximate energy distribution in the radiation emitted by the Earth in the range 0 – 10 μm.

(2)
(Total 4 marks)

53. Here is a Hertzsprung-Russell diagram showing the main sequence.



Mark regions on the diagram where you would find (i) giant stars (ii) white dwarfs.

(2)

L_0, the luminosity of the Sun, is 3.9×10^{26} W. Estimate the temperature of the Sun.

....

(1)

Use the graph to estimate the luminosity of the star H-P 2B.

....

....

....

(2)

Use the Stefan-Boltzmann law to calculate the surface area, and hence the radius of H-P 2B.

....

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Surface area =…………………………………………………

Radius =…………………………………………………

(4)
(Total 9 marks)

54. Our Sun is on the main sequence. Outline its past and expected life story, starting from the time it was first on the main sequence. You may be awarded a mark for the clarity of your answer.

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(Total 4 marks)

55. After thousands and thousands of measurements, first with photographic plates and then with charged-coupled devices, we find a major key to stellar astrophysics, a strict relation between luminosity and mass for main sequence stars. Luminosity L climbs roughly as the mass m raised to the power 3.5. A star like Sirius A, 2.3 times the solar mass, is some 20 times as bright. The main sequence is really a mass sequence. The Sun is in the middle of the mass range. The observed masses run from a minimum of 8% that of the Sun to over 120 times the solar mass at the top end.

[Adapted from J B Kaler: *Stars*, W H Freeman 1992.]

(a) What, roughly, are the sizes of;

individual grains in a photographic emulsion,
pixels in a CCD?

....

....

State *two* advantages of using CCDs rather than photographic plates in astronomical investigations.

....

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(4)

(b) Write an equation linking luminosity and mass for main sequence stars.

....

....

Use your equation to confirm that Sirius A is about 20 times as bright as the Sun.

....

....

....

....

(3)

(c) Explain why there is a minimum to the mass of a star.

....

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(2)
(Total 9 marks)

56. What is meant by the strength of a material?

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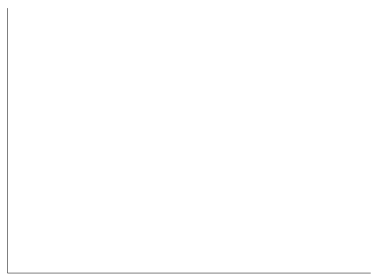
(1)

Sketch a stress-strain graph for a copper wire up to its breaking point.

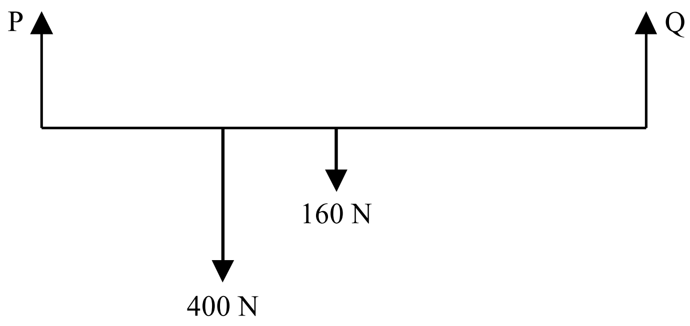


(2)

Label on your graph (i) the yield point, (ii) a region in which the wire’s behaviour is elastic, and (iii) a region in which the wire’s behaviour is plastic.

(3)
(Total 6 marks)

57. A uniform beam of length 4.0 m and weight 160 N is suspended horizontally by two identical vertical wires attached to its ends. A load of 400 N is placed on the beam 1.2 m from one end. The diagram is a free-body force diagram for the beam.



Calculate the tension in each suspended wire.

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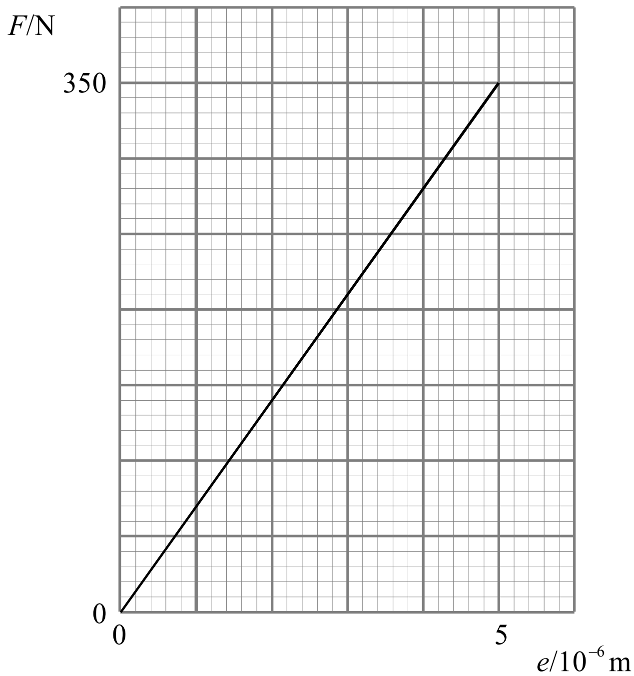
Tension =……………………………………..………

(Total 4 marks)

58.



The graph shows the extension e produced by a tension F on solid bone. The bone, of circular cross-section, has a diameter of 35 mm and an unstressed length of 390 mm. Calculate the Young modulus of bone.

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....

Young modulus =……………………………..……………

(3)

Calculate the energy per unit volume required to stretch the bone by 0.0040 mm.

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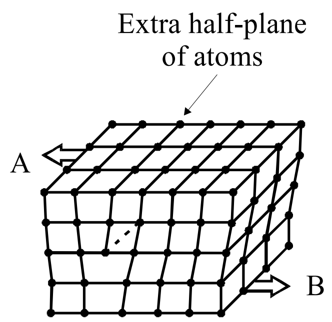
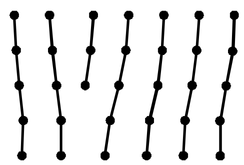
Energy per unit volume =……………………………………………

(4)
(Total 7 marks)

59. The diagram shows the arrangement of the atoms in a crystal in the region of an edge dislocation.



Draw labelled diagrams to show how the dislocation moves when stress is applied as shown by the arrows A, B. You need only draw one plane of atoms. The first diagram is drawn for you.



(4)

Explain why the stress required to deform a perfect crystal is greater than that required to deform one containing dislocations. You may be awarded a mark for the clarity of your answer.

....

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....

....

(3)
(Total 7 marks)

60. Engineers like stiff, strong, light and creep-resistant materials. Plastics are not stiff enough because their working strain is about 1%, whereas that of a typical engineering material is below 0.1%. The combined requirement for stiffness and lightness is equivalent to a high value of the Young modulus E divided by the density ρ. The value for plastics is poor, about one fifth that of metals. The development of composites has already been picked out as a strong growing point. For example, the strength and creep-resistance of glass can be coupled with the toughness of a resin to produce a boat hull.

[Adapted from J Ogborn (ed.): *Materials and Structure*, NAS Physics, Penguin 1971]

(a) Explain what is meant by *creep*.

....

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....

(3)

(b) Show that the unit of E/ρ is $m^2\ s^{-2}$.

....

....

For copper $E/\rho = 1.5 \times 10^7\ m^2\ s^{-2}$.

Calculate the Young modulus of a plastic of density 910 kg m^{-3}.

....

....

Young modulus =...

(4)

(c) What, in general, is meant by a *composite material*?

....

....

What type of composite material is described as being used for a boat hull?

....

....

(2)
(Total 9 marks)

61. The strong force is one of the fundamental interactions. What exchange particle is associated with this force?

....

List the other fundamental interactions.   Circle the one for which the photon is the exchange particle.

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(Total 5 marks)

62. Complete the table below which compares alpha particle scattering with deep inelastic scattering.

	Alpha scattering	Deep inelastic scattering
Target		hydrogen atoms
Incoming particles	alpha particles	
Provided evidence for the existence of		

(Total 4 marks)

63. The Ω^- (omega minus), a particle with strangeness –3, was identified in 1964 in an experiment involving an interaction between a K^- meson of strangeness –1 and a proton.

$$K^- + p \rightarrow \Omega^- + K^+ + K^0$$

Is the Ω^- particle a baryon or a meson?   Give *two* reasons for your answer.

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(2)

Using the information in the table, deduce the quark composition of all particles in the equation.

Quark	Charge	Strangeness
u	+2/3	0
d	–1/3	0
s	–1/3	–1

p ……………………… Ω^- ………………………

K^- …………………….. K^+ …………………. K^0 …………………...

(4)
(Total 6 marks)

64. Complete the following nuclear equation showing the beta-minus decay of an isotope of oxygen.

$${}^{18}_{8}\text{O} \rightarrow \text{X}$$

(2)

Sketch a graph showing the energy spectrum for a typical beta-minus decay.

(2)

Explain why the shape of this graph is consistent with the decay process involving a further particle, an antineutrino. You may be awarded a mark for the clarity of your answer.

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(4)
(Total 8 marks)

65. The theory of relativity established that all forms of energy possess mass and, conversely, that material particles are a form of energy. If enough energy is concentrated, new particles of matter will appear. Thus, the violent collision of two protons, for example, can produce more protons. Whenever matter is created this way in the laboratory it is always accompanied by an equivalent quantity of antimatter. Each lepton and quark possesses an antiparticle in which all the physical properties except mass are reversed. If an antiparticle encounters its mirror particle they annihilate each other, usually in the form of gamma radiation.

[Adapted from Paul Davies: *The particles and forces of nature*, in Revised NAS Physics, Longman 1986.]

(a) The collision between two protons is described as being a violent collision. Explain why the collision must be a violent one in order to produce more protons.

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(2)

(b) Whenever matter is created "*it is always accompanied by an equivalent quantity of antimatter*".

What conservation laws does this statement imply?

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(3)

(c) An electron encounters a positron. The rest mass of an electron and that of a positron is 0.000 55u.

Describe the outcome of the encounter.

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Support your description with relevant calculations.

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(4)
(Total 9 marks)

66. An X-ray tube operating at 65 kV has a tube current of 120 mA. The tube produces X-rays with an efficiency of 0.8%.

Calculate the rate of heat production in the anode.

....

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....

Rate =……………………………………………

(Total 3 marks)

67. State what is meant by the terms *radioactive half-life* and *biological half-life*.

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(2)

Why does biological half-life depend on both the organ and the patient?

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(2)
(Total 4 marks)

68. Outline the use of a radioactive tracer in measuring the volume of blood in a person. You may be awarded a mark for the clarity of your answer.

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(4)

Iodine-131 has a half-life of 8 days. Approximately what percentage of a sample of iodine will remain in the body after a period of one month?

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(2)

Complete the following equation for the decay of iodine-131.

$$^{131}\mathrm{I} \quad \rightarrow \quad {}_{54}\mathrm{Xe} \quad + \quad \beta^{-} \quad + \quad \gamma$$

(2)

A second isotope of iodine, iodine-123, is available. It decays by emission of gamma radiation only.

Explain which isotope of iodine you would prefer for treatment of an over-active thyroid gland.

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(3)
(Total 11 marks)

69. The formula for the reflection coefficient for ultrasound is $[(Z_2 - Z_1)(Z_2 + Z_1)]^2$.
What quantity does Z represent?

....

(1)

In a pregnant woman, the bladder is between the outside of the body and the baby. A pregnant woman needs to have a bladder full of urine if she wishes to have a successful ultrasound scan of her baby. The principal contents of an "empty" bladder are gaseous..

With reference to the formula for reflection coefficient, explain why an "empty " bladder would make an ultrasound scan unsuccessful.

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(3)

Give one reason why ultrasound might be preferred to a method involving a radioisotope for investigating the size of a body organ.

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(1)
(Total 5 marks)

70. An ultrasonic transducer or probe typically produces pulses of 1 μs duration. The pulses are sent into the medium and the returning echoes are detected by the transducer, amplified and recorded. In general, the higher the frequency the better the resolution gained in diagnostic techniques. You would therefore expect that the highest possible frequencies would be used. Unfortunately, the higher the frequency, the greater the absorption of energy from the beam. Because of this, investigations near the surface all use a high frequency probe operating at 10 MHz, and find detail can be seen. Investigations of deeper tissues use a lower frequency, e.g. 3.6 MHz.

[Adapted from G Hart and F Armes: *Medical Physics for Advanced Level*, Simon and Schuster Education 1992.]

(a) Express 1 μs and 3.5 MHz in standard form, i.e. using powers of ten.

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Calculate how many times in 1 μs a 3.5 MHz ultrasonic probe moves in and out.

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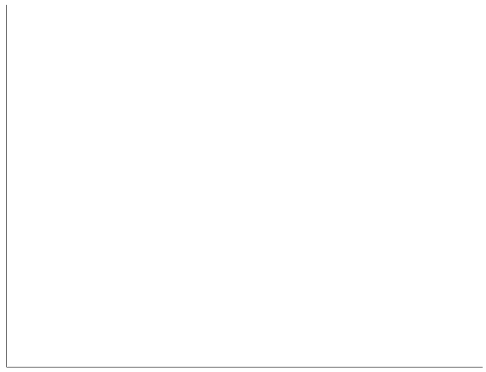
No. of times =………………………………………

Draw a sketch graph of the wave pulse produced in 1 μs. Add a scale to the time axis.



(5)

(b) How is frequency related to wavelength for ultrasonic waves in one medium?

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Explain the phrase "*the higher the frequency the better the resolution*".

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(3)

(c) Give an example of an investigation which would be near the surface of the body.

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(1)
(Total 9 marks)

71. Instructions

For part (*a*):

1 Uniform wooden metre rule.

2 Five 2p coins

3 Five 1p coins.

4 Knife edge or prism to act as a fulcrum.

5 Set square.

For part (*b*):

6 12 V, 24 W lamp in suitable holder.

7 Approximately 15 V d.c. power supply, with switch.

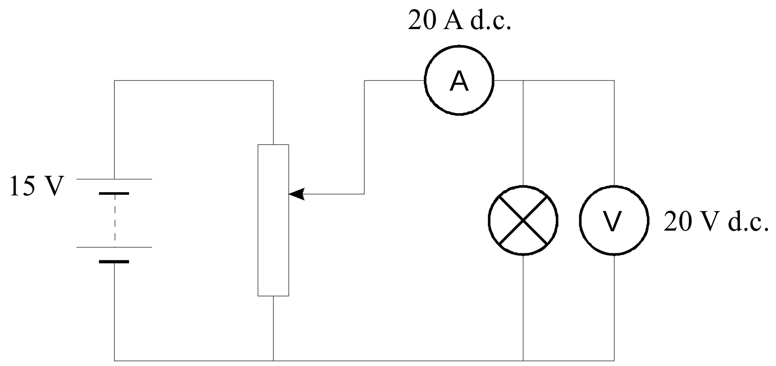
8 Ammeter, capable of reading up to 2 A d.c. to a precision of 0.1 A.

9 Voltmeter, capable of reading up to 15 V d.c. to a precision of 0.1 V.

10 Rheostat, e.g. 41 Ω, 2A.

11 Suitable connecting leads.

The *candidate* will be expected to use items 6 - 11 to set up the circuit below.



(a) (i) Determine a mean value for the diameters of a 1p coin and of a 2p coin. Describe how you did this.

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(4)

(ii) It is suggested that the mass of a 2p coin is twice that of a 1p coin. Use the principle of moments to investigate this hypothesis.

Draw a diagram of your experimental arrangement and show all your measurements and calculations below.

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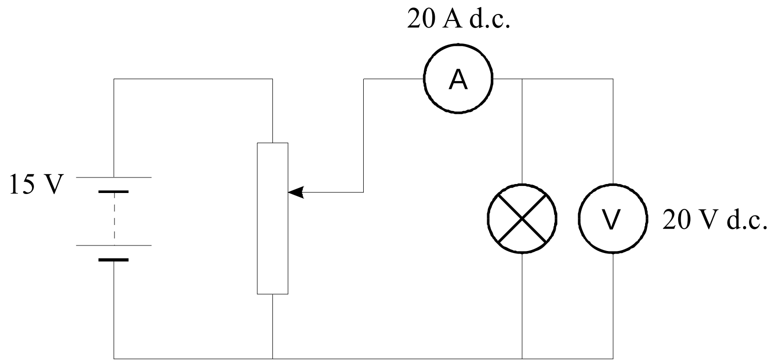
(6)

(b)



(i) Set up the above circuit to enable you to find the current through the lamp for a range of potential differences up to 12 V. Have your circuit checked by the Supervisor before switching on the power supply. If your circuit is incorrect you will be allowed a short time to correct it. If you are unable to do so, you may lose up to 3 marks.

(3)

(ii) Now carry out your experiment, recording your observations below.

SWITCH OFF THE POWER SUPPLY AS SOON AS YOU HAVE TAKEN YOUR READINGS.

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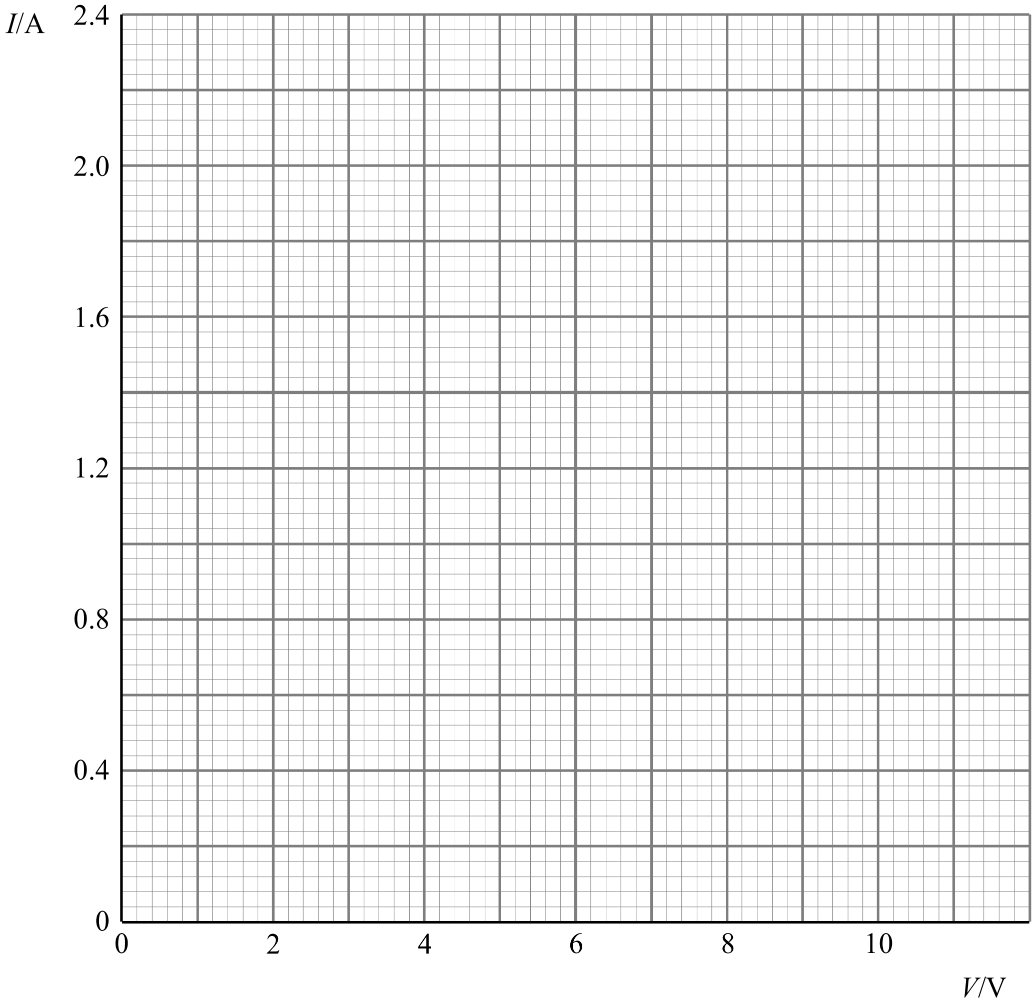
(5)

(iii) Plot a graph of the current I against the p.d. V on the grid below.

(2)



(iv) Use your graph to determine the resistance of the lamp when the p.d. across it is 4.5 V.

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(2)

(v) The lamp is described as being a 12 V, 24 W lamp. Explain what this means and discuss the extent to which your experiment confirms this.

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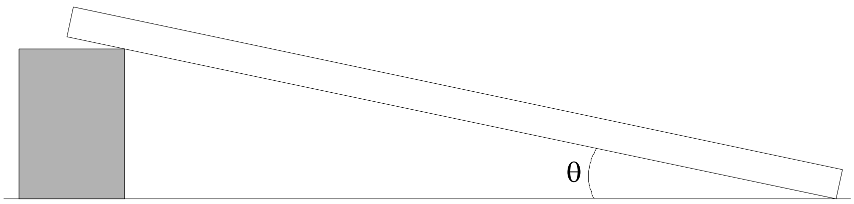
(2)

(Total 24 marks)

72. For part (*a*):

1 Runway of length approximately 1.2 m.

The runway, 1, should be of smooth board or m.d.f. (e.g. a length of shelving), approximately 20 cm wide and of sufficient thickness so that it does not bow. It should be supported securely at one end so that it makes an angle θ with the bench, such that tan $\theta = 0.025$.



2 Ball bearing or marble of diameter between 1 cm – 2 cm..

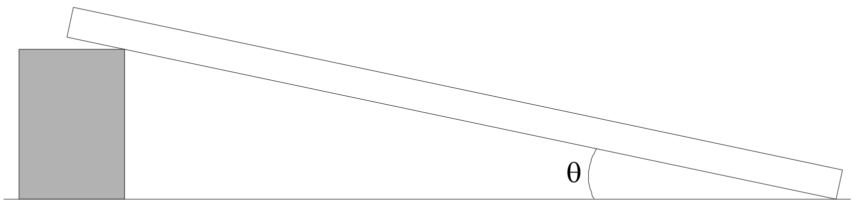
3 Stopwatch.

4 Two metre rules.

5 Small lump of Blu-tack.

6 Set square.

(a) A board has been set up ready for you to use. Do not adjust the angle θ it makes with the bench.



(i) Measure the angle θ that it makes with the bench, using a trigonometric method.

Describe how you did this. You may add to the diagram to illustrate your answer.

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Explain why using a protractor to determine θ would be a poor technique.

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(4)

(ii) Measure the time t for the ball to roll from rest a distance of 1.00 m down the slope.

Explain why taking repeat measurements is particularly important in this instance.

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Calculate the acceleration a of the ball using

$$a = \frac{2x}{t^2} \quad \text{where } x = 1.00\text{m}$$

....

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a =……………………………………………..……

(5)

(iii) Calculate the percentage difference between this experimental value for a and the theoretical value $a = 0.71\ g \sin\ \theta$.

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Percentage difference =………………….

Account for the difference between your two values for *a*

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(4)

(b) (i) You are to plan how the experiment could be further developed to investigate the relationship $a = 0.71\ g \sin\theta$.

Describe the readings you would take and any calculations you would make.

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Sketch the graph you would plot.

Explain how you would use your graph to test the relationship.

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Explain how your graph would enable you to eliminate any systematic error due to the bench not being horizontal.

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(7)

(ii) It is suggested that the timing could be done better by a data logging device. Describe, with the aid of a diagram, how this could be done.

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(4)
(Total 24 marks)

73. (a) State two similarities and one difference between light and radio waves.

Similarity 1 ....

Similarity 2 ....

Difference ....

(3)

(b) Stars β Ori and α Cet have temperatures of approximately 11 000 K and 3600 K respectively. Calculate the wavelength at which the intensity of radiation from each star is a maximum. Give your answers in nanometres.

β Ori ....

....

α Cet ....

....

(3)

Use the Stefan-Boltzmann law to calculate the power emitted per square metre of surface, measured in W m^{-2} , for β Ori.

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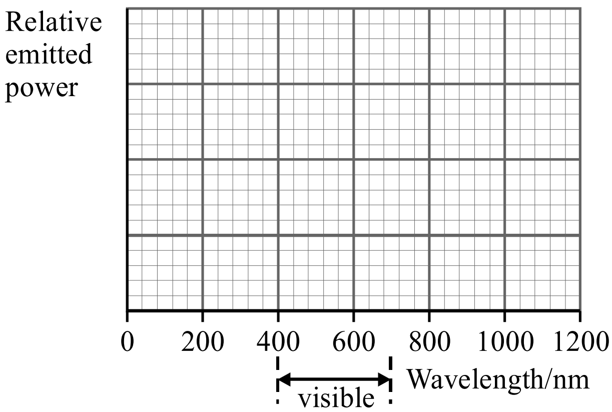
(2)

The power emitted per square metre of surface for α Cet = 1.0×10^7 W m^{-2}.

Sketch two graphs on the axes below, showing how this emitted power is distributed over different wavelengths for each star. Label your graphs Ori and Cet.



(3)

The visible spectrum extends from approximately 400 nm to 700 nm. Use your graphs to explain why β Ori is a bluish star, while α Cet is reddish.

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(2)

(c) Draw a labelled diagram to illustrate the principle of how the distance to a nearby star can be measured using the annual parallax method.

(4)

Why is this method only suitable for nearby stars?

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(1)

(d) Stars of more than eight solar masses may undergo a spectacular supernova explosion. Outline the processes that take place in the star that result in such an event. You may be awarded a mark for the clarity of your answer.

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(4)

What may happen to the core remnant from such an event?

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(1)

(e) Read the short passage below and answer the questions about it.

> The Sun is a typical main sequence star. The conversion of hydrogen to helium in its core where the temperature is ≈ 15×10^6 K releases energy. This energy is chiefly in the form of X-rays of wavelength 0.2 nm – 1 nm and is transported to the Sun's surface by radiation and convection. It takes about 2×10^5 years for the energy to reach the Sun's surface. The radiative zone extends from the centre to $\frac{3}{4}$ of the solar radius. In this zone X-rays are repeatedly absorbed and re-emitted by gas atoms. This happens at approximately 1 mm intervals. The convective zone ranges from $\frac{3}{4}$ solar radius outwards. In this zone the gas is cooler and even more opaque to X-rays so energy is transported by large-scale movement of the gas itself.
> [Adapted from *Life and Death of Stars* by Dr L J Smith]

Sketch a Hertzsprung-Russell diagram to show what is meant by the term main sequence.

(3)

The radius of the Sun is 7×10^8 m. Calculate the time it would take for X-rays to reach the surface of the Sun if they travelled there directly at a speed of 3×10^8 in s^{-1}.

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(2)

Why is convection the main method of energy transfer in the outer region of the Sun?

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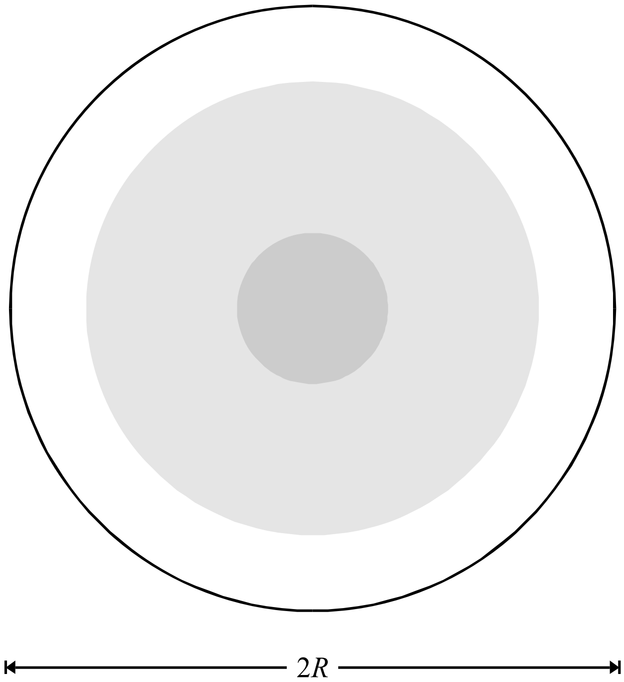
(1)

Label the diagram below to summarise the transport of energy to the Sun's surface.

Sun



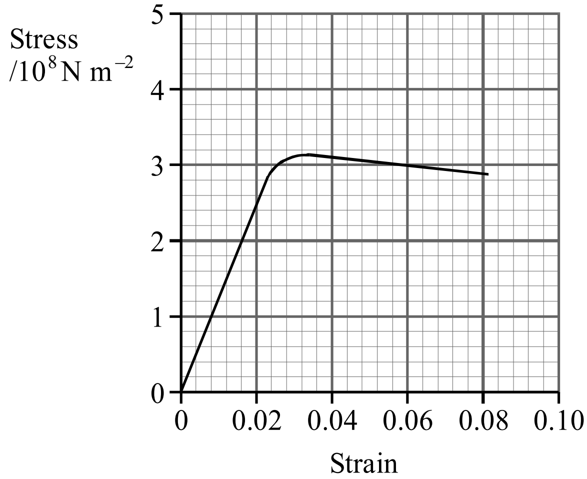
(3)
(Total 32 marks)

74. (a) A bridge is formed from a uniform concrete beam of weight *W* supported at each end by a brick pillar. A vehicle of weight *P* is stationary $\frac{1}{4}$ way along the bridge.

On the diagram below draw arrows to show the forces acting on the beam. Label each force and state the origin of the upward forces.

(3)

(b) Some properties of two materials A and B are given below, material A on the graph, material B in the table.



Material	Young modulus/10^{10} Pa	Ultimate tensile stress/10^8 N m^{-2}	Nature
A			Tough
B	3.0	3.6	Brittle

Use the graph to complete the table for material A.

(2)

Use the table to draw a graph on the grid above showing the behaviour of material B.

(3)

Show on the graph the region in which material A obeys Hooke's law.

(1)

Material A is in the form of a wire of cross-sectional area 8.8×10^{-7} m^2 and length 2.5 m. Calculate the energy stored in the wire when it experiences a strain of 0.020.

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....

Energy = ...

(4)

(c) Describe the difference between a fibre composite and a laminate.

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(2)

Explain how the risk of failure by cracking is reduced in **either** a fibre composite **or** a laminate. You may be awarded a mark for the clarity of your answer.

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(3)

(d) Perspex is an amorphous polymer. Draw a labelled diagram showing the molecular structure of Perspex.

(2)

Describe the difference in behaviour of a thermoplastic polymer and a thermosetting polymer when heated.

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(2)

Is Perspex a thermoplastic polymer or a thermosetting polymer?

....

(1)

(e) Read the short passage below and answer the questions about it.

> Elastic materials under stress store strain energy. In a car with no springs there would be violent interchanges of gravitational potential energy and kinetic energy every time a wheel passed over a bump. The springs of the car enable changes of potential energy to be stored temporarily as strain energy, resulting in a smoother ride. Most ski runs are more bumpy than a normal road. The tendons in the legs of a fast moving skier must be able to store and give up again very large amounts of energy. Light aircraft which may have to land on rough ground often have their undercarriages sprung by means of rubber cords.
> [Adapted from *Structures* by J E Gordon]

Explain what is meant by the term strain energy.

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(1)

Why is it important that the springs, tendons and rubber cords mentioned in the passage are not stressed beyond their elastic limits?

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(1)

Useful data:

	Energy stored per unit mass/J kg^{-1}
Modern spring steel	130
Tendon in leg	2500
Rubber cord	8000

Show that a car of mass 1200 kg would need steel springs of total mass approximately equal to 3 kg to store energy when it encounters pot-holes of depth 3 cm.

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(3)

The sum of the mass of leg tendons of a skier might be of the order of 0.4 kg. Estimate the size of 'bump' that a skier of mass 75 kg could theoretically negotiate.

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(2)

Sketch a hysteresis curve to show the behaviour under stress of a rubber suitable for springing light aircraft undercarriages.

(2)
(Total 32 marks)

75. (a) State one similarity and two differences between alpha and beta particles.

Similarity ....

Difference 1 ....

....

Difference 2 ....

....

(3)

(b) Show that the radius of the nucleus of an atom of silver, $^{108}_{47}\text{Ag}$, is approximately twice the radius of the nucleus of a nitrogen atom, $^{14}_{7}\text{N}$.

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(3)

Explain why measurements of the energies of the β^- particles emitted during nuclear decay led to the suggestion that an additional undetected particle must be emitted during the decay process. You may be awarded a mark for the clarity of your answer.

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(4)

(c) An atom of antihydrogen (a positron orbiting around an antiproton) has been produced.

Is an atom of antihydrogen positive, negative or neutral?

....

(1)

State the quark composition of an antiproton.

....

(1)

Show that an antiproton has a charge of –1.

....

....

(1)

Explain why it is extremely difficult to store antimatter.

....

....

....

....

(2)

Complete the following quark table.

Quarks			Charge
up	charm		+2/3
down	strange		–1/3

(1)

Selecting from the shaded boxes only, use the table to deduce the quark composition of the following particles.

(i) A neutral strange meson

....

(ii) A positive charmed meson

....

(iii) A neutral strange baryon

....

(3)

(d) Use the laws of conservation of charge and baryon number to decide whether the following reactions are possible or not possible. In each case show how you applied the laws. Pions (π^+, π^- and π^0) are mesons.

(i) $\pi^- + p \rightarrow n + \pi^- + \pi^+ + \pi^0$

....

....

....

(ii) $p + p \rightarrow p + p + p + \bar{p}$

....

....

....

(4)

(e) Read the short passage below and answer the questions about it.

Electromagnetic radiation consists of tiny packets of energy called photons. Energy is conserved whenever these are emitted or absorbed. However, photons that do not conserve energy also exist. These are called virtual photons. They borrow energy that must be repaid in accordance with Heisenberg's Uncertainty Principle which states that:

$$\text{Borrowed energy} \times \text{time for loan} \approx 1.1 \times 10^{-34} \text{ J s.}$$

The difference in ranges of the electromagnetic and the weak interactions can now be explained. A large quantity of energy must be borrowed to create the massive W^-, W+, Z^0 exchange particles. This loan must be paid back very quickly. The exchange particles cannot move far in this short time. In contrast, virtual photons are massless and hence can travel an infinite distance.
[Adapted from *The Standard Model* by C Sutton; CERN Courier, June 1994]

What is a photon?

....

....
(1)

How do virtual photons differ from ordinary photons?

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....

....
(1)

Complete the table below which shows some properties of two fundamental interactions.

Interaction	Exchange particle(s)	Mass of exchange particle(s)	Range of interaction
Electromagnetic	Photon		
Weak		$\approx 90 \times m_{\text{proton}}$	< diameter nucleus

(3)

The energy required to create a W^+ is 1.4×10^{-8} J.

Calculate the time for which this energy can be borrowed.

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(2)

Use your value to estimate the maximum possible range of a W^+. (No particle can travel faster than the speed of light.)

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(2)
(Total 32 marks)

76. (a) State one similarity and two differences between alpha and beta radiation.

Similarity ....

Difference 1 ....

....

Difference 2 ....

....

(3)

(b) Complete the table below.

X-ray use	Typical accelerating voltage	Dependence of X-ray absorption on proton number
Diagnosis		
Therapy		

(4)

When using X-rays for therapy it is important that healthy tissue receives as low a dose as possible.

State and explain one way in which these low doses are achieved.

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(3)

(c) The specific acoustic impedance Z of a material is calculated by multiplying its density by the speed of sound in the material. Show that Z has the units kg m^{-2} s^{-1}.

....

....

(2)

Data:

$$Z_{air} = 400 \text{ kg m}^{-2} \text{ s}^{-1}$$
$$Z_{soft\ tissue} = 1.6 \times 10^{6} \text{ kg m}^{-2} \text{ s}^{-1}$$

Use this information to help you explain why it is impossible to use ultrasound to investigate any part of the body which is behind the lungs. You may be awarded a mark for the clarity of your answer.

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(5)

Give a reason why ultrasound is preferred to X-rays for examining unborn babies.

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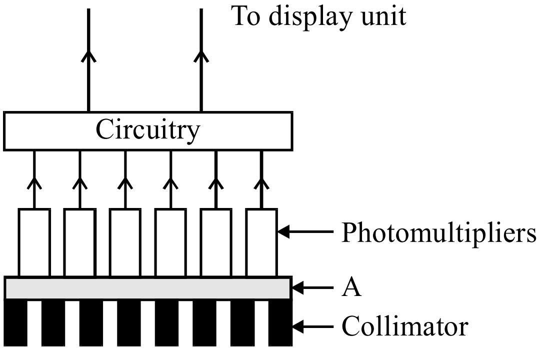
(1)

(d) The diagram shows the essential features of a simple gamma camera.



Add a label to the arrow marked A.

(1)

What is the purpose of the collimator and from what material is it made?

....

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(2)

Describe one physical process that takes place in a photomultiplier.

....

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(2)

(e) Read the short passage below and answer the questions about it.

> $^{99m}_{43}Tc$ is a γ emitting radionuclide of half-life 6 hours used in tracer studies. It is 43 produced when the radionuclide $^{99}_{42}Mo$ decays by β emission. This decay has a half life of 67 hours. Because of its short half-life $^{99m}_{43}Tc$ must be produced in portable generators. These contain the parent isotope $^{99}_{42}Mo$. When required the $^{99m}_{43}Tc$ is obtained by flushing salt solution through the generator, a process known as elution. The molybdenum is not removed by this process and after approximately 1 day enough new daughter isotope will have been produced for another elution to take place. The generator needs replacing approximately weekly since the $^{99}_{42}Mo$ activity falls to an inadequate level after this time.
> [Adapted from *Medical Physics Imaging* by J Pope]

Explain what is meant by elution.

....

....

....

(1)

Write a nuclear equation for the decay of molybdenum.

(2)

Why must $^{99m}_{43}Tc$ be produced in portable generators?

....

....

....

(1)

Show that after 1 week the activity of the $^{99}_{42}\text{Mo}$ in a portable generator would have fallen to less than $\frac{1}{4}$ of its original value.

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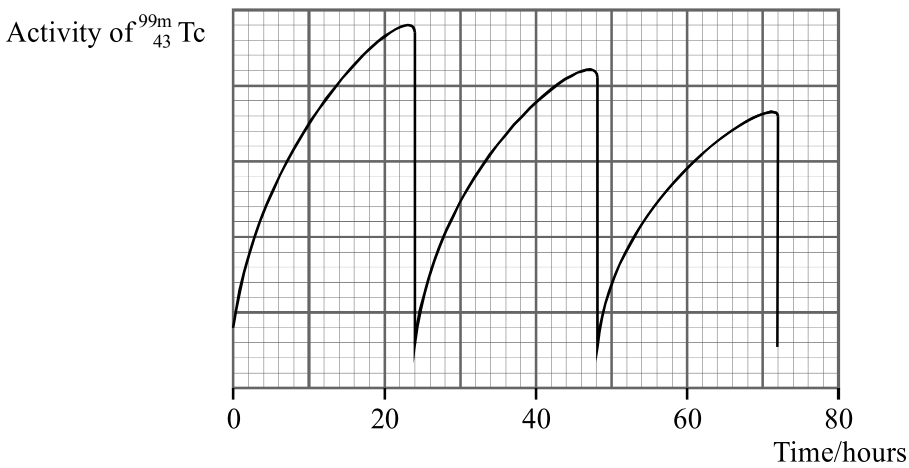
(2)

The sketch graph shows how the activity of the $^{99m}_{43}\text{Tc}$ in a generator varies with time.



Indicate on the graph the time at which the second elution takes place.

(1)

Explain why successive Tc activity peaks are smaller.

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(1)

Why is it advisable to leave a period of approximately 1 day between elutions?

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(1)
(Total 32 marks)

77. (a) (i) Taking care not o damage the wire, determine values for the length l and the average diameter d.

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Explain why it is necessary to take several values of d.

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(4)

(ii) Calculate the volume V of the wire given that

$$V = \frac{\pi d^2 l}{4}$$

....

....

Using the top pan balance, measure the mass of the wire and hence find a value for the density of the material of the wire.

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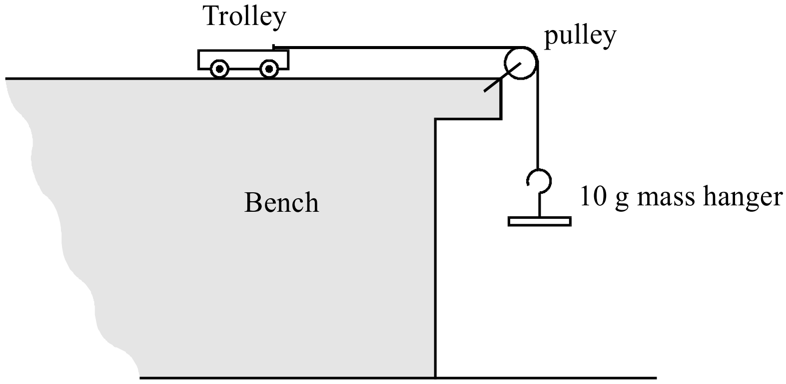
(3)

(b) (i) The apparatus shown in the diagram has been set up for you.



Add masses to the mass hanger until it is clear that the trolley accelerates across the table. Record the total mass m used to accelerate the trolley in the space below.

m = ...

Determine the average time t taken for the trolley to travel a distance x = 0.500 m from the rest when accelerated by this mass.

....

....

Calculate the acceleration a of the trolley given that

$$a = \frac{2x}{t^2}$$

....

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....

....

(6)

(ii) Explain, with the aid of a diagram, how you ensured that the trolley travlled a distance of 0.0500 m in the measured time.

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(3)

(c) (i) Shake the beaker, which contains 48 coins (or discs), and throw the coins (or discs) into the tray. Remove all the coins which land with the head uppermost (or discs with the cross uppermost) and record the number *N* of coins (or discs) remaining in the tray. Place these coins (or discs) back int he beaker and repeat this process for three more throws. Tabulate *N* and the number *x* of throws in the space below.

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Using the grid below plot a graph of *N* against *x*. Draw the line of best fit through your points.

(5)

(ii) Discuss the extent to which your curve is a representation of a radioactive decay.

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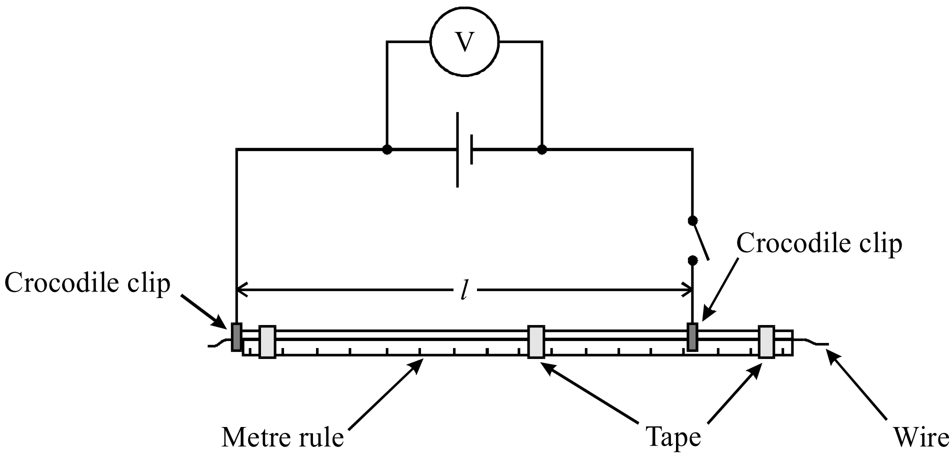
(3)
(Total 24 marks)

78. (a) Set up the circuit as shown in the diagram. The length of wire has already been attached to the metre rule. You should attach the crocodile clips to the wire so that the length l is 0.800 m. Before you close the switch have your circuit checked by the Supervisor. You will be allowed a short time to correct any faults, but if you are unable to set up the circuit, the Supervisor will set it up for you. You will only lose 2 marks for this.



(2)

(b) You may assume that the voltmeter is an ideal voltmeter which takes no current. Use your circuit to determine the e.m.f. $\mathcal{E}$ of the cell and the potential difference V across the length l = 0.800 m.

$\mathcal{E}$ = ...

V = ...

If you are unable to do this ask the Supervisor for the card which will give you brief instructions. You will only lose 2 marks for this.

Leave the switch **open** when you have taken your readings.

(2)

(c) An equation which applies to this arrangement is

$$\frac{\varepsilon}{V} = 1 + \frac{k}{l}$$

Use you results from part (b) to determine a value for *k*.

....

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(2)

(d) (i) Repeat part (b) using a length *l* of 0.400 m. Record your new values of ε and *V*, and calculate a second value for *k*.

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(3)

(ii) Explain, using your knowledge of electrical circuits, any changes which occur in the values of $\mathcal{E}$ and V.

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(5)

(e) (i) Calculate the percentage difference between your two values of *k*. Comment on the extent to which the value of *k* may be regarded as constant if experimental errors amount to approximately 5%.

....

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....

....

(ii) The constant *k* is given by

$$k = \frac{\pi d^2 r}{4p}$$

where r = internal resistance of the cell,
d = diameter of the wire (given on card),
ρ = resistivity of the material of the wire = 4.9×10^{-7} Ω m.

Using the average of your values for k calculate a value for the internal resistance of the cell.

....

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....

(4)

(f) Assuming that both $\mathcal{E}$ and k remain constant, the equation in part (c) may be investigated by plotting a graph of $1/V$ against $1/l$.

(i) Explain carefully how you would carry out the experiment to plot this graph.

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(ii) Sketch the graph you would expect to obtain.

(iii) Explain how both $\mathcal{E}$ and k could be obtained from the results.

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(6)
(Total 24 marks)

79. (a) State two advantages of positioning an optical telescope on the top of a mountain.

1 ....

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2 ....

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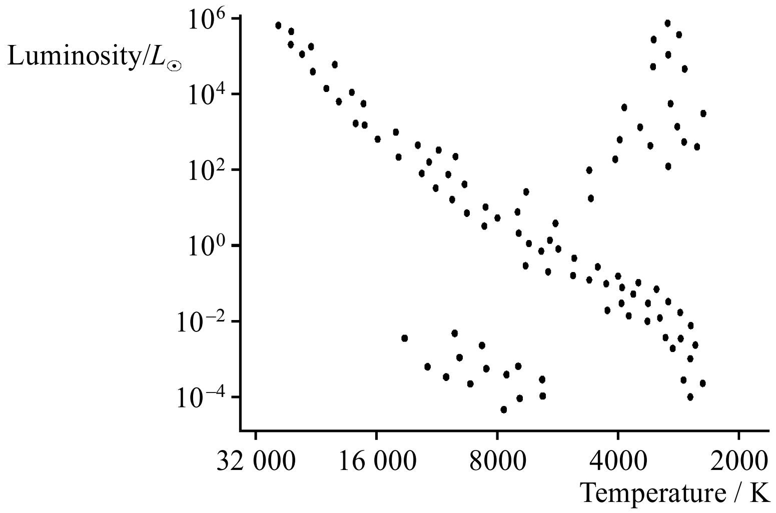
(2)

(b) The table shows the properties of three stars.

	Star	Luminosity/$L_{\odot}$	Temperature/K
A	α Ori	6×10^4	3500
B	Procy B	3×10^{-4}	7000
C	β Per	2×10^2	12 000

On the Hertzsprung-Russell diagram below, mark with an x_A, x_B and x_C the approximate position of each of the three stars.



(1)

State whether each star is a main sequence star, a red giant or a white dwarf.

α Ori ....

Procy B ....

β Per ....

(3)

Use the Stefan-Boltzmann law to calculate the surface area and hence the radius of α Ori. (Luminosity of the Sun = 3.8×10^{26} W.)

....

....

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Surface area = ...

....

....

Radius = ...

(5)

(c) Explain why the term **light year** is a measure of distance and not of time.

....

.... **(1)**

Show that the light year is equivalent to a distance of approximately 9×10^{15} m.

....

....

.... **(2)**

Explain why the annual parallax method is only suitable for measuring the distance to nearby stars.

....

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.... **(3)**

(d) What is a supernova?

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....

Describe briefly what happens during the formation of a supernova. You may be awarded a mark for the clarity of your answer.

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(5)

What are the two possible fates for the central core remnant from a supernova explosion?

....

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(2)

(e) Read the short passage below and answer the questions about it.

Brown dwarfs are faint objects which radiate mainly in the near infra-red part of the spectrum. Analysing the spectra of faint objects can reveal whether they are stars or brown dwarfs. Gliese 570D one of the coolest brown dwarfs detected, has a surface temperature of about 750 K. The spectrum of Gliese 570D shows the presence of methane, the molecules of which break apart in the hotter atmosphere of stars. The spectrum of another brown dwarf PPL 15 indicates the presence of lithium. All stars achieve a sufficiently high core temperature to convert hydrogen to helium. Therefore even a low mass star would consume whatever lithium it originally had in approximately 100 million years, since this nuclear reaction occurs at a slightly lower temperature than hydrogen “burning”.

Use Wien’s law to show that Gliese 570D radiates mainly in the infra-red region of the electromagnetic spectrum. (The visible reaction extends from 400 nm to 700 nm.)

....

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....

(3)

Why are brown dwarfs cooler than 750 K extremely difficult to detect?

....

....

....

What nuclear process distinguishes stars from brown dwarfs?

....

....

(1)

Lithium is destroyed in the core of a star when a proton collides with a nucleus of ${}^{7}_{3}\mathrm{Li}$ creating two helium nuclei, ${}^{4}_{2}\mathrm{He}$. Write a nuclear equation for this reaction.

....

(2)

Why might a very young low mass star be mistaken for a brown dwarf?

....

....

(1)
(Total 32 marks)

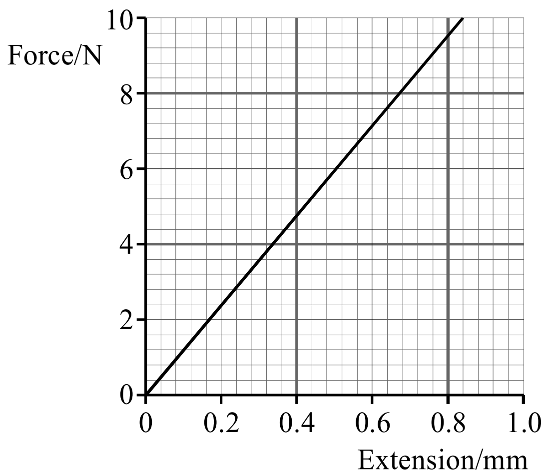
80. (a) Calculate the stress in a steel wire of length 2.6 m and cross-sectional area 1.5×10^{-7} m^2 when it is subjected to a tensile force of 8.0 N.

....

....

(2)

Part of a force-extension graph for such a steel wire is shown below.



Use the graph to find the extension of the wire for an applied force of 8.0 N.

....

Show that the corresponding strain in the wire is approximately 3×10^{-4}.

....

....

Hence determine the Young modulus for steel.

....

....

....

Young modulus = ...

(4)

Calculate the work done in stretching the wire by 0.4 mm.

....

....

....

Work done = ...

(3)

A second wire is made of the same steel. It has the same cross-sectional area but twice the length.

On the same axes draw the force-extension graph for this wire.

(2)

(b) A horizontal concrete beam rests on two pillars, one at each end, forming a bridge. It supports a large load at its centre. Draw the concrete beam and show the regions of the beam which are in tension and the regions which are in compression.

(2)

Explain why microscopic cracks in the lower surface of the beam are more dangerous than any which form in the upper surface of the beam. You may be awarded a mark for the clarity of your answer.

....

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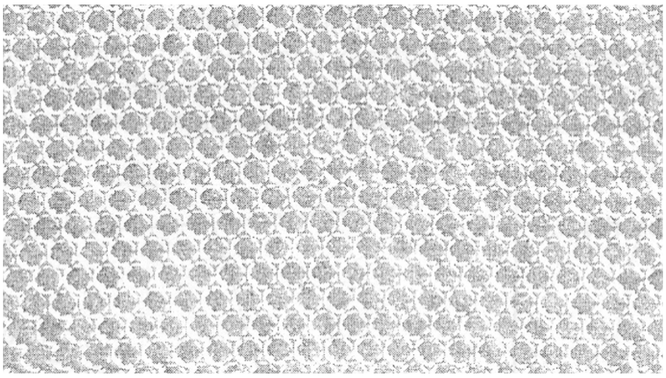
....

(3)

(c) The photograph is of a bubble raft model of an edge dislocation.



What do the bubbles represent?

....

(1)

Indicate on the photograph where the "dislocation" in the bubble raft occurs.

(1)

(d) The table gives the properties of three different materials.

	Ultimate tensile stress/10^6 N m^{-2}	Young modulus/10^9 Pa
A	0.7	30
B	100	2
C	650	40

Use this data to describe each material as either strong or weak and either stiff or flexible.

Material A is .... and ....

Material B is .... and ....

Material C is .... and ....

(3)

The materials are CFRP (carbon fibre reinforced polymer), nylon and polythene. Identify A, B and C.

A is .... B is .... C is ....

(2)

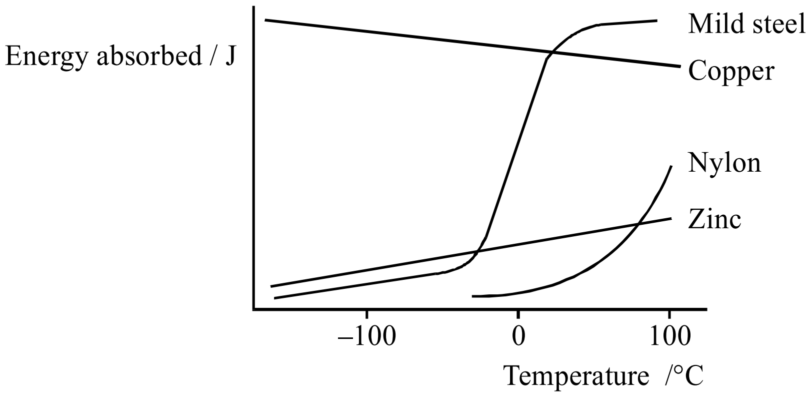
State which of these materials is/are a composite material(s).

....

(1)

(e) Read the short passage below and answer the questions about it.

The toughness of a material can be measured by the energy it absorbs during fracture. Toughness can change with temperature. Materials which are considered to be tough and exhibit ductile failure at room temperature may be brittle at low temperatures. Brittle failure can occur without warning. It has been suggested that temperatures in the North Atlantic at the time of the sinking of the Titanic were such that the steel of the ship's hull was brittle. Ductile-brittle transition curves for some materials are shown below. Different steels have different transition temperatures so provided the correct steel is selected there are no problems in, for example, laying oil pipelines across Alaska (where winter temperatures can be as low as –30 °C).



[Adapted from the *Institute of Materials Teacher Pack* by Claire Davis]

Explain the meaning of the terms

(i) ductile ....

....

(ii) transition temperature ....

....

(2)

Suggest the temperature below which a component made from mild steel risks brittle failure.

....

(1)

Which of the materials on the graph would **not** be at risk of brittle failure at low temperatures? Explain your answer.

....

....

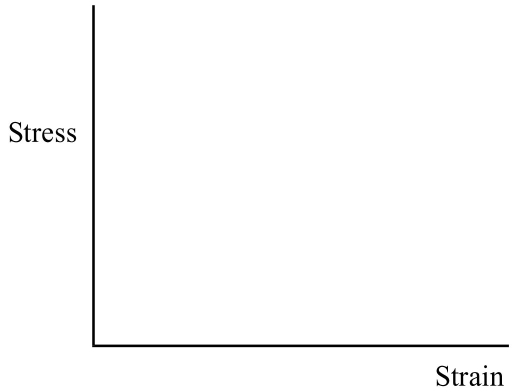
....

(2)

Add to the graph the transition curve of a steel suitable for making pipelines which would be laid in Alaska.

(1)

On the axes below sketch a stress-strain graph to breaking point for mild steel above its ductile-brittle transition temperature.



(2)
(Total 32 marks)

81. (a) A stationary neutron can decay to a proton and an electron. Use the data below to predict the maximum total kinetic energy of the electron and the proton in MeV.

Data: mass of neutron	=	1.008 665u
mass of proton	=	1.007 276u
mass of electron	=	0.000 549u
1u	=	930 MeV

....

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....

Kinetic energy = ... MeV

(3)

Explain why the principle of conservation of linear momentum tells you that almost all this kinetic energy is given to the electron.

....

....

....

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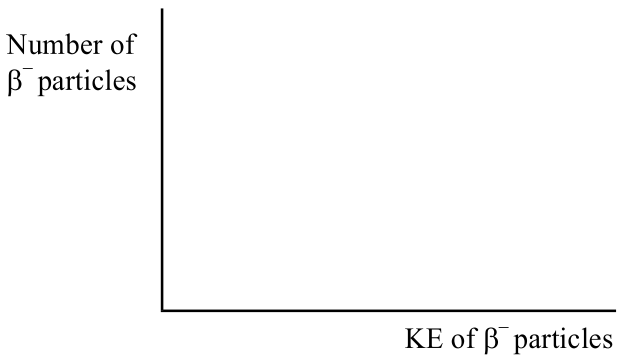
....

(2)

On the axes below sketch a graph showing the energy spectrum for the particles produced during beta decay. Add a scale to the horizontal axis.



(3)

Explain why the shape of this graph led to the prediction of the existence of neutrinos. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

(3)

(b) State one similarity and one difference between a proton and an antiproton.

Similarity ....

Difference ....

....

(2)

Write down two particle-antiparticle pairs of leptons.

....

.... **(2)**

What happens when a particle and its antiparticle collide?

....

....

(c) Use the laws of conservation of charge and baryon number to decide whether the following interactions are possible or not. In each case show how you applied the laws.

$$\Delta^{++} \rightarrow p + \pi^{+}$$
$$(uuu) \qquad (u\bar{d})$$

....

.... **(2)**

$$\Delta^{-} \rightarrow n + \pi^{-}$$
$$(ddd) \qquad (u\bar{d})$$

....

.... **(2)**

These two decays are examples of strong interactions.
What exchange particle is responsible for the decays?

.... **(1)**

Delta particles are baryons consisting of u and d quarks only. Two more members of the delta particle family are the Δ^{+} and the Δ^{0}. These are excited states of the proton and the neutron.

State the quark composition of the Δ^{+} and the Δ^{0}

Δ^{+} .... Δ^{0} .... **(2)**

(d) Read the short passage below and answer the questions about it.

> Pions (π^+, π^-, π^0) are created in the upper atmosphere when cosmic rays collide with protons. Pions are unstable and decay rapidly. All unstable particles decay into particles lighter than themselves. For example, neutrons decay into protons. Since pions are the lightest of the hadrons they cannot decay by means of the strong interaction. They would be stable if they were not also subject to the electromagnetic and weak interactions. π^+ and π^- decay within 10^{-8} s by the weak interaction to produce positive and negative muons which then decay to positrons and electrons. The π^0 decays within 10^{-16} s by the electromagnetic interaction to two gamma ray photons.
>
> [Adapted from *The Particle Explosion,* by Close, Marten and Sutton]

What is a hadron?

....

....

(1)

List all the leptons mentioned in the passage.

....

(1)

Why are pions unable to decay by means of the strong interaction?

....

....

(1)

Complete the following sentence by circling the appropriate word inside the brackets.

Pions which decay by the weak interaction have a {shorter / similar / longer} lifetime than those which decay by the electromagnetic interaction.

(1)

A positive pion π^+ has a quark composition $u\bar{d}$. State one possible quark composition of a neutral pion π^0.

....

(1)

Draw a Feynman diagram showing the decay of a neutron to a proton,
$n \rightarrow p + e^- + \bar{\nu}_e$.

(2)

Why must this be a weak interaction?

....

....

(1)

Label the exchange particle on your Feynman diagram.

(1)
(Total 32 marks)

82. (a) A patient's thyroid function is to be investigated by means of a radionuclide tracer.

Iodine accumulates in the thyroid. Which of the three isotopes of iodine listed below would be most suitable for such an investigation?

Isotope	Mode of decay	Half-life
$^{123}_{53}I$	γ	13 hours
$^{125}_{53}I$	γ	60 days
$^{131}_{53}I$	β^- and γ	8 days

Most suitable isotope ....
(1)

Explain why the other two isotopes would **not** be appropriate.

....

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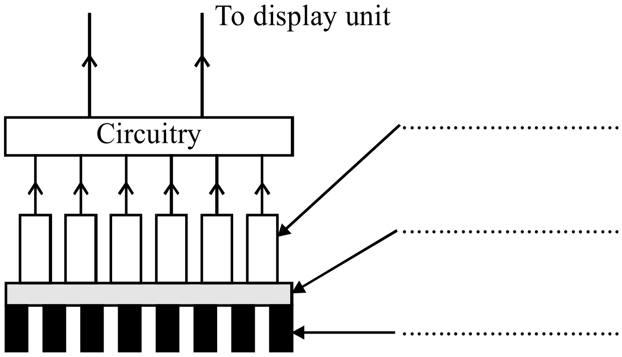
....
(2)

The diagram shows the main features of a gamma camera suitable for monitoring the patient. Label the three parts indicated by the arrows.



(3)

(b) An X-ray tube operating at 65 kV has a tube current of 0.12 A. It produces X-rays with an efficiency of 0.8%. Calculate the rate of production of heat at the anode.

....

....

....

Rate of production of heat = ...
(3)

What feature of the X-ray tube helps dissipate this energy?

....
(1)

Would the X-rays produced by this tube be more suitable for diagnosis or therapy? Justify your answer.

....

....

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....

....

(3)

(c) State two advantages of using ultrasound for diagnosis compared with using X-rays for diagnosis

1 ....

....

2 ....

....

(2)

Explain why high frequency ultrasound is used for scanning an eye but a lower frequency is more suitable for abdominal scans. You may be awarded a mark for the clarity of your answer.

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(3)

Suggest an appropriate wavelength for the ultrasound to be used in an eye investigation. Hence calculate a suitable frequency for such an investigation.
(Speed of sound in water = 1.5×10^3 m s^{-1}.)

....

....

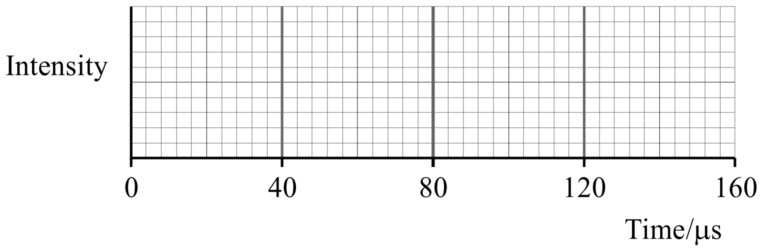
....

Frequency = ...

(3)

During an ultrasound scan single pulses of ultrasound are transmitted at regular intervals. Typically pulses of duration 10 μs are transmitted at 120 μs intervals.

On the grid below draw a scale diagram showing two consecutive pulses.



(2)

Why is it important that the pulses are well separated?

....

....

....

(1)

(d) Read the short passage below and answer the questions about it.

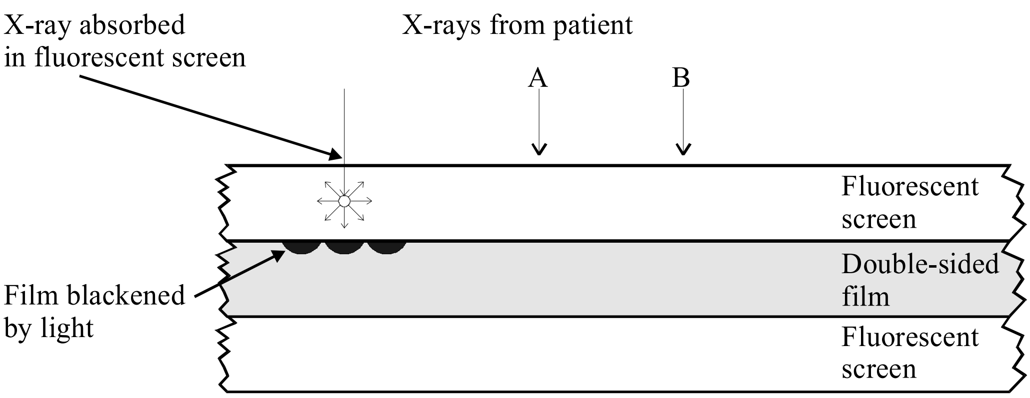
> Most of the X-rays falling on a photographic film pass straight through without any interaction. Light, however, is readily absorbed by photographic film. In a simple intensifying system two fluorescent screens are placed either side of a double-sided photographic film. X-rays from the patient penetrate the film and the two fluorescent screens. The fluorescent screens absorb the X-radiation and re-emit visible radiation in a pattern duplicating that of the original X-ray beam. The main film blackening results from the light emitted in the fluorescent screens. Modern intensifying systems can give intensification factors of up to 250. However, some detail is lost due to the diffusion of light from the fluorescent screens.
> [Adapted from *Medical Physics Imaging* by J. Pope]

Why is photographic film alone not a very sensitive way of detecting X-rays?

....

(1)

The diagram below shows how an intensifying system operates.



Complete the diagram for

(i) X-ray A, which produces direct blackening of the photographic film.

(1)

(ii) X-ray B, which produces blackening of the film after absorption in the lower fluorescent screen.

(2)

State the meaning of the term fluorescent.

....

....

(1)

Explain the benefit to the patient of using an intensifying system.

....

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....

....

(2)

What is the disadvantage of using an intensifying system?

....

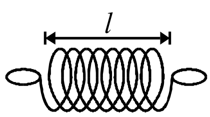
....

(1)
(Total 32 marks)

83. (a) (i) Count the number of turns *N* in the coiled part of the spring.

....

Measure as precisely as possible the length *l* of the coiled part of the spring when the coils are just touching.



....

....

Use your values of N and l to determine a value for the diameter d of the wire from which the spring is constructed.

....

.... **(4)**

(ii) Use the apparatus provided to find the extension x of the spring when different masses m are suspended vertically from the spring.

Plot a graph of x against m. Hence determine the mass M of the wooden block.

Show all your results below and use the grid below to plot your graph.

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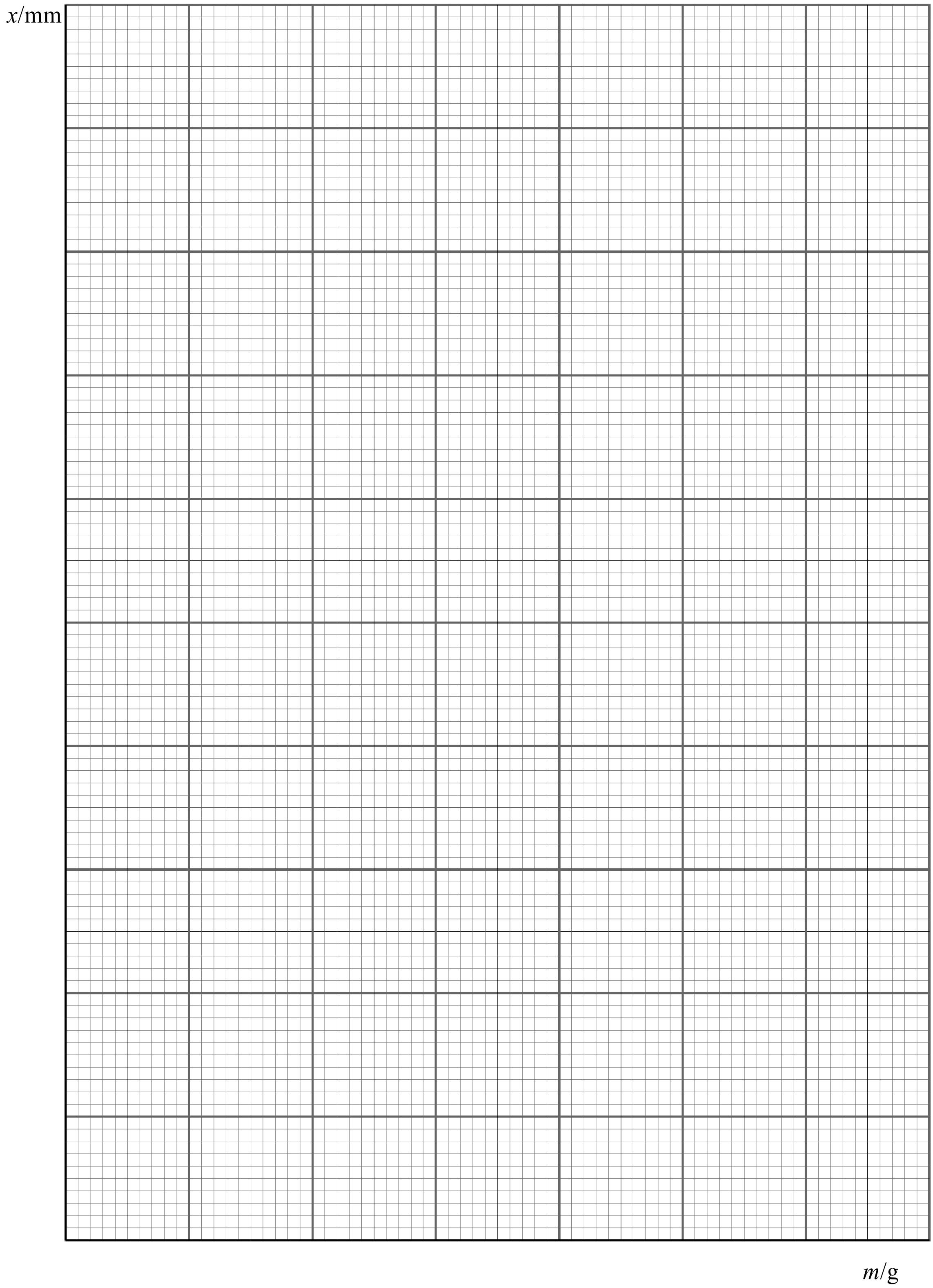

(8)

(b) (i) Use the electronic balance provided to find the mass of th*e candle and card. Use this mass and the data on the card to calculate the mass* m of the candle.

....

Pour 100 ml (cm^3) of water into the Pyrex beaker and place the candle under the beaker. **(Do not adjust the height of the beaker.)**

Use the candle to heat the water for 5.0 minutes and find the rise in temperature $\Delta\theta$ that this produces. Show your readings below and state any precautions that you took to ensure accuracy.

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....

Calculate a value for the power P of the candle assuming that

$$P = \frac{k\Delta\theta}{\Delta t}$$

where $k = 500\ \mathrm{J\ K^{-1}}$ and Δt = time for which water was heated.

....

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....

....

(6)

(ii) Use the balance to find the new mass of the candle and card. Hence find the mass Δm of wax that was burnt whilst heating the water.

....

....

Use this value of Δm and your value of m from part (i) to estimate for how long the candle would burn.

....

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The manufacturer claims that the candle "gives as much light as a small lamp and will last all night". To what extent does your experiment support this?

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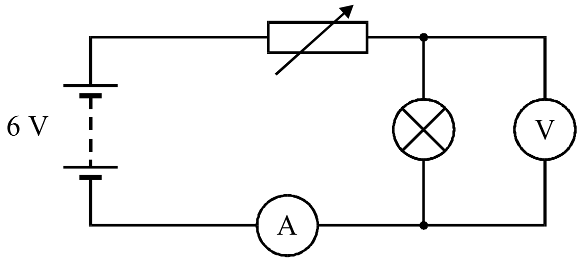
(6)
(Total 24 marks)

84. (a) (i) Set up circuit A as shown below.



Have your circuit checked by the Supervisor before switching on the power supply. You will be allowed a short time to correct any faults, but if you are unable to set up the circuit the Supervisor will set it up for you. You will only lose up to 3 marks for this.

Make measurements to determine the maximum and minimum values of current that this circuit can pass through the lamp.

....

(5)

(ii) Measure the p.d. V across the lamp when the current I is at its minimum value. Hence find the resistance R of the lamp.

....

....

....

Repeat the above to find the resistance of the lamp when the current is at its maximum value.

....

....

....

Discuss whether the lamp obeys Ohm's law.

....

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(5)

(b) (i) It is suggested that $R = k\sqrt{I}$ where k is a constant.

Assuming that the total percentage uncertainty of the meters is 10%, discuss the extent to which your results confirm this relationship.

....

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(4)

(ii) Draw a circuit diagram to show how you would use the variable resistor as a potential divider to further investigate this relationship for values of I in the range 0–60 mA.

Describe how you would take the necessary readings.

....

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....

Sketch the graph you would plot and state how you would use it to find a value for k.

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(10)
(Total 24 marks)

85. (a) (i) Determine as precisely as possible a value for the diameter d of the golf ball.

....

....

Calculate the volume V of the golf ball using $V = \pi d^3/6$.

....

Use the balance provided to find the mass m of the golf ball and hence a value for the average density p of the material from which it is made.

....

(5)

(ii) Golf balls are sold in packs of three. If the packet is rectangular in shape, and the three golf balls just fit inside, how much "wasted space" is there in the packet?

....

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....

If the packet is made from rigid plastic, describe how you could check your answer experimentally.

....

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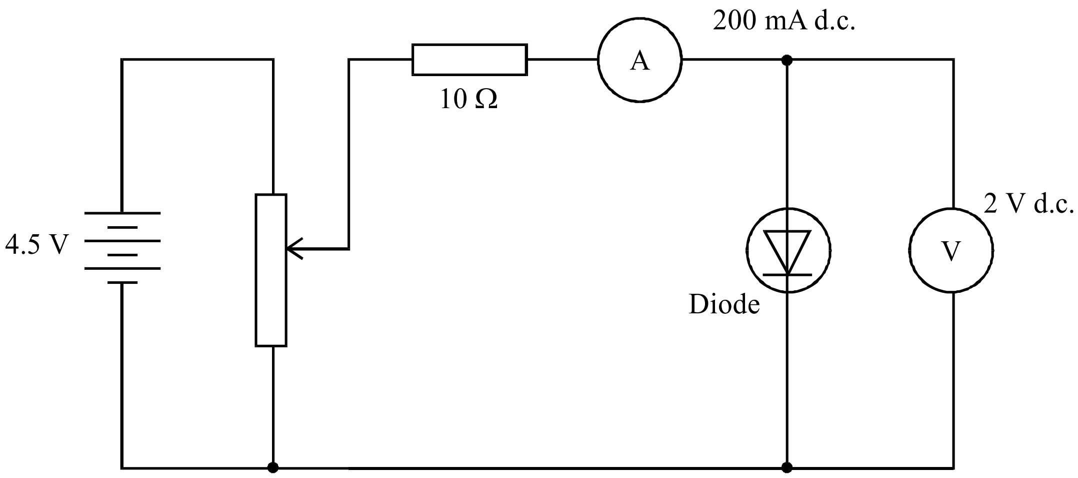
(5)

(b) (i) Set up the circuit below to find the current *I* in the diode for a range of potential differences *V* across it up to a maximum current of 100 mA.



Have your circuit checked by the Supervisor before connecting the power supply. You will be allowed a short time to correct any faults, but if you are unable to set up the circuit the Supervisor will set it up for you. You will only lose up to 3 marks for this.

(3)

(ii) Now carry out your experiment, recording your observations below.

DISCONNECT THE POWER SUPPLY AS SOON AS YOU HAVE TAKEN YOUR READINGS.

....

....

....

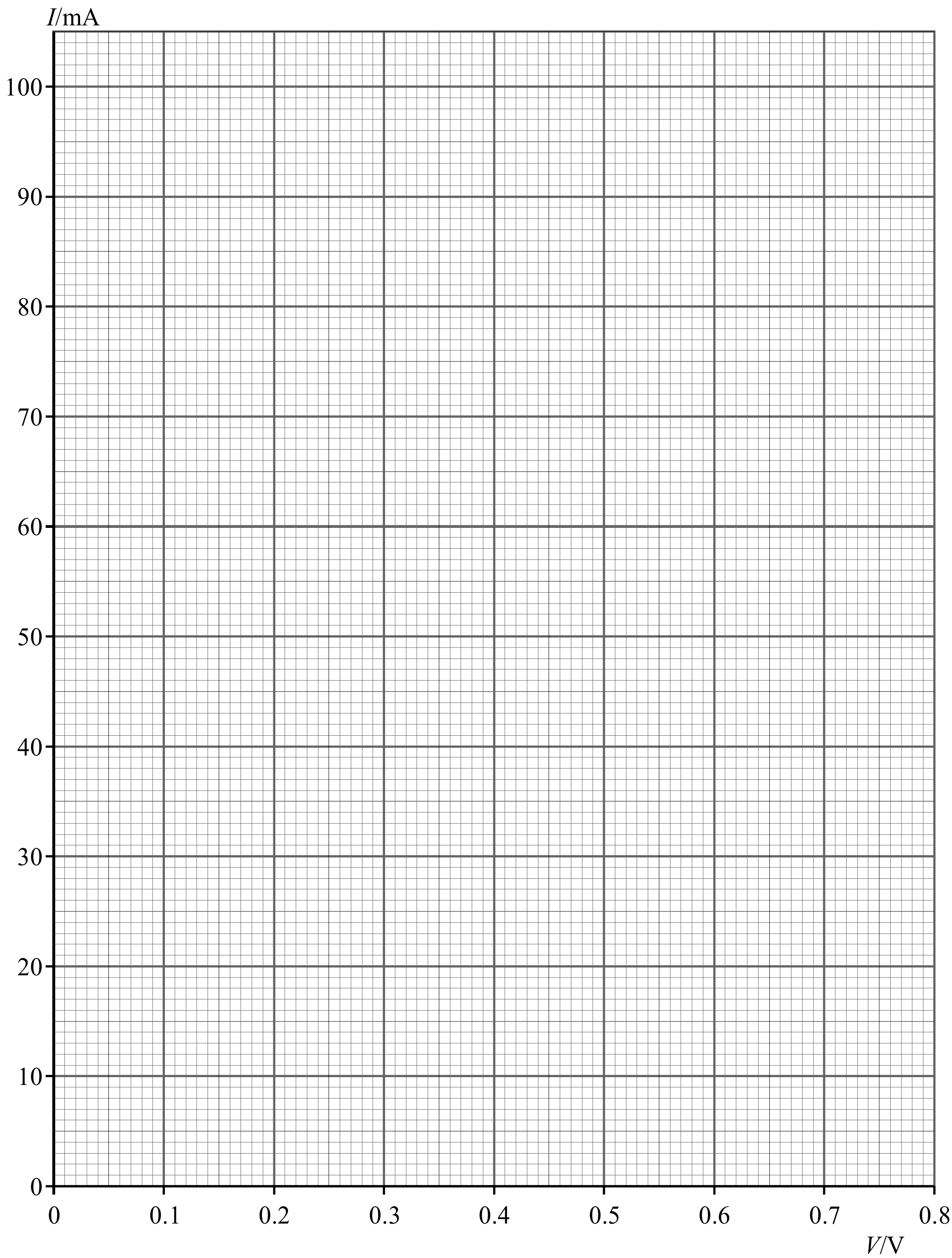
....

....

....

(5)

(iii) Plot a graph of the current I against the p.d. V on the grid below.



(2)

(iv) Use your graph to determine the resistance of the diode when the p.d. across it is 0.70 V.

....

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....

What is the current through the diode when its resistance is 50 Ω?

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(4)
(Total 24 marks)

86. (a) The depression x at the centre of a rule supported symmetrically between two knife edges is given by the expression

$$x = \frac{Mgl^3}{4Ebd^3}$$

where M = mass suspended at centre of rule
g = gravitational field strength
l = distance between knife edges
b = width of rule
d = thickness of rule
E = a property of the material of the rule, called its Young modulus.

(i) Make accurate measurements of b and d for the **metre rule**.

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....

(4)

(ii) Set up the apparatus to enable you to determine a value for x when $l = 0.800$ m and $M = 1.00$ kg.

Draw a diagram of your arrangement in the space below, showing clearly your values of l and x. Explain, with the aid of your diagram, how you measured x as accurately as possible.

....

....

....

....

(5)

(iii) Record your value of x. Estimate the percentage uncertainty in your value.

....

....

....

(2)

(iv) Use your measurements to calculate a value for E. The unit for E is kg m^{-1} s^{-2}.

....

....

....

....

(3)

(b) You are to plan how the experiment could be further developed to investigate the relationship between x and l given by the expression in (a), using only the apparatus provided.

(i) Describe the readings that you would take.

....

....

(2)

(ii) Sketch the graph you would plot.

Explain how you would use your graph to test the relationship.

....

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....

(4)

(iii) Explain how you would use your graph to calculate a value for *E*.

....

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....

Explain why using your graph in this way gives a more accurate value for *E* than your value in part (a).

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(4)
(Total 24 marks)

87. (a) The intensity of solar radiation at the top of the Earth's atmosphere is 1.4 kW m^{-2}. The Sun's average distance from the Earth is 1.5×10^{11} m.

Show that the luminosity of the Sun is approximately 4×10^{26} W.

....

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(3)

Why is the intensity at the top of the Earth's atmosphere used in this calculation?

....

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(1)

The Sun's energy is produced when hydrogen 'burns' to form helium. Four protons are required to make each helium nucleus. Use the data below to estimate the energy released for each helium nucleus created. (Your answer will be only approximate as it ignores the positrons which are also released in the process.)

Data: mass of proton = 1.67×10^{-27} kg
mass of helium nucleus = 6.64×10^{-27} kg

....

....

....

Energy released = ...

(4)

Show that the number of helium nuclei created per second in the Sun is approximately 1×10^{38}.

....

....

....

(1)

Hence estimate the mass of hydrogen burned per second in the Sun.

....

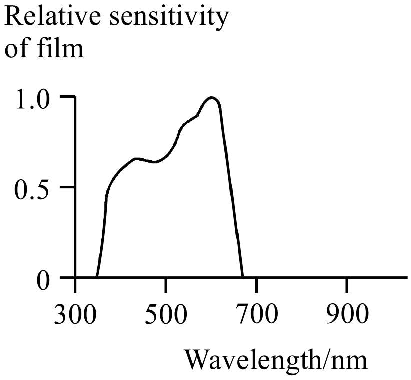
....

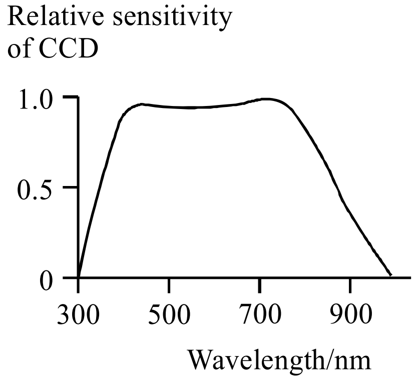
....

Mass of hydrogen = ...

(2)

(b) The graphs show the sensitivity of a particular brand of photographic film and that of a charge coupled device, CCD, to different parts of the electromagnetic spectrum.





The surface temperature of a star can be calculated once the wavelength of the peak of its spectrum (λ_{max}) is known. Use the graphs to explain why photographic film would be less suitable than CCDs for determining λ_{max} of a star which radiates mainly in the visible region (400 nm – 700 nm) of the electromagnetic spectrum.

....

....

....

....

....

(3)

State one other advantage of using CCDs suggested by these graphs.

....

(1)

(c) State what happens to the hydrogen 'burning' process in a star as it moves off the main sequence to become a red giant.

....

....

....

(2)

Why is a red giant more luminous than the main sequence star from which it originated, even though its temperature is lower?

....

....

(1)

(d) Describe how observations of Cepheid variable stars are used to estimate the distance to nearby galaxies. You may be awarded a mark for the clarity of your answer.

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(5)

(e) Read the short passage below and answer the questions about it.

> In a simple binary system two stars move in circular orbits of different radii about a common centre. The two stars take the same time T to complete one revolution. If the binary system is viewed more or less edge-on the stars periodically pass in front of one another, reducing the amount of light that reaches us. Such a system is called an eclipsing binary and can be detected from its light curve, which is a plot showing how the observed light intensity varies with time. Once the orbital period T has been determined the total mass M of the binary system can be calculated from the relationship $M = 4\pi^2 d^3 / GT^2$ where d is the sum of the radii and G is the gravitational constant.
>
> [Adapted from TRUMP *Astrophysics Project*]

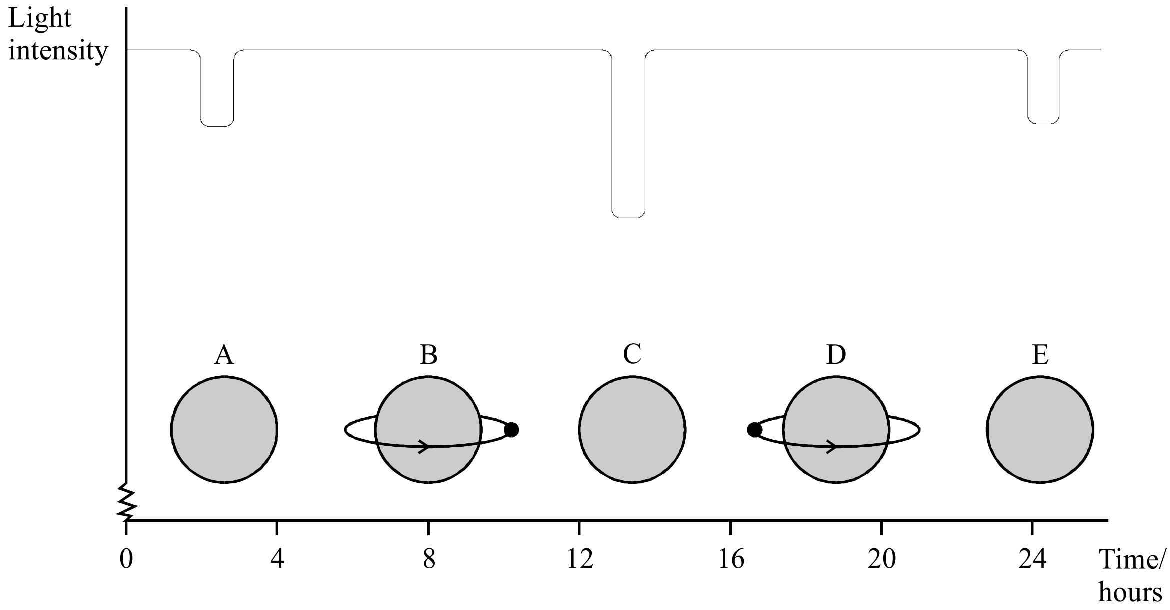
Explain the meaning of the term **binary system.**

....

....

(1)

The light curve for an eclipsing binary consisting of a small very bright star and a much larger star is shown below. The system is being viewed edge-on. Diagrams B and D (not to scale) show the relative positions of the small and large star at two times between the dips in the light curve.



Complete diagrams A, C and E to show the positions of the small bright star at the times of the dips in the light curve.

(2)

Explain why the dip in the curve at A is smaller than the dip at C.

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(2)

Estimate the orbital period of this binary.

....

(1)

Approximately how long does it take the small star to cross the disc of the larger one?

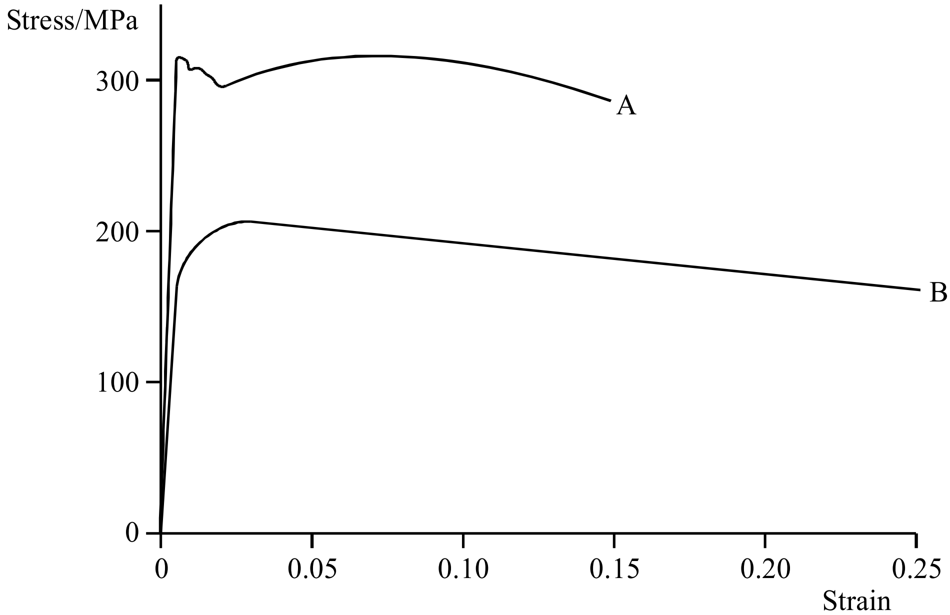
....

(1)

On the light curve above show how the observed light intensity varies with time when this system is viewed perpendicular to the plane of the orbits.

(2)
(Total 32 marks)

88. (a) Typical stress-strain curves for two metals, A and B, up to their breaking points are shown below.



Which metal is stiffer? Justify your answer.

....

....

(1)

Stating appropriate magnitudes where possible, explain which metal is

(i) stronger ....

....

....

(ii) more ductile ....

....

....

(2)

The two metals are mild steel and copper. Identify A and B.

A = ... B = ...

(1)

Estimate the work done per unit volume in stretching material A to its breaking point.

....

....

....

....

Work done per unit volume = ...

(3)

High carbon steel can be made harder and more brittle if it is quench hardened. State what is involved in this process.

....

....

....

(2)

(b) Draw a labelled diagram of the apparatus you could use in a school laboratory to determine the Young modulus of copper in the form of a wire.

(3)

Suggest an appropriate length for the wire being tested.

....

How would you determine the cross-sectional area of the wire?

....

....

....

....

(3)

State the unit of *k*, the constant of proportionality in Hooke's law.

....

(1)

Show that for a wire of length *l* and cross-sectional area *A* the Young modulus $E = kl/A$.

....

....

....

(3)

(c) Describe how a pre-stressed reinforced concrete beam is produced. You may be awarded a mark for the clarity of your answer.

....

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....

(4)

(d) Read the short passage below and answer the questions about it.

> Copper deforms and breaks at stresses much lower than its 'theoretical' strength. Most successful attempts to increase the strength of crystalline materials have centred upon stopping the movement of dislocations by introducing defects into the lattice or by creating a tangle of dislocations. Weak materials can also be strengthened by including tough filaments such as glass fibres in them. Unfortunately, increasing the number of obstacles also interferes with the movement of electrons in the material. A new family of composites has been developed featuring much finer filaments which are much more closely spaced. A tangle of ultrafine niobium filaments (10 nm thick) in copper increases the copper's strength ten-fold. The filaments occupy only 18% of the volume and the high conductivity and ductility of the copper are retained.

Draw labelled diagrams to show the way in which a dislocation in a lattice moves.

(3)

State two differences between the filaments in the new and traditional composites.

1 ....

....

2 ....

....

(2)

Calculate the ratio

$$\frac{\text{cross-sectional area of a copper wire of 1mm diameter}}{\text{cross-sectional area of an ultrafine niobium filament}}$$

....

....

....

....

Ratio = ...

(2)

State **two** advantages of using ultrafine niobium filaments to strengthen copper wire.

1 ....

....

2 ....

....

(2)
(Total 32 marks)

89. (a) Use the data below to calculate the binding energy in MeV of a nucleus of oxygen, ${}^{16}_{8}\mathrm{O}$.

Data:	mass of proton	=	1.007 276 u
	mass of neutron	=	1.008 665 u
	mass of oxygen nucleus	=	15.990 527 u

....

....

....

....

Binding energy = ... MeV

(3)

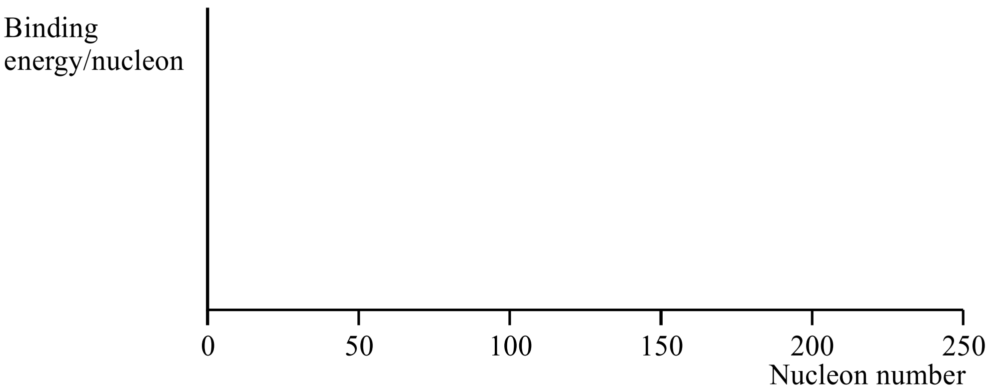
Calculate the binding energy per nucleon of ${}^{16}_{8}\mathrm{O}$.

....

Binding energy per nucleon = ...

(1)

On the axes below sketch a graph of binding energy per nucleon against nucleon number.



(2)

Show on the graph the approximate position of

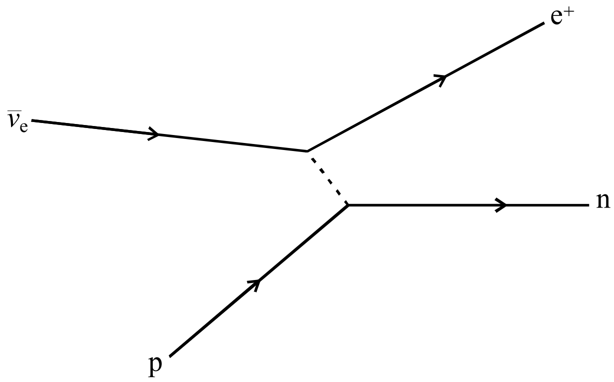
(i) oxygen, labelling this point O,

(ii) iron, the most stable element, labelling this point Fe,

(iii) uranium, ${}^{238}_{92}\mathrm{U}$,labelling this point U.

(3)

(b) The Feynman diagram below represents an interaction between an antineutrino and a proton, known as inverse beta decay.



Write an equation for this interaction.

....

(1)

Show that charge is conserved in this interaction.

....

....

(1)

What type of interaction is responsible for inverse beta decay?

....

(1)

Justify your answer.

....

(1)

What exchange particle is involved?

....

(2)

Suggest why the interaction is known as inverse beta decay.

....

....

....

....

(2)

(c) State what is meant by a fundamental particle.

....

....

Circle any fundamental particles in the following list.

positron; neutron; muon; K^0 meson.

(3)

Explain why it is not possible to have a meson with a charge of +2. You may be awarded a mark for the clarity of your answer.

....

....

....

....

(3)

(d) Read the short passage below and answer the questions about it.

> One theory to explain the strong force is built on the idea of a "strong charge" that occurs on quarks but not on leptons. The strong charge occurs in three varieties and has been given the name *colour.* This has nothing to do with colour in the everyday sense of the word. When the three primary colours (red, blue, green) combine they give white light. Quarks only combine if their colour charges produce a colourless hadron. Thus a proton contains one red, one blue and one green quark. Mesons contain a coloured quark and an antiquark of matching anticolour. A π^+ meson, quark composition $u\bar{d}$, could be $u_{red}\,\bar{d}_{antired}$. Gluons also carry colour charge, so gluons interact with each other as well as with quarks.
>
> [Adapted from *The Standard Model* by C. Sutton, CERN Courier, June 1994]

Give an example of a lepton. ....

(1)

How do we know that leptons carry no colour charge?

....

....

(1)

State one possible coloured quark combination for a proton.

....

....

(2)

Three coloured quark combinations for a π^- meson are listed below. For each example state whether it is a possible or an impossible combination and explain your answer.

π^-: $\bar{u}_{\text{antigreen}} d_{\text{green}}$

....

....

π^- : $d_{\text{blue}} \bar{d}_{\text{antiblue}}$

....

....

π^-: $\bar{u}_{\text{antired}} d_{\text{blue}}$

....

....

(4)

What type of particle is a gluon?

....

(1)

(Total 32 marks)

90. (a) An isotope of iodine ^{131}I is produced when unstable tellurium $^{131}_{52}Te$ undergoes β^- decay.

Write a nuclear equation for this decay.

....

(2)

The unstable tellurium is produced when stable $^{130}_{52}Te$ is bombarded with neutrons. Where might such a reaction be carried out?

....

(1)

State **three** factors which must be considered when choosing a radionuclide for organ imaging.

....

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....

....

(3)

^{131}I has a half-life of 8 days and a biological half-life of 21 days.

Calculate the effective half-life of ^{131}I.

....

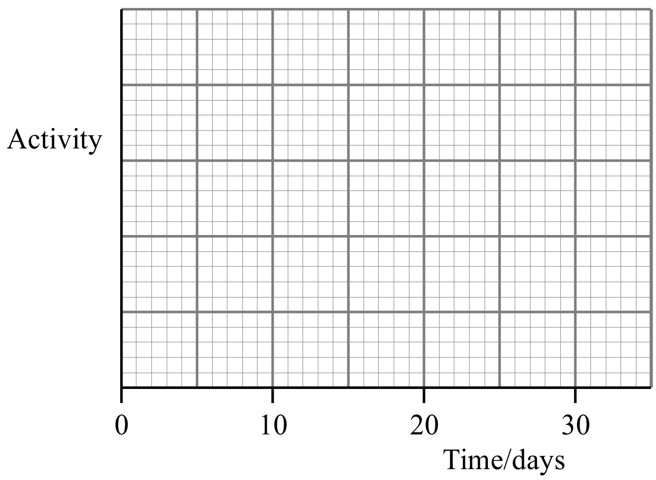
....

....

Effective half-life = ...

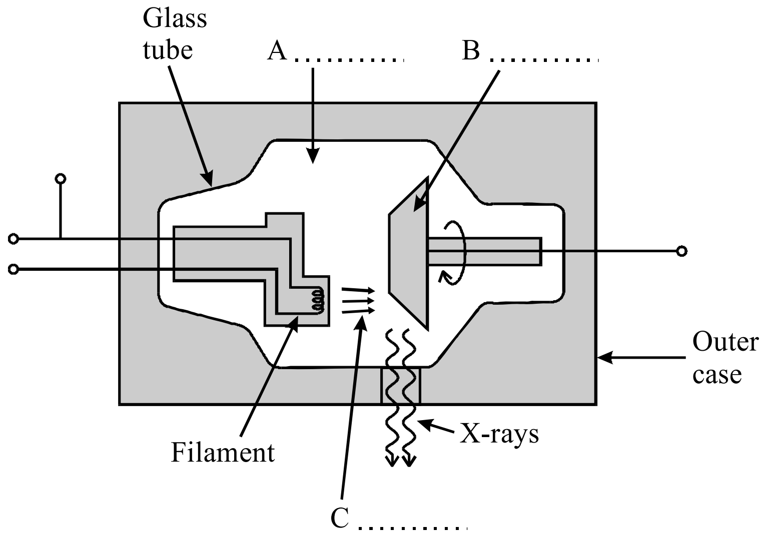
(2)

On the axes below sketch two curves, one showing the activity of a sample of ^{131}I kept in a laboratory and the other showing the activity of a sample given to a patient. Assume both samples have the same initial activity. Label your curves L (laboratory) and P (patient).



(3)

(b) The diagram shows the main features of an X-ray tube. Label features A, B and C.



(3)

An X-ray beam has an intensity of 20 MW m^{-2} at a distance of 0.10 m from a point source of X-rays.

What will be the intensity 1.0 m from the source?

....

....

....

....

Intensity = ...

(2)

(c) Describe how it is possible to obtain information about the depths of structures in a patient's body by using an ultrasonic A-scan. You may be awarded a mark for the clarity of your answer.

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(5)

Explain why a coupling medium is essential between the body surface and the ultrasound probe.

....

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....

....

(2)

State a suitable substance for use as a coupling medium.

....

(1)

(d) Read the short passage below and answer the questions about it.

> The piezoelectric effect is a reversible relationship between mechanical stress and electric potential difference exhibited by certain crystals such as quartz. When a piezoelectric crystal is compressed, positive and negative charges appear on opposite crystal faces producing a potential difference across the crystal. Replacing the pressure by tension reverses this potential difference. If instead an electric potential difference is applied across the crystal then its thickness changes. A piezoelectric crystal placed in an alternating electric circuit will thus expand and contract. These effects are used in ultrasonic generators and detectors. The maximum transfer of energy occurs at a particular frequency called the resonant frequency. The wavelength of the ultrasound produced by a piezoelectric crystal at its resonant frequency is equal to twice the crystal thickness.
>
> [Adapted from Phaidon Concise Encyclopaedia of Science and Technology]

Explain what is meant by a reversible relationship.

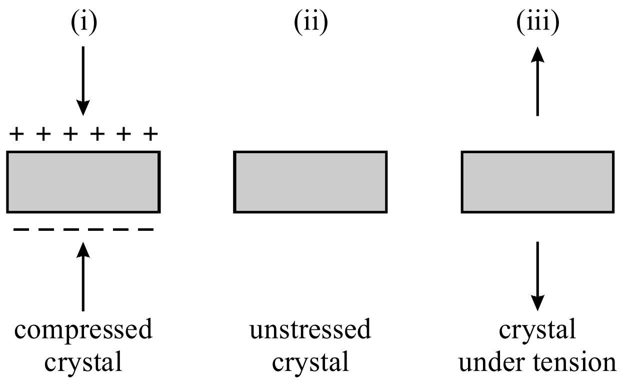
....

....

....

(2)

Diagram (i) shows the charge distribution on a compressed piezoelectric crystal. Show the charge distribution on the crystals in diagrams (ii) and (iii).



(2)

Calculate the thickness of a quartz crystal which will have a resonant frequency of 1.50 MHz. (Speed of sound in quartz = 5740 in m s^{-1})

....

....

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Thickness = ...

(3)

What is the benefit of applying the alternating potential difference at the resonant frequency of the quartz crystal?

....

....

(1)
(Total 32 marks)

91. (a) (i) You have been provided with a sheet of foil. Measure its length *I* and width *w*. Explain with the aid of a diagram how you obtained accurate values for *I* and *w*.

....

....

....

....

(3)

(ii) Determine the thickness t of the sheet by folding it so that a total thickness of $16t$ is recorded. Estimate the percentage uncertainty in your value of t.

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Explain one advantage and one disadvantage of measuring t in this way.

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(6)

(iii) Calculate the volume V of the sheet.

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....

Measure the mass of the sheet using the balance provided and hence determine the density of the material from which the sheet is made.

....

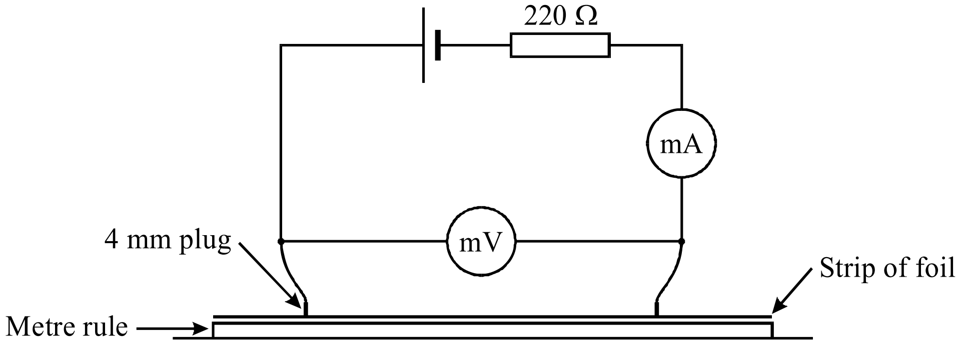
....

....

....

(3)

(b) (i) Set up the circuit as shown in the diagram below to enable you to measure the resistance of an 80.0 cm strip of foil. Before pressing the 4 mm plugs on to the foil, have your circuit checked by the Supervisor. You will be allowed a short time to correct any faults. If you are unable to set up the circuit the Supervisor will set it up for you. You will only lose two marks for this.



(2)

(ii) Taking care not to damage the foil, press the ends of the 4 mm plugs firmly against the strip of foil so that you can measure the voltage V across a length $l = 80.0$ cm. Also measure the current I in this length. Record your measurements in the space below.

....

....

Hence calculate a value for the resistance R of the 80 cm length of foil.

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(4)

(iii) Explain whether your value for R is likely to be greater than, equal to or less than the actual resistance of this length of foil.

....

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....

(2)

(iv) Calculate a value for the cross-sectional area A through which the current is passing. You may assume that the width of the strip is 5.0 mm and that its thickness is the same as that determined in part (a).

....

....

Use your results to determine a value for the resistivity ρ of the material from which the foil is made. This is given by

$$\rho = \frac{RA}{l}$$

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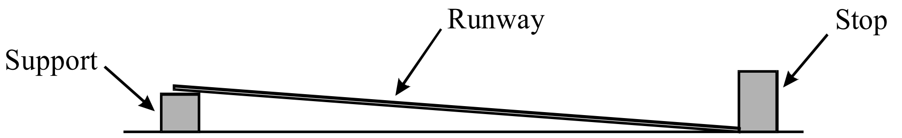
(4)
(Total 24 marks)

92. (a) Set up the apparatus as shown in the diagram below with support A placed under one end of the runway and the stop secured at the other end.



Determine the mean time t for the ball to travel a distance s of 1.00 m from rest down the runway.

....

....

Hence calculate the speed υ of the ball after moving 1.00 m, which is given by

$$\upsilon = \frac{2s}{t}$$

....

....

(3)

(b) Determine the vertical height *h* through which the ball falls as it travels this distance of 1.00 m down the runway. Draw a diagram to show how this height was determined.

h =...

Using the mass of the ball, which is given on the card, calculate the potential energy E_p lost by the ball as it falls through the height *h*.

....

....

Using your results from part (a) calculate the linear kinetic energy E_K gained by the ball as it moves down the runway.

....

....

Because the ball has both linear and rotational kinetic energy in this experiment, it is expected that $E_p = kE_K$, where *k* is a constant. Use your energy values to calculate a value for *k*.

....

....

(6)

(c) Repeat parts (a) and (b) of the experiment using support B in order to obtain a second value for *k*.

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(5)

(d) Determine the percentage difference between your two values of *k*. If the total experimental uncertainty in the energies is of the order of 20%, comment on the validity of assuming that *k* is constant.

....

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....

(2)

(e) You are to plan an experiment to further investigate the equation $E_p = kE_K$. Your plan should include

(i) a description of how E_p can be changed,

(ii) a description of the experiment to be performed,

(iii) a sketch graph showing the expected results,

(iv) an indication of how the constant *k* may be found from the graph.

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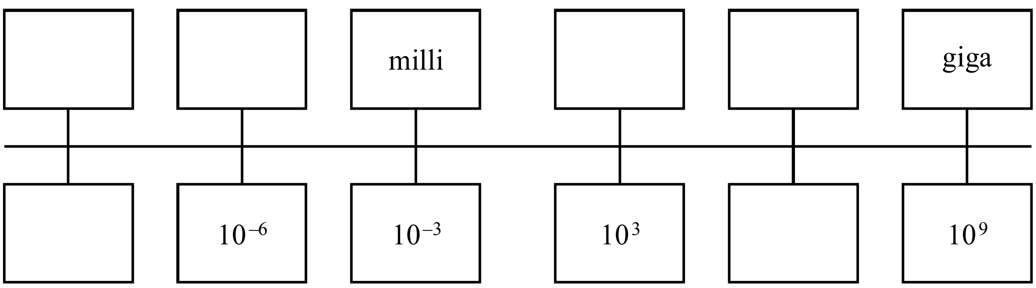
(8)
(Total 24 marks)

93. (a) The diagram shows part of the range of unit prefixes. Complete the diagram below by filling in the empty boxes.



(4)

(b) When a star moves off the main sequence It initially becomes a red giant. Describe the processes occurring which result in it becoming "giant-sized". You may be awarded a mark for the clarity of your answer.

....

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(4)

Use Wien's law to explain why these giant stars look red compared with their appearance when they were on the main sequence.

....

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....

(2)

Use Stefan's law to explain why a red giant has greater luminosity than when it was a main sequence star.

....

....

....

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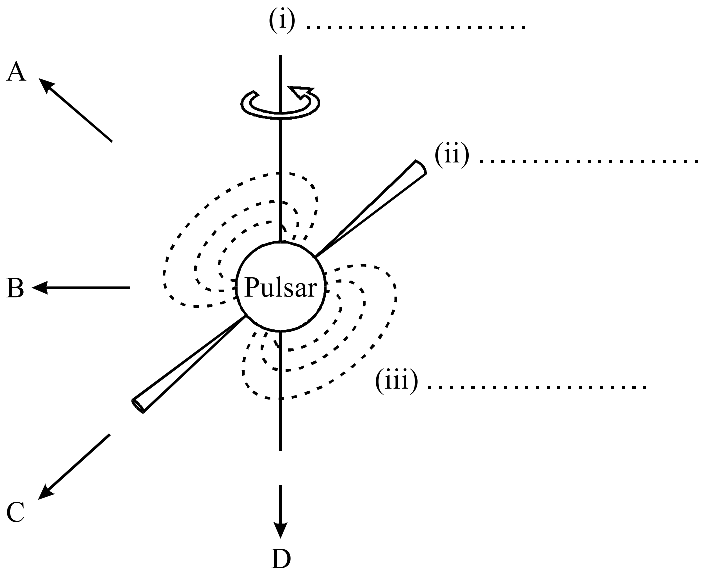
(3)

(c) Label the diagram of a pulsar below in the places (1), (ii), (iii), indicated by the dotted lines.



(3)

What type of star is a pulsar?

....

(1)

In which possible directions, A, B, C, D, might the Earth be situated and receive signals from this pulsar? Explain your answer.

....

....

....

....

....

....

(3)

(d) State two advantages of observing stars using radio telescopes.

1 ....

2 ....

(2)

A radio telescope sensitive to certain frequencies in the GHz range detects a radio flux (intensity) of 1.6×10^{-15} W m^{-2} from the Crab Nebula (one of the brightest radio sources in the sky). What is the radio luminosity of the Crab Nebula in this frequency range? (Distance of the Crab Nebula from Earth = 6.8×10^{19} m.)

....

....

....

....

(4)

(e) Light can be regarded as a stream of tiny packets of energy called photons. The energy of a photon (in joules) is related to the wavelength of the light (in metres) by the expression $E = \frac{k}{\lambda}$ where k is a constant equal to 2.0×10^{-25} kg m^3 s^{-2}.

Show that a photon of red light ($\lambda = 700 \times 10^{-9}$ m) has an energy of about 3×10^{-19}J.

....

....

....

(1)

Hence estimate the number of photons emitted per second by a red giant of luminosity 2.3×10^{31} J s^{-1}.

....

....

....

(2)

Explain why your answer is only an approximation.

....

....

(1)

State two advantages of CCDs compared with photographic film for recording images of distant stars.

1 ....

....

2 ....

....

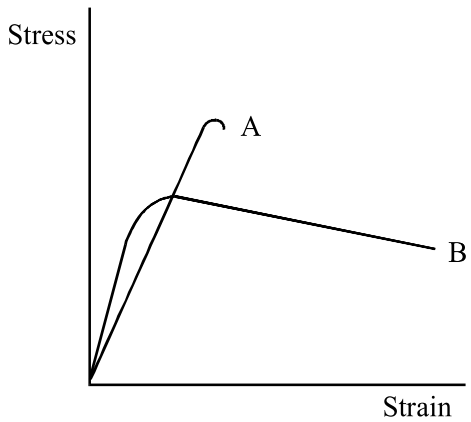
(2)
(Total 32 marks)

94. (a) The diagram shows part of the range of unit prefixes. Complete the diagram below by filling in the empty boxes.

		milli			giga
	10^{-6}	10^{-3}	10^{3}		10^{9}

(4)

(b) The stress-strain curves for two materials A and B up to their breaking points are shown below.



State, giving the reason for your choice in each case, which material is

(i) tougher ....

....

(ii) stiffer ....

....

(iii) more ductile ....

....

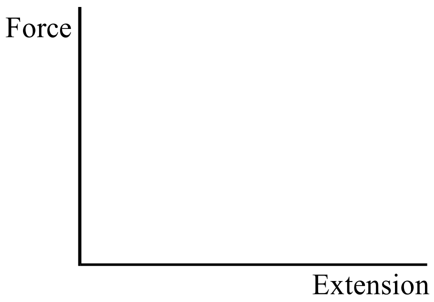
(3)

Add a third line to the graph above showing the behaviour of a material C which has the following properties:

C has a smaller Young modulus than A or B, is stronger than A or B and is brittle.

(3)

(c) On the axes below sketch a force-extension graph for natural rubber, showing its behaviour for both increasing and decreasing force.



(2)

Use your graph to explain what is meant by elastic hysteresis. You may be awarded a mark for the clarity of your answer.

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....

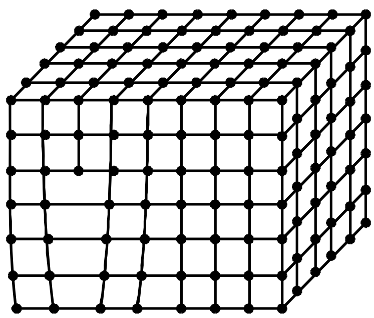
....

....

....

(3)

(d) The diagram shows an edge dislocation in a crystal lattice.



Label the slip plane on the diagram.

Explain how an edge dislocation makes it easier for layers of atoms to slip over each other.

....

....

....

....

....

(3)

How can a metal be work hardened?

....

....

Complete the following sentence by circling any word(s) in the square brackets that describe(s) a metal after it has been work hardened.

After work hardening a metal is [stronger, stiffer, more ductile, more brittle]

(3)

Describe the process of annealing and explain in microscopic terms why it can return a work-hardened metal to its original softer state.

....

....

....

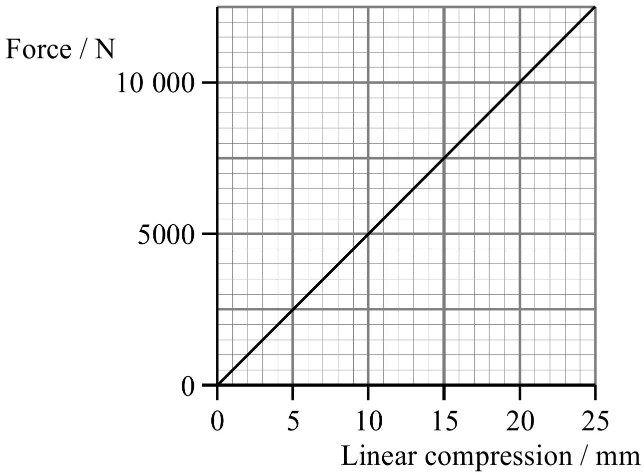
....

....

(3)

(e) Cycle helmets have a polystyrene foam lining. In the event of an accident the foam lining is compressed (crushed) and provides a stopping distance for the cyclist's head, reducing deceleration of the brain.

The graph shows the relationship between the force transmitted by a typical foam liner and the amount of linear compression of the foam.



Use the graph to calculate the energy stored by this foam liner when it is crushed by 18 mm.

....

....

....

....

(4)

Calculate the deceleration of a head of mass 5.8 kg when acted upon by a force of 10 000 N.

....

....

....

....

(2)

Helmets are designed to reduce head decelerations to no more than 200*g* (*g* = acceleration of free fall). Does this helmet fulfil the design requirements at this force? Justify your answer.

....

....

(1)

Suggest one reason why a cycle helmet should be replaced once it has suffered an impact.

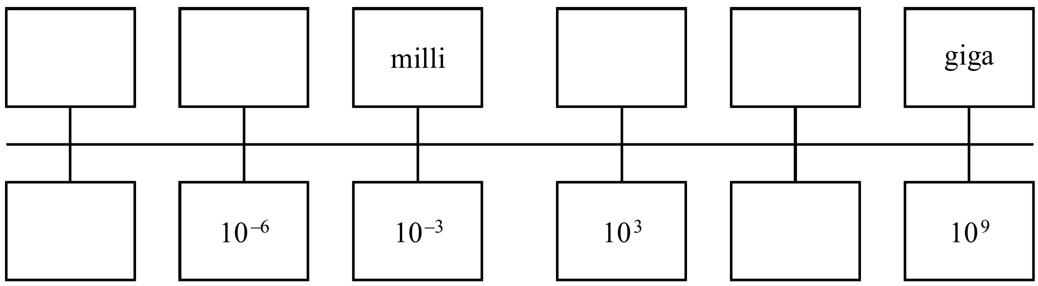
....

....

....

(1)
(Total 32 marks)

95. (a) The diagram shows part of the range of unit prefixes. Complete the diagram below by filling **in** the empty boxes.



(4)

(b) What is meant by the term binding energy? You may be awarded a mark for the clarity of your answer.

....

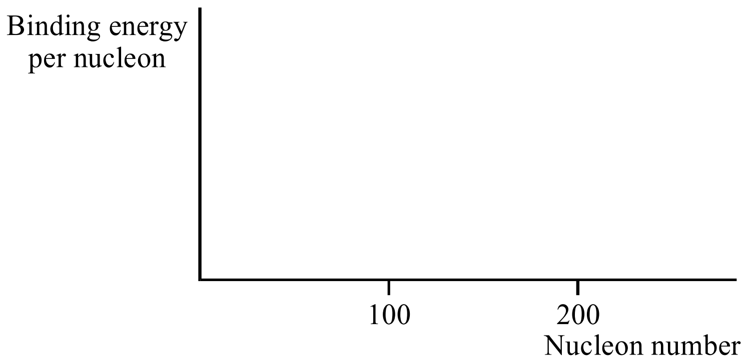
....

....

....

(3)

On the axes below sketch a graph of binding energy per nucleon against nucleon number.



(2)

The binding energy of $^{16}_{8}O$ is 123.45 MeV and the binding energy of 170 is 126.43 MeV.
Which of these two isotopes of oxygen would you expect to be more stable? Explain your answer.

....

....

....

....

....

(3)

(c) Add the quark content of the proton to column (ii) of the table below.

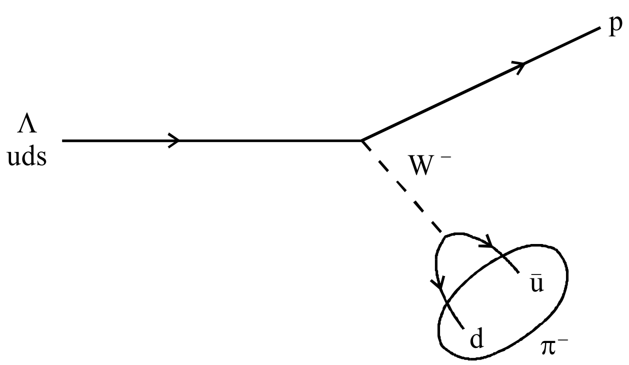
(i) particle	(ii) quark content	(iii) antiparticle	(iv) quark content
proton			
π^-	$d\bar{u}$		
K^0	$d\bar{s}$		

Complete column (iii) to give the antiparticles of the particles in column (i).

Complete column (iv) to show the quark content of the antiparticles.

(5)

(d) The Feynman diagram shows the decay of a neutral lambda particle (Λ) to a proton and a negative pion (π^-)



Show that the strange quark has a charge of $-\frac{1}{3}$.

....

....

(1)

Circle any of the following words which can be used to describe a π^-:

hadron, lepton, meson, baryon

What type of particle is the W^-?

....

(3)

Write down an equation for the decay of the lambda particle.

....

(1)

Show that both charge and baryon number are conserved in this decay.

....

....

....

....

(2)

Explain why this cannot be a strong interaction.

....

(1)

(e) A radioactive isotope of carbon, ${}^{14}_{6}C$, is continuously produced in the upper atmosphere when neutrons ejected from nuclei by cosmic rays collide with atmospheric nitrogen ${}^{14}_{7}N$.

Complete the nuclear equation below to show the production of radioactive carbon in the upper atmosphere. Hence identify X, the other product of the reaction.

$$^{\cdots\cdots}_{\cdots\cdots}N + {}^{\cdots\cdots}_{\cdots\cdots}n \rightarrow {}^{14}_{6}C + {}^{\cdots\cdots}_{\cdots\cdots}X$$

X = ...

(3)

Living plants take up carbon dioxide from the atmosphere and have a normal activity of 15.3 counts per minute per gram of carbon due to absorption of some carbon dioxide containing carbon-14. On death, the plant no longer takes in carbon-14 and the amount already taken up decays with a half-life of 5730 years.

Estimate the age of an archaeological specimen with an activity of 1.9 counts per minute per gram of carbon.

....

....

....

(3)

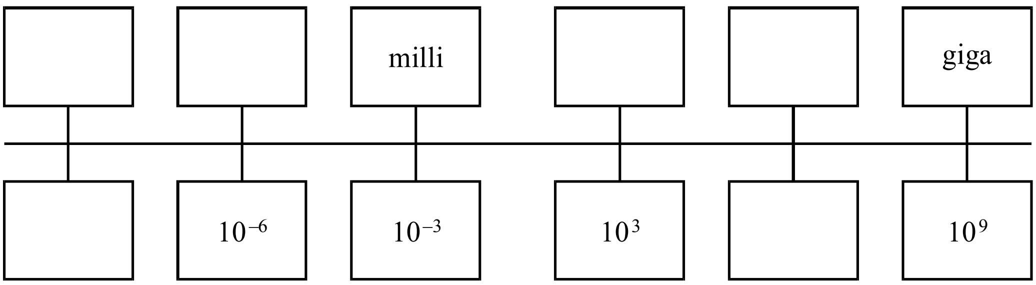
Suggest one problem in measuring an activity as low as 1.9 counts per minute per gram of carbon.

....

....

(1)
(Total 32 marks)

96. (a) The diagram shows part of the range of unit prefixes. Complete the diagram below by filling in the empty boxes.



(4)

(b) Describe how a radionuclide can be used to investigate the function of the thyroid gland by carrying out an uptake test. You may be awarded a mark for the clarity of your answer.

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(4)

Technetium-99m, ${}^{99m}_{43}\text{Tc}$, decays by gamma emission with a half-life of 6 hours. Give three reasons why ${}^{99m}_{43}\text{Tc}$ is suitable for this procedure.

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(3)

Technetium-99m is produced when molybdenum (Mo) decays by β^- emission. Write a nuclear equation for this decay.

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(2)

(c) The radioactive half-life of ${}^{131}_{53}\text{I}$ is 8 days, but when this is given to a patient the observed activity decreases to half its initial value in 6 days. Explain this observation.

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(1)

What will the observed activity fall to in 24 days?

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(2)

(d) Give two reasons why MeV X-rays are preferred to keV X-rays for therapy.

1 ....

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2 ....

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(2)

Explain, with the aid of a diagram, the benefit to the patient of using a multiple beam technique.

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(3)

State two precautions taken to protect the radiographer carrying out multiple beam therapy.

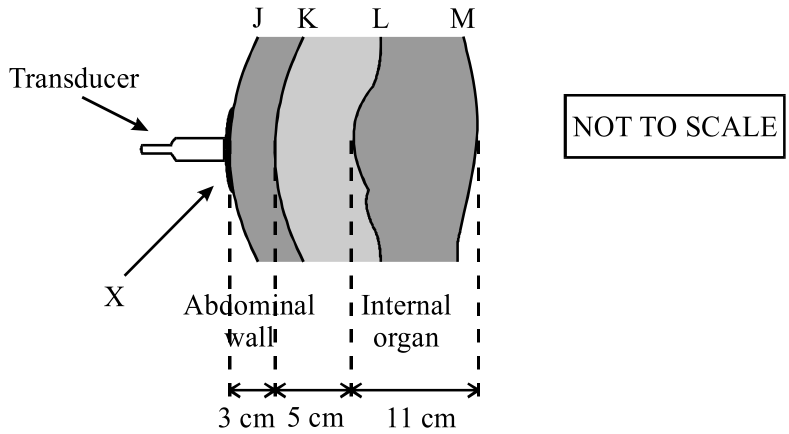
1 ....

2 ....

(2)

(e) In an ultrasound A-scan, a single transducer can be used both to send and receive pulses of ultrasound.

The diagram shows a lateral cross-section through part of the abdomen (not to scale).



What is X and what is its function?

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(2)

Calculate the time delay between sending out a single pulse and receiving its echo from interface K. (Speed of ultrasound in soft tissue = 1500 m s^{-1})

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(3)

The **interval** between pulses emitted by the transducer is 200 μs. At what frequency are pulses emitted?

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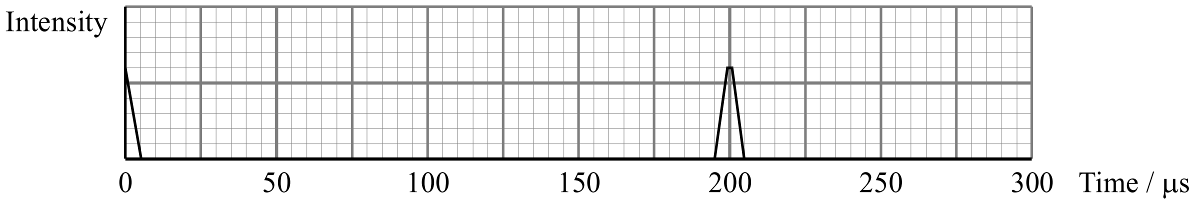
(2)

Two successive emitted pulses are **shown** on the grid below.



Add to the grid any traces produced by the echoes from interface K.

(1)

An echo from interface M takes 250 μs to return to the transducer. Suggest why reflections from M will be difficult to interpret.

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(1)
(Total 32 marks)

97. (a) (i) You are provided with 10 glass spheres. Determine an accurate value for the average diameter d of the spheres. Explain with the aid of a diagram how you tried to ensure that d was determined as accurately as possible.

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(5)

(ii) Estimate the percentage uncertainty in your value for *d*.

....

.... **(2)**

(iii) Calculate the average volume V of a sphere given that

$$V = \frac{\pi d^3}{6}$$

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.... **(1)**

(iv) Use the balance provided to determine the average mass of a sphere. Record all your measurements. Use your data to calculate a value for the density of the glass from which the spheres are made.

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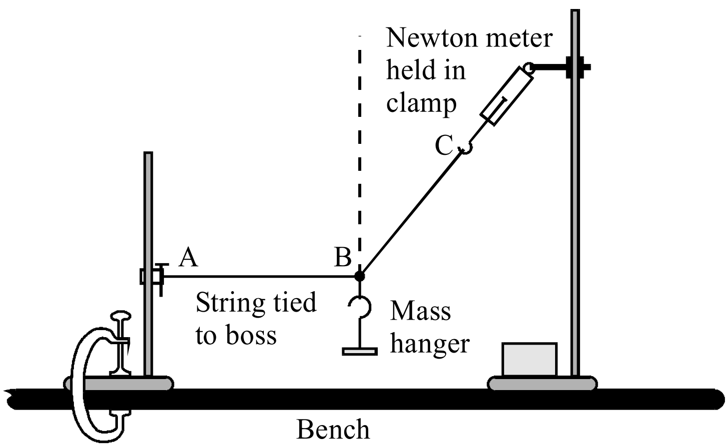
.... **(4)**

(b) (i) The apparatus shown in the diagram below has already been set up for you.



Place 300 g on the mass hanger to give a total mass M of 400 g. Adjust the height of the clamp holding the newton meter until the section of string AB is horizontal. Explain carefully how you ensured that the string was horizontal, adding to the above diagram if you wish. Record the reading R on the newton meter.

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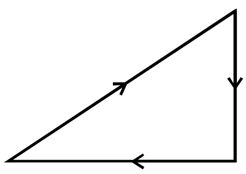
(4)

(ii) Draw a free-body diagram to show the forces acting at the point B, carefully labelling the forces.

(3)

(iii) The diagram below shows the equilibrium of the three forces acting at point B.



Add your data to the diagram and calculate the tension in the horizontal section of the string.

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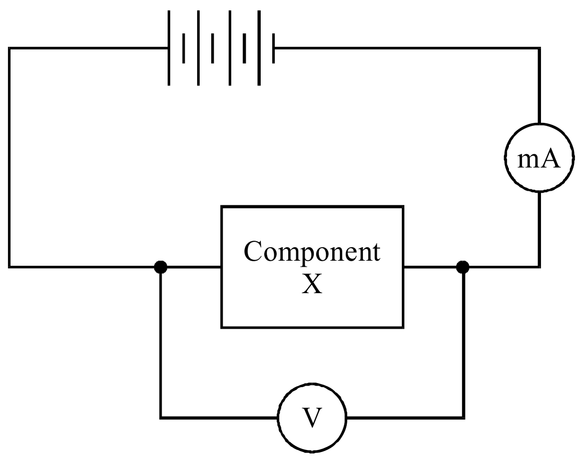
(5)
(Total 24 marks)

98. (a) (i) Set up the circuit as shown in the diagram below. Before you connect the power supply have your circuit checked by the Supervisor. You will be allowed a short time to correct any faults, but if you are unable to set up the circuit the Supervisor will set it up for you. You will only lose 2 marks for this.



Connect the 6 V supply to the circuit with the positive terminal of the power supply connected to terminal T of component X. Record the current I_1 in and the voltage V_1 across X.

....

....

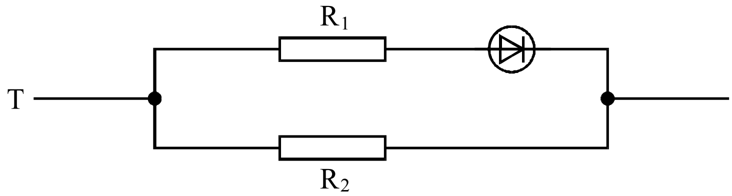
(ii) Reverse component X and measure the new values of the current I_2 in and the voltage V_2 across X.

....

....

(6)

(b) Component X contains the elements shown in the diagram below.



Use your results from part (a) to deduce the resistance of the resistor R_2.

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(4)

(c) The voltage drop across a conducting diode may be assumed to be 0.70V. For the situation when both arms of component X are conducting, calculate

(i) the current in the resistor R_2,

....

....

....

(ii) the current in the series arrangement of the diode and the resistor RI,

....

....

....

(iii) the resistance of resistor R_1.

....

....

(6)

(d) (i) Draw a circuit diagram to show how you would use a potential divider to further investigate the current-potential difference relationship for component X.

Describe how you would take the necessary readings.

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(3)

(ii) Sketch a graph of the results you would expect. You may assume that a diode does not start to conduct until the voltage drop across it exceeds 0.70 V.

Explain how the resistance of the resistor R_2 may be found from the graph.

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(5)
(Total 24 marks)

99. (a) The runway has been set up at the angle given on the card. Do not adjust.

(i) Determine the time t taken for the trolley to travel a distance s = 0.800 in from rest along the runway.

....

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(2)

(ii) Explain, with the aid of a diagram, any special precautions which you took to ensure that t was as accurate as possible.

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(3)

(iii) Estimate the percentage uncertainty in your value of *t*.

....

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(2)

(iv) Calculate the acceleration a of the trolley given that

$$a = \frac{2s}{t^2}$$

....

....

....

....

(1)

(v) Calculate the frictional force F opposing the motion of the trolley which is given by

$$F = mg\sin\theta - ma$$

where m = the mass of the trolley, which is given on the card,
θ = the angle of inclination of the slope, which is given on the card,
g = the gravitational field strength.

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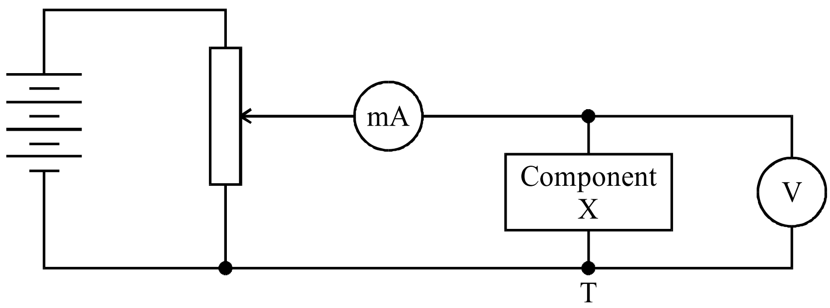
(2)

(b) (i) Set up the circuit as shown in the diagram below with the negative of the power supply connected to terminal T of component X. Before you connect the positive of the power supply, have your circuit checked by the Supervisor. You will be allowed a short time to correct any faults, but if you are unable to set up the circuit the Supervisor will set it up for you. You will lose no more than 3 marks for this.



(3)

(ii) Complete the circuit and set the current I_1, to 20 mA. Record the voltage V_1 across component X.

....

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(1)

(iii) Reverse component X and set the current I_2 to 40 mA. Record the voltage V_2 across component X.

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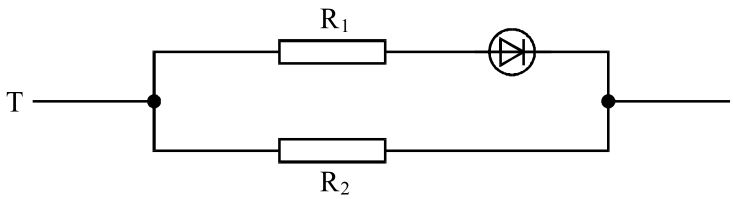
(1)

(iv) Component X contains the elements shown in the diagram below.



Use your results from part (ii) to deduce the resistance of the resistor R_2.

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(3)

(v) The voltage drop across a conducting diode may be assumed to be 0.70 V. For the situation in part (iii) when both arms of component X are conducting, calculate

the current in the resistor R_2,

....

....

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the current in the series arrangement of the diode and the resistor R_1,

....

....

....

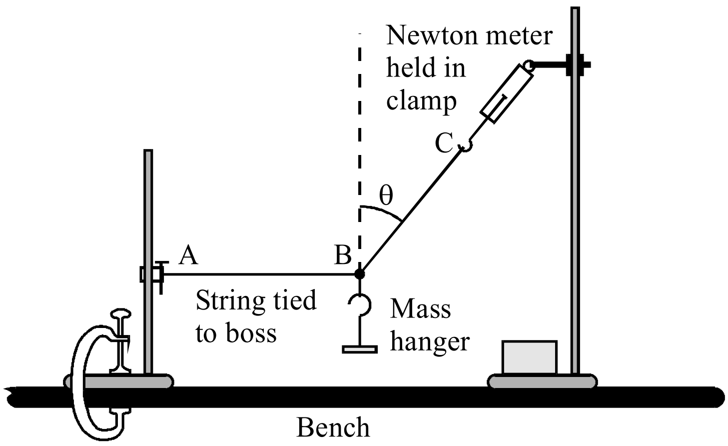
the resistance of the resistor R_1.

....

....

(6)
(Total 24 marks)

100. (a) The apparatus shown below has already been set up for you.



Place 300 g on the mass hanger to give a total mass M of 400 g. Adjust the height of the clamp holding the newton meter until the section of string AB is horizontal. Explain carefully how you ensured that the string was horizontal, adding to the above diagram if you wish. Record the reading R on the newton meter.

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(4)

(b) Record the length 1 of the section BC of the string. The position of C is marked on the string.

l = ...

Record the vertical height h between the points B and C on the string.

h = ...

Explain carefully how you measured h. You may add to the diagram opposite if you wish.

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Use your values of l and h to calculate cos θ where θ is the angle shown on the diagram.

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(6)

(c) If the section AB of the string is horizontal, theory suggests that

$$\cos\theta = \frac{W}{R}$$

where W = weight of the suspended mass,
and R = the reading on the newton meter.

Calculate W/R.

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The uncertainty in the newton meter reading may be taken to be 0.2 N. Calculate the percentage uncertainty this would give in your value for R. Discuss whether this alone could account for any difference between your value for W/R and your value of cos 0 as calculated in (b).

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(6)

(d) You are to plan an experiment to verify the equation shown in part (c).

(i) Describe the experiment you would perform.

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(ii) Sketch the graph you would expect to obtain and explain how you would use it to verify the equation.

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(8)
(Total 24 marks)

101. (a) State the meaning of T in the Stefan-Boltzmann law.

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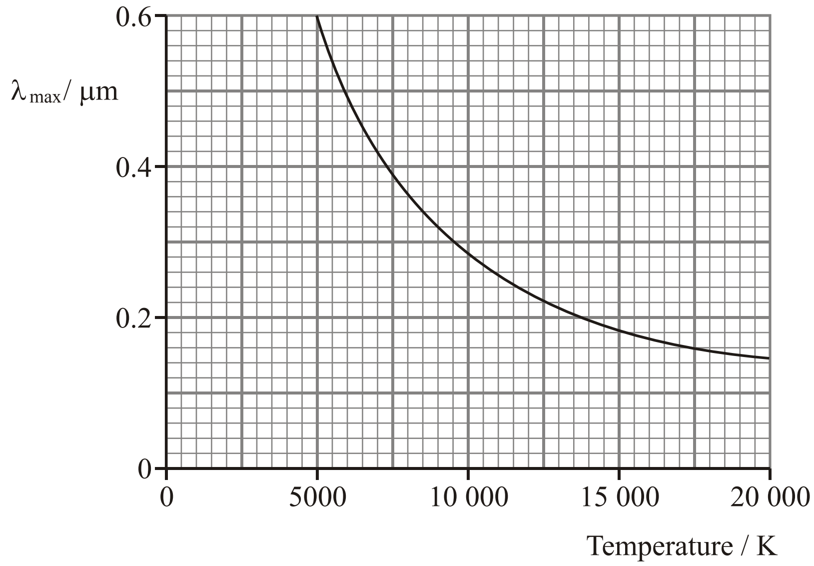
....

State the unit of luminosity.

....

(3)

(b) The graph shows how λ_{max} (the wavelength of the peak of the radiation spectrum) for a range of stars varies with the surface temperatures of the stars.



Carry out appropriate calculations to show that this graph is consistent with Wien's law.

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(3)

Use the graph to estimate the surface temperature of a star whose intensity peaks at a wavelength of 0.4 μm.

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(1)

This star has a radius of 9.0×10^7 m. Calculate its luminosity.

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(4)

Calculate the rate in kg s^{-1} at which matter is being consumed in this star.

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(3)

(c) Complete the sentence below by circling the appropriate term within each pair of brackets.

A red giant is a { cool, hot } star of { high, low } luminosity and large { mass, surface area } which has moved { higher up the main sequence, lower down the main sequence, off the main sequence }.

(4)

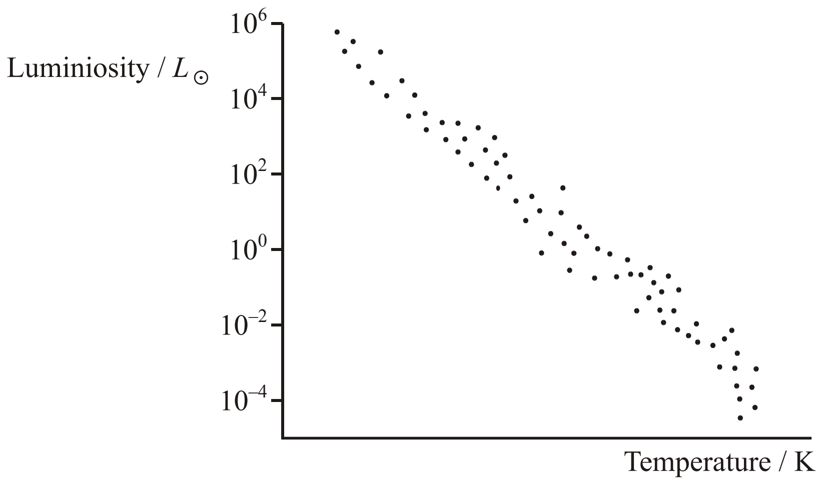
On the incomplete Hertzsprung-Russell diagram below

(i) add a scale to the temperature axis,

(ii) mark the approximate position X_s of the Sun (luminosity of the Sun = $L_\odot$),

(iii) shade in a region labelled W where a white dwarf star might be found,

(iv) shade in a region labelled R where the future red giant formed from the Sun will be found.



(5)

(d) Stars much more massive than the Sun may become supernovae. How do astronomers recognise a supernova?

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(2)

How is a supernova formed? You may be awarded a mark for the clarity of your answer.

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(3)

(e) Astronomers announced in January 2000 that they had found our nearest black hole at a distance of 1600 light years from Earth.

What is meant by a light year?

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(1)

Show that 1600 light years is equal to a distance of 1.5×10^{19} m.

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(2)

The black hole was detected because of its effect on a neighbouring star.

Why do astronomers have to rely on indirect evidence for locating black holes?

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(1)
(Total 32 marks)

102. (a) Energy density is the energy stored per unit volume. Show that the expression *Energy density = ½ stress × strain* is homogeneous with respect to units.

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(4)

(b) State Hooke's law.

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(2)

A brass wire of length 2.8 m and cross-sectional area 1.5×10^{-7} m^2 is stretched by a force of 34 N. The wire extends by 5.3 mm. Calculate the Young modulus of brass. Assume the stretched wire is still within the Hooke's law region.

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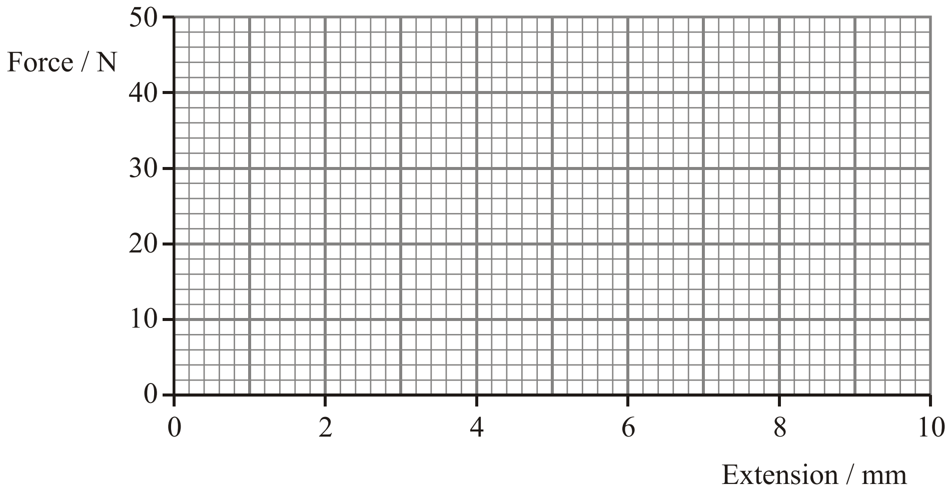
(4)

The wire obeys Hooke's law for forces up to 46 N.

On the axes below draw a force-extension graph for this brass wire in the Hooke's law region.



(2)

How could the graph be used to find the energy stored in the wire when it is stretched by a force of 24 N?

....

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(1)

A second wire is made from the same brass and has the same length but a greater cross-sectional area.

This wire is also stretched by a force of 24 N.

Does the second wire store more energy, the same energy or less energy than the original wire? Justify your answer.

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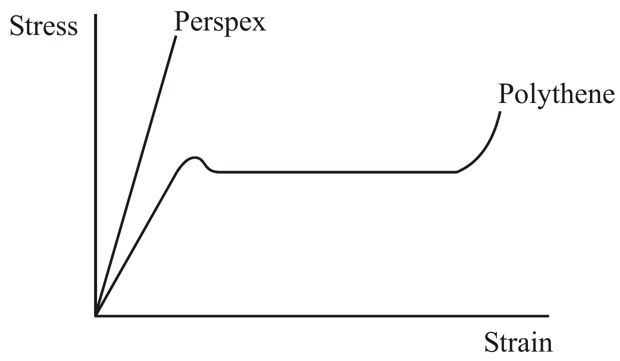
(3)

(c) The stress-strain curves for Perspex and polythene up to their breaking points are drawn below.



Describe the **differences** in behaviour of Perspex and polythene when they are stretched until they break. You may be awarded a mark for the clarity of your answer.

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(5)

(d) Draw a labelled diagram showing the molecular structure of an amorphous thermoplastic polymer such as Perspex.

(2)

How does the molecular structure of a thermoset such as Melamine differ from that of Perspex.

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(1)

(e) A rod of quench hardened carbon steel can have its surface properties changed by tempering. What must be done to the rod to temper it?

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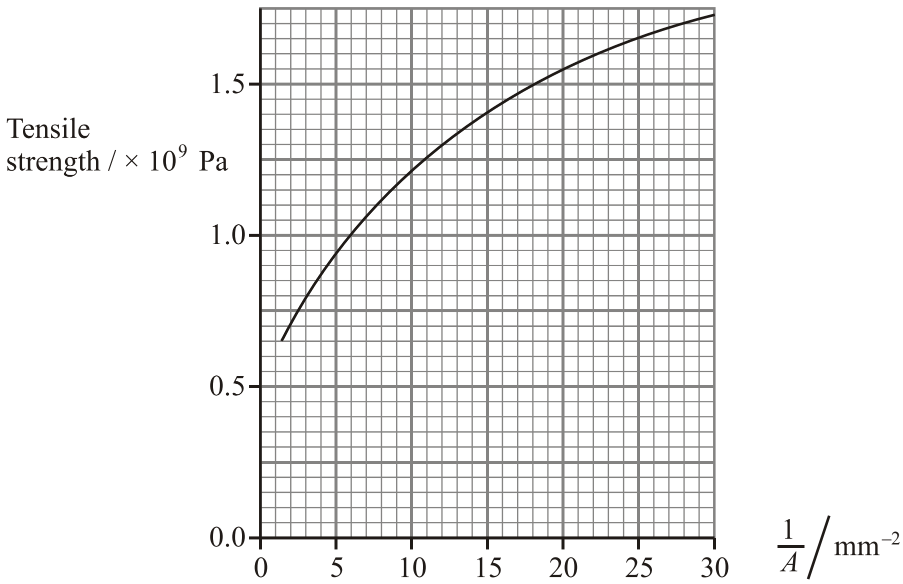
(1)

In what way do the properties of the surface of the rod change during this process?

....

(1)

The graph below shows how the tensile strength of glass in the form of fibres depends upon the cross-sectional area *A* of the fibres.



Complete the sentence below by circling the correct term within the brackets.

Thin glass fibres are { the same strength as, stronger than, weaker than } thick glass fibres.

(1)

Use the graph to determine the tensile strength of a glass fibre of cross-sectional area 0.125 mm^2.

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(2)

Could a glass fibre of cross-section 0.125 mm^2 (0.125×10^{-6} m^2) safely support a mass of 20 kg? Justify your answer.

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(3)
(Total 32 marks)

103. (a) The momentum p of a photon of energy E is given by the expression $p = E/c$ where c is the speed of light. Show that this expression is homogeneous with respect to units.

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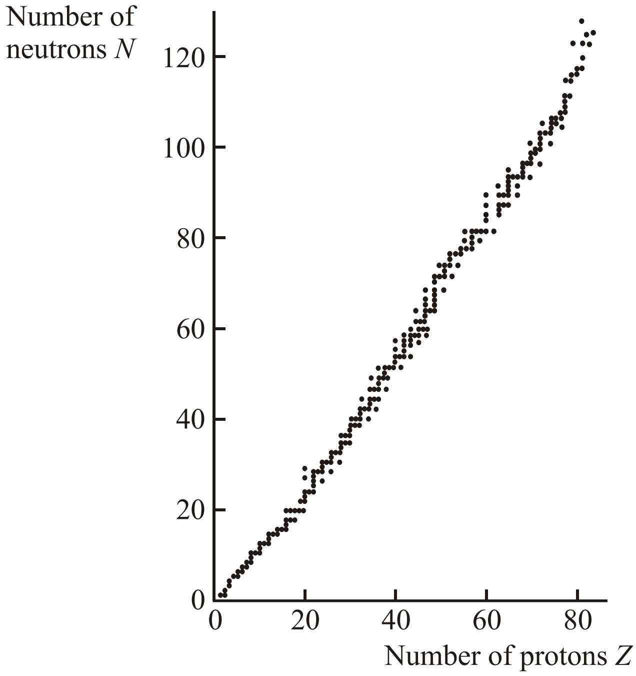
(4)

(b) The scatter diagram shows the relationship between number of neutrons and number of protons for stable nuclides.



Show on the diagram the region where nuclides which decay by β^- emission would be found.

(1)

Use the diagram to help you explain your choice of region. You may be awarded a mark for the clarity of your answer.

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(3)

(c) A xi minus particle Ξ^- decays to a lambda particle Λ and a pi meson π as shown below.

$$\underset{(dss)}{\Xi^-} \rightarrow \underset{(uds)}{\Lambda} + \underset{(ud)}{\pi^-}$$

Classify each particle as either a baryon, a meson or a lepton.

Ξ^- ....

Λ ....

π^- ....

(3)

By considering the quark composition of the Ξ^- show that the strange quark has charge of $-\frac{1}{3}$.

....

....

(1)

Is the Λ particle positive, negative or neutral? Justify your answer.

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....

....

(2)

Explain why this decay must be a weak interaction. What exchange particle is involved?

....

....

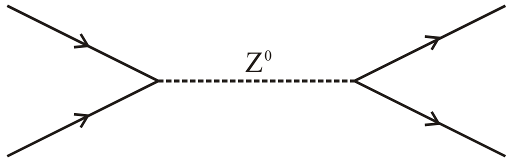
....

....

(3)

(d) Z^0 particles were produced during annihilation reactions between high energy electrons and positrons at CERN. A Z^0 may then decay into any quark-antiquark pair.

Complete the labelling of the Feynman diagram below representing the production and subsequent decay of a Z^0.



(2)

Calculate the mass in kg of the Z^0s produced when the electrons and positrons have energies of 45.6 GeV each.

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(3)

How does this mass compare with the mass of a proton?

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(1)

(e) List the four fundamental interactions.

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....

Which of these interactions does **not** act between electrons?

....

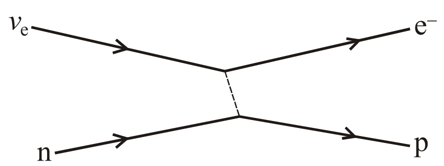
Which of these interactions act upon quarks **and** electrons?

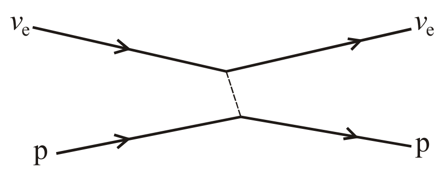
....

(5)

(f) Neutrinos undergo two types of weak interactions: the neutral current interaction, in which the neutrino loses a small amount of energy but is itself unchanged, and the charged current interaction, in which the neutrino not only loses energy but also is transformed into its lepton partner (e^-, μ^-, or τ^-).

The Feynman diagrams below show two different weak interactions.





....

Identify which diagram shows a neutral current interaction (nci) and which a charged current interaction (cci).

Label the exchange particle on each diagram.

(3)

Write an equation to show what happens when a muon neutrino undergoes a charged current interaction.

....

(1)
(Total 32 marks)

104. (a) Show that 20 keV is equivalent to 3.2×10^{-15} J.

....

....

Hence find the maximum possible speed of an electron accelerated from rest by a potential difference of 20 kV.

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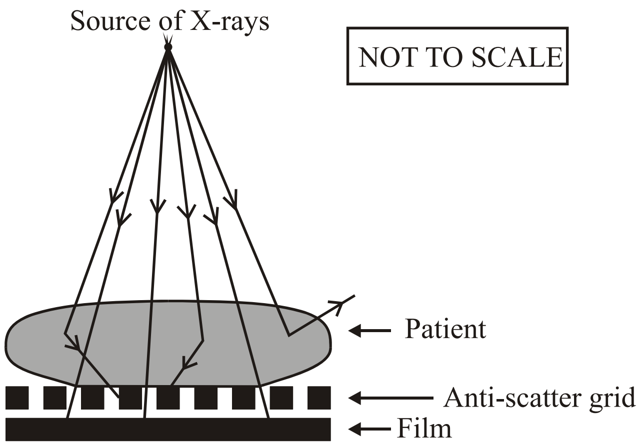
(5)

(b) The diagram shows keV X-rays being used for diagnosis.



Use the diagram to explain how an anti-scatter grid improves the sharpness of an X-ray image. You may be awarded a mark for the clarity of your answer.

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(3)

State the material from which the anti-scatter grid is made.

....

(1)

(c) Describe how an ultrasound A-scan can be used to obtain information about the depths of structures in the human body. Explain how the diameter of the head of a fetus could be determined using this technique.

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(5)

Explain with the aid of a suitable calculation why ultrasound of frequency 1.2 MHz would **not** be suitable for carrying out detailed eye investigations. (Speed of ultrasound used in eye investigations = 1500 m s^{-1}.)

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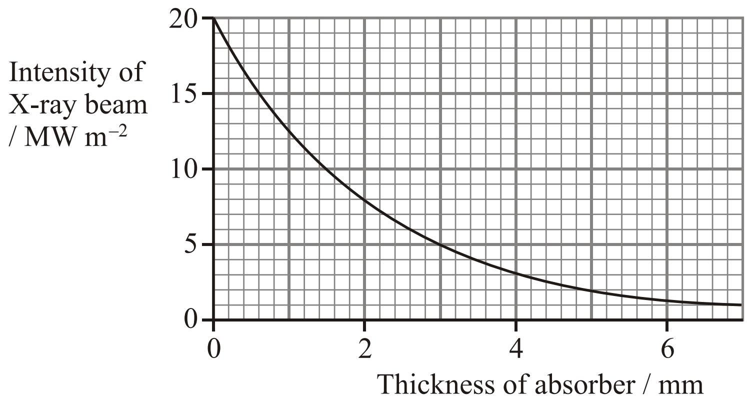
(3)

(d) The intensity of a homogeneous (single wavelength) X-ray beam decreases as it passes through matter as shown on the graph below. Equal thicknesses of absorber absorb equal fractions of the energy. The half-value thickness (HVT) is the thickness of material required to reduce the intensity of the X-ray beam of half its original value.

What is meant by a homogeneous X-ray beam?

....

.... **(1)**



What is the HVT of this absorber for this X-ray beam?

.... **(1)**

Use the graph to justify the statement, "Equal thickness of absorber absorb equal fractions of the energy".

....

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.... **(2)**

The HVT for a homogeneous 30 keV X-ray beam in aluminium is 2.4 mm. What thickness of aluminium is needed to reduce the intensity of this beam from 400 kW m^{-2} to 50 kW m^{-2}?

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....

.... **(2)**

Explain why absorbers of specific shapes and thicknesses are often necessary when using X-rays for therapy.

....

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(2)

(e) A nucleus of $^{131}_{53}\text{I}$ decays to a nucleus of xenon (Xe) by emitting a β^- particle and some γ radiation. Write a nuclear equation for this decay.

....

(2)

Sketch a labelled diagram showing the essential features of a γ-camera, indicating the position of the patient and the source of the γ-rays.

(5)
(Total 32 marks)

105. (a) (i) You are to determine the volume *V* of the Plasticene by a displacement method. Shape the Plasticene so that it will fit into the measuring cylinder. (You are advised to wear a disposable glove.) After you have shaped it, measure its mass *m*.

m = ...

Now place sufficient water in the measuring cylinder to ensure that the Plasticene is fully immersed. This may take several trials. Draw diagrams showing the sequence of your experimental arrangements and record all your measurements in the space below.

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State any special precautions which you took when determining *V*.

....

....

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Use your values of *m* and *V* to calculate a value for the density of Plasticene.

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(7)

(ii) Calculate the percentage uncertainty in your value for V.

....

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....

Manufacturers quote the density of Plasticene as 1800 kg m^{-3} (1.8 g cm^{-3}) ± 10%.

Calculate the percentage difference between your value for the density and that quoted by the manufacturers.

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Assuming that the percentage uncertainty in the mass is negligible, comment on the extent to which the Plasticene you used meets the manufacturers' specification.

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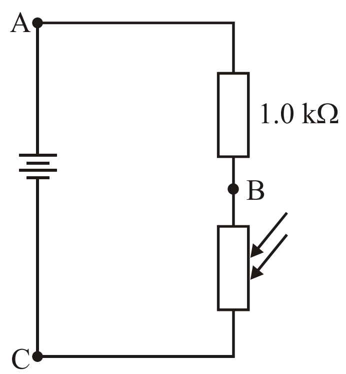
(4)

(b) (i) Set up the circuit as shown in the diagram below. Before connecting to the power supply, have your circuit checked by the Supervisor. You will be allowed a short time to correct any faults. If you are unable to set up the circuit the Supervisor will set it up for you. You will lose only two marks for this.



(2)

(ii) Connect the voltmeter between points A and C to measure the terminal potential difference V_{AC} of the power supply.

V_{AC} = ...

Now connect the voltmeter between points B and C to measure the potential difference V_{BC} across the light dependent resistor (LDR).

V_{BC} = ...

Hence calculate the potential difference V_{AB} across the 1.0 kΩ resistor.

V_{AB} = ...

Calculate the current I in the circuit and the resistance R of the LDR.

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(5)

(iii) Keeping the voltmeter between points B and C, cover the LDR with the disc. Using your knowledge of potential dividers, explain what happens to V_{BC} when the LDR is covered by the disc.

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Calculate a value for the resistance R of the LDR when it is covered by the disc.

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(6)
(Total 24 marks)

106. (a) The apparatus has been set up for you. Do not adjust it in any way. Determine the mean time *t* for the trolley to descend a distance *s* of 0.80 m from rest down the runway.

....

....

Hence calculate the speed υ of the trolley after moving 0.80 m, which is given by

$$\upsilon = \frac{2s}{t}$$

....

....

(3)

(b) Explain with the aid of a diagram how you ensured that the trolley travelled a distance of exactly 0.80 m.

....

....

....

....

(3)

(c) Determine the vertical height h through which the trolley moves as it travels a distance of 0.80 m down the runway. Draw a diagram to show how this height was determined.

h = ...

Using the mass of the trolley, which is given on the card, calculate the potential energy E_p lost by the trolley as it moves through the height h.

....

....

Using your results from part (a), determine the kinetic energy E_k gained by the trolley as it moves down the runway.

....

....

In this experiment it is expected that $E_p = E_k + k$ where k is a constant. Calculate a value for k.

....

....

(6)

(d) You are to plan an experiment to further investigate the equation in part (c). Your plan should include

(i) a description of how E_p can be changed,

(ii) a description of the experiment to be performed,

(iii) a sketch graph, showing the expected results.

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How would you find *k* from the graph?

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(8)

(e) The speed of the trolley at the end of the 0.80 m run has been found by doubling the average speed of the trolley as it moves down the runway. Describe how this final speed could be measured directly using a datalogging system.

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(4)
(Total 24 marks)

107. (a) Charge coupled devices (CCDs) have a higher efficiency than photographic emulsion. Explain what is meant by the term 'higher efficiency'. State one advantage of this higher efficiency.

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(3)

(b) The satellite COBE was launched in 1989 to investigate the cosmic background radiation. COBE detected the peak in the spectrum of the background radiation at a wavelength of 1.1×10^{-3} m. Use this value to calculate the temperature of space.

....

....

....

....

(2)

To what part of the electromagnetic spectrum does radiation of wavelength 1.1×10^{-3} m belong?

....

(1)

(c) State two ways in which a white dwarf star differs from a main sequence star.

1 ....

....

2 ....

....

(2)

Describe what happens to a star after it has become a white dwarf.

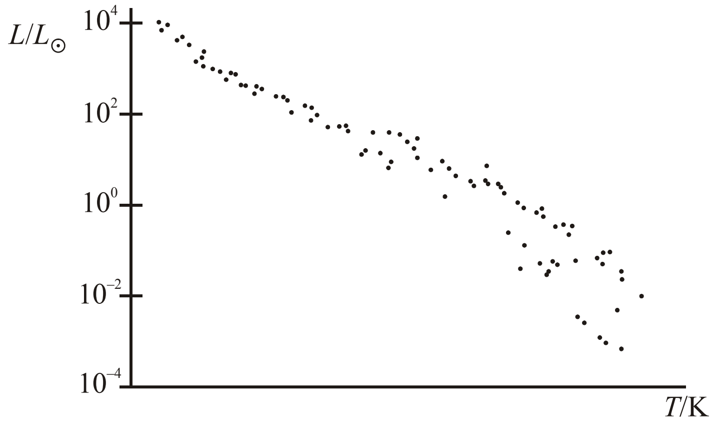
....

....

....

(2)

A Hertzsprung-Russell diagram showing the main sequence is drawn below. The luminosity of the Sun = $L_\odot$.



Add a scale to the temperature axis.

(2)

Identify **one** star on the diagram which has a luminosity very similar to that of the Sun. Label this star X.

(1)

Shade in a region on the diagram where white dwarf stars are located. Label this region W.

(1)

Label with an M the region on the diagram where the most massive main sequence stars are located.

(1)

Explain why the most massive main sequence stars have the shortest lifetimes. You may be awarded a mark for the clarity of your answer.

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(4)

(d) Two stars, Deneb and Vega, are similar in colour. What can be deduced about the surface temperatures of the two stars? Explain your answer.

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....

(2)

The table gives some information about the two stars.

Star	Luminosity/W	Distance from Earth/m
Deneb	2.5×10^{31}	1.5×10^{19}
Vega	1.9×10^{28}	2.3×10^{17}

Which star has the greater surface area? Justify your answer.

....

....

....

....

(3)

Which star will have the higher intensity and therefore appear brighter as seen from the Earth? Show all your working.

....

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....

(4)

(e) The Gemini telescope on Hawaii has a diameter of 8.0 m; the Hubble space telescope has a diameter of 2.4 m. Show that Gemini has more than 10× the light gathering power of Hubble.

....

....

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....

(2)

Give one situation in which large light-gathering power is important.

....

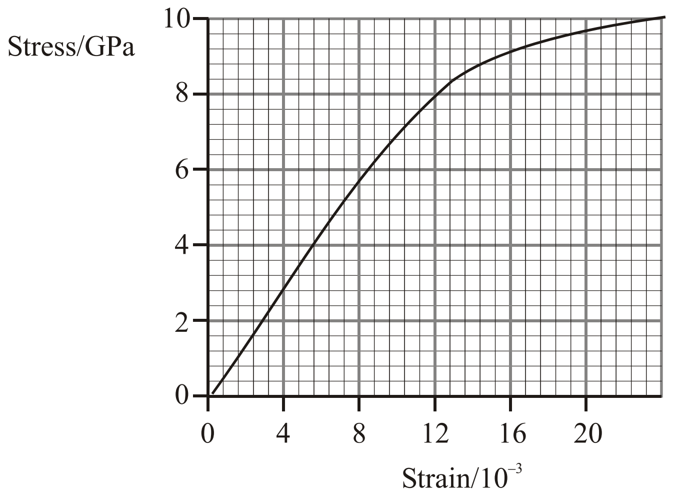
....
(1)

A telescope of diameter 100 m could be sunk into the ground. Suggest an operational disadvantage of having an extremely large telescope sunk into the ground.

....

....
(1)
(Total 32 marks)

108. (a) The graph shows the stress-strain relationship for a material from which car seat belts can be made.



What physical quantity does the area under this graph represent?

....

(1)

A car seat belt is 2 m long, 6 cm wide and 1.5 mm thick. Show that the volume of the seat belt is approximately 2×10^{-4} m^3.

....

....

(1)

A passenger of mass 55 kg wears the seat belt when travelling in a car at a speed of 24 m s^{-1}. Show that the kinetic energy of the passenger is about 16 kJ.

....

....

(2)

Calculate the energy per unit volume which must be absorbed by the seat belt as it restrains the passenger when the car stops suddenly. Assume that all the passenger's kinetic energy is absorbed by the seat belt.

....

....

(1)

Use the graph to show that a seat belt made from this material would be satisfactory for restraining the passenger in the situation described above. Assume the maximum strain in the belt is 20×10^{-3}.

....

....

....

....

(2)

In what way would the design of a seat belt, made from the same material, need to be changed to make it suitable for restraining the driver of a racing car when the car stops suddenly? Explain your answer.

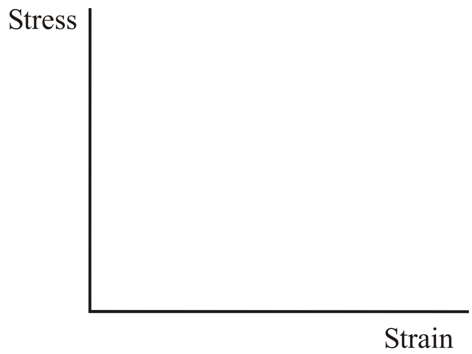
....

....

....

(2)

(b) On the axes below, sketch a stress-strain graph for rubber, showing its behaviour for both increasing and decreasing stress.



(2)

Use your graph to explain why a rubber band which is repeatedly stretched and relaxed becomes noticeably warmer. You may be awarded a mark for the clarity of your answer.

....

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....

(3)

(c) Metals sometimes suffer fatigue failure. Explain what is meant by fatigue in this context.

....

....

(1)

In 1950 two Comet aircraft crashed after only two years of flying as a result of fatigue failure. The Comet was one of the first aircraft to have a pressurised cabin and had riveted panels close to square windows. Explain in terms of cracks and stress concentrations why these features may have caused the aircraft to suffer fatigue failure.

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(3)

(d) Chipboard and plywood are both composite materials. State what is meant by a composite material.

....

.... **(1)**

In the space below sketch labelled diagrams showing the structure of each of these materials and classify each as either a laminate, a fibre composite or a particle composite.

Chipboard Plywood

(4)

(e) State the energy conversions which take place when a rock-climber falls and is then stopped by a climbing rope.

....

.... **(2)**

From the list below circle three properties that would be most desirable in a climbing rope:

strength stiffness toughness elasticity brittleness

(2)

During a fall, a climber exerts a force of 6.0 kN on a rope. Use the rope data below to calculate the theoretical extension of the rope when this force is exerted assuming the elastic limit of the rope is not exceeded.

Effective Young modulus	=	1.4×10^9 Pa
Length	=	45 m
Diameter	=	11 mm

....

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....

(4)

Suggest one reason why a rope that has been involved in an extreme fall should be replaced as soon as possible.

....

....

(1)
(Total 32 marks)

109. (a) Name the experiment which was used to find out about the structure of

(i) the proton ....

(ii) the atom ....

(2)

Show that the radius of a nucleus of calcium ^{40}Ca is approximately 4×10^{-15} m ($r_0 = 1.2 \times 10^{-15}$ m).

....

....

(2)

Hence calculate the density of a calcium nucleus. (u = 1.66×10^{-27} kg)

....

....

....

(3)

(b) Part of the uranium decay series is shown below.

$$^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} \rightarrow {}^{234}_{91}\text{Pa} \rightarrow {}^{234}_{92}\text{U} \rightarrow {}^{230}_{90}\text{Th} \rightarrow {}^{226}_{88}\text{Ra}$$

Write above each arrow the charged particle emitted during that decay.

(2)

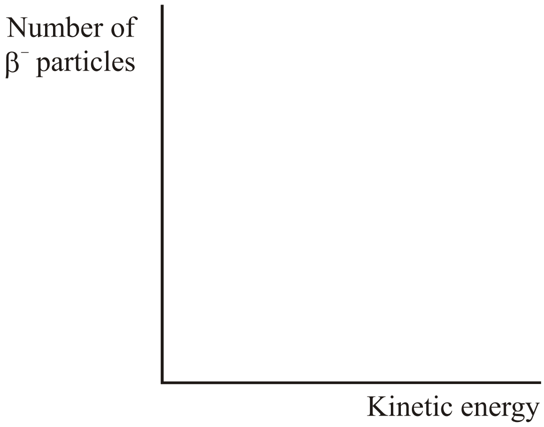
The stable end product of the complete uranium decay series is lead, $^{206}_{82}$Pb . How many alpha particles are emitted between $^{226}_{88}$Ra and the end of the series?

....

....

(1)

(c) On the axes below sketch a graph showing the energy spectrum of the β^- particles leaving a typical source.



(2)

Explain how this energy spectrum led to the prediction of the existence of the antineutrino. You may be awarded a mark for the clarity of your answer.

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(4)

(d) Give one similarity and one difference between an antiparticle and its particle pair.

Similarity: ....

Difference: ....

(2)

What is the quark composition of an antiproton?

....

(1)

State the baryon number of the antiproton.

....

(1)

At CERN protons and antiprotons, each of energy 45 GeV, were collided when trying to create W and Z particles. The antiprotons had to be stored until enough of them were available to be accelerated to the required energy.

Explain why it is difficult to store antiprotons.

....

....

....

(2)

What is the maximum possible mass which can be created from such a collision? Give your answer in u.

....

....

....

(3)

Give two reasons why the following interaction cannot take place.

$$p + p \rightarrow p + \pi^{+} + \pi^{0} + \pi^{-}$$

....

....

....

....

(2)

(e) Typical decays for three mesons (ρ^0, π^-, π^0) are shown below.

(i) $\rho^0 \rightarrow \pi^+ + \pi^-$

(ii) $\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$

(iii) $\pi^0 \rightarrow \gamma + \gamma$

Complete the table to show the three different fundamental interactions and exchange particles involved in these decays.

	Fundamental interaction	Exchange particle
Decay (i)		Gluon
Decay (ii)		
Decay (iii)	Electromagnetic	

(4)

State the fundamental interaction **not** given in your table.

....

(1)
(Total 32 marks)

110. (a) Iodine-123 has a half-life of 13.3 hours. A sample of Iodine-123 has an initial activity of 8000 Bq. How long will it take for the activity to fall to 1000 Bq?

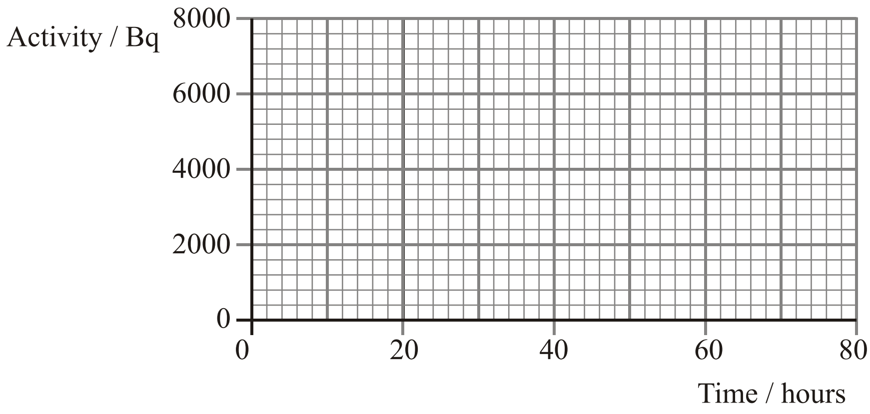
....

....

....

(2)

On the axes below sketch a graph to show how the activity of the sample varies with time over a period of 80 hours.



(3)

An identical sample is administered to a patient. Explain why the measured activity from the patient would not produce the same graph as you have sketched.

....

....

....

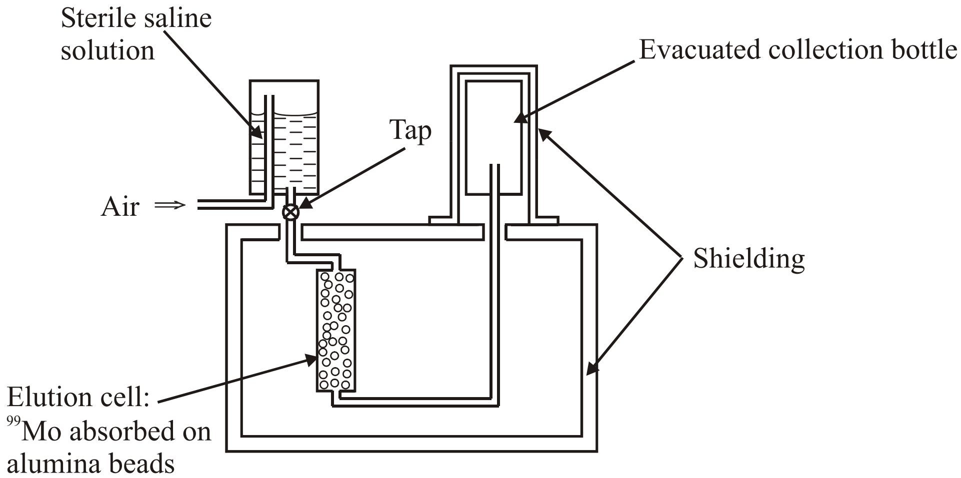
(1)

(b) Technetium-99m ($^{99m}_{43}Tc$) is produced when molybdenum $^{99}_{42}Mo$ decays. Write a nuclear equation for this decay.

....

(1)

The diagram shows a generator for supplying $^{99m}_{43}Tc$.



In which part of the generator is the $^{99m}_{43}Tc$ produced?

....

(1)

Describe what happens when the tap is opened and air is forced into the space above the saline solution.

....

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....

....

....

(3)

Name a suitable material for the shielding.

....

(1)

State one advantage of producing ^{99m}Tc in such a generator.

....

.... **(1)**

$^{99}_{42}Mo$ has a half-life of 67 hours. Suggest two reasons why this half-life makes $^{99}_{42}Mo$ for use in this generator.

1. ....

....

2. ....

.... **(2)**

(c) State the function of the following parts of an X-ray tube:

(i) the filament,

....

(ii) the high voltage supply,

....

(iii) the glass tube which encloses the anode and filament.

.... **(3)**

State two ways in which the radiographer is protected from over-exposure to X-rays.

1. ....

....

2. ....

....

(2)

On an X-ray photograph, bones show up as bright areas and air spaces such as the lungs produce very dark regions. Explain why. You may be awarded a mark for the clarity of your answer.

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(4)

(d) Ultrasound can be used to treat muscle injuries.

Why is a gel applied between the transducer and the patient's skin?

....

(1)

State one way in which energy is lost from an ultrasound pulse as it passes through a material and state what happens to this energy.

....

.... **(2)**

Beyond the layer of damaged muscle there is bone. Calculate the reflection coefficient for ultrasound at the muscle-bone interface.

Specific acoustic impedance of muscle = 1.7×10^6 kg m^{-2} s^{-1}
Specific acoustic impedance of bone = 7.8×10^6 kg m^{-2} s^{-1}

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....

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.... **(3)**

If energy loss in the muscle halves the intensity *I* of the ultrasound pulse, calculate how much of the intensity of the initial pulse actually enters the bone.

....

....

....

.... **(2)**

(Total 32 marks)

111. (a) (i) Check that the rod part of the stand labelled S is of uniform cross-section by taking suitable measurements. Your method and all your measurements should be shown below.

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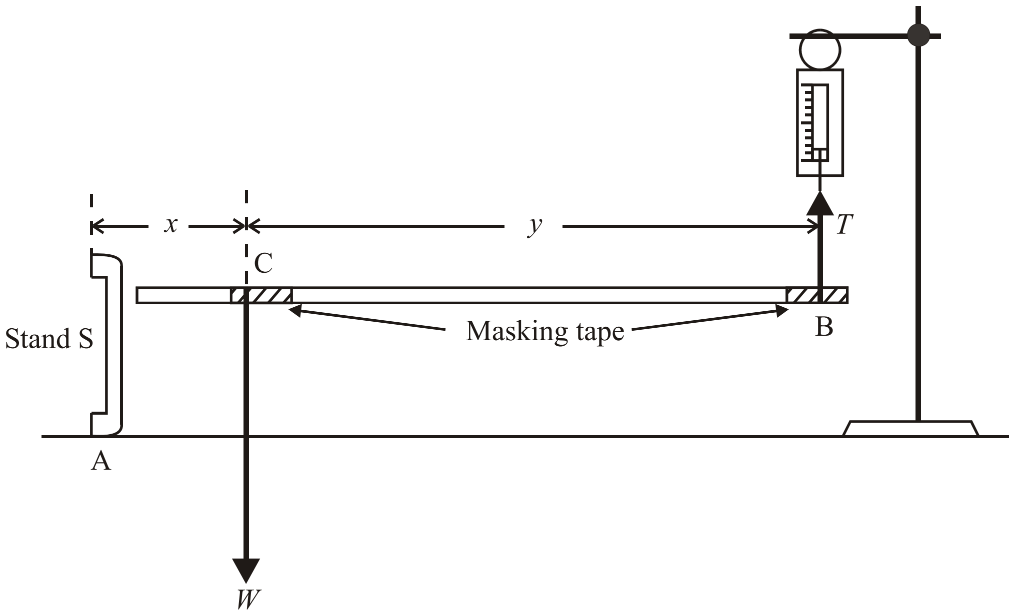
(4)

(ii) Balance the stand on the knife edge so that the rod is horizontal. Mark on the piece of tape the position C of the balance point. Now set up the arrangement shown below.



Support the rod with the newton-meter at a point B on the tape near the end. Mark this point.

Adjust the height of the newton-meter so that the rod is horizontal. Explain how you ensured that the rod was horizontal.

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…………………………………………………………………………………..

…………………………………………………………………………………..

(1)

(iii) The principle of moments shows that

$$W = \frac{T(x + y)}{x}$$

where W is the weight of the stand and T is the newton-meter reading.

Measure and record the distances x and y, and record the value of T.

x ....

y ....

T ....

Use these data to calculate a value for the weight W of the stand.

....

....

(4)

(iv) Estimate the percentage uncertainty in your value for y. Discuss the difficulty of estimating the percentage uncertainty for x.

....

....

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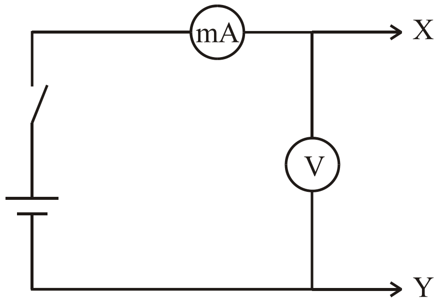
....

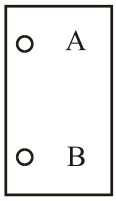
....

(3)

(b) (i) Set up the test circuit as shown in the diagram. Leads X and Y are labelled. Before you switch on the power supply, have your circuit checked by the Supervisor. You will be allowed a short time to correct any faults, but if you are unable to set up the circuit, the Supervisor will set it up for you. You will only lose two marks for this.



Test circuit



Unknown circuit

(2)

(ii) Connect X to A and Y to B to measure the current in and the voltage across the unknown circuit.

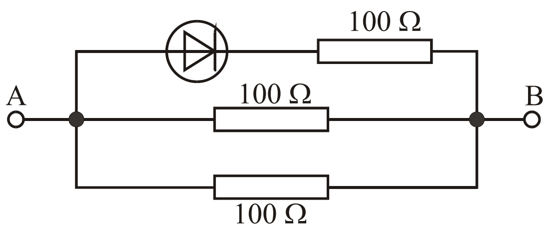
Repeat this with X connected to B and Y connected to A.

Summarise your results in the table below. Complete the table by inserting appropriate units and determining the resistance in each case.

X connected to	Y connected to	Current/	Voltage/	Resistance/
A	B			
B	A			

(4)

(iii) A technician makes up the following 3 circuits for an examination such as this.



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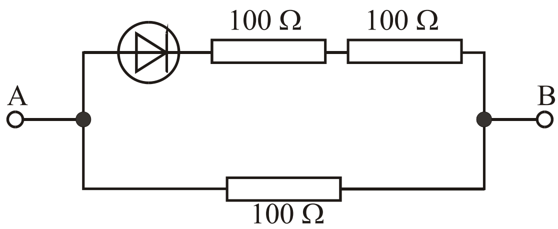
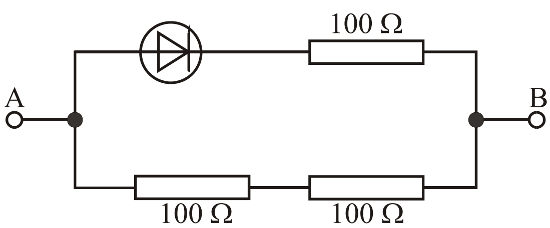


K



L

Explain carefully which of the circuits is the one you tested.

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…………………………………………………………………………………………..

(3)

(iv) Deduce the resistance of the diode when it is conducting.

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…………………………………………………………………………………………..

(3)
(Total 24 marks)

112. (a) Record the temperature θ_0 of the water in the beaker labelled 'Water at room temperature'.

....

Pour 20 cm^3 (20 ml) of this water into the measuring cylinder.

The beaker which is labelled 'For hot water' has a horizontal line drawn on it at the 100 cm^3 mark. Fill the beaker to the horizontal line with boiling water from the kettle. You are now to measure the fall in temperature $\Delta\theta$ of this hot water when 20 cm^3 of the water at room temperature is added. Record the temperature θ_i of the hot water just before the 20 cm^3 is added and the temperature θ_f just after the water is added. Show all your measurements and calculations in the space below. State any special precautions which you took to ensure an accurate value for $\Delta\theta$.

....

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(5)

(b) For the mixing of a fixed volume of hot water and a fixed volume of water at room temperature it is suggested that

$$\Delta\theta = k(\theta_f - \theta_0)$$

where k is a constant.

Using your results from part (a) determine a value for k.

....

....

....

....

(3)

(c) You are now to repeat the experiment using a lower value of θ_i, keeping the volume of hot water as 100 cm^3 and the volume of added water at 20 cm^3. Describe carefully how you can do this without refilling the beaker with hot water. Record your results and determine a second value for k.

....

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(5)

(d) Determine the percentage difference between your two values of *k*. Comment on the extent to which your results confirm the suggested relationship, assuming that the total experimental error is of the order of 10%.

....

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(3)

(e) Describe how you would continue the experiment in order to investigate more fully the suggested relationship. Your account should include

(i) a description of what you would do,

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(ii) a sketch of the graph that would be plotted, showing the expected result,

(iii) an indication of how the value of *k* could be determined from the graph.

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(8)
(Total 24 marks)

113. (a) (i) Check that the metre rule labelled R is of uniform width and thickness by taking suitable measurements. Your method and all your measurements should be shown below.

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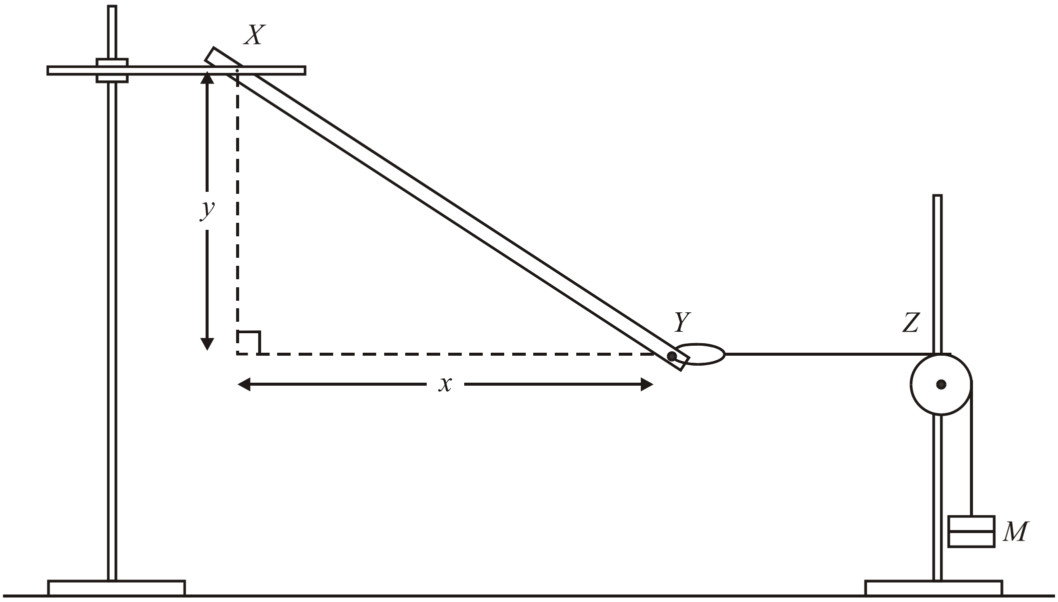
(4)

(ii) The arrangement shown below has been set up ready for you to use.



Adjust the height of the pulley and/or the position of the stands so that the string YZ is horizontal. Measure the distances x and y.

x ....

y ....

The principle of moments gives the equation

$$W = 2Mg\frac{y}{x}$$

where W is the weight of the suspended rule and Mg is the weight of the slotted masses. You may assume $M = 0.200$ kg. Use this equation to find the weight W.

…………………………………………………………………………………..

…………………………………………………………………………………..

(5)

(iii) Explain how you measured x and y, adding to the diagram above if you wish.

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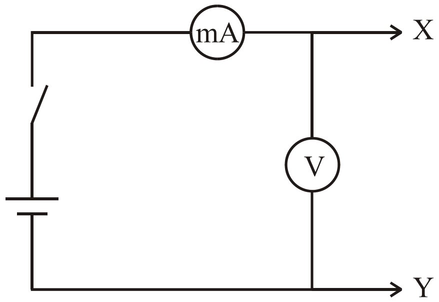
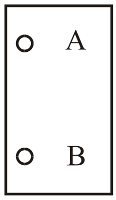
(3)

(b) (i) Set up the test circuit as shown in the diagram. Leads X and Y are labelled. Before you switch on the power supply, have your circuit checked by the Supervisor. You will be allowed a short time to correct any faults, but if you are unable to set up the circuit, the Supervisor will set it up for you. You will only lose two marks for this.



Test circuit



Unknown circuit

(2)

(ii) Connect X to A and Y to B to measure the current in and the voltage across the unknown circuit.

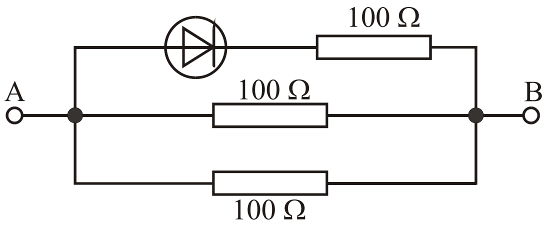
Repeat this with X connected to B and Y connected to A.

Summarise your results in the table below. Complete the table by inserting appropriate units and determining the resistance in each case.

X connected to	Y connected to	Current/	Voltage/	Resistance/
A	B			
B	A			

(4)

(iii) A technician makes up the following 3 circuits for an examination such as this.



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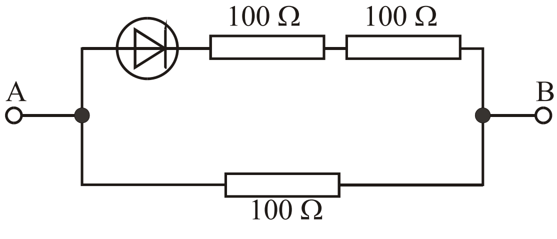
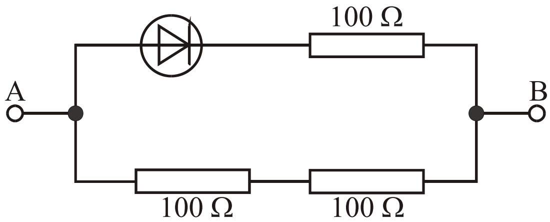


K



L

Explain carefully which of the circuits is the one you tested.

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(3)

(iv) Deduce the resistance of the diode when it is conducting.

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(3)
(Total 24 marks)

114. (a) Pour a known volume V of water at room temperature into the beaker containing the coil of resistance wire so that the coil of wire and the bulb of the thermometer are just covered. Describe how you did this. Record the volume V and the temperature θ_0 of the water in the space below.

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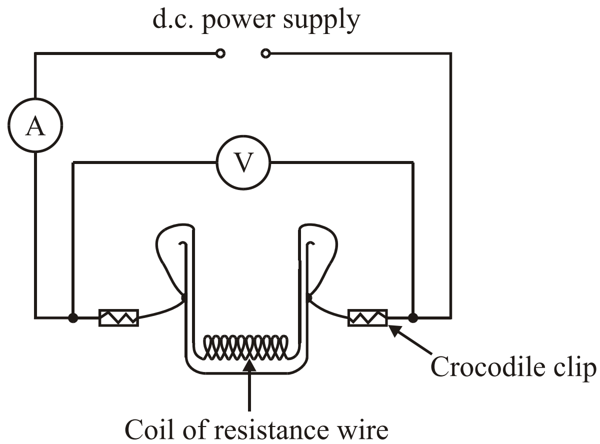
(2)

(b) The circuit has been set up ready for you to use.



Switch on the power supply and start the stopwatch. Record the temperature θ of the water as a function of the time t for a period of 5 minutes. Tabulate your readings in the space below. Also record the current I in the circuit and the potential difference V across the coil of wire.

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(5)

(c) Using the grid below plot a graph of θ against t.

(3)

(d) Draw the best straight line through your points. Determine the rate of rise of temperature $\Delta\theta/\Delta t$ from the gradient.

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If all the power P supplied by the coil of wire is used to heat the water then

$$P = m_w c_w \frac{\Delta\theta}{\Delta t}$$

where m_w = mass of water in the beaker and c_w = specific heat capacity of the water.

Using your results from part (b), calculate P and hence determine c_w assuming that a volume of 1.0 cm^3 (1.0 ml) of water has a mass of 1.0 g.

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(6)

(e) State whether your value of c_w is likely to be too high or too low. Give a reason for your answer.

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State two ways in which the experiment could be made more accurate.

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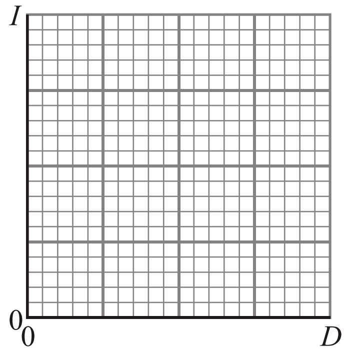
(4)

(f) Draw a circuit diagram to show how a thermistor may be used in a potential divider circuit to produce a temperature sensor.

Draw a block diagram to show how a datalogger may be used to collect data from this temperature sensor.

(4)
(Total 24 marks)

115. (a) On the axes below sketch a graph showing how the intensity *I* of a star varies with distance *D* from the star.



(2)

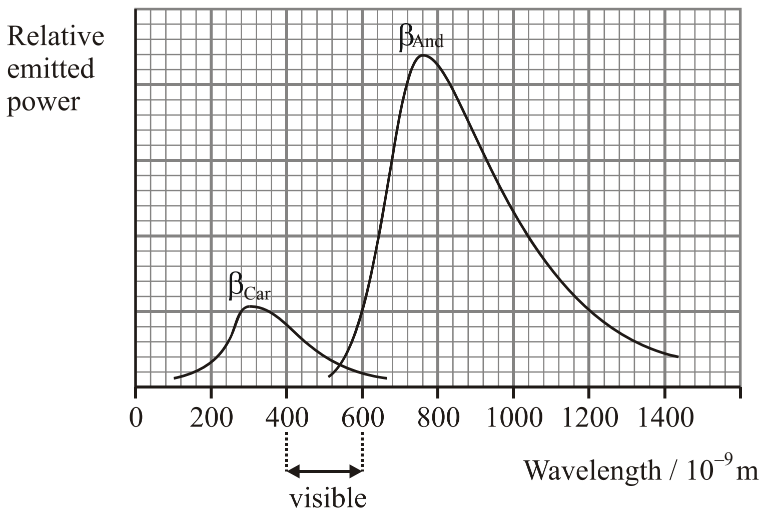
Give two reasons why measurements of a star's intensity are often made from above the Earth's atmosphere.

1. ....

2. ....

(2)

(b) The graph shows the energy distribution in the spectra of two stars β_{Car} and β_{And}.



What can be deduced about the colours of the two stars from the graph?

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(1)

Estimate the surface temperature of β_{And}.

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(3)

The luminosity of β_{Car} is 2.0×10^{28} W and it has a surface temperature of 9300 K. Calculate the surface area of β_{Car}.

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(3)

By comparing the areas under the two graphs, estimate the luminosity of β_{And}.

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(2)

(c) Explain what is meant by a main sequence star.

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(1)

Outline the life story of a white dwarf star starting from when it was a main sequence star. You may be awarded a mark for the clarity of your answer.

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(4)

What determines whether or not a main sequence star eventually becomes a white dwarf? Quantify your answer.

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(2)

(d) Sirius A has a luminosity of 9.96×10^{27} W. Calculate the rate at which mass is being converted to energy in Sirius A.

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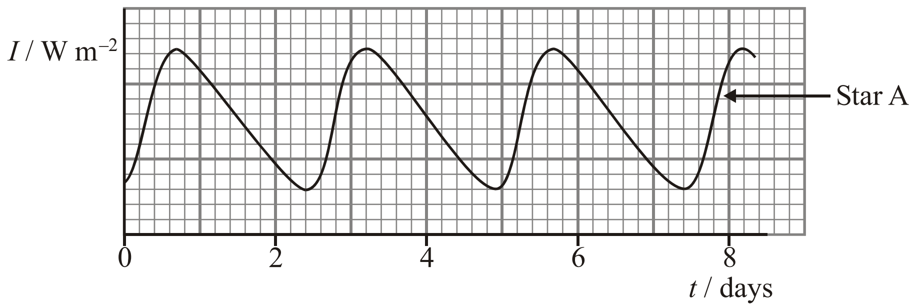
(4)

(e) Cepheid variables are giant stars that have entered an unstable stage of their evolution. More luminous Cepheid variables pulsate at a slower rate than less luminous ones.

The graph, called a light curve, shows how the intensity of a Cepheid variable (star A) varies with time.



Determine the period of pulsation of star A. Show how you arrived at your answer.

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(2)

Add to the graph another light curve showing how the intensity of a more luminous Cepheid variable (star B) might vary with time. Assume that star B has approximately the same average intensity as star A.

(3)

Describe how the pulsations of a Cepheid variable can be used to estimate the distance to the galaxy in which it is found.

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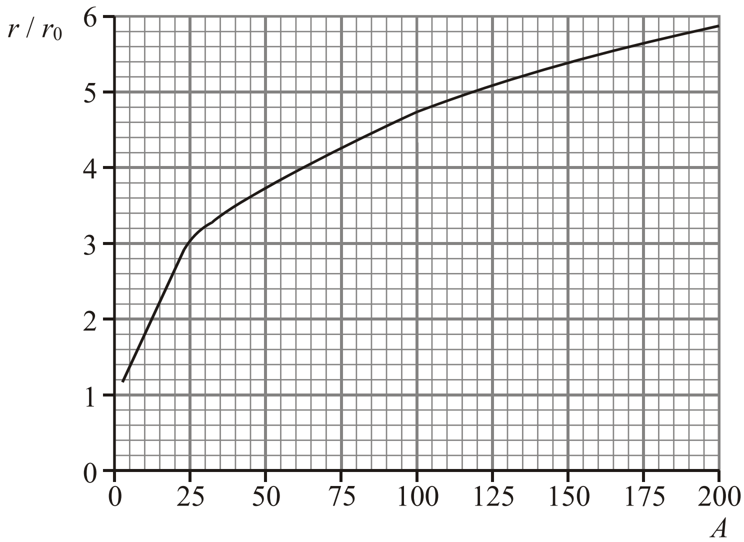
(3)
(Total 32 marks)

116. (a) The graph shows how measured ratios r/r_0, where r is the radius of the nucleus, vary with nucleon number A.



Show that this graph is consistent with the relationship $r = r_0A^{1/3}$ for two values of $A \geq 50$.

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(3)

(b) The radius of a nucleus of tin, ${}^{119}_{50}\text{Sn}$, is 6.0×10^{-15} m. Calculate the density of this nucleus of tin.

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(4)

(c) Explain what is meant by the term binding energy.

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Iron has the highest binding energy per nucleon of any nucleus. What does this tell you about an iron nucleus?

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(3)

(d) Carbon-14, ${}^{14}_{6}\text{C}$, is unstable and decays by β^- emission to nitrogen, N. Write a full nuclear equation for this decay.

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(3)

Carbon-14 has a half-life of 5730 years. Living organisms contain approximately 100 atoms ${}^{14}_{6}\text{C}$ for every 10^{20} atoms of stable carbon-12, ${}^{12}_{6}\text{C}$. Estimate the age of a fossil which is found to contain approximately 12 atoms of ${}^{14}_{6}\text{C}$ for every 10^{20} atoms of ${}^{12}_{6}\text{C}$.

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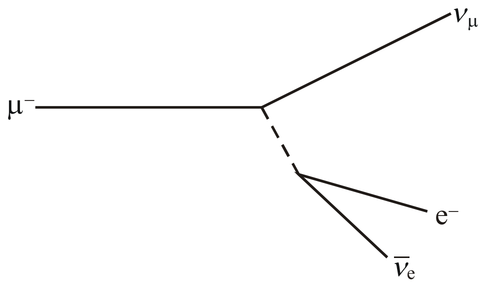
(2)

(e) The Feynman diagram represents the decay of a muon.



By what type of interaction does this decay take place? Justify your answer.

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....

....

(2)

Label the exchange particle on the diagram with its name.

(1)

(f) The following strong interaction has been observed.

$$\underset{(dds)}{\Sigma^-} + p \rightarrow \underset{(\bar{u}s)}{X} + K^- + n$$

Is particle X positive, negative or neutral?

....

(1)

Is particle X a baryon, a meson or a lepton?

....

(1)

State the quark composition of the proton and the neutron.

proton .... neutron ....

(1)

Explain why particle X cannot contain a strange quark, and deduce the identity of particle X. You may be awarded a mark for the clarity of your answer.

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(4)

(g) High energy collisions occur in machines that either collide hadrons such as protons and antiprotons or leptons such as electrons and positrons.

Name one other hadron and one other lepton.

hadron .... lepton ....

(2)

Are hadrons fundamental particles? Explain your answer.

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(2)

An electron and a positron each of energy *E* collide head on and annihilate. Calculate the minimum value of *E* in MeV needed to produce a Z^0 particle of mass 98 u.

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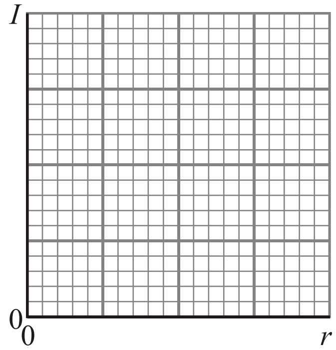
(3)

(Total 32 marks)

117. (a) On the axes below sketch a graph showing how the intensity I of an X-ray beam varies with distance r from a point X-ray source in air.



(2)

If the X-ray intensity is 7.0 MW m^{-2} at a distance of 0.20 m from the source, calculate the intensity at a distance of 2.0 m from the source.

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(3)

(b) Complete the table below to compare α, β and γ radiation by ticking in the appropriate boxes.

	α	β	γ
Useful for imaging			
Useful for therapy			
Most damaging to tissue			
Least penetrating			

(4)

Beta radiation can be either positive or negative. Phosphorus, $^{32}_{15}P$, decays to sulphur, S, by β^- emission. Sodium, $^{24}_{11}Na$, decays to neon, Ne, by β^+ emission. The equations below show these two decays. Complete the equations by adding the missing nucleon and proton numbers.

$$^{32}_{15}P \rightarrow S + \beta^-$$

$$^{24}_{11}Na \rightarrow Ne + \beta^+$$

(3)

(c) A known quantity of a radionuclide which can label red blood cells is injected into a patient. Describe what further steps are needed to estimate the patient's blood volume. You may be awarded a mark for the clarity of your answer.

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(5)

(d) Calculate the wavelength in soft tissue of an ultrasound pulse of frequency 6.0 MHz (speed of sound in soft tissue = 1540 m s^{-1}).

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(3)

Would ultrasound of this frequency be suitable for eye investigations? Explain your answer.

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(1)

Show that the reflection coefficient for ultrasound at a boundary between muscle and blood is approximately 1×10^{-3}.

Data: Specific acoustic impedances

$Z_{\text{muscle}} = 1.70 \times 10^6$ kg m^{-2} s^{-1}
$Z_{\text{blood}} = 1.59 \times 10^6$ kg m^{-2} s^{-1}
$Z_{\text{brain tissue}} = 1.58 \times 10^6$ kg m^{-2} s^{-1}

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(3)

The reflection coefficient at a boundary between brain tissue and blood is approximately 1×10^{-5}.

Use this value to explain why ultrasound can be used to investigate blood flow in muscle but not in the brain.

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(2)

(e) Each accelerated electron in an X-ray tube has an energy of 120 keV. State the value of the operating voltage of this X-ray tube.

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(1)

Explain what happens to most of the energy of these electrons.

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(1)

State **two** features of the target anode in an X-ray tube.

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(2)

This tube produces X-rays with energies of the order of tens of keV. Would these X-rays be more suitable for diagnostic or therapeutic use? Explain your answer.

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(2)
(Total 32 marks)

118. (a) (i) Measure the mass m_b of the 250 cm^3 (250 ml) beaker. You have access to a top pan balance. Pour the salt into the beaker and measure the total mass m_t of the beaker and salt. Hence determine the mass m of salt.

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Fill the measuring cylinder with water to within a few cm^3 of 100 cm^3. Record this volume.

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Pour this water into the beaker. Repeat the process. Record your second volume.

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State the total volume transferred to the beaker.

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Stir the water thoroughly so that a salt solution is formed. Assuming that 1.00 cm^3 (1.00 ml) of water has a mass of 1.00 g and that there is no change in liquid volume as the salt dissolves, calculate the theoretical value for the density of the salt solution.

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(3)

(ii) Use the apparatus provided and the top pan balance to find the density of the salt solution experimentally. To gain full credit you must show all your working.

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(5)

(iii) Estimate the percentage uncertainty in your value for the volume of the solution.

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Assuming that the uncertainty in your mass values is negligible, discuss whether your two values for the theoretical and experimental density of the solution indicate that there is a change in the volume when the salt is dissolved in water. Your answer should be based on a quantitative argument.

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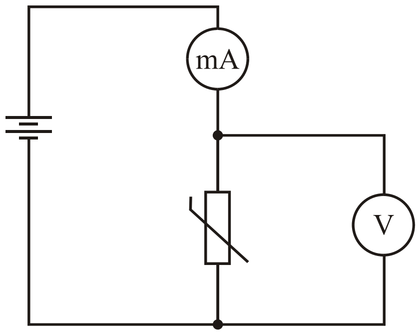
(4)

(b) (i) Set up the circuit as shown in the diagram below. Before connecting to the power supply have your circuit checked by the Supervisor. You will be allowed a short time to correct any faults. If you are unable to set up the circuit the Supervisor will set it up for you. You will only lose two marks for this.



(2)

(ii) Using the space below, record the potential difference *V* across the thermistor and the current *I* in the thermistor.

V = ...

I = ...

Hence calculate a value for the resistance *R* of the thermistor.

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(3)

(iii) You are to observe how the current changes with time as you warm the thermistor and then sketch a graph of this.

Hold the thermistor between your thumb and forefinger and observe what happens to the current in the thermistor. Continue holding the thermistor until the current reaches a steady value. Record the final steady values for the current I_f in the thermistor and the potential difference V_f across it.

V_f ....

I_f ....

Hence calculate a second value R_f for the resistance of the thermistor.

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In the space below **sketch** a graph of the current in the thermistor against the time for which the thermistor is held.

(7)
(Total 24 marks)

119. (a) (i) The apparatus has been set up ready for you to use and should not be moved.

Approximately half fill the beaker with the hot water provided. Quickly pour this water into the plastic cup up to the marked line, which is calibrated to give 100 cm^3 of water in the cup.

Observe the temperature of the water in the cup and start the stopwatch when the temperature reaches 80.0 °C. Record the temperature θ at regular intervals of time t for five minutes.

Tabulate your readings in the space below.

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(5)

(ii) Plot a graph of θ against t on the grid below.

(4)

(iii) Determine the gradient $\Delta\theta/\Delta t$ of your graph when θ = 70.0 °C.

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Hence calculate the rate at which the water is losing energy when θ = 70.0°C, given that the density of water is 1.0 g cm^{-3} (1000 kg m^{-3}) and its specific heat capacity is 4.2 J g^{-1} K^{-1} (4200 J kg^{-1} K^{-1}).

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(4)

(b) (i) It is suggested that an insulated cup could be made by using two cups with an air gap between them.

Draw a labelled diagram to show how you could do this with the apparatus provided.

(2)

(ii) Outline the steps you would take in repeating the experiment with the double cup in order to test its insulating properties compared with the single cup.

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(3)

(iii) In the space below, sketch the results you would expect to get. You should sketch the curves for the single cup and the double cup on the same set of axes. Label your curves.

(3)

(iv) It is suggested that the double cup should insulate at least twice as well as the single cup. Explain how you would test this from the curves that you have sketched in part (iii).

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(3)
(Total 24 marks)

120. (a) (i) The equation $I = L/\ 4\pi D^2$ can be used to determine the luminosity L of a star of known distance D and intensity I. Use this equation to show that the base units of intensity are kg s^{-3}.

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....

....

(3)

(ii) Calculate the luminosity of a star which has a measured intensity of 1370 W m^{-2} and which is known to be 1.49×10^{11} m from Earth.

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(3)

(b) (i) Give three advantages that charge coupled devices (CCDs) have compared with photographic emulsions.

Advantage 1 ....

....

Advantage 2 ....

....

Advantage 3 ....

....

(ii) Give one disadvantage of CCDs compared with photographic emulsions.

....

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(4)

(c) In 1983 the Infrared Astronomical Satellite (IRAS) conducted a survey of the sky by observing stars. Explain why such a survey would give far better results than a similar one made from the Earth's surface. You may be awarded a mark for the clarity of your answer.

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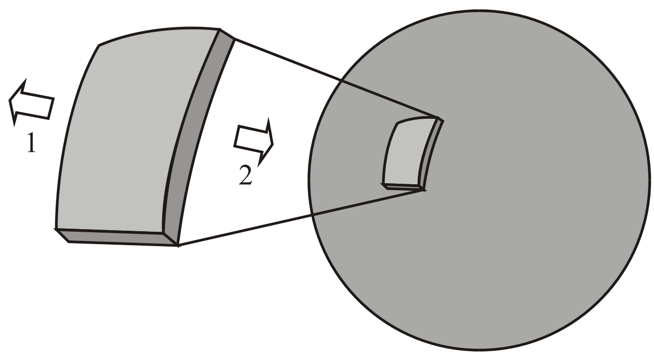
(3)

(d) The diagram shows a main-sequence star. The arrows on the enlarged section of star material represent the forces acting on it.



(i) State the origin of these forces.

1. ....

....

2. ....

....

(2)

(ii) How do these forces compare in size?

....

(1)

(iii) State three differences between white dwarf stars and red giant stars. One of your answers should be numerical.

1. ....

....

2. ....

....

3. ....

....

(3)

(iv) What determines whether a neutron star will be formed from a supernova?

....

....

(2)

(e) When the Sun was formed some 4.6×10^9 years ago, it was slightly smaller than it is today. Theoretical calculations show that it has become 40% more luminous and grown in radius by 6% (i.e. $L_\odot = 1.4\ L$ and $r_\odot = 1.06\ r$ where L and r represent the luminosity and radius of the Sun when it was formed).

Data for the Sun today:

Luminosity $L_\odot$ $= 3.9 \times 10^{26}$ W

Radius $r_\odot$ $= 7.0 \times 10^5$ km

Temperature $T_\odot$ $= 5800$ K

(i) Calculate the luminosity of the Sun when it was formed.

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....

....

(2)

(ii) Calculate the surface area of the Sun when it was formed.

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(2)

(iii) Hence show that the surface temperature of the Sun has increased by approximately 300 K during its lifetime.

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(4)

(iv) The Sun has become slightly more yellow during its lifetime. It used to be more orange in colour. This is because the wavelength at which the peak intensity of its emitted radiation occurs has decreased. Use Wien's law to calculate the decrease in the wavelength of the peak intensity.

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(3)

(Total 32 marks)

121. (a) (i) When calculating the energy density of a material, the area under a stress-strain graph is calculated. Show that the base units of energy density are kg m^{-1} s^{-2}.

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(3)

(ii) A sample deforms elastically obeying Hooke's law. A stress of 200 MPa produces a strain of 9.5×10^{-4}. Show that the energy density is approximately 100 kJ m^{-3}.

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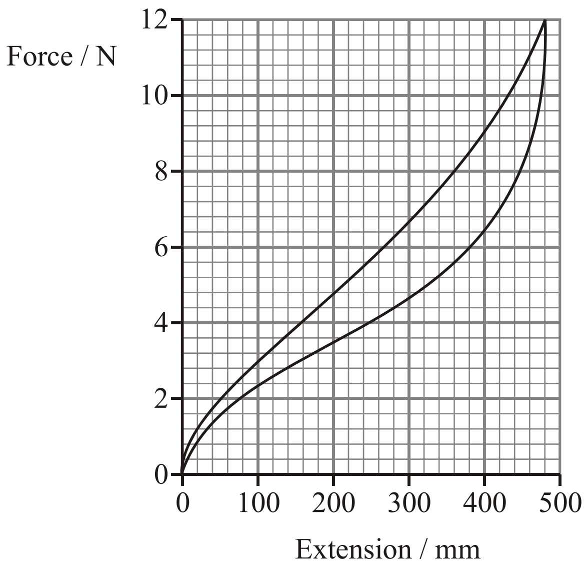
(3)

(b) In an experiment to measure the extension of a rubber band the following graph was obtained. The line represents the extension during loading and unloading.



(i) Label the two lines to indicate which represents loading and which represents unloading.

(1)

(ii) What is the name for the characteristic behaviour shown by the shape of this graph?

....

(1)

(iii) If the rubber band has a cross-sectional area of 6.0×10^{-6} m^2 calculate the stress produced in the elastic band when it is fully loaded.

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(2)

(iv) Estimate how much work is done on the rubber band as it is fully loaded.

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(4)

(v) Hence show that the energy dissipated during the loading and unloading process is approximately 1 J.

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(2)

(vi) When the rubber band has a load placed on it a new reading is taken. Over the next minute this reading increases by a few millimetres. If a material deforms plastically in this way when stress is applied, what is the name of this mechanism?

....

(1)

(vii) State Hooke's law.

....

....

(1)

(viii) Draw a labelled diagram of the apparatus that could be used to produce a force-extension graph for a rubber band, for loads up to 12 N.

(4)

(c) (i) Glass objects are often referred to as being fragile. Circle any of the following words which could be used to describe the properties of glass at room temperature.

brittle   tough   flexible   stiff   plastic

(ii) A cylindrical glass rod has a diameter of 4.0 mm, a length of 30 cm and a Young modulus of 7.0×10^{10} Pa. If a load of 880 N is applied to the rod, calculate its extension.

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(6)

(d) Modern canoes can be made of polyethylene (polythene). One canoe manufacturer describes how their canoes can withstand being dropped from the factory roof without being damaged because they are made from cross-linked polymers. Describe with the aid of a diagram the microscopic properties of such a polymer. You may be awarded a mark for the clarity of your answer.

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(4)
(Total 32 marks)

122. (a) (i) Particle energies are often quoted in units of mega-electronvolts (MeV). Show that the base units of the electronvolt can be expressed as kg m^2 s^{-2}.

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(3)

(ii) Calculate the theoretical energy released when a $^{238}_{92}U$ nucleus is formed from individual protons and neutrons. Give your answer in MeV.

Data (masses):

$^{238}_{92}U$ = 238.0003 u
proton = 1.0073 u
neutron = 1.0087 u

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(4)

(b) Name the two main forces acting in the nucleus of an atom. State what each of these forces acts upon in the nucleus and indicate their ranges.

Force 1: ....

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Force 2: ....

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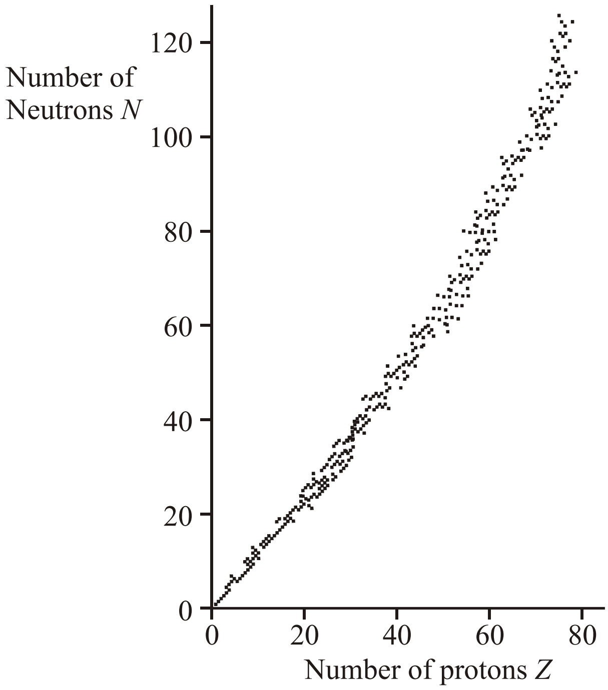
(4)

(c) (i) On the *N*-*Z* plot shown below, indicate the regions where nuclei that might undergo α, β^- and β^+ decay would occur.



(3)

(ii) Explain the significance of the region indicated by the dots in this plot. You may be awarded a mark for the clarity of your answer.

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(3)

(d) (i) In the Sun, fusion reactions convert hydrogen nuclei into helium nuclei. One step of this process involves a β^+ decay. Complete a full nuclear equation for this part of the reaction by adding nucleon and proton numbers to each particle.

$$p \rightarrow n + \beta^+ + \nu$$

(2)

(ii) Tick the appropriate boxes to indicate which particles fit which classification.

	baryon	hadron	meson	lepton	antimatter
proton					
neutron					
β^+					
ν					

(4)

(e) A sigma-plus particle Σ^+ can decay to a particle X^+ and a π^0 particle. Quark flavours are shown for the Σ^+ and π^0 particles.

$$\underset{(usu)}{\Sigma^+} \rightarrow \underset{(qqq)}{X^+} + \underset{(\bar{u}u)}{\pi^0}$$

(i) Show that this decay is permitted by using appropriate conservation laws.

....

....

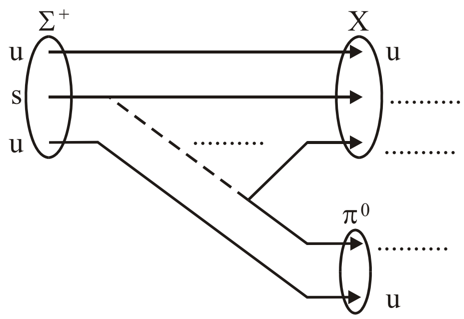
.... **(2)**

(ii) In this decay, the strange quark turns into an up quark by emitting a W^- particle, which in turn decays into down and anti-up quarks.

$$s \rightarrow u + W^-$$

$$W^- \rightarrow d + \bar{u}$$

Use this information to complete the diagram to show the W^- particle and the quarks by adding labels to each of the four dotted lines.



(2)

(iii) Identify particle X.

.... **(1)**

(iv) What sort of particle is a W^-?

.... **(1)**

(v) Give two reasons why a W^- particle must be responsible for the interaction.

....

.... **(2)**

(vi) The Σ^+ + can also decay to produce a neutron. Three decays are shown.

1. $\Sigma^+ \rightarrow \; n \; + \; \pi^-$

2. $\Sigma^+ \rightarrow \; n \; + \; \pi^0$

3. $\Sigma^+ \rightarrow \; n \; + \; \pi^+$

Which of these decays is possible? Explain your answer. Pions (π^-, π^0 and π^+) are mesons.

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(1)

(Total 32 marks)

123. (a) (i) The equation $I = P/4\pi r^2$ can be used in calculating intensity of X-rays from a source. Use this equation to show that the base units of intensity are kg s^{-3}.

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(3)

(ii) An X-ray beam has an intensity of 5.7 W mm^{-2} at a distance of 0.4 m from an X-ray tube. How far from the X-ray tube should a radiographer stand in order to reduce the intensity to 0.80 W mm^{-2}?

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(3)

(b) An X-ray tube works by accelerating electrons through a potential of 65 kV towards a target.

(i) Show that the energy of an electron arriving at the target is approximately 1×10^{-14} J.

....

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(2)

(ii) Assuming that the usual kinetic energy formula is valid, calculate the theoretical speed reached by an electron.

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(3)

(iii) What happens to the energy of the electrons when they strike the X-ray tube target?

....

....

(2)

(iv) A typical X-ray tube has an efficiency of less than 1%. List two features of an X-ray tube target that enable it to cope with this low efficiency.

1. ....

2. ....

(2)

(c) An ultrasound image of a 19-week-old unborn baby is shown below.

(i) Is this an A-scan or a B-scan?

....

(1)

(ii) Outline the principles for producing such a scan, with reference to the above image. You may be awarded a mark for the clarity of your answer.

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(5)

(d) (i) Define each of the following in terms of a radioactive tracer which may be given to a patient.

Radioactive half-life ....

....

Biological half-life ....

....

Effective half-life ....

....

(3)

(ii) An isotope of iodine ^{125}I has an effective half-life of 16 days when it is used to label the human serum albumin. If it has a radioactive half-life of 60 days calculate its biological half-life.

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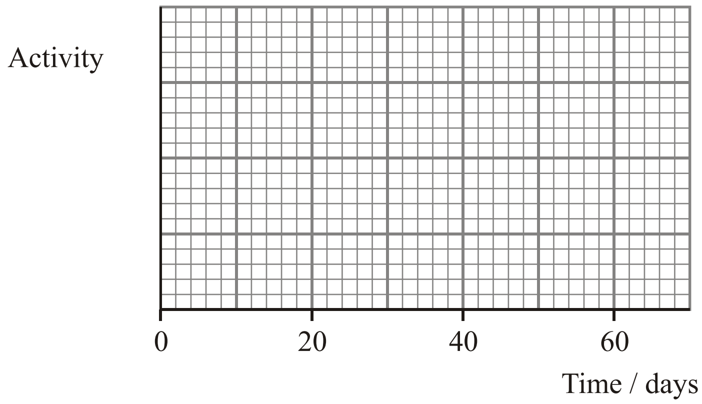
(3)

(iii) On the axes below sketch two curves, one showing the activity of the ^{125}I within a patient and the other showing the activity of an identical sample that was kept in a laboratory. Label your curves P (patient) and L (laboratory).



(3)

(iv) What type of radiation should ^{125}I emit in order to be used as a tracer? Justify your answer.

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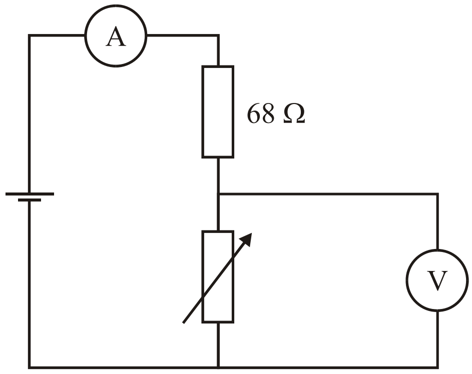
(2)
(Total 32 marks)

124. (a) (i) Using the voltmeter provided measure the potential difference between the terminals of the cell. Because the voltmeter has a very high resistance, you may assume that this reading is the e.m.f. *E* of the cell.

E = ...

(1)

(ii) Set up the circuit shown in the diagram below. Before you connect your circuit to the cell, have your circuit checked by the Supervisor. You will be allowed a short time to correct any faults. If you are unable to set up the circuit, the Supervisor will set it up for you. You will lose only two marks for this.



(2)

(iii) Connect the cell to your circuit and adjust the variable resistor until the potential difference V_1 across the variable resistor is approximately $\frac{1}{2}E$. Record V_1 and the corresponding current I_1.

V_1 = ...

I_1 = ...

Hence calculate the resistance R_1 of the variable resistor at this setting.

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(3)

(iv) Using your knowledge of potential dividers, what is the expected value of R_1 when V_1 is $\frac{1}{2}E$?

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....

Calculate the percentage difference between your value of R_1 and the expected value.

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....

(2)

(v) Repeat the experiment with the potential difference V_2 across the variable resistor set to approximately $\frac{1}{4}E$. Record V_2 and the corresponding current I_2.

V_2 = ...

I_2 = ...

Calculate the resistance R_2 of the variable resistor at this setting.

....

....

What value would you expect to get for R_2 when $V_2 = \frac{1}{4}E$?

....

....

(3)

(vi) Suggest three reasons why your experimental values of R_1 and R_2 differ from the expected values.

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(3)

(b) (i) Determine accurate values for the internal diameter d_i and the external diameter d_e of the washer provided. State any special precautions which you took to ensure that the diameters were as accurate as possible.

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(5)

(ii) Determine an accurate value for the thickness t of the washer.

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(2)

(iii) Calculate the volume V of the washer given that

$$V = \frac{1}{4}\pi(d_e^2 - d_i^2)t$$

....

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Using the top pan balance measure the mass m of the washer.

m = ...

Hence determine the density of the material from which the washer is made.

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(3)

(Total 24 marks)

125. (a) Use the principle of moments, with the metre rule and the other apparatus provided, to find the mass m_0 of the matchbox and string, in grams. Draw a diagram to explain how you did this and show all your results and calculations in the space below. If you are unable to do this you should ask for the card from the Supervisor. You will lose 4 marks but you need not draw the diagram.

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(7)

(b) Put a mass of 60 g into the matchbox. Place the matchbox near the top of the slope provided and increase the angle α of the slope until the matchbox just starts to slide. The coefficient of static friction, μ, between the matchbox and the slope is given by

$$\mu = \tan \alpha$$

Take measurements to determine the value of tan α and hence a value for μ. Draw a diagram to show how you did this and record all your measurements and calculations in the space below.

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Assuming the uncertainty in μ is 0.02, what is the percentage uncertainty in your value?

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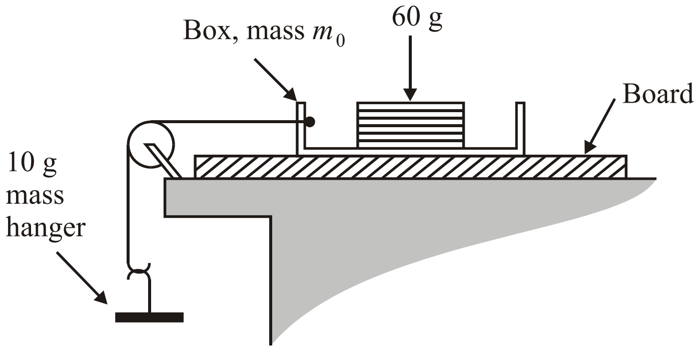
(7)

(c) Keeping 60 g in the matchbox, set up the arrangement shown below, using the board from part (b).



Add masses to the hanger until the matchbox *just* begins to slide. Estimate the total mass m_s in grams needed for this to occur. Hence find a second value for μ given that

$$\mu = \frac{m_s}{M}$$

where $M = m_0 + 60$ grams.

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(3)

(d) Estimate the percentage uncertainty in your value for m_s, explaining how you did this.

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....

(2)

(e) You are to plan an experiment to further investigate the equation in part (c). Your plan should include

(i) a description of the experiment to be performed,

(ii) a sketch graph showing the expected results,

(iii) an indication of how μ can be found from the graph.

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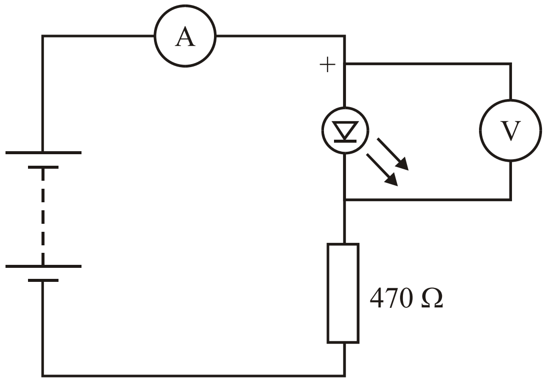
(5)
(Total 24 marks)

126. (a) (i) Set up the circuit shown in the diagram below. Use the red LED (light emitting diode). Before you connect your circuit to the power supply, have it checked by the Supervisor. You will be allowed a short time to correct any faults. If you are unable to set up the circuit, the Supervisor will set it up for you. You will lose no more than two marks for this.



(2)

(ii) Connect the circuit to the power supply. Record the potential difference V_r across the red LED and the corresponding current I_r.

V_r = ...

I_r = ...

Hence calculate the resistance R_r of the red LED in this circuit.

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....

(3)

(iii) Replace the red LED with the green LED. Ensure that the positive end of the LED is connected as in the previous circuit. Record the potential difference V_g across the green LED and the corresponding current I_g.

V_g = ...

I_g = ...

Hence calculate the resistance R_g of the green LED in this circuit.

....

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....

....

(3)

(iv) Repeat your measurements and calculations with the 220 Ω resistor connected into the circuit in place of the 470 Ω resistor.

1 Red LED with 220 Ω resistor

V_r' = ...

I_r' = ...

....

....

....

R_r' = ...

2 Green LED with 220 Ω resistor

V_g' = ...

I_g' = ...

....

....

....

R_g' = ...

(5)

(v) Write three conclusions based on your experimental observations.

....

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(3)

(b) (i) Determine an accurate value for the diameter *d* of the marble. Explain, with the aid of a diagram, how you tried to ensure that an accurate value for the diameter was found.

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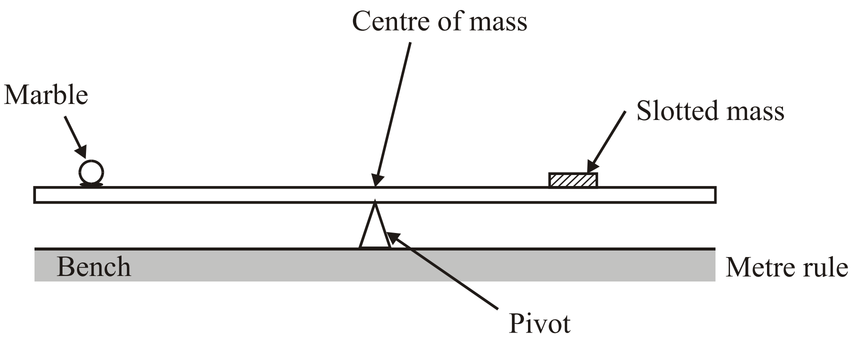
(3)

(ii) The metre rule has a small piece of Blu-tack attached to it at the 5 cm mark. Balance the rule on the knife edge to determine the position of the centre of mass of the rule and Blu-tack combination.

Scale reading at centre of mass = ...

(iii) Secure the marble to the metre rule at the position of the Blu-tack. Set up the arrangement shown in the diagram below.



Determine the mass *m* of the marble using the principle of moments. Using the above diagram, show carefully the measurements which you took in order to determine the mass *m*. Record all your measurements and calculations in the space below. The slotted mass has a mass of 10 g

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(5)
(Total 24 marks)

127. (a) Without using calipers, determine a value for the average diameter *d* of the table tennis ball. Draw a diagram to show how you did this and record your measurements in the space below.

....

....

The moment of inertia I is a rotational property of the table tennis ball. Calculate a value for I given that

$$I = \frac{md^2}{6}$$

where m = mass of table tennis ball which is given on the card.

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....

(5)

(b) Use the apparatus provided to find the time t it takes for the ball to roll from rest through a distance of 1.00 m down the slope set up for you. **DO NOT ADJUST THE ANGLE OF THE SLOPE.**

Draw a diagram to explain how you did this and record your measurements in the space below.

....

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Measure the height h through which the ball has fallen whilst travelling 1.00 m down the slope. Show how you did this on your diagram and record your measurements below.

....

....

Calculate a value for sin α, where α is the angle the slope makes with the bench.

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....

(7)

(c) The speed v of the ball after travelling a distance s is given by

$$v = \frac{2s}{t}$$

Calculate the speed of the ball after it has travelled a distance of 1.00 m and hence determine the linear kinetic energy E_k that it gains.

....

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....

....

Calculate the potential energy E_p that it loses when falling through the height h.

....

....

(3)

(d) These energies differ because some of the potential energy is converted into rotational kinetic energy.

When this is taken into account

$$t^2 = \frac{10s}{3g\sin\alpha}$$

where g = gravitational field strength.

Use your value for sin α from part (b) to calculate a theoretical value for t when s = 1.00 m.

....

....

Calculate the percentage difference between this theoretical value for *t* and the experimental value you found in part (b). Comment on the extent to which your answer supports the equation.

....

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....

(3)

(e) You are to plan an experiment to further investigate the equation in part (d). Your plan should include

(i) a description of the experiment to be performed,

(ii) a sketch graph showing the expected results,

(iii) how you would use the graph to test the equation.

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(6)
(Total 24 marks)

128. (a) The Cosmic Background Explorer satellite (COBE), launched in 1989, measured a cosmic background temperature of 2.725 K. Calculate the peak wavelength of the background spectrum that gives this temperature.

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....

....

(3)

Which type of electromagnetic radiation forms this background spectrum?

....

(1)

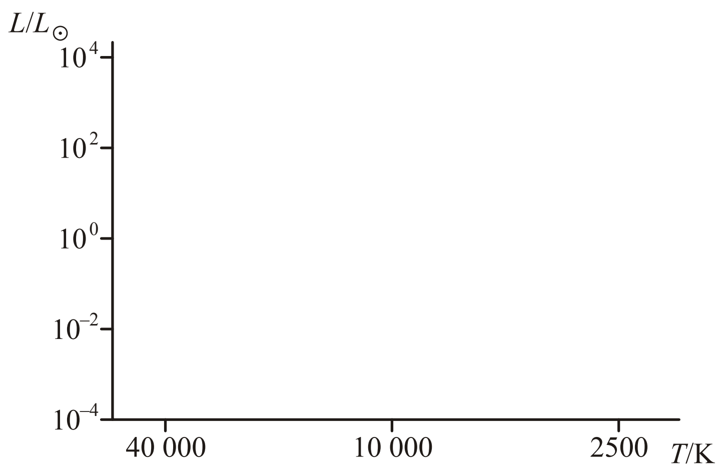
(b) Define what is meant by a main sequence star.

....

....

(2)

A Hertzsprung-Russell diagram can be used to plot the luminosity of a star in terms of the luminosity of the Sun ($L_\odot$) against the star's surface temperature.



Add to the diagram a line to indicate where main sequence stars occur.

Mark clearly with a cross the location of the Sun.

(3)

Add to the diagram the regions where (i) white dwarf stars and (ii) red giant stars may typically be found. Label these clearly.

Use the diagram to estimate the average surface temperature of a red giant star.

....

(3)

(c) The table shows the properties of three main sequence stars.

Star	Luminosity/$L_\odot$	Surface temperature/K
α Cen B	0.53	5250
Sirius A	26	9230
γ Cas	930 000	29 500

State which star would

(i) have the greatest mass ....

(ii) spend the greatest time on main sequence ....

(2)

The luminosity of the Sun is 3.9×10^{26}W. Calculate the luminosity of Sirius A.

....

....

(2)

Show that the area of Sirius A is approximately 2.5×10^{19} m^2.

....

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....

(2)

Hence calculate the diameter of Sirius A.

....

....

....

....

(2)

(d) When a star in excess of eight solar masses leaves the main sequence it may become a supernova. Describe the processes which occur as this happens and explain what might subsequently happen to such a star. You may be awarded a mark for the clarity of your answer.

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(5)

(e) When hydrogen nuclei fuse to form a helium nucleus, a small fraction of the mass of the hydrogen going into the nuclear reaction does not show up in the mass of the helium. Use the data below to show that the mass decrease is approximately 5×10^{-29} kg.

Mass of hydrogen nucleus $= 1.673 \times 10^{-27}$ kg

Mass of helium nucleus $= 6.645 \times 10^{-27}$ kg

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....

(2)

Hence calculate the energy released when one helium nucleus is created from four hydrogen nuclei.

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(2)

Calculate the ‘small fraction’ that is referred to in the paragraph above. Give your answer as a percentage.

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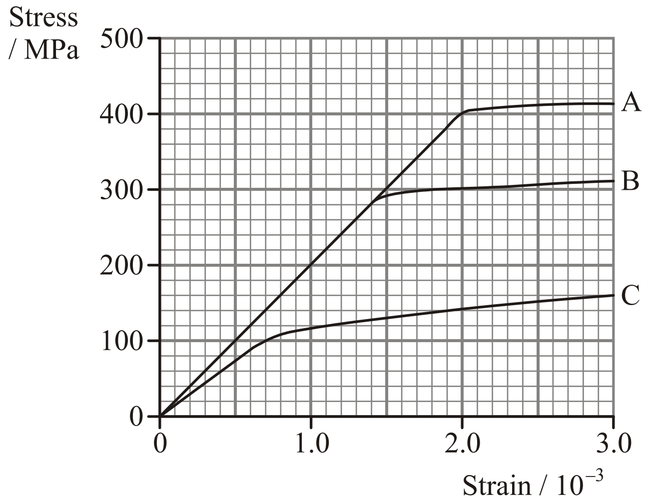
(3)
(Total 32 marks)

129. (a) The graph shows the behaviour of three materials A, B and C when stress is applied to them.



(i) Show that the material C has a Young modulus of 130 GPa.

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(3)

(ii) Show that material B has an energy density of approximately 700 kJ m^{-3} at a strain of 3.0×10^{-3}.

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(4)

Which material(s) is/are the strongest? Explain your answer.

....

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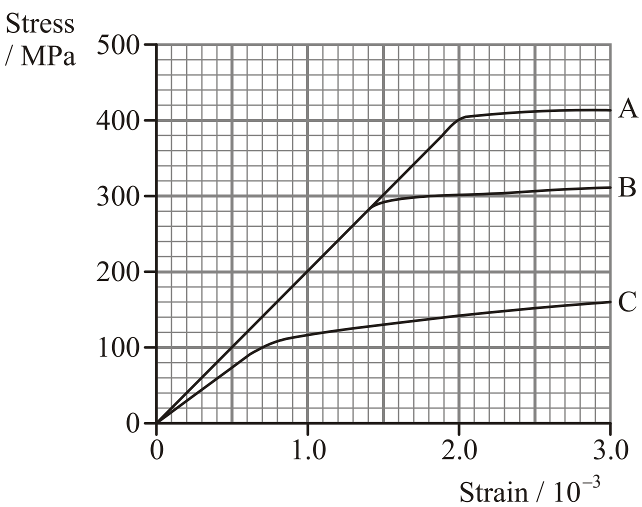
(2)

(b)



Mark with a cross the point on each line where Hooke's law is no longer obeyed.

The three materials shown are copper, mild steel and high carbon steel.
Identify which is which.

A: ....

B: ....

C: ....

Which of these materials would you expect to be the most brittle?

....

(4)

Describe what happens to the molecular structure of one of these materials as it is stressed with reference to elastic behaviour, plastic flow and fracture. You may be awarded a mark for the clarity of your answer.

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(4)

On the axes above add a further line to show the stress-strain graph produced by loading natural rubber up to a strain of 3.0×10^{-3}. The Young modulus of the rubber is 21×10^{6} Pa.

(1)

(c) Describe the process by which a pre-stressed reinforced concrete beam is produced. Illustrate your answer with diagrams.

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(5)

(d) Define what is meant by the term elastomer.

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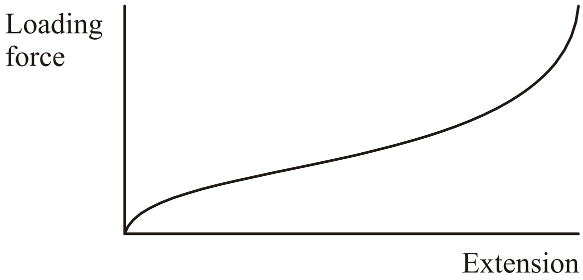
(1)

The graph shows how the extension of a length of rubber varies with the applied force. Describe what happens to the molecular structure of the rubber during this process.



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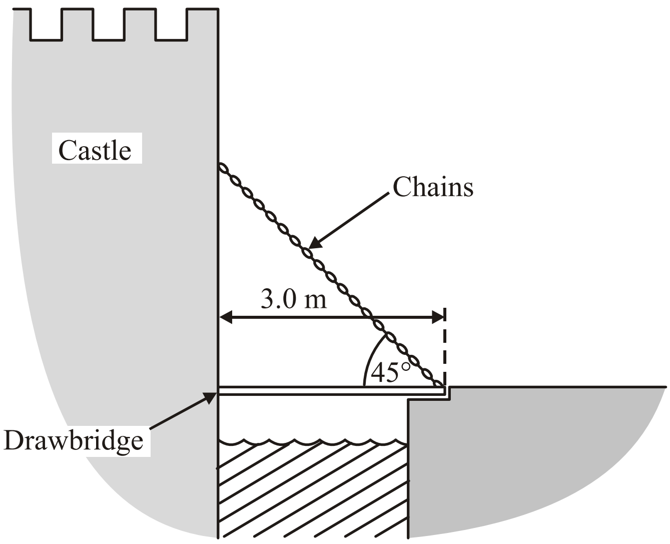
(3)

(e) A uniform drawbridge of mass 2000 kg and length 3.0 m is being held in a horizontal position by two chains of negligible mass as shown. The end of the drawbridge is not in contact with the ground. The chains make an angle of 45° to the horizontal.



Calculate the weight of the drawbridge.

....

....

(1)

Add an arrow to the diagram to show the position and direction of the weight of the drawbridge.

(1)

Using the principle of moments, calculate the value of the tension in each chain.

....

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(3)
(Total 32 marks)

130. (a) In a fast breeder reactor a nucleus of uranium $^{238}_{92}U$ absorbs a neutron to produce uranium, $^{239}_{92}U$. Write a balanced nuclear equation for this reaction.

....

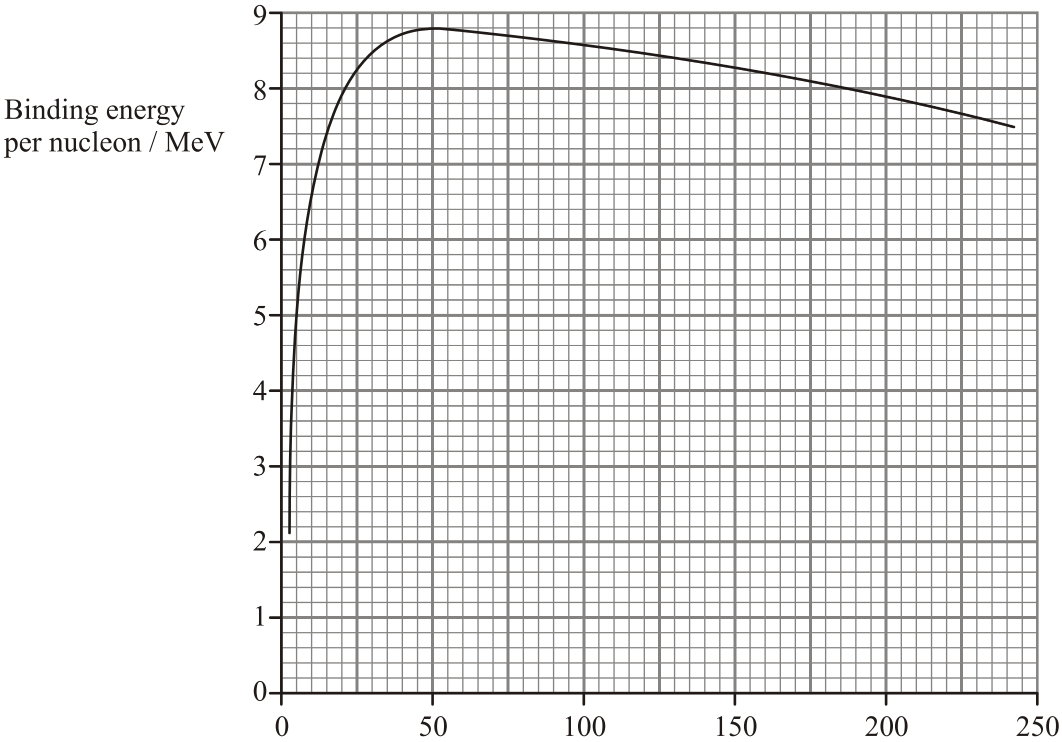
(1)

The $^{239}_{92}U$ subsequently undergoes a beta-minus decay to form neptunium Np. Write a balanced nuclear equation for this reaction.

....

(3)

(b) The graph shows how the binding energy per nucleon varies with another quantity.



(i) Add an appropriate label to the *x*-axis.

(1)

(ii) Mark clearly on the graph the approximate position of

- deuterium $^{2}_{1}H$, labelling this point H,
- iron $^{56}_{26}Fe$, labelling this point Fe,
- uranium $^{235}_{92}U$, labelling this point U.

(2)

(iii) Circle the most stable nucleus on the graph.

(1)

(iv) Use the graph to calculate the binding energy of a uranium-235 nucleus. Give your answer in GeV.

....

....

....

....

Binding energy = ... GeV

(3)

(c) Positronium is a light hydrogen-like 'atom' formed when an electron and a positron orbit a common centre.

What is the overall charge of positronium? Explain your answer.

....

....

Why must an electron and a positron have the same mass?

....

....

(3)

Positronium is unstable as the electron and the positron may interact with each other. Suggest the outcome of such an interaction.

....

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(2)

Explain which fundamental force(s) might be responsible for this interaction.
You may be awarded a mark for the clarity of your answer.

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(4)

Give two similarities and one difference between a π^0 meson and a positronium 'atom'.

Similarity 1: ....

....

Similarity 2: ....

....

Difference: ....

....

(3)

(d) In 1964 the following reaction was observed for the first time. The K particles are kaons (a type of meson) and X was a new particle.

$$K^- + p \rightarrow K^0 + K^+ + X$$

Use conservation laws to deduce the nature of particle X in order to underline the correct words in the sentence below. Show all your working.

Particle X is a meson/baryon/lepton with a charge of –1 / 0 / +1

....

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(4)

Add the quark content of the proton and the K^+ to the table.

Particle	Quark content
K^-	$s\bar{u}$
P	
K^0	$d\bar{s}$
K^+	

(2)

Given that this reaction was mediated by the strong force, deduce the quark content of particle X.

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(3)
(Total 32 marks)

131. (a) Give two physiological effects of radiation on cells.

1 ....

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2 ....

....

(2)

(b) Iodine $^{131}_{53}\text{I}$ is a radioisotope that is sometimes used in nuclear medicine. It decays with the emission of both a β^- particle and a γ-ray to form xenon Xe. Write a balanced nuclear equation to represent this decay process, showing nucleon and proton numbers for **all** symbols.

....

(3)

(c) Technetium $^{99m}_{43}Tc$ is the radioisotope most widely used in diagnostic studies. Explain the meaning of the symbol 'm' and what this implies about this radioisotope.

....

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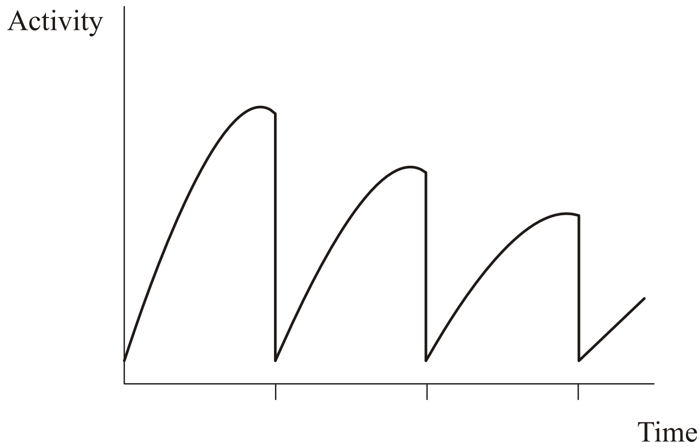
(2)

$^{99m}_{43}Tc$ is produced in hospitals from molybdenum in an elution cell. The graph shows the activity of the elution cell against time during several elutions.



Add a suitable time scale to the graph.

(1)

Explain clearly the shape of the graph. You may be awarded a mark for the clarity of your answer.

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(4)

(d) What is meant by the term ultrasound?

....

....

(2)

The acronym 'sonar' stands for '**so**und **na**vigation and **r**anging' and is a principle used for ultrasonic diagnosis. Outline the sonar principle and state what sort of information it provides.

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(3)

Show that the speed of ultrasound in soft tissue is approximately 1500 m s^{-1} using the data given below.

Ultrasound frequency = 1.50 MHz

Ultrasound wavelength = 1.03 mm

....

....

(2)

Calculate the specific acoustic impedance of soft tissue which has a density of 1060 kg m^{-3}.

....

....

(2)

An ultrasonic pulse travelling through soft tissue is incident on a bone within the human body which has a specific acoustic impedance of 6.5×10^6 kg $m^{-2}ss^{-1}$. Calculate the percentage of the incident intensity of the ultrasound that is transmitted into the bone.

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(4)

(e) X-rays can be used for diagnosis or for therapy. With reference to energies, distinguish between the X-rays used in diagnosis and those used in therapy.

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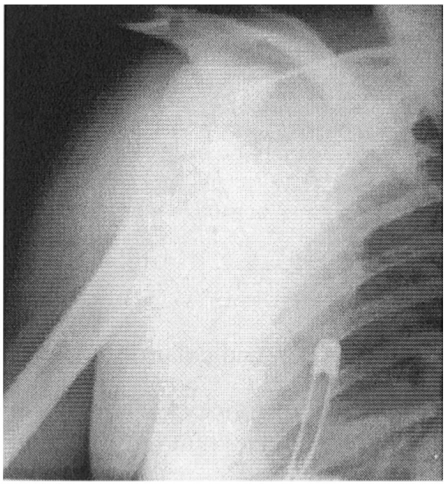
(3)

The X-ray image below shows a dislocated shoulder.



Explain why some areas of the image are white, whilst others are grey. Use the information given to quantify your explanation.

Medium	Proton number
Bone	20
Soft tissue	9

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(4)
(Total 32 marks)

132. (a) (i) Measure the thickness of the single coin.

....

Measure the thickness of the stack of coins.

....

Hence determine the number *n* of coins in the stack.

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(4)

(ii) You are provided with a metre rule and knife-edge. Use the principle of moments to determine the ratio of the mass of the stack of coins to the mass of the single coin and hence a second value for *n*. Draw a diagram of the arrangement you used, showing carefully the distances you measured. Show all your measurements and calculations in the space below.

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(6)

(iii) State **one** source of experimental error in **each** of these methods of determining *n*.

Error in method (i): ....

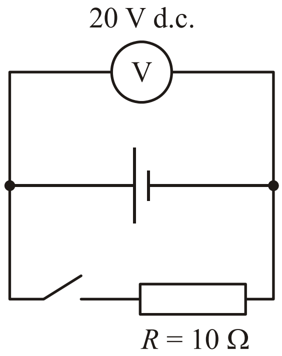
....

Error in method (ii): ....

....

(2)

(b) (i) Set up the circuit shown below, with the switch open and the multimeter set on the 20 V d.c. range.



If you are unable to set up the circuit ask the Supervisor. You will lose no more than 2 marks for this.

(2)

Record the e.m.f. ε of the cell.

ε = ...

Close the switch and record the potential difference V across the cell.

V = ...

Calculate a value for the internal resistance r of the cell given that

$$r = \left(\frac{\varepsilon}{V} - 1\right)R$$

where R = 10 Ω.

....

....

....

(2)

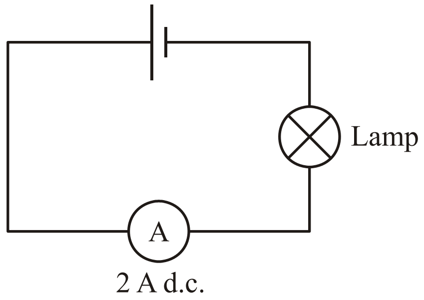
(ii) Disconnect the multimeter and set it to the 200 Ω range. If you are unable to do this ask the Supervisor. You will lose only 1 mark.

Use the meter to measure the resistance R_0 of the **lamp** when it is at room temperature.

R_0 = ...

(2)

(iii) Set the multimeter to the 2 A d.c. range and then set up the circuit below.



If you are unable to do this ask the Supervisor. You will lose only 1 mark. Record the current I in the lamp.

I = ...

Use the p.d. V that you found in part (i) to calculate a value for the resistance R_T of the lamp when it is glowing.

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In view of the value you have obtained for R_T, discuss whether it is reasonable to use this value of V for the calculation.

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(4)

(iv) Calculate the ratio $\frac{R_T}{R_0}$ and use the graph below to estimate the temperature T of the glowing filament.

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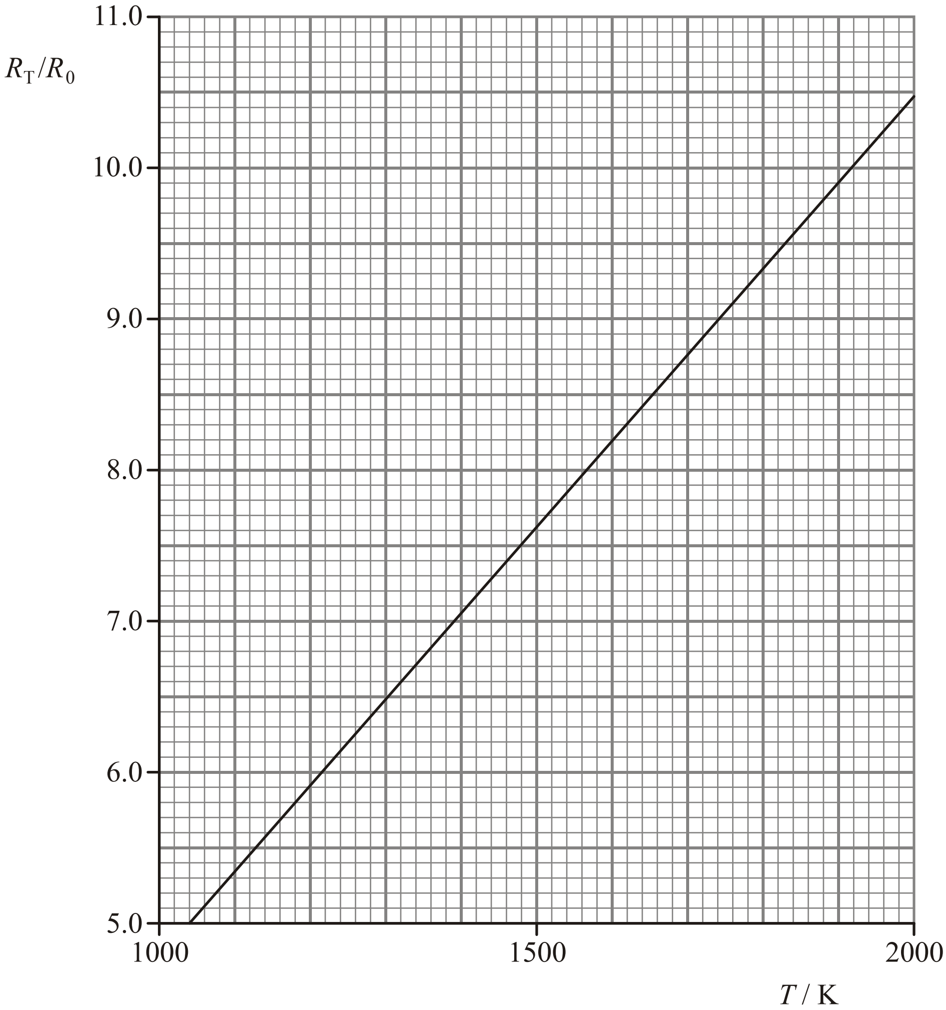

(2)
(Total 24 marks)

133. (a) (i) Place the 250 ml beaker on a heat proof mat. Pour water from the supply of boiling water up to the 75 ml mark on the 250 ml beaker and place the thermometer in the water. When the temperature starts to fall start the stopwatch and record, in the table below, the temperature θ_1 as a function of the time t for a period of 5 minutes. Add units to the headings of the columns of the table.

(ii) Repeat the above experiment using the 100 ml beaker rather than the 250 ml beaker. Fill the 100 ml beaker to the 75 ml mark from the supply of boiling water. Record your readings of θ_2 in the table below, adding the appropriate units.

Time t/	Temperature θ_1 of the water in the 250 ml beaker/	Temperature θ_2 of the water in the 100 ml beaker/

(6)

(b) Plot a graph of θ_1 against t on the grid below. Label this graph A.

On the same axes plot a graph of θ_2 against t on the grid below. Label this graph B.

(4)

(c) Determine the gradient of graph A at a **temperature** which is common to both graphs.

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(4)

(d) A student suggests that the rate of fall of temperature at a given temperature is directly proportional to the area of the surface of the water, provided there is no loss of heat from the sides and base of the beaker. Plan an experiment to investigate this suggestion. Your plan should include:

(i) a description of the experiment to be performed,

(ii) sketches of any graphs you would plot,

(iii) an explanation of how the results would be analysed.

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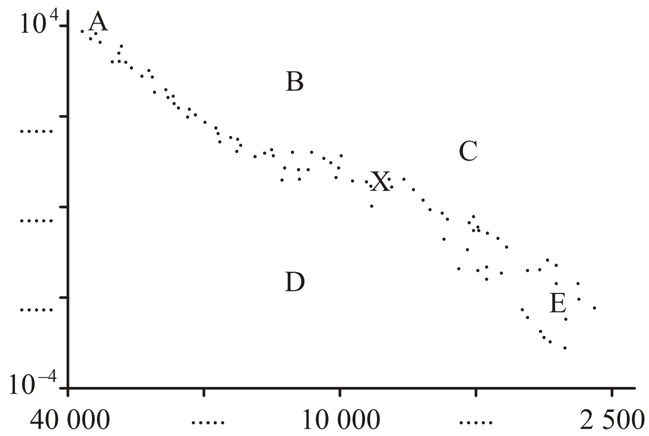
(10)
(Total 24 marks)

134. (a) On the Hertzsprung-Russell diagram shown below X indicates the position of the Sun.



(i) Add labels and units to each axis.

(2)

(ii) Complete the scale on the *y*-axis by adding three further values where indicated.

(2)

(iii) Complete the scale on the *x*-axis by adding two further values where indicated.

(1)

(iv) Letters A, B, C, D and E represent different stars. Identify all stars which could be:

a red giant	
a low mass star on the main sequence	

(2)

(v) Use the data below to show that the luminosity of the star ς Tau (Zeta Tauri) is approximately 4×10^{30} W.

Intensity = 1.9×10^{-8} W m^{-2}

Distance from Earth = 4.0×10^{18} m

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(3)

(vi) One of the labelled stars on the Hertzsprung-Russell diagram is ξ Tau. Calculate the luminosity of ξ Tau in terms of solar luminosities and thus deduce which letter must represent this star. Luminosity of the Sun $L_\odot = 3.9 \times 10^{26}$ W.

....

....

....

Luminosity = ...

Star = ...

(3)

(b) When stars undergo nuclear fusion, hydrogen is fused to form helium. As part of this process two ${}^{3}_{2}\text{He}$ nuclei react to form ${}^{4}_{2}\text{He}$.

$$ {}^{3}_{2}\text{He} + {}^{3}_{2}\text{He} \rightarrow {}^{4}_{2}\text{He} + {}^{1}_{1}\text{H} + {}^{1}_{1}\text{H} $$

(i) Calculate the change in mass in one such fusion reaction.

Nucleus	Mass / 10^{-27} kg
${}^{3}_{2}\text{He}$	5.0055
${}^{4}_{2}\text{He}$	6.6447
${}^{1}_{1}\text{H}$	1.6726

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Change in mass = ...

(2)

(ii) Hence calculate the energy released by this fusion reaction.

....

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Energy = ...

(2)

(c) In 2004 astronomers discovered a double pulsar: a system of two pulsars orbiting each other.

(i) Underline the four options that can be used to correctly describe pulsars.

A pulsar is a {neutron star/red giant /white dwarf/core remnant}.
A pulsar was previously a {white dwarf/ black hole / supernova}.
A pulsar has a mass of at least {0.4/1.4/2.5/8} solar masses.

(4)

(ii) Explain how astronomers detect pulsars and suggest how a double pulsar might be recognised. You may be awarded a mark for the clarity of your answer.

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(4)

(iii) It is suggested that these two stars will spiral in towards each other and coalesce into a single mass after 85 million years. Suggest what might be formed by such an event.

....

(1)

(d) (i) Write an equation for the density of a star in terms of its mass and radius.

....

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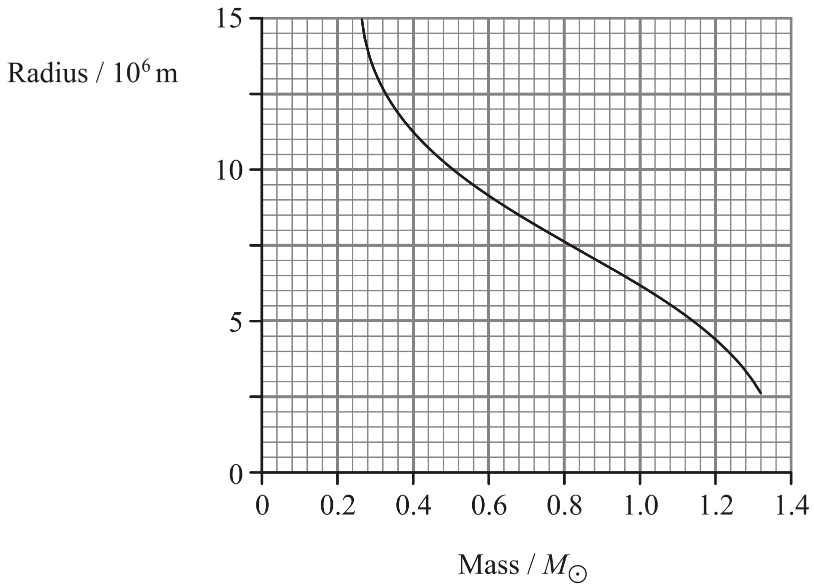
(1)

(ii) The graph shows the mass-radius relationship for white dwarf stars. The mass of the Sun $M_\odot = 2.0 \times 10^{30}$ kg.



Using the graph, calculate the density of two white dwarf stars and hence show that the density of a white dwarf increases as its mass increases.

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(3)

(iii) Describe what eventually happens to a white dwarf star.

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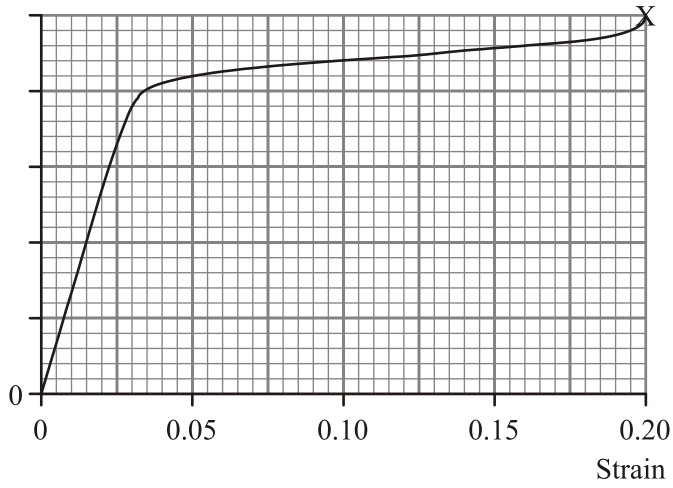
(2)
(Total 32 marks)

135. (a) A copper wire is stretched in an experiment. The graph shows the behaviour of the copper until it breaks at point X.



(i) The area under the graph represents energy density. Add a suitable label and unit to the *y*-axis of this graph.

(2)

(ii) The Young modulus of copper is 130 GPa. By using an appropriate calculation add a suitable scale to the *y*-axis.

....

....

....

....

(3)

(iii) From the graph determine the ultimate tensile stress of the copper.

....

(1)

(iv) State what is meant by the term yield stress.

....

....

....

(1)

(v) Label the yield point with a Y on the graph.

(1)

(vi) A second material is less stiff than copper and follows Hooke's Law to a strain beyond 0.20. Add a second line to the graph to indicate its behaviour.

(2)

(vii) Use the graph to estimate the energy density of the copper when it is stretched until it breaks.

....

....

....

....

Energy density = ...

(3)

(viii) The volume of the copper wire is 3.8×10^{-7} m^3. Calculate the work done on this wire in the experiment.

....

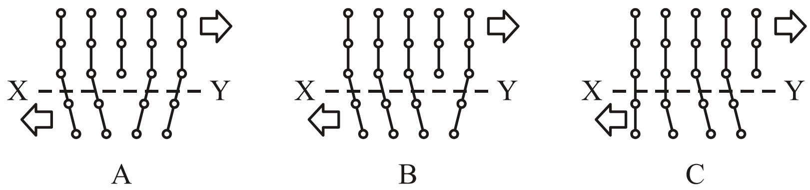
....

....

Work done = ...

(2)

(b) The series of diagrams shows the molecular arrangement of part of a crystal lattice. The arrows indicate forces applied to the crystal.



(i) Name the feature XY.

....

(1)

(ii) With reference to the diagrams explain how the presence of a dislocation makes plastic deformation easier. You may be awarded a mark for the clarity of your answer.

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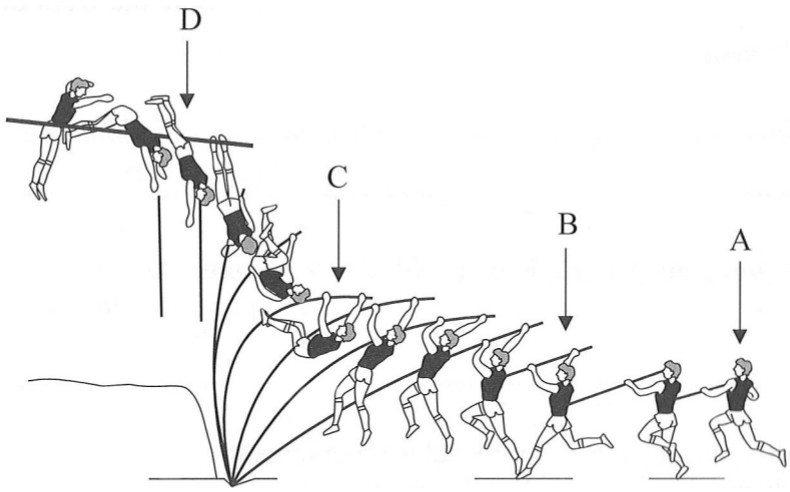
(4)

(c) The pole vault is an athletic event that requires high levels of sprinting, jumping and gymnastic ability. The diagram shows the sequence of actions involved in a jump. The pole is off the ground at A and B.



(i) State the energy changes that occur during the stages

$A \rightarrow B$ ....

$B \rightarrow C$ ....

$C \rightarrow D$ ....

(3)

(ii) Calculate the speed of a pole vaulter of mass 65 kg who has 2.1 kJ of kinetic energy on take off.

....

....

Speed = ...

(1)

(iii) Assuming no energy losses, and using the data below, show that the theoretical maximum height that could be reached by this athlete is over 5 m.

Initial height of centre of mass of pole vaulter from ground = 0.9 m
Additional height gained from technique during jump = 1.2 m

....

....

....

....

(2)

(d) Modern vaulting poles are made of a carbon fibre composite material.

(i) State what is meant by a composite material.

....

.... **(1)**

(ii) What is the benefit of using a composite material?

.... **(1)**

(iii) Circle the words that describe the properties of this composite material.

elastic flexible plastic stiff strong tough **(3)**

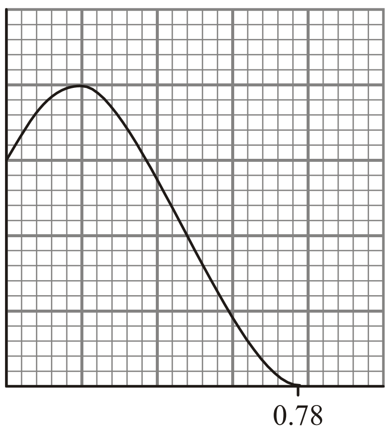
(iv) Before carbon fibre poles were developed, fibreglass poles were used. These had the disadvantage of being brittle. State what is meant by brittle.

....

.... **(1)**

(Total 32 marks)

136. (a) During an experiment into the energy spectrum of β^- particles, the following graph was produced.



(i) Add suitable labels, with units where appropriate, to each axis. **(3)**

(ii) State the significance of the figure 0.78. Explain how the results of this experiment led to the prediction of the existence of an antineutrino. You may be awarded a mark for the clarity of your answer.

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(4)

(b) The equation for β^- decay can be written as:

$$n \rightarrow p + \beta^- + \bar{\nu}$$

(i) For each particle, either give its quark composition or state that fundamental particle.

n ....

p ....

β^- ....

$\bar{\nu}$ ....

(2)

(ii) Write a similar equation for β^+ decay.

(2)

(iii) Explain fully why these reactions can only be mediated by the weak interaction.

....

....

....

....

(3)

(iv) Name the exchange particle for each of these decays.

β^- ……….. β^+ ………..

(2)

(c) (i) The density of a nucleus of strontium Sr is 2.29×10^{17} kg m^{-3}. Calculate the mass of a nucleus of radius 5.34×10^{-15} m.

....

....

....

Mass = ...

(3)

(ii) Show that the nucleon number of this isotope is 88. (u = 1.66×10^{-27} kg)

....

....

....

(2)

(iii) Hence calculate the radius r_0 of a single nucleon.

....

....

....

Radius = ...

(3)

(d) A hydrogen atom consists of one proton and one electron. For each particle underline **all** the words that could be used to make a correct statement.

A proton is a {baryon / meson / lepton / hadron}

An electron is a {baryon / meson / lepton / hadron}

(2)

(e) In 1995 scientists at CERN created atoms of antihydrogen.

(i) Name the particles that make up antihydrogen.

....

....

(1)

(ii) Describe these particles in terms of charge and quark structure where relevant.

....

....

(2)

(iii) State the charge of an atom of antihydrogen.

....

(1)

(iv) Explain why it is not possible to store atoms of antihydrogen.

....

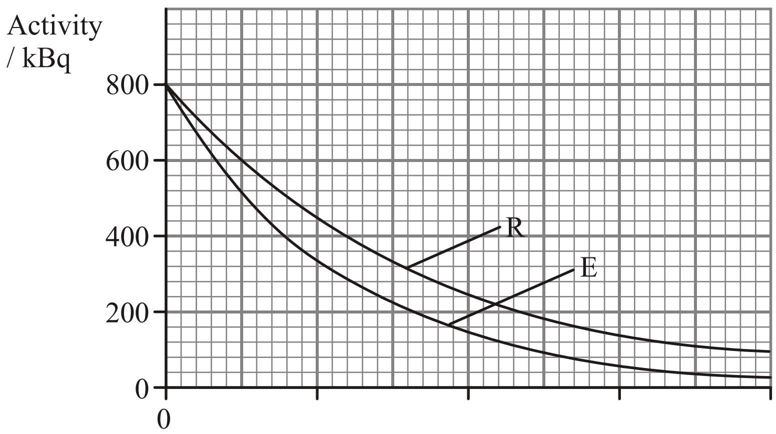
....

....

(2)

(Total 32 marks)

137. (a) Graph R shows the radioactive decay of technetium ^{99m}Tc which has a radioactive half-life of 6 hours. Graph E shows the observed decay of the same isotope when it is used in a tracer investigation in a patient.



(i) Label the *x*-axis.

(1)

(ii) Use graph R to add a scale and units to the *x*-axis. Show how you did this on the graph.

(2)

(iii) Use graph E to calculate the biological half-life of the isotope in this investigation.

....

....

....

Biological half-life = ...

(3)

(b) (i) Molybdenum $^{99}_{42}\text{Mo}$ decays to ^{99m}Tc by beta-minus emission. Write a balanced nuclear equation for this decay.

....

(1)

(ii) In what is radioactive molybdenum produced?

....

(1)

(iii) Describe and explain the process of elution that is used to extract the ^{99m}Tc from an elution cell. You may be awarded a mark for the clarity of your answer.

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....

(4)

(iv) Technetium ^{99m}Tc decays by gamma emission. Write a balanced nuclear equation for this decay.

....

(1)

(v) The product of this decay has a half-life of 210 000 years. Explain the importance of this long half-life when ^{99m}Tc is used as a tracer.

....

....

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....

(2)

(c) In X-ray diagnosis the absorption of keV X-rays is highly dependent on *Z*.

(i) State what *Z* represents in this context.

....

(1)

(ii) Explain the relevance of the value of *Z* in the production of radiographic images.

....

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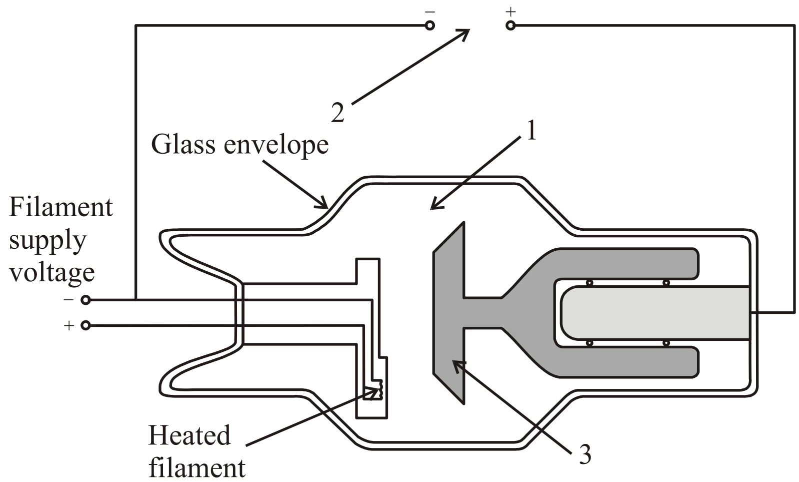
....

(2)

The diagram shows a rotating anode X-ray tube.



(iii) Name and explain the function of the numbered parts of the X-ray tube.

	Name	Function
1		
2		
3		

(6)

(d) In ultrasonic diagnosis the reflection coefficient α can be written as

$$\alpha = \left(\frac{Z_1 - Z_2}{Z_1 + Z_2}\right)^2$$

(i) State what is represented by Z_1 and Z_2 in this equation.

....

....

(2)

(ii) Show that the units of Z are kg m^{-2} s^{-1}.

....

....

(2)

(iii) Calculate the reflection coefficient using the data given below.

Medium	Z / kg m^{-2} s^{-1}
Blood	1.59×10^6
Muscle	1.70×10^6

....

....

....

....

α = ...

(2)

(iv) Hence find the percentage of the incident ultrasound that will be transmitted through a muscle-blood boundary.

....

....

(2)

(Total 32 marks)

138. (a) (i) Measure the length *l* and the width w of the aluminium foil. State any special precaution that you took to ensure that accurate values of *l* and *w* were obtained.

....

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....

(4)

(ii) Fold the foil in half four times to create a total foil thickness of 16*t* where *t* is the thickness of the foil. Measure 16*t* and hence determine *t*. State any special precautions that you took to ensure that an accurate value of 16*t* was obtained.

....

....

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....

....

(4)

(iii) Estimate the percentage uncertainty in your value for *t*.

....

....

....

(2)

(iv) Using the top pan balance provided, measure the mass *m* of the foil. Hence determine a value for the density of the foil.

....

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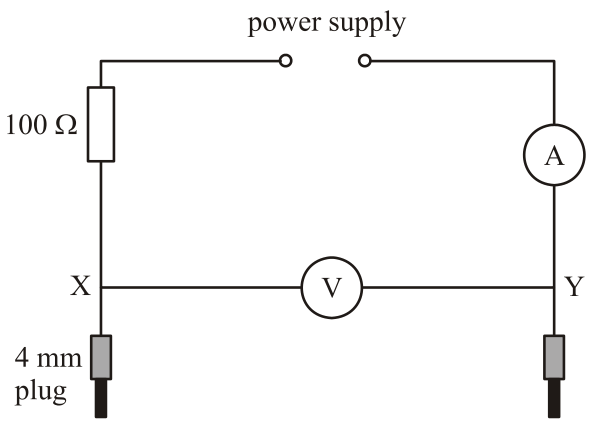
....

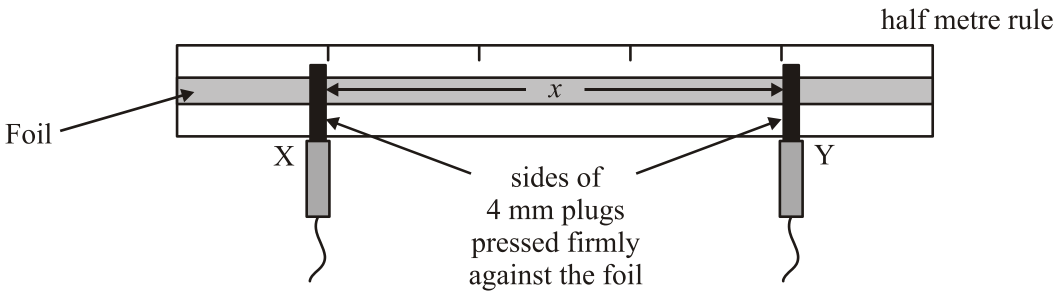
(3)

(b) (i) Set up the circuit as shown in the diagram below using the 100 Ω resistor. Before you connect your circuit to the power supply, have your circuit checked by the Supervisor. You will be allowed a short time to correct any faults. If you are unable to set up the circuit, the Supervisor will set it up for you. You will lose only two marks for this.



(2)

(ii) Connect the power supply and use the 4-mm plugs to make connections to a length x = 30.0 cm of the strip of foil which is attached to the half metre rule. In order to make good electrical contact with the foil the **sides** of the 4-mm plugs should be pressed **firmly** against the foil as shown in the diagram below.



Measure the current I in the circuit and the potential difference V across the 30.0 cm length of foil.

I = ...

V = ...

(3)

(iii) Hence calculate the resistance R of the foil.

....

....

(2)

(iv) Determine an average value for the width b of the foil. Hence determine a value for the resistivity ρ of the foil given that $\rho = \dfrac{Rbt}{x}$.

....

....

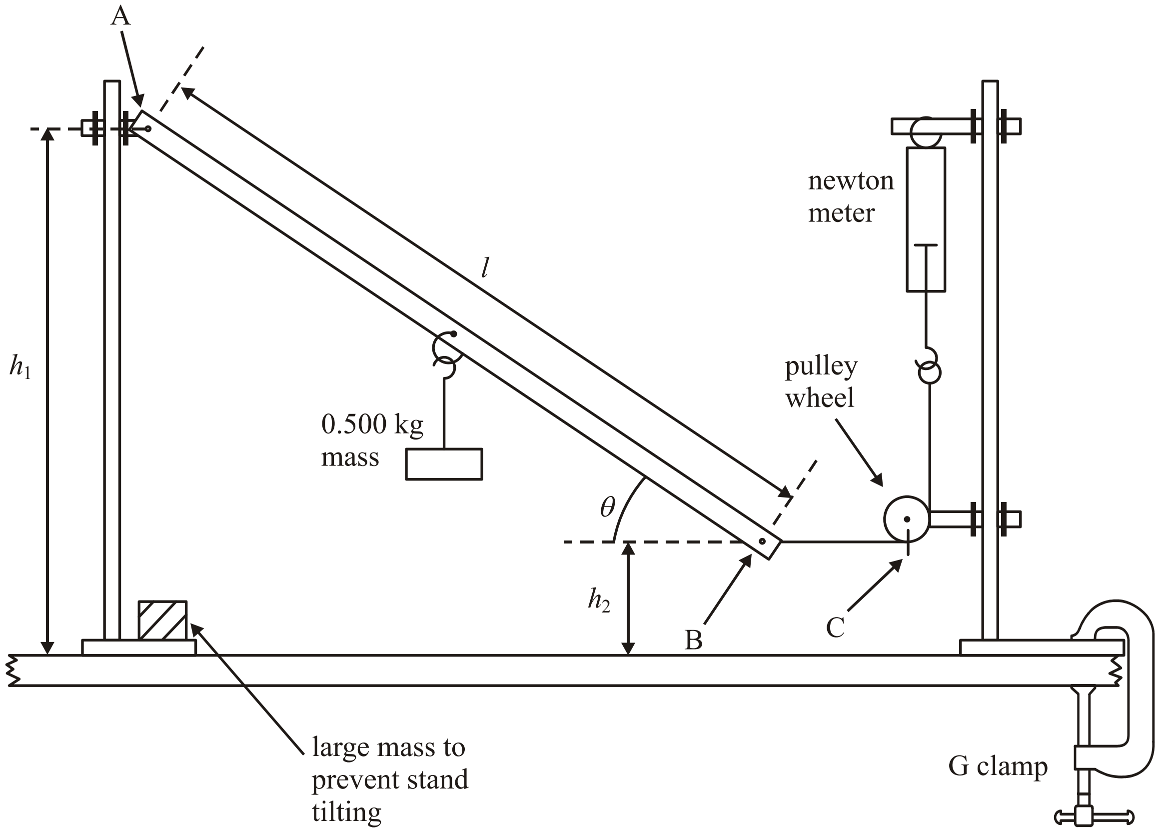
....

....

(4)

(Total 24 marks)

139. (a) The Supervisor has set up the apparatus shown in the diagram below. The newton meter is clamped vertically but the Supervisor has not made the section BC of the string horizontal.



Do not move the stand that is clamped to the bench. Adjust the separation of the stands and the height of the nail at A until the section BC of the string is horizontal and the angle θ is between 20° and 40°. You have been provided with a 30° set square so that you can easily estimate an angle in this range. Explain how you checked that BC was horizontal. You may add to the above diagram if you wish.

....

....

....

....

(2)

(b) Measure the vertical height h_1 of the point A above the bench and the vertical height h_2 of the point B above the bench. Also record the distance, l, between the points A and B. Hence blank calculate a value for the angle θ using:

$$\sin \theta = (h_1 - h_2) / l$$

....

....

....

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....

....

(4)

(c) If the string is horizontal the principle of moments may be used to show that

$$W = 2T \tan \theta - mg$$

where W = the weight of the metre rule,
T = the reading on the newton meter,
m = the mass which is suspended from the rule, which may be taken as 0.500 kg,
and g = the gravitational field strength.

Record T.

T = ……………………..

Hence, using your result from part (b), calculate the weight of the metre rule.

....

....

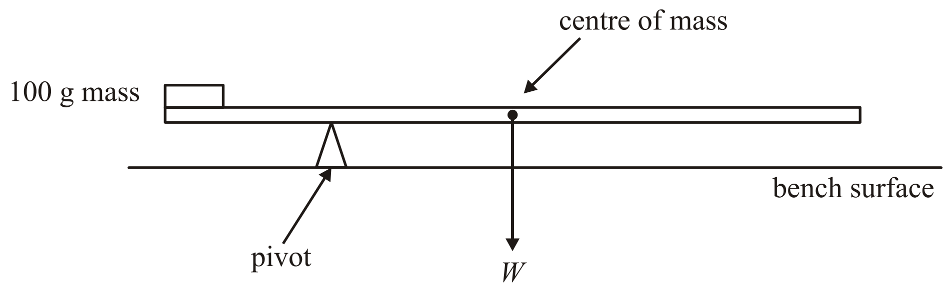
....

....

Weight = ...

(4)

(d) Set up the apparatus as shown in the diagram below using the second metre rule, which is identical to the suspended rule. Use one of the 100 g masses from the first experiment. Adjust the position of the pivot so that the system rests in equilibrium with the metre rule horizontal.



The centre of mass of the rule may be taken to lie at the 50.0 cm mark. Take such measurements as are necessary to find the weight *W* of the rule. **Show these measurements on the diagram.**

Now use the principle of moments to calculate *W*.

....

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....

(5)

(e) The equation in part (c) may be rewritten in the form

$$T \tan \theta = \frac{1}{2}mg + \frac{1}{2}W$$

A student suggests that the value of *W* may be found by a graphical method if the value of *m* is varied. Plan an experiment to investigate this suggestion. Your plan should include

(i) a description of how the experiment would be performed;

(ii) a sketch of the graph to be plotted;

(iii) how you would use the graph to find a value for *W*.

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(9)
(Total 24 marks)

140. (a) (i) You have been provided with a 4.0 m length of constantan wire which has the same diameter as the constantan wire which is attached to the metre rule. Using the top pan balance provided, measure the mass m of the 4.0 m length of wire.

m = ...

Carefully separate the turns of the 4.0 m length and measure the diameter d of the wire. State any precautions that you took to ensure that an accurate value of d was obtained.

....

....

....

....

(3)

(ii) Estimate the percentage uncertainty in your value for d.

....

....

....

(2)

(iii) Determine a value for the density of constantan given that

volume of wire = $V = \dfrac{\pi d^2 l}{4}$

where l = length of wire = 4.0 m.

....

....

....

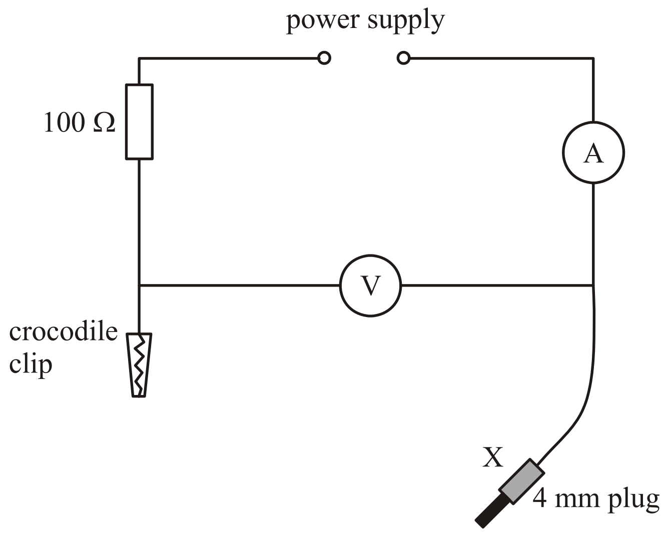
....

....

....

(5)

(b) (i) Set up the circuit as shown in the diagram below using the 100 Ω resistor. Before you connect your circuit to the power supply, have your circuit checked by the Supervisor. You will be allowed a short time to correct any faults. If you are unable to set up the circuit, the Supervisor will set it up for you. You will lose only two marks for this.



(2)

(ii) Connect the crocodile clip to the wire at the zero end of the rule. Connect the power supply and use the 4-mm plug labelled X to make a connection to the wire at the 20.0 cm mark. To make good electrical contact the 4-mm plug should be pressed **firmly** against the wire.

Measure the current I in the circuit and the potential difference V across the 20.0 cm length of wire.

I = ...

V = ...

(3)

(iii) Hence calculate the resistance R_1 of a 20.0 cm length of wire.

....

....

(2)

(iv) Repeat parts (ii) and (iii) to find the resistance R_2 of an 80.0 cm length of wire.

....

....

....

....

(3)

(v) Use your results from parts (iii) and (iv) to determine the resistance R of a length x = 60.0 cm of wire, where $R = R_2 - R_1$. Hence determine a value for the resistivity ρ of the wire given that $\rho = \dfrac{R\pi d^2}{4x}$.

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....

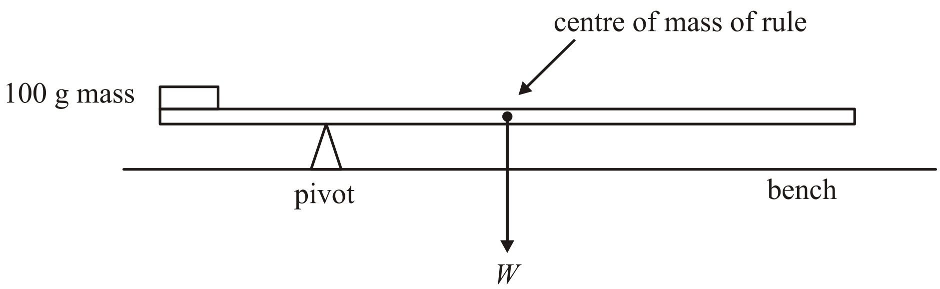
(4)
(Total 24 marks)

141. (a) Determine the position of the centre of mass of the metre rule labelled X by balancing it on the pivot so that it is approximately horizontal.

Position of centre of mass = ...

(1)

(b) Set up the apparatus as shown in the diagram below using the metre rule labelled X. The system should rest in equilibrium with the metre rule approximately horizontal.



Take such measurements as are necessary to find the weight W of the rule. **Show these measurements on the diagram.**

Now use the principle of moments to calculate W.

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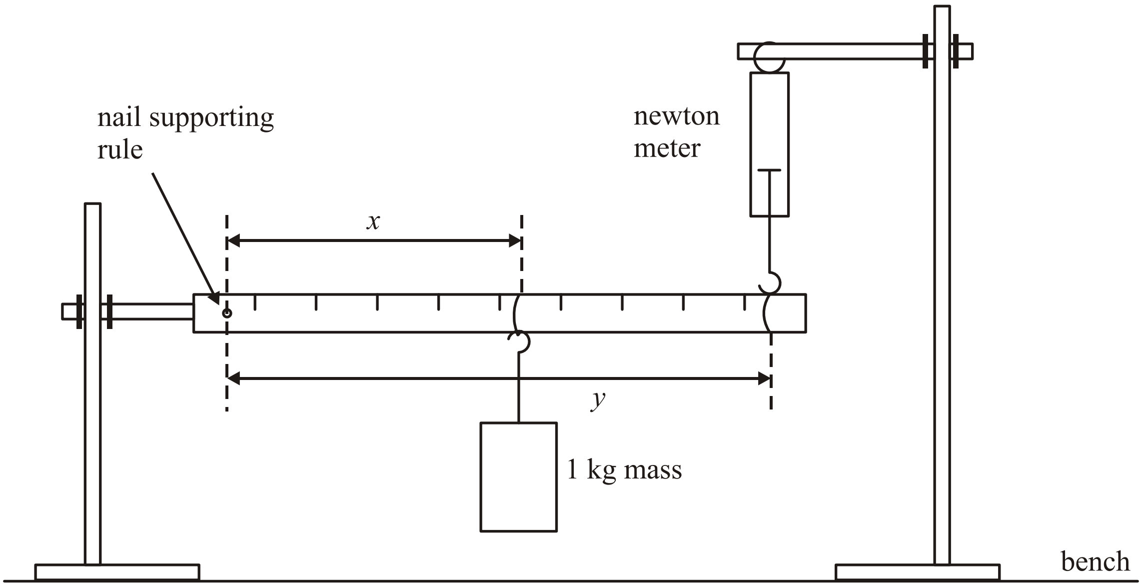
....

(6)

(c) Set up the apparatus as shown in the diagram below using the metre rule labelled X with the nail passing through the hole at the 1.0 cm mark. The loop of thread from which the 1.00 kg mass is suspended should be placed in the position of the centre of mass of the rule.



Adjust the height of the newton meter until the metre rule is horizontal. Explain how you ensured that the rule was horizontal. You may add to the above diagram if you wish.

....

....

....

....

(2)

(d) By applying the principle of moments to the horizontal rule it can be shown that:

$$(W + mg)x = Ty$$

where W = the weight of the metre rule,
mg = weight of the 1.00 kg mass = 9.81 N,
T = the reading on the newton meter,
and x and y are the lengths shown in the diagram.

Record the reading on the newton meter and determine values for x and y. Hence calculate a second value for W.

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(4)

(e) Calculate the percentage difference between your two values for W.

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Which value of W do you consider to be more accurate? Give a reason for your answer.

....

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....

....

(3)

(f) A student wishes to investigate how the force supporting the rule varies with the distance of the newton meter from the nail. The equation in part (d) may be rewritten in the form

$$T = \frac{(W + mg)x}{y}$$

You are to plan this investigation. Your plan should include

(i) an indication of the values in the equation which would need to be kept constant;

(ii) a description of how the experiment would be performed;

(iii) a sketch of the graph to be plotted;

(iv) an indication of the expected results.

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(8)
(Total 24 marks)