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

For uniformly accelerated motion:

$v \ = u + at$

$x \ = ut + ½\, at^2$

$v^2 \ = + 2ax$

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

Power $\quad$ P = Fv

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

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

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

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	$\Delta W = ½F\Delta x$	(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 $pV = \frac{1}{3} Nm(c^2)$

$T \propto$ *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

$\sin (90° - \theta) = \cos \theta$

$\text{In}\ (x^n) = n \ln x$

$\text{In}\ (e^{kx}) = kx$

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 $= {}^4/_3\, \pi r^3$

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.

....

....

....

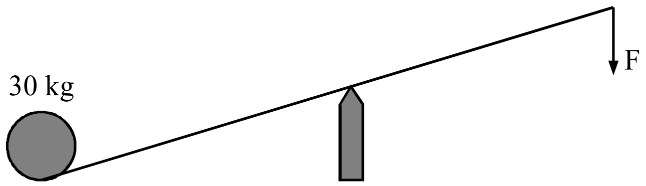
(2)

Is potential difference a scalar or vector quantity?

....

(1)
(Total 10 marks)

3. The diagram shows a lever with two arms of equal length and with a 30 kg mass at one end. The force *F* is just strong enough to raise the 30 kg mass off the ground.



Calculate the magnitude of the force *F*.

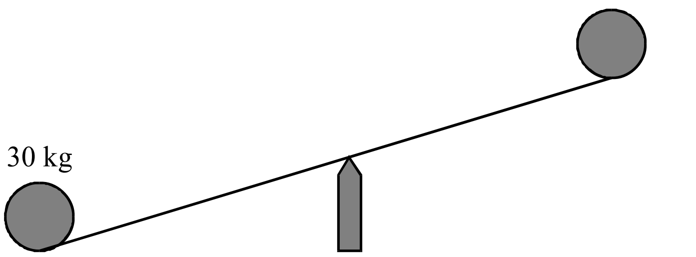
....

....

F = ...

(2)

Instead of applying the force *F* to the far end of the lever, a 34 kg mass is placed there.



Draw on the diagram above, the forces acting on the 34 kg mass. Explain why it accelerates downwards.

....

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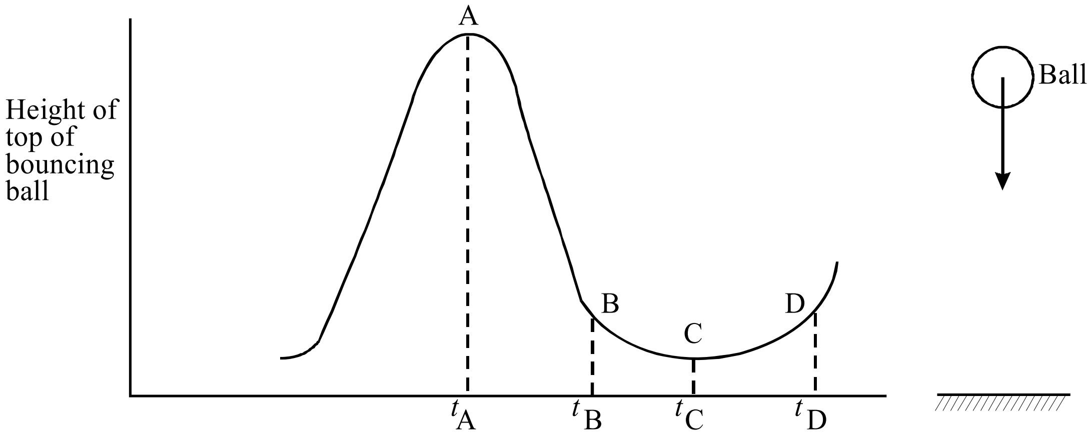
....

....

(4)
(Total 6 marks)

4. The graph shows how the height above the ground of the top of a soft bouncing ball varies with time.



Describe briefly the principal energy changes which occur between the times

t_A and t_B ....

....

....

(2)

t_A and t_C ....

....

....

(3)

t_C and t_D ....

....

....

(1)
(Total 6 marks)

5. Draw a labelled diagram of the apparatus you would use to measure the acceleration of a body in free fall.

(3)

List the measurements you would make and show how you would use them to calculate the acceleration.

....

....

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....

....

....

....

(5)
(Total 8 marks)

6. $^{12}_{6}C$ and $^{14}_{6}C$ are two isotopes of carbon.

State the number of electrons in a neutral atom of $^{14}_{6}C$.

....

State the number of neutrons in a neutral atom of $^{14}_{6}C$.

....

(2)

$^{14}_{6}C$ decays by beta minus emission. Complete the nuclear equation below.

$$^{14}_{6}C \rightarrow \quad N \; +$$

(2)

Describe briefly how you would test whether $^{14}_{6}C$ decays *only* by beta emission

....

....

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(3)
(Total 7 marks)

7. State Newton’s second law of motion.

....

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....

....

(2)

A student says, incorrectly, “Momentum is conserved completely in elastic collision, but not in inelastic collisions.” Rewrite this sentence to make a correct statement about momentum conservation.

....

....

(1)

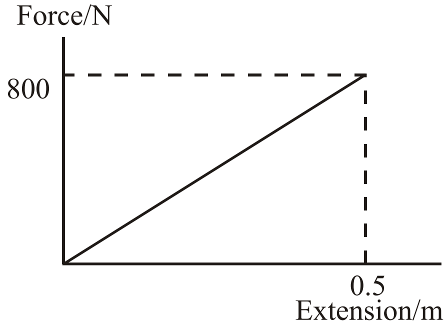
In what circumstance is kinetic energy conserved in a collision?

....

....

(1)
(Total 4 marks)

8. At the battle of Agincourt in 1415, the English archers overcame a much stronger French army by shooting arrows from longbows which required a maximum force of about 800N to draw the string back a distance of half a metre. The graph shows the force-extension graph for a helical spring stretched elastically throughout his distance by this force.



Calculate the energy stored in the spring for an extension of half a metre.

....

....

Energy = ...

(2)

The arrows used at Agincourt were able to penetrate light armour and had a mass of about 60 g. Use your calculated value of energy to find an approximate value for the speed at which the arrow would leave the bow.

....

....

....

(3)

In practice, the energy stored in the drawn bow is more than that stored in the helical spring stretched the same amount by the same force. Sketch, on the axes bow, a possible force-extension graph for this bow.

(2)

The arrows were fired upwards at an angle of 45° to the horizontal. Describe and explain what happens during the flight to the

(i) horizontal velocity component

....

....

....

(2)

(ii) vertical velocity component.

....

....

....

....

(3)
(Total 12 marks)

9. Describe, with the aid of a diagram, how you would measure the acceleration of free fall by a method involving the use of a freely-falling body.

....

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....

....

(6)

Identify and explain one precaution you would take to minimise the errors in your experiment.

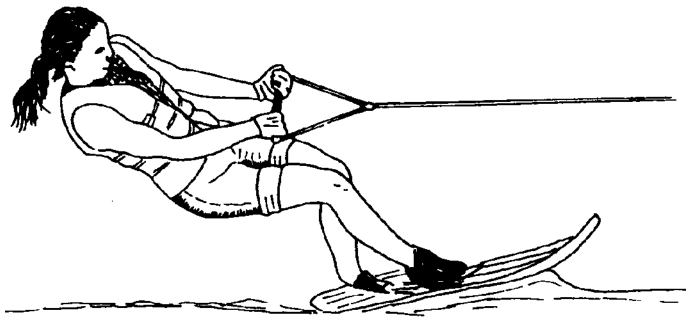
....

....

....

(2)
(Total 8 marks)

10. The diagram shows a water-skier being pulled at a steady speed in a straight line. Her mass plus the mass of the ski is 65 kg. The pull of the tow-rope on her is 520 N.



(a) (i) What is the vertical component Y of the push of the water on the ski?

What is the horizontal component X of the push of the water on the ski? (Ignore air resistance.)

(ii) Component X and the 520 N towing force form a clockwise couple acting on the water skier. Explain how she can remain in equilibrium as she is towed along.

(4)

(b) She suddenly lets go of the tow-rope. Calculate her initial deceleration. Why does her deceleration reduce as she slows down?

(4)

(c) On another occasion while being towed, she moves in a curved path from behind the boat to approach a ramp from which she makes a jump, remaining in the air for over two seconds.

(i) Explain why the pull of the tow-rope on her is greater as she moves in the curved path than when she is being towed in a straight line.

(ii) Explain why she feels "weightless" while in the air during her jump.

(4)

(d) The speedboat pulling the water skier produces waves which travel away from the boat. Those with a wavelength of over a metre travel faster than those with a wavelength of less than a quarter of a metre.

The waves reach and pass through a gap of two metres leading into a boatyard. Draw a diagram to show their appearance soon after the speedboat passes. Label your diagram carefully.

(4)
(Total 16 marks)

11. The energy for a pendulum (long case) clock is stored as gravitational potential energy in a heavy brass cylinder. As the cylinder descends its energy is gradually transferred to a steel pendulum to keep it swinging with a constant amplitude.

(a) In one clock the brass cylinder has a mass of 5.6 kg.

(i) The cylinder descends 1.4 m in seven days. What is the power transfer during its descent?

(ii) In an accident the brass cylinder suddenly fell 1.4 m to the ground. Estimate by how much its temperature would rise. State any assumption you make.

(Take the specific heat capacity of brass to be 360 J kg^{-1} K^{-1}.)

(6)

(b) The pendulum swings in an East-West plane with a time period of 2.00 s.

(i) Explain why a potential difference will be induced between the top and the bottom of the steel pendulum.

(ii) Sketch a graph to show the variation of this induced p.d. with time.
Add a scale to your time axis.

(6)

(c) It is suggested that the induced p.d. described in (b) could be used to energise an electromagnet. This could then be placed so as to attract the steel pendulum during part of each swing and thus do away with the need for the brass cylinder.

Discuss this suggestion, concentrating on the physical principles involved.

(4)
(Total 16 marks)

12. 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.

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....

....

(1)

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

....

....

(2)

13. An athlete of mass 55 kg runs up a flight of stairs of vertical height 3.6 m in 1.8 s. Calculate the power that this athlete develops in raising his mass.

....

....

....

....

Power = ...

(3)

One way of comparing athletes of different sizes is to compare their power-to-weight ratios. Find a unit for the power-to-weight ratio in terms of SI base units.

....

....

....

....

(2)

Calculate the athlete's power-to-weight ratio.

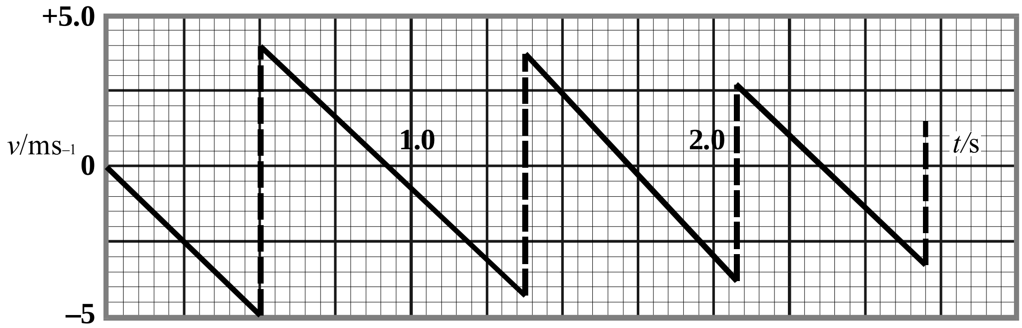
....

....

Power-to-weight ratio = ...

(2)
(Total 7 marks)

14. The diagram shows a velocity-time graph for a ball bouncing vertically on a hard surface.



At what instant does the graph show the ball to be in contact with the ground for the third time?

....

(2)

The downwards-sloping lines on the graph are straight. Why are they straight?

....

....

....

....

(2)

Calculate the height from which the ball is dropped.

....

....

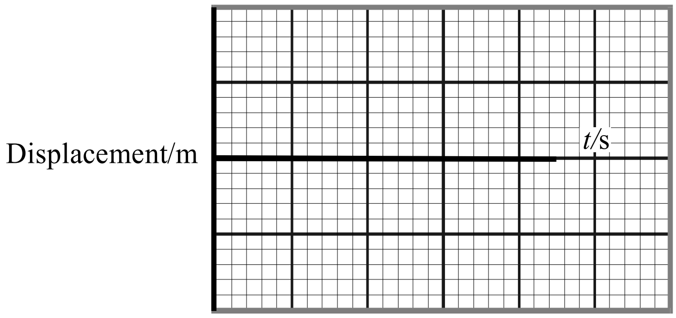
....

....

Height = ...

(3)

Sketch a displacement-time curve on the axes below for the first second of the motion.



(3)

What is the displacement of the ball when it finally comes to rest?

....

(1)
(Total 11 marks)

15. Describe an experiment you would perform to provide a *single* illustration of the principle of conservation of linear momentum.

(i) Sketch and label a diagram of the apparatus you would use.

(2)

(ii) List the physical quantities you would measure and state how you would measure them.

....

....

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....

(4)

(iii) How would you use this information to provide a single illustration of the law

....

....

....

....

(2)
(Total 8 marks)

16. In 1909 Geiger and Marsden carried out an important experiment to investigate alpha particle scattering. Alpha particles were directed towards a thin gold sheet and detectors were used to observe the distribution of scattered alpha particles.

State what was observed in this experiment.

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....

(3)

Explain why these observations led to the conclusion that an atom was composed mainly of space, with a very small positive nucleus.

....

....

....

....

....

(3)

State an approximate value for

(i) the diameter of a gold atom

....

(ii) the diameter of a gold nucleus

....

(2)
(Total 8 marks)

17. Name *two* sources of natural background radiation.

1 ....

2 ....

(2)

Caesium-137 is a by-product of nuclear fission within a nuclear reactor. Complete the two boxes in the nuclear equation below which describes the production of $^{137}_{55}Cs$.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{137}_{55}Cs + \boxed{^{95}Rb} + \boxed{{}^{1}_{0}n}$$

(2)

The half-life of caesium-137 is 30 years. When the fuel rods are removed from a nuclear reactor core, the total activity of the caesium-137 is 5.8×10^{15} Bq. After how many years will this activity have fallen to 1.6×10^{6} Bq?

....

....

....

....

....

....

Number of years = ...

(4)

Comment on the problems of storage of the fuel rods over this time period.

....

....

....

....

(2)
(Total 10 marks)

18. An artery has a cylindrical cross-section of diameter 8 mm. Blood flows through the artery at an average speed of 0.3 m s^{-1}.

Calculate the average mass of blood flowing per second through the artery.

Density of blood at body temperature, 37 °C = 1060 kg m^{-3}.

....

....

....

....

Mass of blood = ...

(5)

How would you verify experimentally the value of the density of blood quoted above, given a sample of volume approximately 5 cm^3?

....

....

....

....

....

....

(3)
(Total 8 marks)

19. State Coulomb's law for the electric force between two charged particles in free space.

....

....

....

....

(2)

What are the base units of ε_0 (the permittivity of free space)?

....

....

....

....

(2)
(Total 4 marks)

20. (a) Describe briefly how you would determine a value for the *specific heat capacity c* of water using normal laboratory apparatus.

(4)

(b) A jogger of mass 75 kg, who runs for 30 minutes, generates 840 kJ of thermal energy.

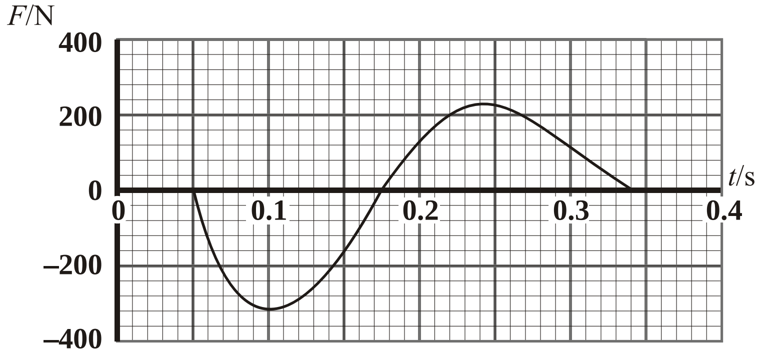
(i) Explain, in molecular terms, the way in which the removal of some of this energy by evaporation can help to prevent the jogger's body temperature from rising.

(3)

If 40% of the thermal energy is removed by evaporation, calculate the mass of water evaporating during the 30 minute jog. Take the specific latent heat (enthalpy) of vaporisation of water to be 2260 kJ kg^{-1} and the density of water to be 1000 kg m^{-3}

(3)

(c) During a single stride the *horizontal push F* of the ground on the jogger's foot varies with time *t* approximately as shown in the graph. *F* is taken to be positive when it is in the direction of the jogger's motion.



(i) What physical quantity is represented by the area between the graph line and the time axis?

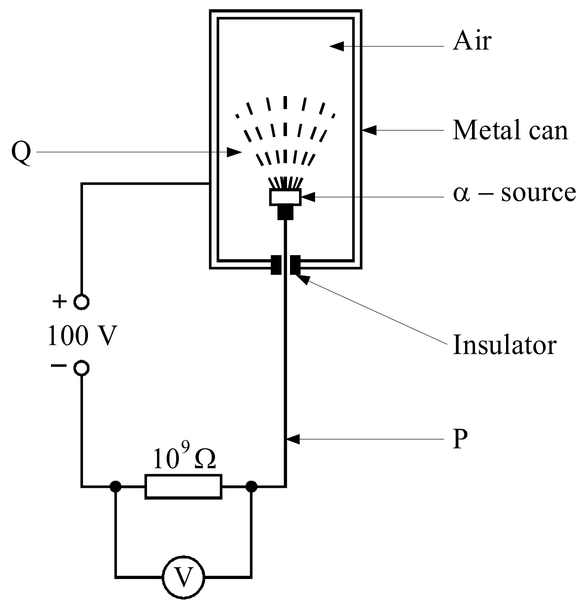
Estimate the size of this quantity for the part of the graph for which F is positive. Explain how you made your estimate.

(4)

(ii) The area above the time axis is the same as the area below it. Explain what this tells you about the motion of the jogger.

(2)
(Total 16 marks)

21. An α-source with an activity of 150 kBq is placed in a metal can as shown. A 100 V d.c. source and a 10^9 Ω resistor are connected in series with the can and the source. This arrangement is sometimes called an ionisation chamber.



(a) What is meant in this case by *an activity of 150 kBq*?

(2)

(b) Describe how the nature of the electric current in the wire at P differs from that in the air at Q.

(3)

(c) A potential difference of 3.4 V is registered on the voltmeter.

(i) Calculate the current in the wire at P. State any assumption you make.

(ii) Calculate the corresponding number of ionisations occurring in the metal can every second. State any assumption you make.

(5)

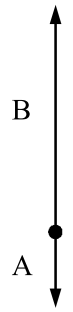
(d) With the α-source removed from the metal can, the voltmeter still registers a potential difference of 0.2 V. Suggest two reasons why the current is not zero.

(2)

(e) The half-life of the α-source is known to be 1600 years. Calculate the decay constant and hence deduce the number of radioactive atoms in the source.

(4)
(Total 16 marks)

22. The free-body force diagram shows the two principal forces which act on a parachutist at the instant of first contact with the ground.



What does the force A represent?

....

(1)

What does the force B represent?

....

(1)

Why are these forces not equal?

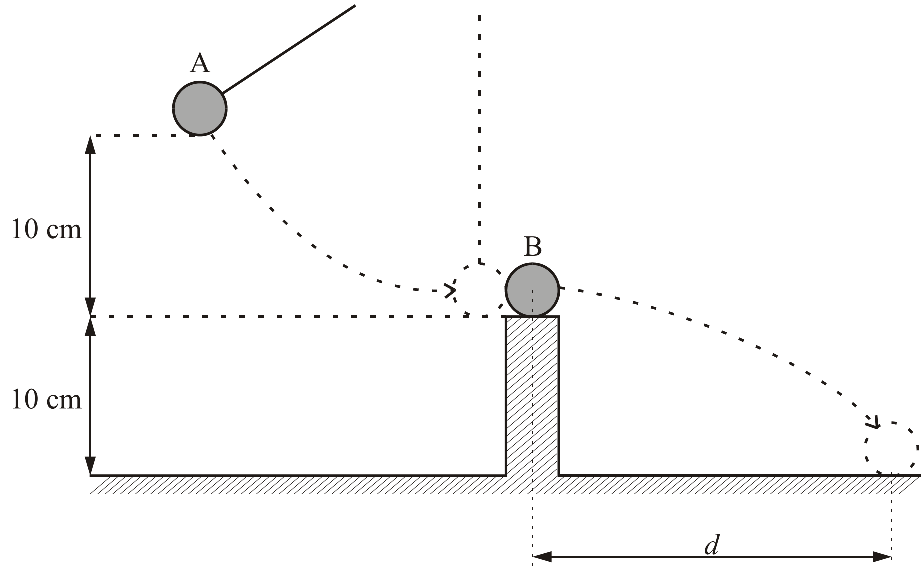
....

....

....

(2)
(Total 4 marks)

23. The diagram illustrates an elastic collision between two spheres, A and B, of equal mass.



Sphere A is tied to the end of a long vertical thread and pulled to one side until it has risen a distance of 10 cm. It is then released and comes to rest when it strikes the sphere B which is resting on a smooth flat support.

Sphere B travels a horizontal distance *d* before it hits the ground after falling 10 cm.

Calculate the speed of A as it strikes B.

....

....

....

....

Speed = ...

(4)

How long does B take to fall 10cm?

....

....

....

Time= ....

(3)

What is the speed of B just after the collision?

....

(1)

Calculate the distance d

....

....

Distance = ...

(2)

Explain briefly why B drops a distance of 10 cm much more quickly than A.

....

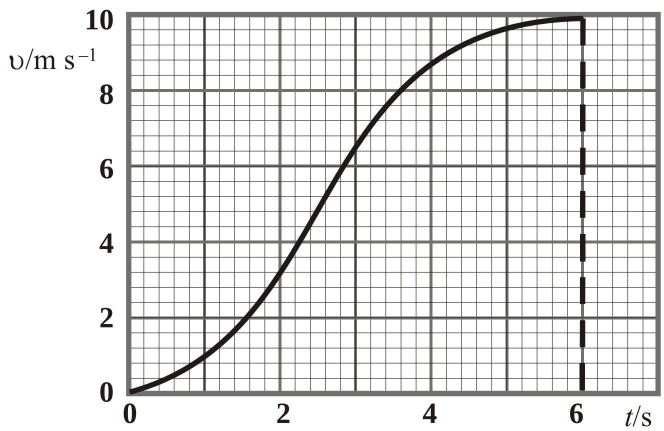
....

....

....

(2)
(Total 12 marks)

24. The graph shows the horizontal speed υ of a long jumper from the start of his run to the time when he reaches the take-off board.



Use the graph to estimate his maximum acceleration.

....

....

....

Acceleration = ...

(3)

Use the graph to estimate the distance of the ‘run-up’.

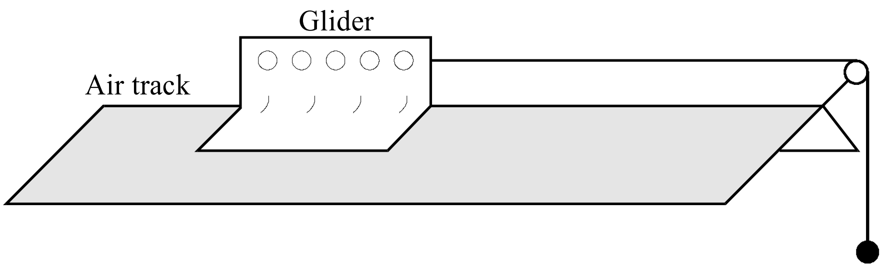
....

....

Distance = ...

(2)
(Total 5 marks)

25. The diagram shows a mass attached by a piece of string to a glider which is free to glide along an air track.



A student finds that the glider takes 1.13 s to move a distance of 90 cm starting from rest.

Calculate the speed of the glider after 1.13 s.

....

....

....

....

Speed = ...

(4)

Calculate its average acceleration during this time.

....

....

....

Average acceleration = ...

(3)

How would you test whether or not the acceleration of the glider is constant?

....

....

....

....

....

....

(3)
(Total 10 marks)

26. A mass is oscillating vertically on the end of a spring. Explain what happens to the following quantities as the mass rises from the bottom of its motion to the top.

Kinetic energy

....

....

....

Gravitational potential energy

....

....

....

Elastic potential energy

....

....

....

(4)

After a long time, the mass stops oscillating. What has happened to the energy?

....

....

....

(2)
(Total 6 marks)

27. Using the usual symbols write down an equation for

(i) Newton's law of gravitation

....

(ii) Coulomb's law

....

(2)

State one difference and one similarity between gravitational and electric fields.

Difference ....

....

Similarity ....

(2)

A speck of dust has a mass of 1.0×10^{-18} kg and carries a charge equal to that of one electron. Near to the Earth's surface it experiences a uniform downward electric field of strength 100 N C^{-1} and a uniform gravitational field of strength 9.8 N kg^{-1}.

Draw a free-body force diagram for the speck of dust. Label the forces clearly.

Calculate the magnitude and direction of the resultant force on the speck of dust.

....

....

....

....

....

Force = ...

(6)

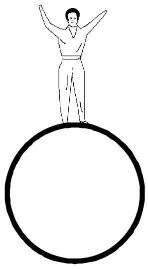
(Total 10 marks)

28. 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.

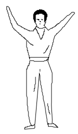
A base quantity	mole	☐	length	☐	kilogram	☐
A base unit	coulomb	☐	ampere	☐	volt	☐
A scalar quantity	torque	☐	velocity	☐	kinetic energy	☐
A vector quantity	mass	☐	weight	☐	density	☐

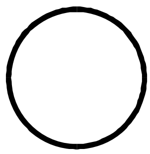
(Total 4 marks)

29. The diagram shows a man standing on a planet.



Complete and label two free-body force diagrams in the space below, one for the man and one for the planet.





(4)

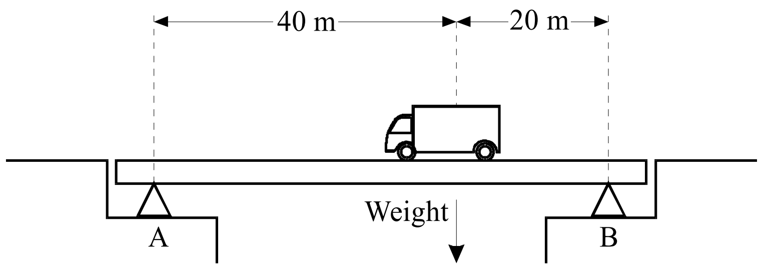
The man is in equilibrium. Explain what can be deduced about the forces acting on the man.

....

....

(1)
(Total 5 marks)

30. The diagram shows a lorry on a bridge.



The total mass of the lorry is 45 000 kg. Calculate its weight.

....

....

....

Weight = ...

(1)

By taking moments about A, find the increase in the upward force provided by support B when the lorry is on the bridge and in the position shown in the diagram.

....

....

....

....

Increase = ...

(2)

Calculate the corresponding increase in the force provided by support A.

....

....

....

....

Increase = ...

(1)
(Total 4 marks)

31. State Newton's second law of motion.

....

....

....

(2)

You are asked to test the relation between force and acceleration.

Draw and label a diagram of the apparatus you would use.

State clearly how you would use the apparatus and what measurements you would make.

....

....

....

....

(6)

Explain how you would use your measurements to test the relationship between force and acceleration.

....

....

....

....

....

(3)
(Total 11 marks)

32. A semiconducting strip, 6mm wide and 0.5 mm thick, carries a current of 8mA. The carrier density is 7×10^{-23} m^{-3}. Calculate the carrier drift speed.

....

....

....

....

Drift speed = ...

(3)

An approximate value for the drift speed in a copper wire of the same dimensions and carrying the same current would be about 10^{-7} ms $^{-1}$. Compare this figures with your calculated result and account for any difference in terms of the equation $I = nAqv$.

....

....

....

....

....

....

(3)

Explain why the resistance of a semiconducting strip decreases when its temperature rises.

....

....

....

....

(2)
(Total 8 marks)

33. The "engine" of a hang-glider is the gravitational field of the Earth. Hang-gliders drop slowly through the air during their flight. The weight of a reasonably efficient hang-glider, including the pilot, is about 900N. When the forward flight speed has a steady value of 18 ms^{-1}, the sinking speed is approximately 1.2 m s^{-1}.

Calculate the decrease in potential energy per second.

....

....

Decrease = ...

Explain what happens to this potential energy.

....

....

....

....

(4)

The maximum steady power output of a fit racing cyclist over several hours is about 400 W. Explain why sustained man-powered flight is difficult to achieve.

....

....

....

....

(2)
(Total 6 marks)

34. Radon-220 (also know as thoron) is a radioactive gas which decays by α emission to polonium $^{216}_{84}\text{Po}$. The half-life of this decay is approximately 1 minute.

Write a nuclear equation for this decay.

....

(1)

Describe an experiment you could perform in a school laboratory to determine the half-life of an α emitter of half-life approximately 1 minute.

....

....

....

....

....

....

(5)

A sample of milk is contaminated with a very small quantity of strontium-90. This isotope decays by β^- emission with a half-life of approximately 28 years.

Give two reasons why it would be very difficult to use this contaminated sample of milk to obtain an accurate value for the half-life of strontium-90.

....

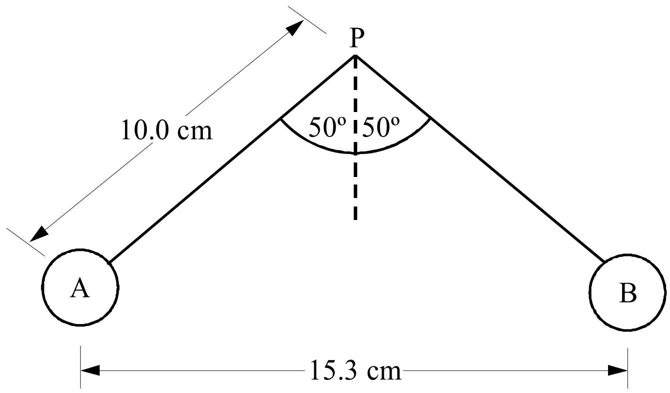
....

....

....

(2)
(Total 8 marks)

35. Two identical table tennis balls, A and B, each of mass 1.5g, are attached to non-conducting threads. The balls are charged to the same positive value. When the threads are fastened to a point P the balls hang as shown in the diagram. The distance from P to the centre of A or B is 10.0 cm.



Draw a labelled free-body force diagram for ball A.

(3)

Calculate the tension in one of the threads.

....

....

....

Tension = ...

(3)

Show that the electrostatic force between the two balls is 1.8×10^{-2} N.

....

....

(1)

Calculate the charge on each ball.

....

....

....

....

Charge = ...

(3)

How does the gravitational force between the two balls compare with the electrostatic force given above?

....

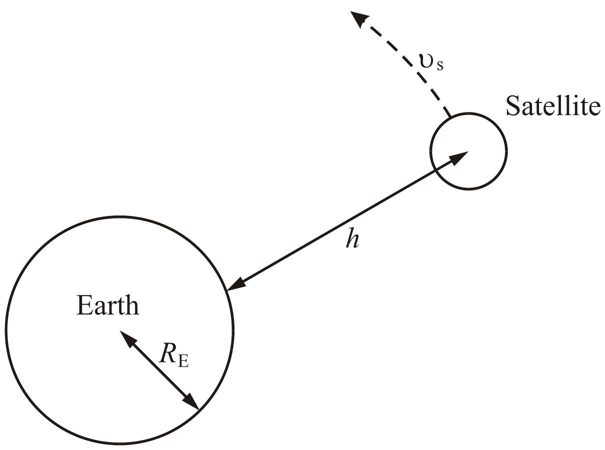
....

....

....

(2)
(Total 12 marks)

36. The diagram (not to scale) shows a satellite of mass m_s in circular orbit at speed υ_s around the Earth, mass M_E. The satellite is at a height h above the Earth's surface and the radius of the Earth is R_E.



Using the symbols above write down an expression for the centripetal force needed to maintain the satellite in this orbit.

....

....

....

(2)

Write down an expression for the gravitational field strength in the region of the satellite.

....

....

....

State an appropriate unit for this quantity.

....

(3)

Use your two expressions to show that the greater the height of the satellite above the Earth, the smaller will be its orbital speed.

....

....

....

....

....

(3)

Explain why, if a satellite slows down in its orbit, it nevertheless gradually spirals in towards the Earth's surface.

....

....

....

....

....

(2)
(Total 10 marks)

37. Write down a word equation which defines the magnitude of a force.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

(2)

Two forces have equal magnitudes. State three ways in which these two equal forces can differ.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

(3)
(Total 5 marks)

38. Demonstrate that the following equation is homogeneous with respect to units. The symbols have their usual meanings.

$$x = ut + \tfrac{1}{2}at^2$$

………………………………………………………………………………………………

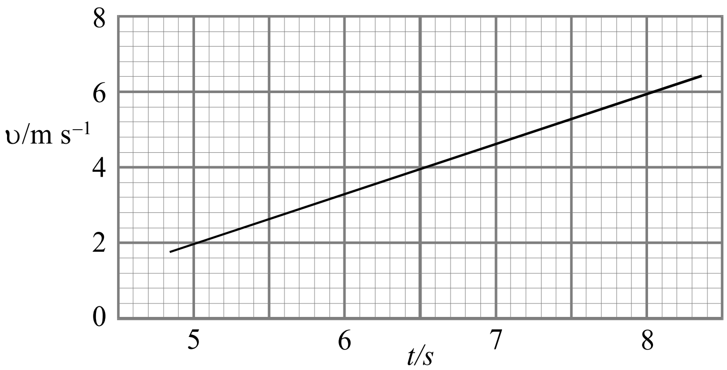
………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

(2)

The following graph shows the speed *v* of a body during a time interval of just 3 seconds.



Use the graph to determine the magnitude of the acceleration *a*.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

(3)

Find the distance travelled by the body between $t = 6$ s and t=8 s..

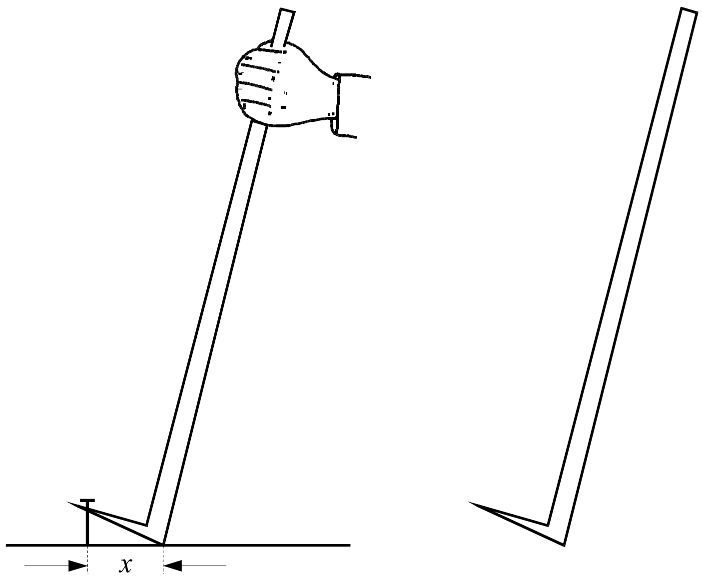
………………………………………………………………………………………………

………………………………………………………………………………………………

Distance = …..………………………

(2)
(Total 7 marks)

39. The diagram on the left shows a crowbar being used to pull a nail out of a wooden floor.



Use the diagram on the right to draw and to label a free-body force diagram for the crowbar. For each of the four forces which act on the crowbar, show the line of action, the direction and the source.

(4)

Identify one of the above forces which is not involved in an energy transfer process. Explain your answer.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

(2)

Give one advantage and one disadvantage of keeping the distance x as small as possible.

Advantage ……………………………………………………………………………….

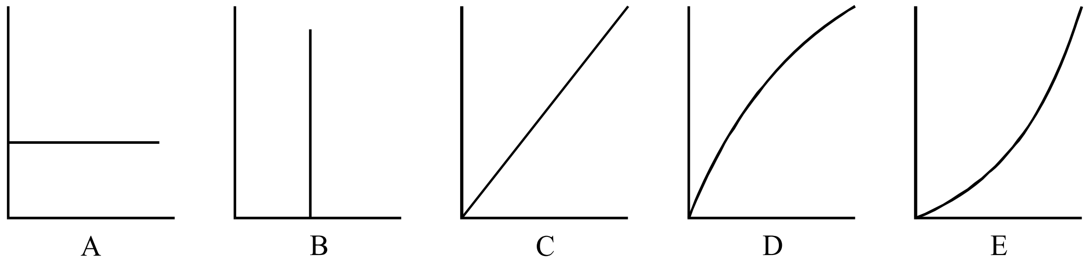
……………………………………………………………………………………………

Disadvantage ……………………………………………………………………………

……………………………………………………………………………………………

(2)
(Total 8 marks)

40. Each of the following graphs can be used to describe the motion of a body falling from rest. (Air resistance may be neglected.)



Which graph shows how the kinetic energy of the body (y-axis) varies with the distance fallen (x-axis)?

Graph ....

Explain your answer.

....

....

....

(3)

Which graph shows how the distance fallen (y-axis) varies with the time (x-axis)?

Graph ....

Explain your answer.

....

....

....

(3)

Which graph shows the relationship between acceleration (y-axis) and distance (x-axis)?

Graph ....

Explain your answer.

....

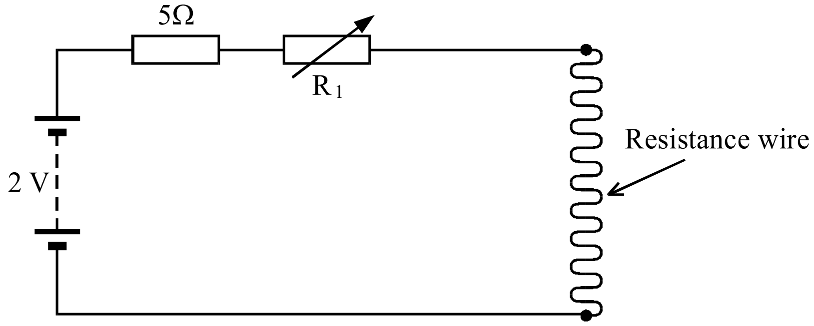
....

....

(3)
(Total 9 marks)

41. You are given a piece of resistance wire. It is between two and three metres long and has a resistance of about 15 Ω. You are asked to measure the resistivity of the metal alloy it is made from.

Make the necessary additions to the following circuit to enable it to be used for the experiment.



(2)

Describe briefly how you would use the circuit above to measure the resistance of the wire.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(5)

Once the resistance of the wire is known, two more quantities must be measured before its resistivity can be calculated. What are they?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(2)

Is there any advantage in finding the resistance of the wire from a graph compared with calculating an average value from the measurements? Explain your answer.

....

....

....

....

(2)
(Total 11 marks)

42. 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)

43. State the principle of moments.

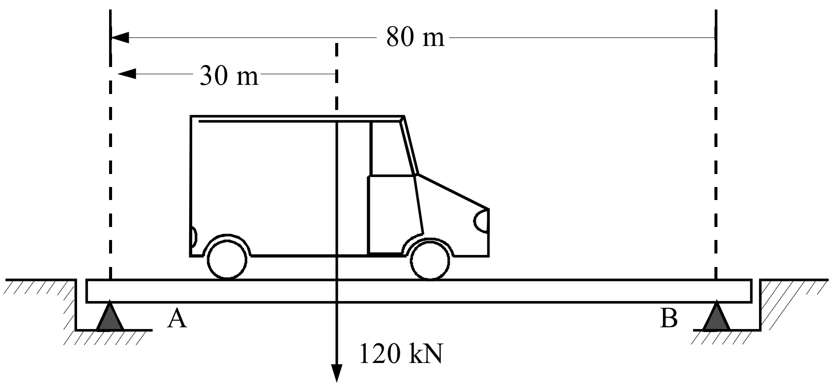
....

....

....

(2)

The diagram shows a lorry on a light bridge.



Calculate the downwards force on each of the bridge supports.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Force at A = ……………………………………

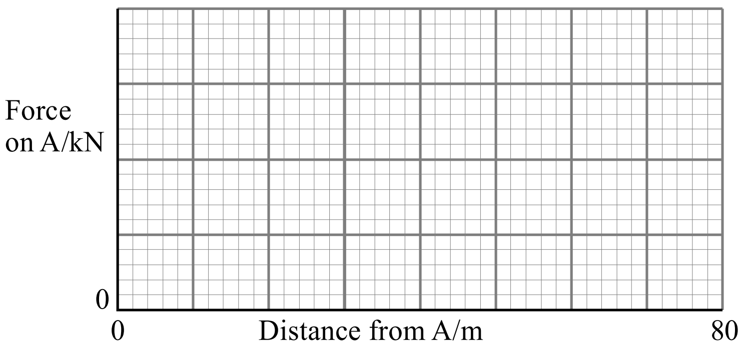
…………………………………………………………………………………………………

…………………………………………………………………………………………………

Force at B = ……………………………………

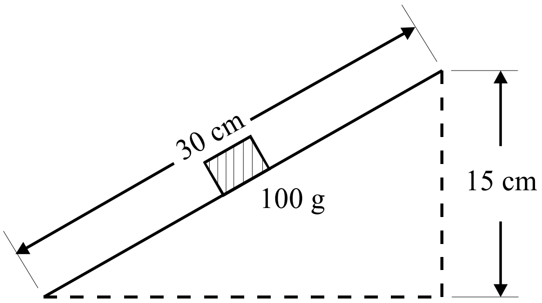
(4)

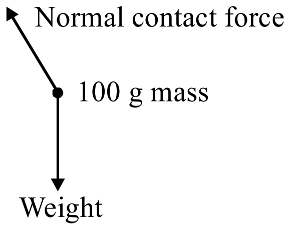
Sketch a graph on the axes below to show how the force on the support at A changes as the centre of gravity of the lorry moves from A to B Mark the value of the intercept on the force axis.



(3)
(Total 9 marks)

44. The diagram shows a smooth wooden board 30 cm long. One end is raised 15 cm above the other. A 100 g mass is placed on the board. The two forces acting on the 100 g mass are shown on the free-body force diagram.





Explain with the aid of a sketch why the resultant force on the 100 g mass acts parallel to the board and downwards.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

……………………………………………………………………………………………… **(2)**

Calculate the magnitude of this resultant force.

………………………………………………………………………………………………

………………………………………………………………………………………………

Magnitude = ………………………………… **(2)**

Calculate the kinetic energy gained by the 100 g mass as it slides down 20 cm of the slope.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

Kinetic energy = …………………………………

(2)

The smooth board is replaced by a similar rough board which exerts a frictional force of 0.19 N on the 100 g mass. Calculate the new value for the kinetic energy gained by the 100 g mass as it slides down 20 cm of slope.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

Kinetic energy = …………………………………

(2)

Explain why the final kinetic energy of the 100 g mass is greater when the board is smooth.

………………………………………………………………………………………………

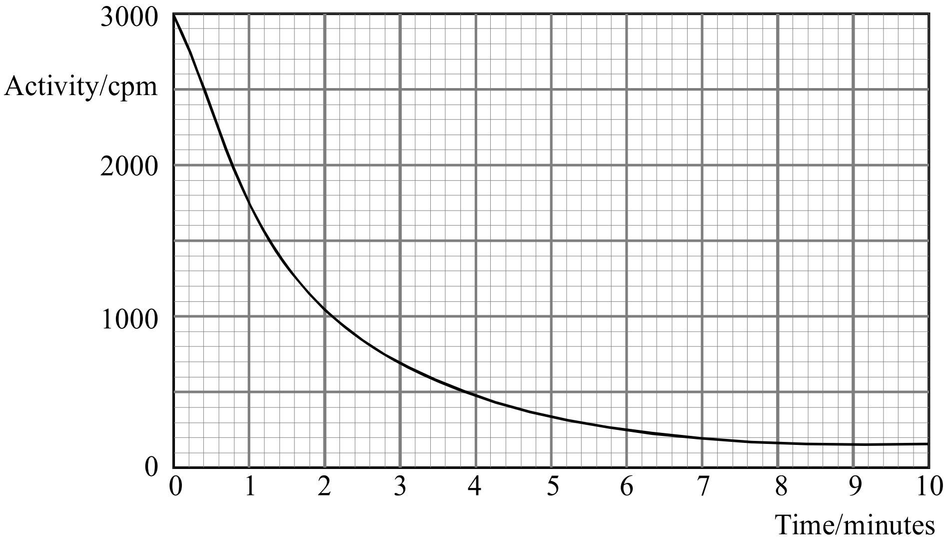
………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

(2)
(Total 10 marks)

45. A student carries out an experiment to determine the half-life of a radioactive isotope M. After subtracting the mean background count from the readings, the student plots the smooth curve shown on the graph below.



From this graph the student concludes that the isotope M is not pure, but contains a small proportion of another isotope C with a relatively long half-life.

State a feature of the graph that supports this conclusion.

....

.... **(1)**

Estimate the activity of isotope C.

.... **(1)**

Determine the half-life of isotope M. Show clearly how you obtained your answer.

....

....

....

....

Half-life of M = ... **(3)**

Isotope M decays by β^- emission. Write down a nuclear equation showing how the β^- particles are produced.

.... **(1)**

Describe briefly how the student could determine the nature of the radiation emitted by isotope C.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

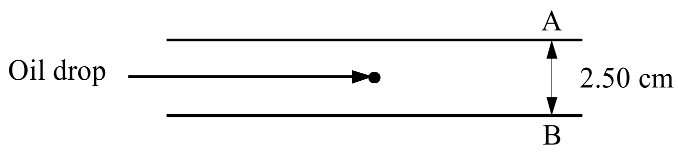
…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(3)
(Total 9 marks)

46. The diagram shows a positively charged oil drop held at rest between two parallel conducting plates A and B.



The oil drop has a mass 9.79 x 10^{-15} kg. The potential difference between the plates is 5000 V and plate B is at a potential of 0 V. Is plate A positive or negative?

…………………………………………………………………………………………………

Draw a labelled free-body force diagram which shows the forces acting on the oil drop. (You may ignore upthrust).

(3)

Calculate the electric field strength between the plates.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Electric field strength =…………………………………

(2)

Calculate the magnitude of the charge Q on the oil drop.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Charge =……………………………………

How many electrons would have to be removed from a neutral oil drop for it to acquire this charge?

…………………………………………………………………………………………………

(3)
(Total 8 marks)

47. A ball rolls over an obstacle which has been placed on a flat horizontal surface. The diagrams opposite show a velocity-time graph, a displacement-time graph and the axes for an acceleration-time graph for the horizontal motion of the ball. The time axes for the three graphs are identical.

Calculate the changes of displacement during the time intervals (i) $t = 0$ to $t = \text{X}$ and (ii) $t = \text{X}$ to $t = \text{Y}$.

(i) ....

Chance of displacement during time interval 0X = ...

(ii) ....

Change of displacement during time interval XY =..............................

(3)

Add in the scale values for the displacement axis on the second graph.

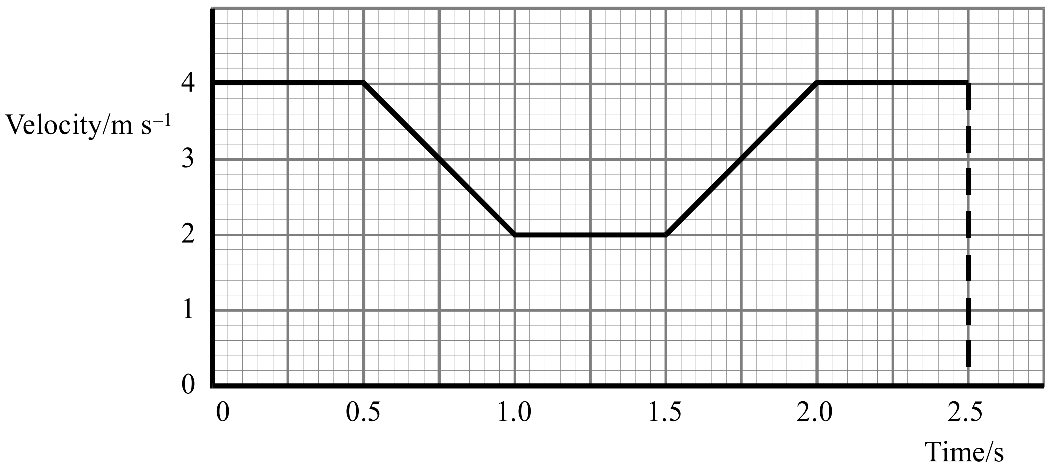
(1)

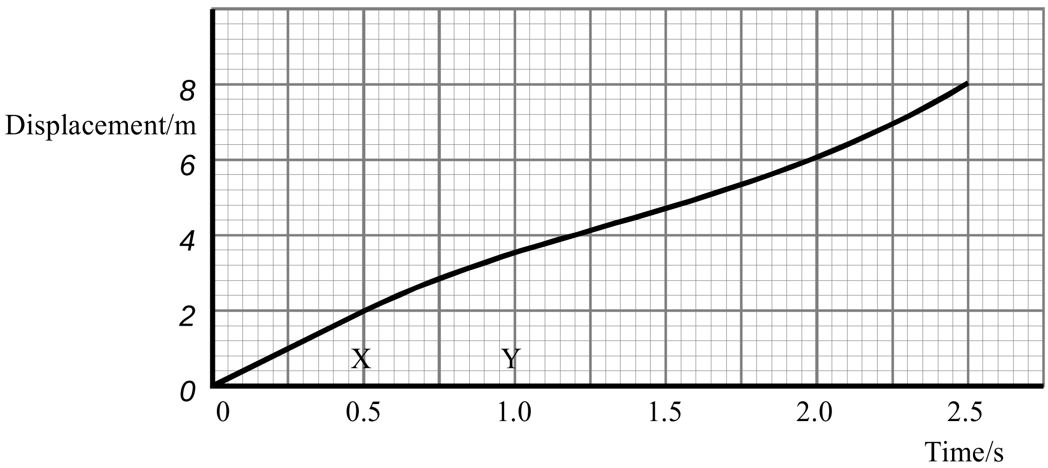
Sketch the acceleration-time graph and add the scale values to the acceleration axis.

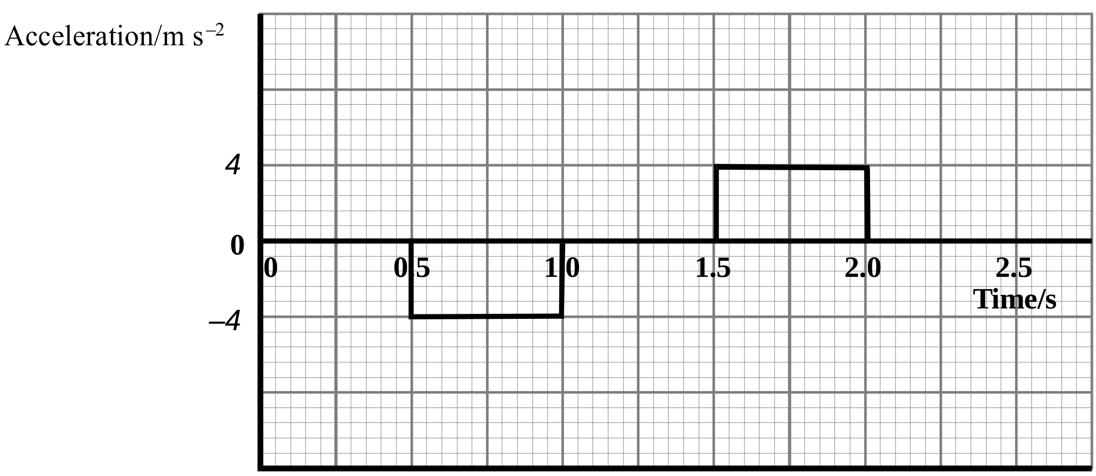
(4)

Sketch the shape of a vertical cross-section of the obstacle (without showing any of the dimensions) in the space below.

(2)







(Total 10 marks)

48. State the difference between scalar and vector quantities.

....

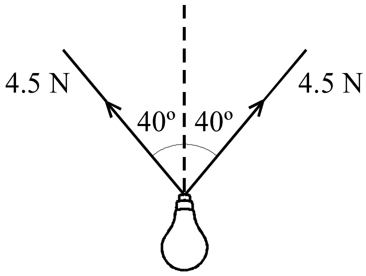
....

....

....

(2)

A lamp is suspended from two wires as shown in the diagram. The tension in each wire is 4.5N.



Calculate the magnitude of the resultant force exerted on the lamp by the wires.

....

....

....

(3)

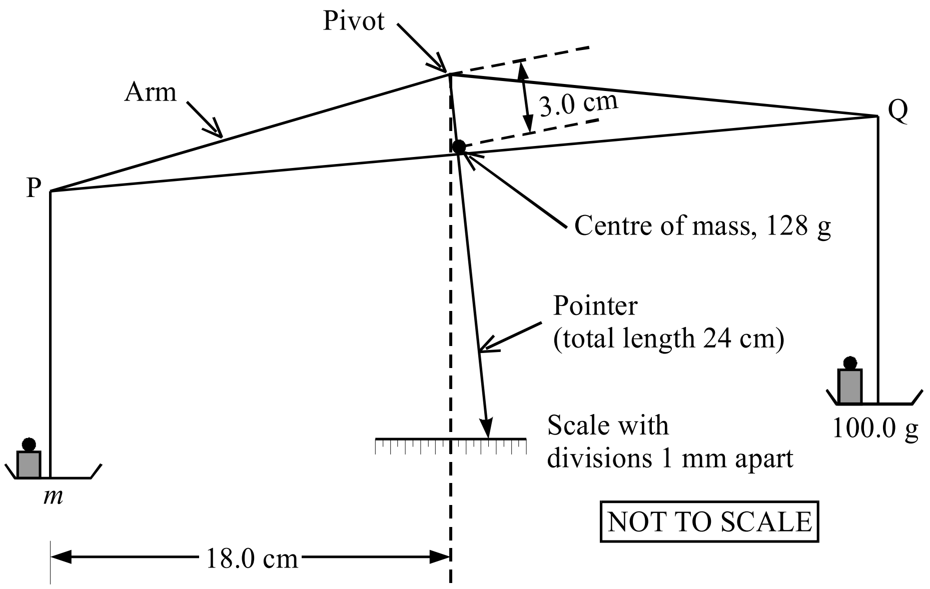
What is the weight of the lamp? Explain your answer.

....

....

(2)
(Total 7 marks)

49. The diagram shows an old-style chemical balance. The total mass of the moving part (i.e arm, pointer and two scale pans) is 128 g and when the pointer is vertical the centre of mass is 3.0 cm vertically below the pivot.



The pointer, which is 24.0 cm long, moves over a scale whose divisions are 1.0 mm apart. The pointer is deflected five scale divisions to the right.

Show that the horizontal displacement of the centre of mass is 0.625 mm.

....

....

....

....

(3)

The mass in the right-hand scale pan is 100.0 g. Assume that the horizontal distance of P and Q from the pivot are constant. Calculate the mass *m* in the left-hand scale pan.

....

....

....

....

Mass *m* = ...

(3)

Explain why the scale over which the pointer moves is not calibrated.

....

....

....

....

(2)
(Total 8 marks)

50. It is thought that an extremely short-lived radioactive isotope $^{269}_{110}X$, which decays by ?-emission, has a half-life of 200 ?s.

After a series of ? decays the element $^{A}_{104}Y$ is formed from the original isotope. There are no ? decays.

Deduce the value of A.

....

....

(2)

Calculate the decay constant λ of $^{269}_{110}X$.

....

....

λ = ...

(1)

The number of nuclei *N* of $^{269}_{110}X$ in a sample of mass 0.54 ?g is 1.2 ?10[15]. Determine the activity of 0.54 ?g of $^{269}_{110}X$

....

....

Activity = ...

(2)

Why is this value for the activity only approximate?

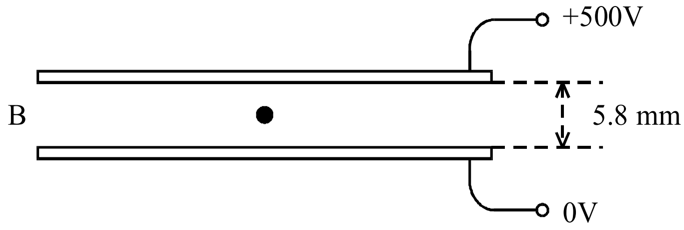
....

....

....

(1)
(Total 6 marks)

51. Lots of tiny plastic spheres are sprayed into the space between two horizontal plates which are electrically charged. After a time one sphere of mass 1.4×10^{-11}g is seen to be suspended at rest as shown.



(a) Explain how the sphere can be in equilibrium and calculate the charge on it.

Why must the plates be horizontal for the plastic spere to be at rest?

(6)

(b) A radioactive β-source is now placed at B for a short time and then removed. The plastic sphere is seen to move down at a steady speed.

Explain how the presence of the β-source has altered the charge on the sphere.

Draw a free-body force diagram of the sphere as it falls.

(3)

(c) Experiments of this kind confirm that *electric charge is quantised*.

Explain the meaning of the phrase in italics.

Name one other physical quantity which is quantised. Describe one situation where this quantum property is significant.

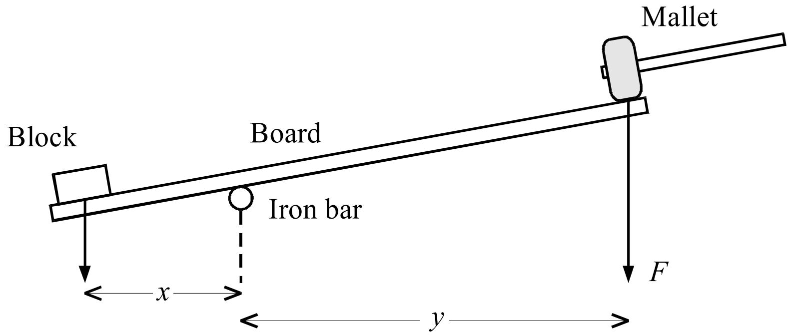
(4)

(d) The experiment above is repeated with plastic spheres which have a much smaller mass and using a lower potential difference between the plates. At no stage does any sphere appear to be completely at rest or to move steadily up or down. This agitated motion of the spheres is less noticeable when the temperature is considerably lowered.

Explain these observations.

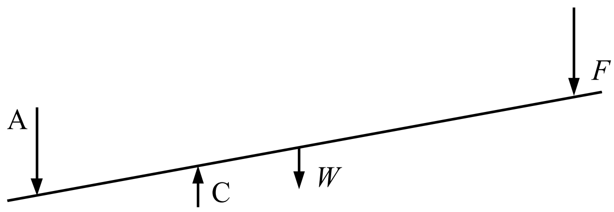
(3)
(Total 16)

52. The diagram shows a flat wooden board resting on an iron bar and with a heavy block resting on the left hand end of the board.



The block is thrown into the air when the right hand end of the board is struck by a mallet.

The diagram below is the free-body force diagram for the wooden board *just after the block has begun to move.*



Four forces are shown on the free-body force diagram. *W* is the weight of the board and A is the downward push on the board from the block. State whether the magnitude of the force A is greater than, equal to or less than the weight of the block. Explain your answer.

....

....

....

....

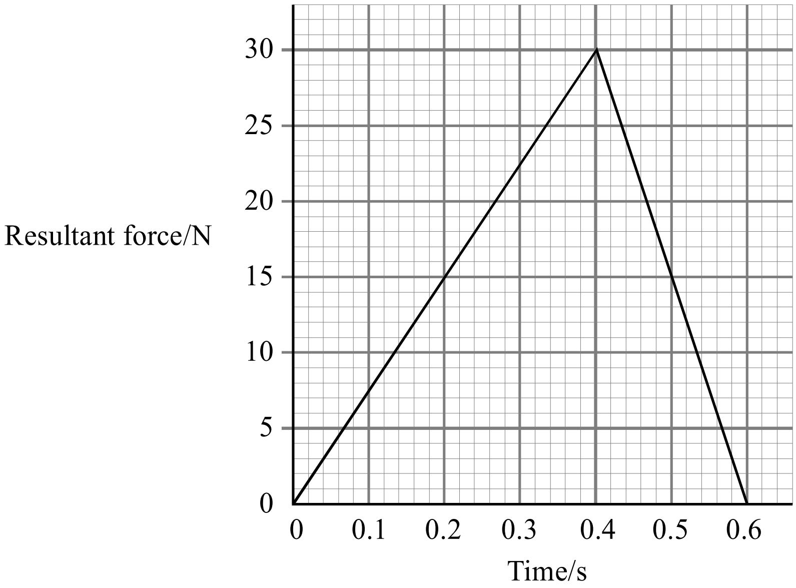
Write down suitable labels for the forces F and C.

Force F..

Force C..

(4)

The graph below shows how the resultant force on the block varies with time.



Use the graph to find a value for the impulse applied to the block

....

....

Impulse = ...

The mass of the block is 7.1 kg. Calculate its maximum upward speed.

....

....

Speed = ...

The force of the board on the block is not equal to the resultant force on the block. Why not?

....

....

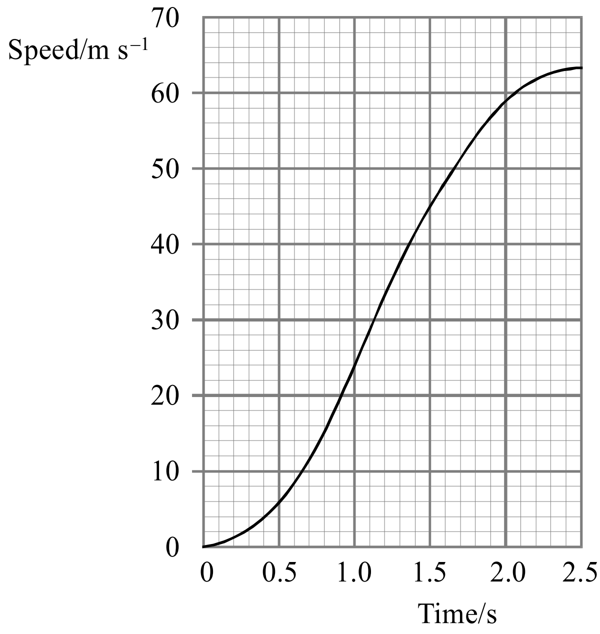
....

....

....

(6)
(Total 10 marks)

53. The graph shows the speed of a racing car during the first 2.6 seconds of a race as it accelerates from rest along a straight line.



Use the graph to estimate

(i) the displacement 1.5 s after the start.

....

....

....

Displacement = ...

(ii) the acceleration at 2.0 s

....

....

....

Acceleration = ...

(iii) the kinetic energy after 2.5 s given that the mass of the racing car is 420 kg

....

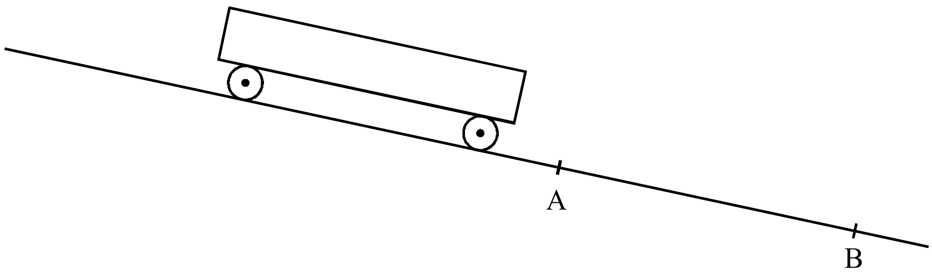
....

....

Kinetic energy = ...

(Total 6 marks)

54. The diagram shows a toy truck, about 30 cm long, accelerating freely down a gentle incline.



Explain carefully how you would measure the average speed with which the truck passes the point A.

....

....

....

....

....

....

....

(4)

You find that the measured average speed of the truck is 1.52 m s^{-1} when it passes the point A and 1.64 m s^{-1} when it passes the point B. The distance from A to B 1.20 m. Calculate the acceleration of the truck.

....

....

....

....

....

....

Acceleration = ……..........…..........

(2)
(Total 6 marks)

55. Define the term *work*.

....

....

....

....

(2)

A particle is moving along a circular path at constant speed. *Use your definition of the term work* to explain why the resultant force acting on the particle must be acting at right angles to its path.

....

....

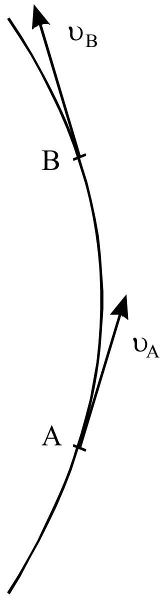
....

....

....

(3)

The diagram shows the velocity vectors at two points along the circular path.



With reference to this diagram, explain briefly why the direction of the acceleration must be towards the centre of the circle.

....

....

....

....

....

....

(3)
(Total 8 marks)

56. 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)

57. Geiger and Marsden carried out a scattering experiment which led to a revised understanding of the structure of the atom. The tables below refer to this experiment. Complete the tables and sentences.

	Name
Incoming particle	
Target atoms	

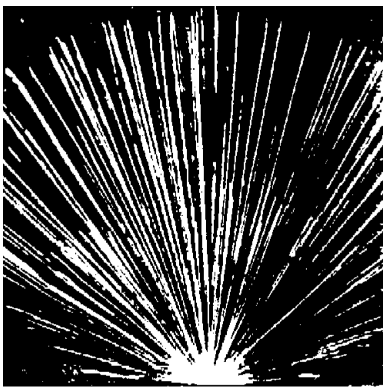
Observation	**Conclusion about atomic structure**
The incoming particles were mostly undeflected.	
A few particles were deflected by angles greater than 90°.	

The diameter of …….. is approximately 10^{-15} m.

The diameter of ....…….. is approximately 10^{-11} m.

(Total 6 marks)

58. The photograph shows α particle tracks.



What properties of the α particles can be deduced from this photograph?

....

....

....

....

(4)

A different source emits both α and β particles. How would you use a Geiger counter to determine the approximate count rate due to the α radiation only?

....

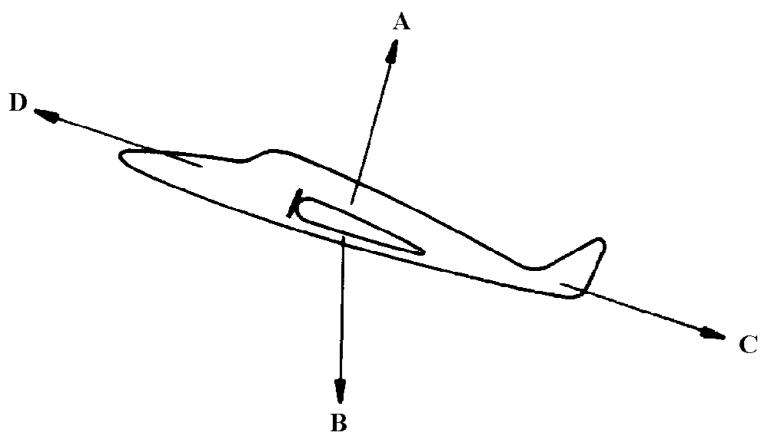
....

....

....

(2)
(Total 6 marks)

59. The diagram shows a free–body force diagram for an aircraft flying along a straight path and climbing at constant speed.



Name each of the four forces shown and identify in each case what exerts the force.

Force A ....

....

Force B ....

....

Force C ....

....

Force D ....

....

(4)

State whether or not the resultant force is zero. Explain your answer.

....

....

....

....

(2)
(Total 6 marks)

60. A small house uses a tank containing 1.2 m^3 water as a thermal store. During the night its temperature rises to 98 °C. During the day, its temperature drops as the water is pumped round, the house radiators to keep the house warm.

The density of water is 1 000 kg m^{-3} and its specific heat capacity is 4200 J kg^{-1} K^{-1}. Calculate the energy given out by the water on a day when its temperature drops from 98 °C to 65 °C.

....

....

....

Energy = ...

(3)

The six radiators in the house give out an average power of 1.5 kW each. For how long can they all operate at this power before the water temperature drops to 65°C?

....

....

....

Time = ...

(3)

Explain why this heating system operates more effectively early in the morning than towards the evening.

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

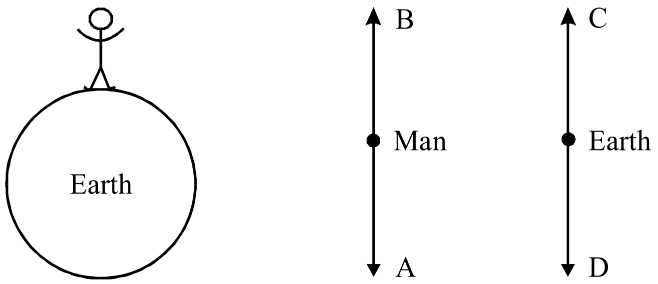
.............................……………………………………………………………………………

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

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

(2)
(Total 8 marks)

61. The diagrams show a man standing on the Earth and two free-body force diagrams, one for the man and one for the Earth.



Force A can be described as ‘the Earth pulling the man down with a gravitational force’. Use a similar form of words to describe force C which forms a Newton third law pair with force A.

....

....

....

(2)

Noting that forces A and C are a Newton third law pair, write down three similarities and two differences between these two forces.

Similarities:

(i) ……………………………………………………………………………………….

(ii) ………………………………………………………………………………………

(iii) ……………………………………………………………………………………..

Differences:

(i) ………………………………………………………………………………………….

(ii) …………………………………………………………………………………………

(5)

Which two forces show whether or not the man is in equilibrium?

....

(1)
(Total 8 marks)

62. Twin engine aircraft use less fuel than those with four engines. Recent improvements in engine reliability mean that they are now considered safe for long commercial flights over water. An aircraft powered by two Rolls-Royce Trent engines demonstrated its endurance by flying nonstop round the world. During this flight it used 1.7×10^5 litres of aviation fuel.

Each litre of fuel releases 38 MJ when combined with oxygen in the air.

Calculate the total amount of energy released during the flight.

....

....

....

Energy = ……….......……..............

(2)

The flight lasted 47 hours. Calculate the average input power to the engines.

....

....

Power = ……….......……..............

(2)

The distance covered by the aircraft was 41000 km. Calculate the aircraft's average speed.

....

....

....

Speed = ……………...……..............

The *maximum* thrust of each engine is 700 kN. Multiply the total maximum thrust by the average speed and comment on your answer.

....

....

....

....

(6)

(Total 10 marks)

63. A careless soldier shoots a bullet vertically into the air at 450 m s^{-1}. Calculate the time the bullet takes to reach the top of its flight. State any assumption you have made.

....

....

....

....

Time ……………………………

(3)

Sketch and label fully a velocity-time graph for the bullet's complete flight.

Explain the shape of your graph.

....

....

....

Use your graph to calculate the distance travelled by the bullet before it hits the ground.

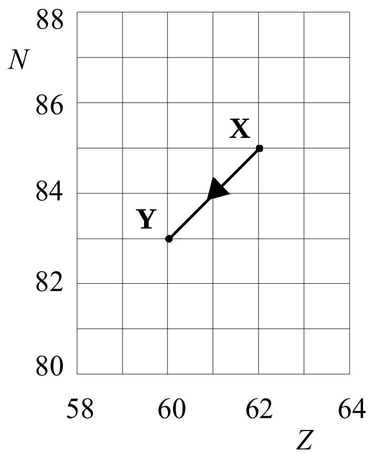
....

....

....

(7)
(Total 10 marks)

64. The grid enables different nuclei to be represented by plotting the number of neutrons N against the number of protons Z in a nucleus. The arrow shows a nucleus X decaying to a nucleus Y.



What type of radioactive decay is taking place?

....

Write a nuclear equation for this decay.

....

Add another arrow to the grid to represent what happens if nucleus Y subsequently decays by β^- emission to nucleus W.

Mark a point P on the grid that could represent the nucleus of an isotope of X.

(Total 5 marks)

65. It is thought that some soil could be contaminated with a radioisotope.

You have a sample of this soil. Design an experiment to find what types of radiation are emitted.

....

....

....

....

....

....

....

....

....

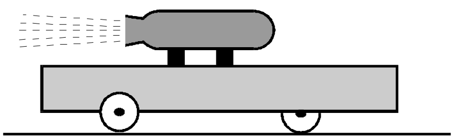
....

....

....

(Total 5 marks)

66. In a laboratory experiment a small cylinder containing liquid carbon dioxide is attached to a trolley. When the cylinder is punctured CO_2 gas rushes out and the trolley accelerates.



(a) Explain from first principles the origin of the force accelerating the trolley.

(3)

(b) The trolley and cylinder have a mass of 0.68kg and reach a final speed of 2.7 ms^{-1}. The total mass of CO_2 initially in the cylinder is 12 g.

(i) Show that the average speed of ejection of CO_2 molecules during the acceleration is 150 ms^{-1}. State any assumption that you make.

(ii) Calculate the total kinetic energy of the CO_2 gas after it has left the cylinder and the kinetic energy of the trolley and cylinder at its final speed.

(7)

(c) It is found that the cylinder which contained liquid CO_2 is cold at the end of the experiment.

(i) Explain this drop in temperature.

(ii) What would you use to measure the change in temperature of the cylinder between the start and finish of the experiment? Give one possible source of error in your measurement.

(iii) What other measurement would you take and what data would you need to look up in order to calculate the loss in internal energy of the cylinder?

(6)
(Total 16 marks)

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

....

....

(1)

Show that the equation $x = \mathrm{u}t + 1/2\mathrm{a}t^2$ is homogeneous with respect to its units.

....

....

....

....

....

(3)

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

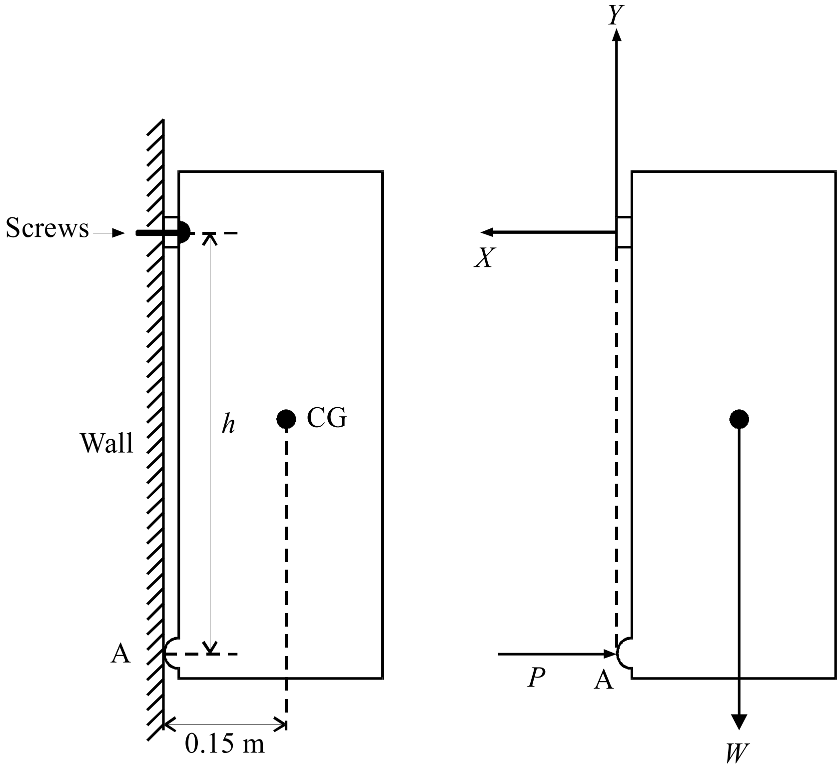
....

....

(1)
(Total 5 marks)

68. Diagram (a) shows a side view of a kitchen wall cupboard . Its lower edge rests against the wall at A. It is fastened by screws at a height h vertically above A. The mass of the cupboard is 10kg and its centre of gravity is 0.15 m from the wall.

Diagram (b) is a free-body force diagram for the cupboard.



(a) (b)

State the magnitude of force Y.

....

(1)

Explain why forces X and P must have equal magnitude.

....

....

(1)

Calculate the moment of the weight of the cupboard about point A.

....

....

Moment = ...

(2)

Calculate the value of force *X* when $h = 0.06$ m

....

....

Force *X* = ...

(2)

In principle the fixing screws could be positioned anywhere between point A and the top of the cupboard. Sketch a graph to show how the size of force X would depend on *h* for values of *h* from zero up to 0.60m.

(2)

Explain why in practice the screws are usually situated as high in the cupboard as possible.

....

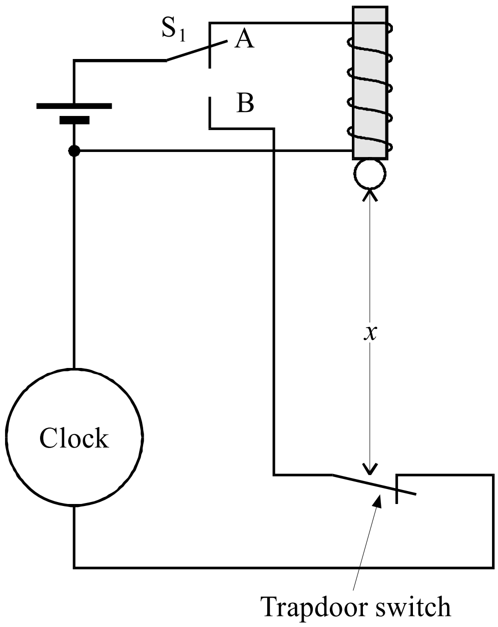
....

....

....

(2)
(Total 10 marks)

69. The diagram shows an apparatus for timing a falling ball.



State what happens at the instant when the switch S_1 is moved from A to B.

....

....

....

....

(2)

The distance *x* is 1.00 m. Calculate the time for the ball to fall this distance.

....

....

....

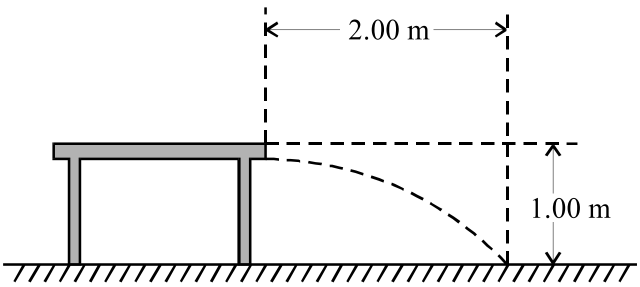
....

....

Time = ...

(3)

In a second experiment the ball is fired horizontally from the edge of a table 1.00 m high.



State with a reason the time for the ball to reach the ground.

....

....

(2)

The ball hits the floor a horizontal distance of 2.00 m from the edge of the table. Calculate the speed at which the ball was fired.

....

....

Speed = ...

(2)
(Total 9 marks)

70. Read the following paragraph carefully and CIRCLE the correct response to the choices in the brackets.

Geiger and Marsden carried out an experiment to investigate the structure of the atom.

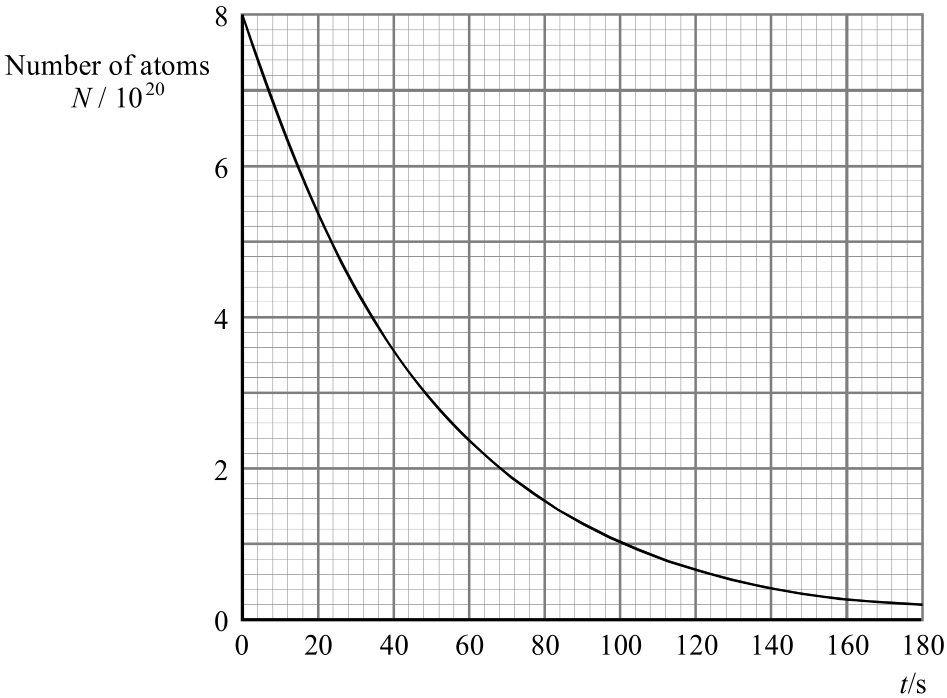
In this experiment $\begin{Bmatrix}\text{Alpha particles}\\ \text{Beta particles}\\ \text{Gamma rays}\end{Bmatrix}$ were $\begin{Bmatrix}\text{diffracted}\\ \text{refracted}\\ \text{scattered}\end{Bmatrix}$ by thin films of metals such as gold.

The experiment led to the conclusion that the atom had an $\begin{Bmatrix}\text{uncharged}\\ \text{negatively charged}\\ \text{positively charged}\end{Bmatrix}$ nucleus of

diameter approximately $\begin{Bmatrix}10^{-15}\text{ m}\\ 10^{-10}\text{ m}\end{Bmatrix}$ and containing $\begin{Bmatrix}\text{all the mass}\\ \text{most of the mass}\\ \frac{1}{2000}\text{ of the mass}\end{Bmatrix}$ of the atom.

(Total 5 marks)

71. The graph shows the decay of a radioactive nuclide.



Determine the half-life of this radionuclide.

....

....

....

Half-life = ...

(2)

Use your value of half-life to calculate the decay constant λ of this radionuclide.

....

....

Decay constant = ...

(1)

Use the graph to determine the rate of decay dN/dt when $N = 3.0 \times 10^{20}$.

....

....

....

....

Rate of decay = ...

(3)

Use your value of the rate of decay to calculate the decay constant λ of this radionuclide.

....

....

....

Decay constant = ...

(2)

Explain which method of determining the decay constant you consider to be more reliable.

....

....

(1)
(Total 9 marks)

72. (a) (i) Radioactivity is a random process. Explain what is meant by this statement.

(ii) The decay of a sample of radioactive material can be described by the equation.

$$\frac{dN}{dt} = -\lambda N$$

where dN/dt is the activity of the sample.

Calculate the activity of a sample of nitrogen–13 when N=2.5 × 10^5. The half-life of nitrogen–13 is 10 minutes.

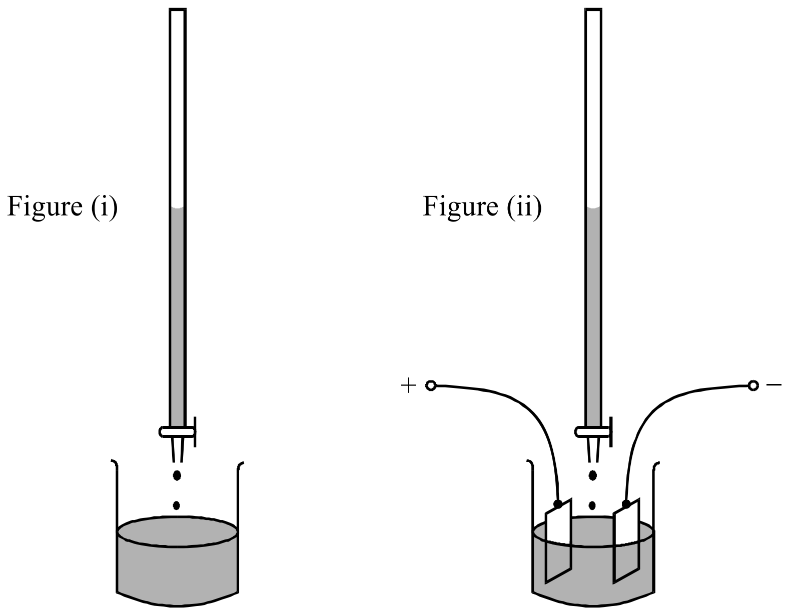
(iii) Nitrogen–13 ($^{13}_{7}N$) decays to a stable nuclide by emitting a beta-plus particle. Write an equation for this process.

(7)

(b) A student develops an experiment, shown in figure (i), to model a radioactive decay process such as that for nitrogen–13. A burette containing copper sulphate solution is allowed to drain into a beaker. The student monitors the levels of the copper sulphate solution in the burette and beaker.

(i) Discuss to what extent the experiment illustrated in figure (i) is analogous to the decay of nitrogen–13.

(3)



(ii) The student develops an electrical method of monitoring the depth of solution in the beaker. This is shown in figure (ii). Two square sheets of copper of side 4.0cm are placed 5.0cm apart in the beaker. The copper sheets are connected in series with a d.c. supply of 1.5V, an ammeter and a 5.6Ω resistor.

Calculate the current in the circuit when the copper sulphate solution covers half the copper sheets. Take the resistivity of copper sulphate solution to be 0.12Ωm. State any assumption you have made.

(6)
(Total 16 marks)

73. 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

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

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)

74. According to Newton's second law of motion, the rate of change of momentum of an object is proportional to the resultant force *F* acting on it. Show how this statement leads to the equation

$$F = ma$$

where *m* is the mass and *a* the acceleration of the object.

....

....

....

....

....

(4)

When jumping from a height on to a hard surface, it is advisable to bend one's knees on landing.

How does bending the knees affect the time one takes to come to rest?

....

....

(1)

With reference to Newton's second law, explain why it is a good idea to bend one's knees.

....

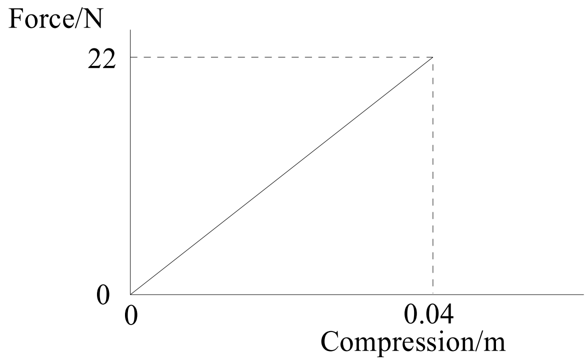
....

....

....

(2)
(Total 7 marks)

75. A toy frog has a spring which causes it to jump into the air. The force-compression graph for the spring is shown below.



Calculate the work done on the spring when it is compressed by 4.0 cm.

....

....

....

Work done =..........................

(3)

The frog has a mass of 24 g and rises 0.60 m vertically into the air. Calculate the gravitational potential energy gained by the frog.

....

....

....

Energy =.....................................

(2)

Compare your two answers for energy and explain how they are consistent with the law of conservation of energy.

....

....

....

....

(2)
(Total 7 marks)

76. Explain why a body moving at constant speed in a circular path needs a resultant force acting on it.

....

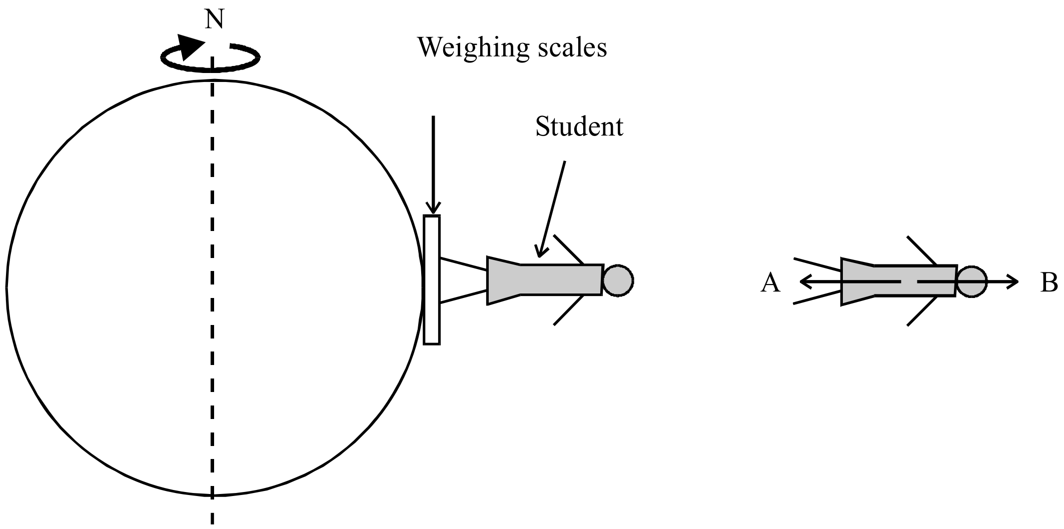
....

....

....

(2)

The diagram shows a student at the equator standing on a set of weighing scales, and a free-body force diagram for the student.



Identify the bodies applying forces A and B.

....

.... **(2)**

Because of the Earth's daily rotation the student is performing circular motion about the Earth's axis. Calculate the angular speed of the student.

....

....

....

Angular speed =................................ **(2)**

The radius of the Earth is 6400 km. The student's mass is 55 kg. Calculate the resultant force on the student.

....

....

....

Resultant force =.................................... **(3)**

Force A is 539 N. Calculate the value of force B.

....

....

Force B =..................................

State, with a reason, the force indicated by the weighing scales.

....

....

(3)
(Total 12 marks)

77. Uranium decays into thorium, Th, by emitting an alpha particle.

The thorium produced is itself radioactive and decays by beta minus emission to element X.

Complete the nuclear equations for both decays below. Ensure that all symbols have the appropriate nucleon and proton number.

$$\mathrm{U} \quad \rightarrow \quad {}^{234}_{90}\mathrm{Th} \quad +$$

$$ {}^{234}_{90}\mathrm{Th} \quad \rightarrow \qquad\qquad + $$

(4)

How could a strong magnetic field be used to distinguish alpha particles from beta particles?

....

....

....

....

(2)
(Total 6 marks)

78. The density of water is 1000 kg m^{-3}. How would you verify this value experimentally in a laboratory?

What other measurement ought to be quoted when a value for the density of a liquid is stated?

....

....

....

....

....

....

(4)

With reference to their molecular structures, explain why gases have very different densities from either solids or liquids.

....

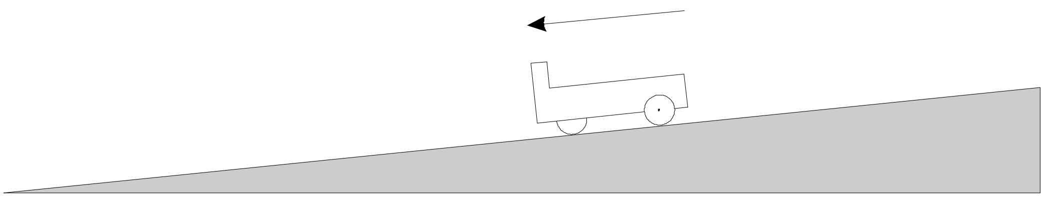
....

....

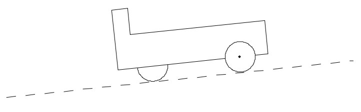
....

(2)
(Total 6 marks)

79. The diagram shows a trolley moving down a gentle slope.

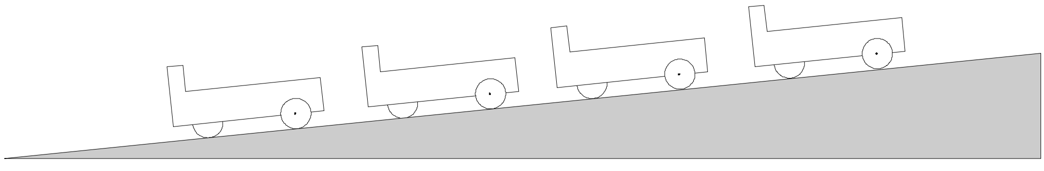


Add forces to the diagram below to produce a free-body force diagram for the trolley.



(3)

The trolley is photographed by a multiflash technique. The result is shown below.



What evidence is there that the trolley is moving with constant velocity?

....

(1)

State the acceleration of the trolley down the slope.

....

(1)

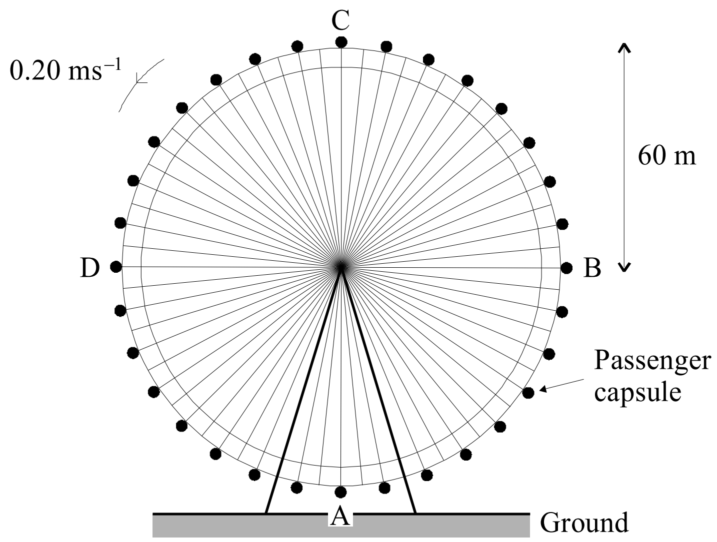
What does the value of the acceleration indicate about the forces acting on the trolley?

....

(1)
(Total 6 marks)

80. The 'London Eye' is a large wheel which rotates at a slow steady speed in a vertical plane about a fixed horizontal axis. A total of 800 passengers can ride in 32 capsules equally spaced around the rim.

A simplified diagram is shown below.



On the wheel, the passengers travel at a speed of about 0.20 m s^{-1} round a circle of radius 60 m. Calculate how long the wheel takes to make one complete revolution.

....

....

Time = ...

(2)

What is the change in the passenger's velocity when he travels from point B to point D?

....

....

....

....

(2)

When one particular passenger ascends from point A to point C his gravitational potential energy increases by 80 kJ.   Calculate his mass.

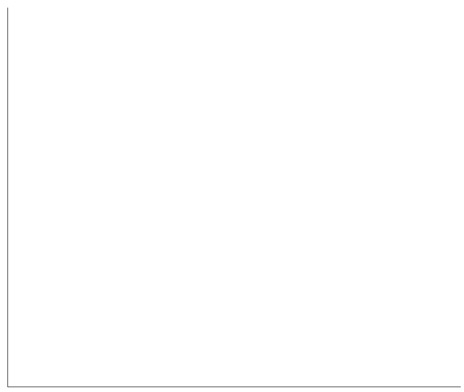
....

....

Mass =..........................

(3)

On the axes below sketch a graph showing how the passenger's gravitational potential energy would vary with time as he ascended from A to C. Add a scale to each axis.



(3)

Discuss whether it is necessary for the motor driving the wheel to supply this gravitational potential energy.

....

....

....

....

(2)

(Total 12 marks)

81. Define linear momentum.

....

....

(1)

The principle of conservation of linear momentum is a consequence of Newton's laws of motion. An examination candidate is asked to explain this, using a collision between two trolleys as an example. He gives the following answer, which is correct but incomplete. The lines of his answer are numbered on the left for reference.

1. During the collision the trolleys push each other.
2. These forces are of the same size but in opposite directions.
3. As a result, the momentum of one trolley must increase at the same rate as the momentum of the other decreases.
4. Therefore the total momentum of the two trolleys must remain constant.

In which line of his argument is the candidate using Newton's second law?

....

(1)

In which line is he using Newton's third law?

....

(1)

The student is making one important assumption which he has not stated. State this assumption. Explain at what point it comes into the argument.

....

....

....

....

(2)

Describe how you could check experimentally that momentum is conserved in a collision between two trolleys.

....

....

....

....

(4)
(Total 9 marks)

82. State the number of protons and the number of neutrons in ${}^{14}_{6}C$.

Number of protons =...

Number of neutrons =...

(2)

The mass of one nucleus of ${}^{14}_{6}C = 2.34 \times 10^{-26}$ kg.

The nucleus of carbon-14 has a radius of 2.70×10^{-15} m.

Show that the volume of a carbon-14 nucleus is about 8×10^{-44} m^3.

....

....

(2)

Determine the density of this nucleus.

....

....

....

Density =...................................

(2)

How does your value compare with the densities of everyday materials?

....

(1)

Carbon-14 is a radioisotope with a half-life of 5700 years. What is meant by the term half-life?

....

....

(2)

Calculate the decay constant of carbon-14 in s^{-1}

....

....

....

....

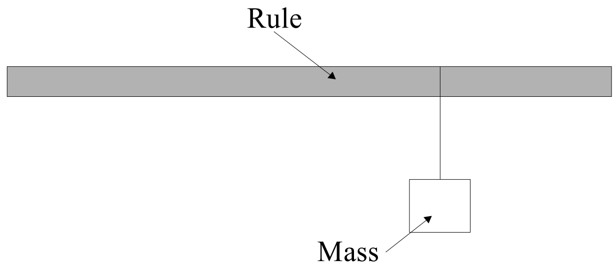
Decay constant .... s^{-1}

(2)

(Total 11 marks)

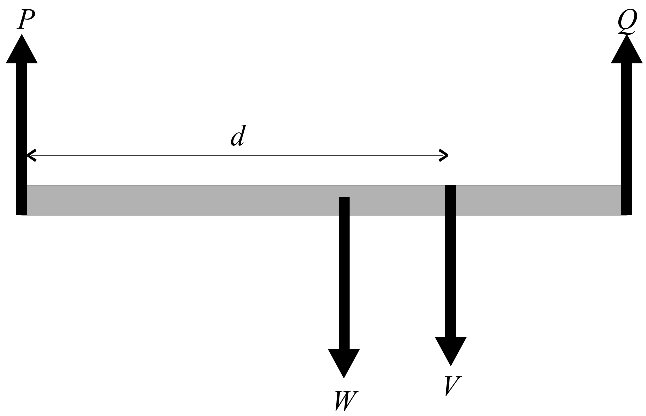
83. A student performs an experiment to investigate how the forces exerted on a bridge by its supports vary as a vehicle crosses the bridge. She models the bridge and vehicle using a metre rule and a suspended mass.

Complete and label the diagram below to show a way of supporting the ends of the rule so that the forces exerted on them can be measured.

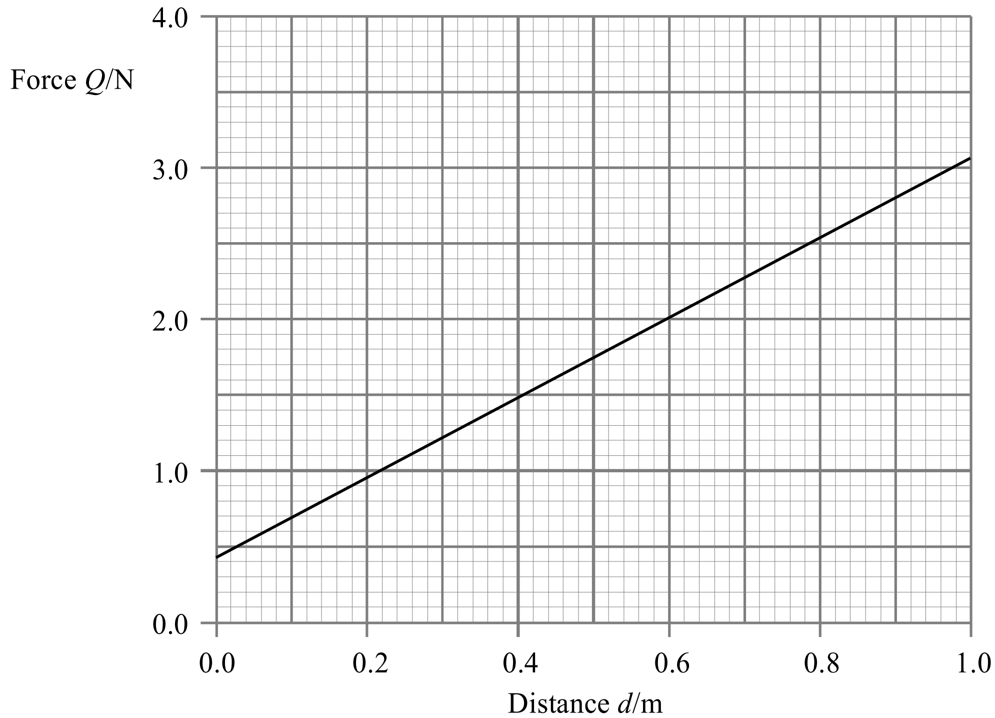


(2)

Below is a free-body force diagram for the rule. *P* and *Q* are the forces exerted by the supports; *W* and *V* are equal to the weights of the rule and suspended mass.



The graph shows how *Q* was found to vary with the position of the mass.



State the principle of moments.

....

....

....

(2)

Use this principle to explain, without calculation, why force *Q* increases as distance *d* increases.

....

....

....

....

(2)

Using information from the graph, calculate the value of *W*.

....

....

....

....

W =..

(3)
(Total 9 marks)

84. A student has a sample of a radioactive element which is thought to be a pure beta emitter. The student has **only** the following apparatus available:

- a thin window Geiger-Muller tube connected to a counter
- a piece of aluminium 3 mm thick, and
- a half-metre rule

How would the student determine the background radiation level in the laboratory?

....

....

....

....

(2)

The student investigates how the count rate varies with distance from the source to the G-M tube and also the effect of inserting the aluminium absorber. From these experiments explain how the student could confirm that the sample was a pure beta emitter. You may be awarded a mark for the clarity of your answer.

....

....

....

....

(5)
(Total 7 marks)

85. Complete the following table which compares alpha particle scattering and deep inelastic scattering experiments.

	Alpha particle scattering	Deep inelastic scattering
Incident particles	Alpha particles	
Target		Nucleons

(2)

Write a short paragraph describing the conclusion from each experiment.

Alpha particle scattering

....

....

....

....

Deep inelastic scattering

....

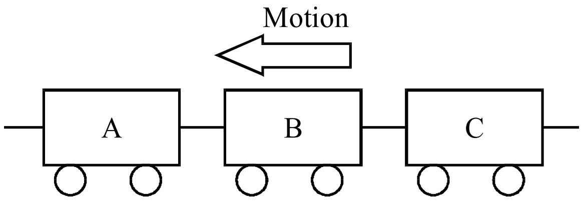
....

....

....

(4)
(Total 6 marks)

86. The diagram shows three trucks which are part of a train. The mass of each truck is 84 000 kg.



The train accelerates uniformly in the direction shown from rest to 16 m s^{-1} in a time of 4.0 minutes. Calculate the resultant force on each truck.

....

....

....

Resultant force =...

(3)

The force exerted by truck B on truck C is 11 200 N. Draw a free-body force diagram for truck B, showing the magnitudes of all the forces. Neglect any frictional forces on the trucks.

(4)

The total mass of the train is 3.0×10^6 kg. Calculate the average power delivered to the train during the accelerating process.

....

....

....

Average power =...

(3)

The locomotive is powered by an overhead cable at 25 kV. Neglecting any power dissipation, calculate the average current drawn from the supply during the accelerating period.

....

....

....

Average current =.......................................

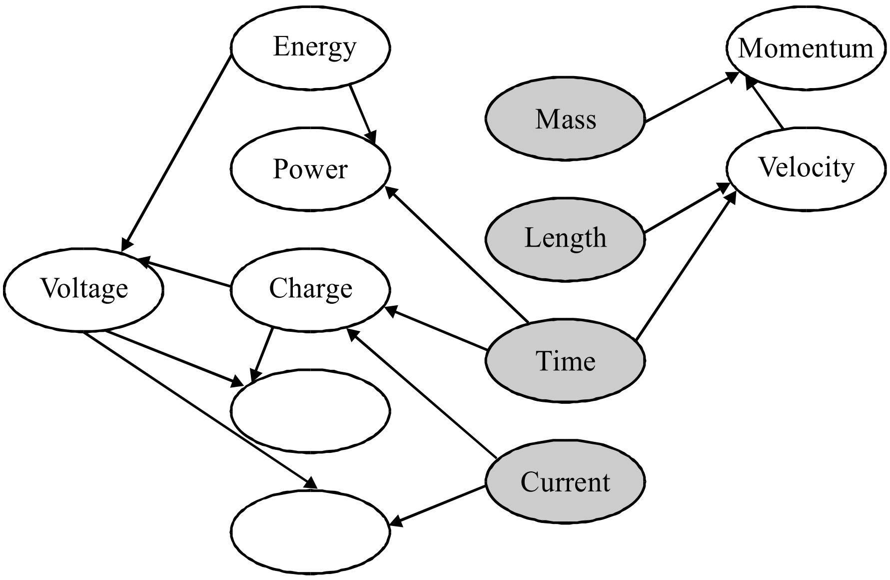
(2)

(Total 12 marks)

87. 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.

....

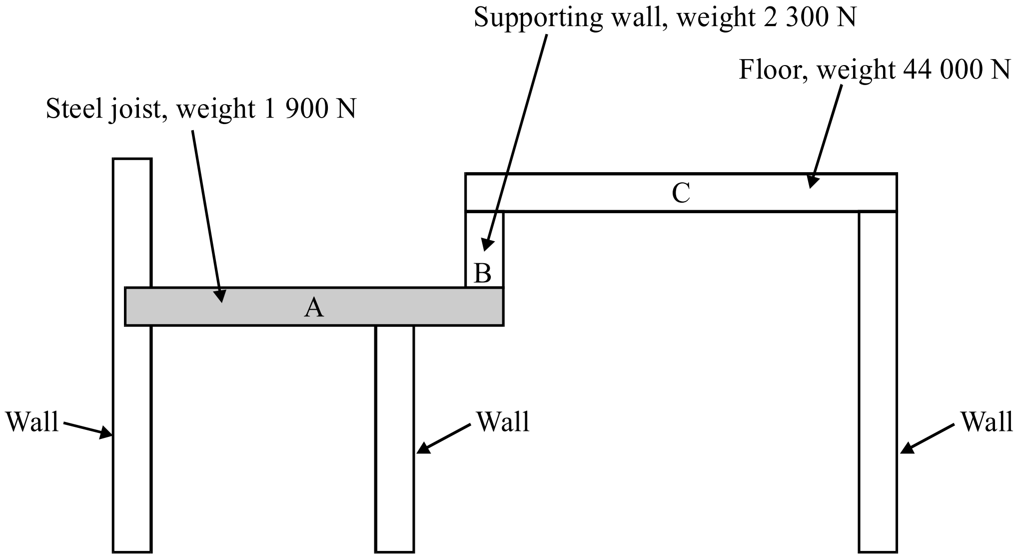
....

....

(2)

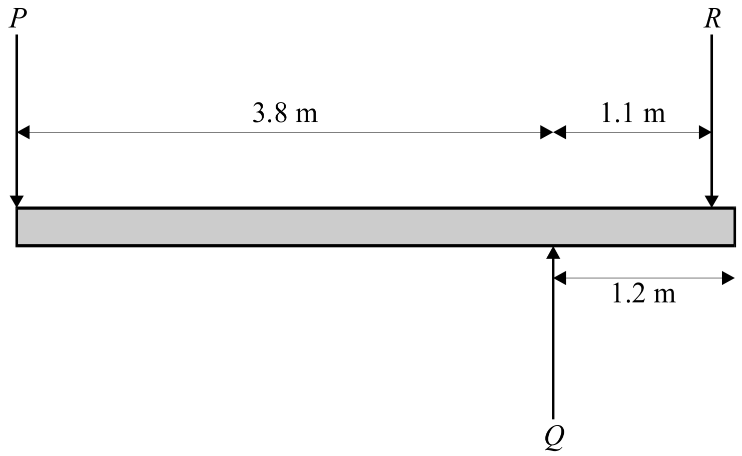
(Total 4 marks)

88. The diagram shows part of a steel and concrete building.



The steel joist A supports the supporting wall B and the left-hand side of floor C. Both the joist and floor C may be treated as uniform bars.

Below is an incomplete free-body force diagram for joist A.



Show that force R equals 24 300 *N*.

....

....

(1)

Add the remaining force acting on joist A to the diagram, indicating its magnitude and the position where it acts.

(2)

Calculate the forces P and Q.

....

....

....

....

....

Force P = ...

Force Q = ...

(3)
(Total 6 marks)

89. State the principle of conservation of linear momentum.

....

....

....

(2)

This principle is a consequence of two of Newton's laws of motion. Which two?

....

(1)

In one experiment to test the principle of conservation of momentum, a moving trolley collides with and sticks to an identical trolley which is initially at rest on a horizontal bench. Describe how you would check whether momentum was conserved.

....

....

....

....

....

....

(4)

A student performing this experiment found that the final momentum was always slightly smaller than the initial momentum. Assuming that the measuring technique was accurate, suggest a reason for this.

....

....

(1)

In a test laboratory, a car is crashed into a concrete wall and comes to rest. There is no damage to the wall. Explain how the principle of conservation of momentum applies to this situation.

....

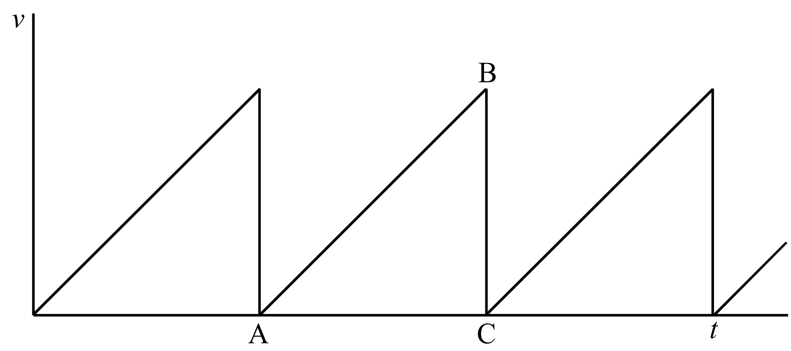
....

....

....

(2)
(Total 10 marks)

90. The diagram is a velocity-time graph for an electron.



Describe carefully the motion represented by lines AB and BC.

AB: ....

....

BC: ....

....

(2)

The graph is a much simplified model of how an electron moves along a wire carrying a current. Explain what causes the motion represented by AB and BC.

AB: ....

....

BC: ....

....

(2)

Explain the term *drift velocity* and indicate its value on the graph above.

....

....

(2)

With reference to the behaviour of the electron, explain why the wire gets warm.

....

....

(1)
(Total 7 marks)

91. 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.

....

....

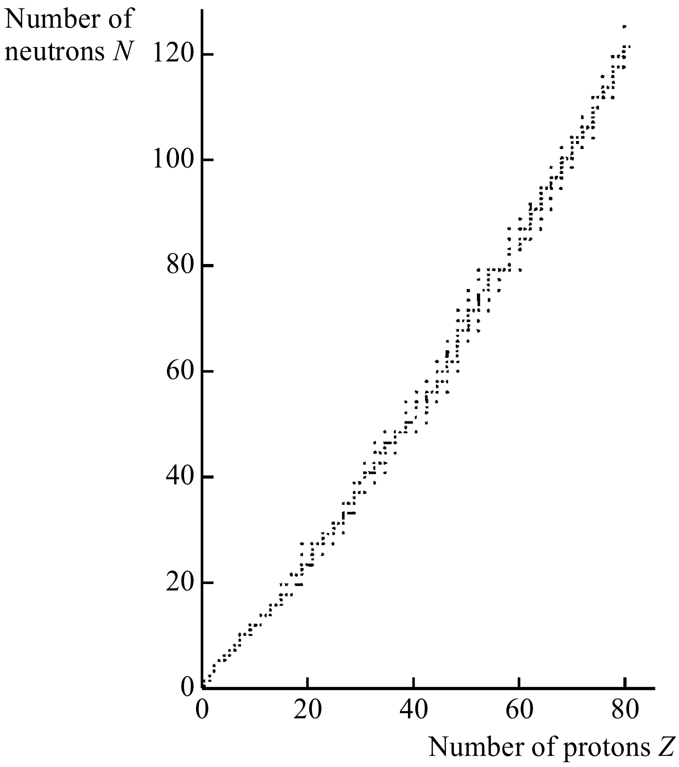
....

....

....

(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)

92. A car travelling at 30 m s^{-1} collides with a wall. The driver, wearing a seatbelt, is brought to rest in 0.070 s.

The driver has a mass of 50kg. Calculate the momentum of the driver before the crash.

....

....

....

Momentum = ...

(2)

Calculate the average resultant force exerted on the driver during impact.

....

....

....

Average resultant force = ...

(3)

Explain why the resultant force is not the same as the force exerted on the driver by the seatbelt.

....

....

(1)
(Total 6 marks)

93. Alpha particle radiation has a short range in matter. With reference to the effect of alpha particles on atoms, explain why they only travel a short distance.

....

....

....

(2)

A worker in the nuclear industry accidentally swallows some liquid that emits alpha particles.

The Plant Manager tells him not to worry as the swallowed liquid will be excreted within a day.

However, the health physicist investigating the accident is still anxious to determine the half-life of the radioisotope involved. Explain the significance of the radioactive half-life for the health of the worker.

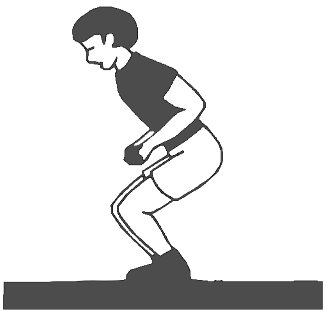
....

....

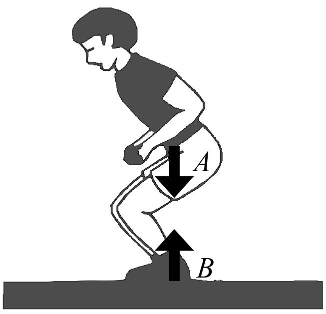
....

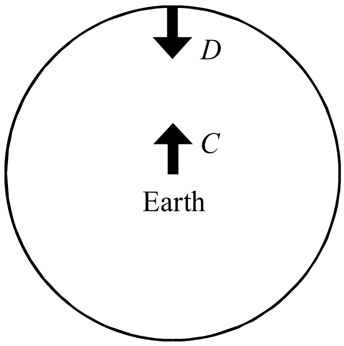
(2)
(Total 4 marks)

94. A child is crouching at rest on the ground



Below are free-body force diagrams for the child and the Earth.





Complete the following table describing the forces *A*, *B* and *C*.

Force	Description of force	Body which exerts force	Body the force acts on
A	Gravitational	Earth	Child
B			
C			

(4)

All the forces *A, B, C* and *D* are of equal magnitude.

Why are forces *A* and *B* equal in magnitude?

....

....

Why must forces *B* and *D* be equal in magnitude?

....

....

(2)

The child now jumps vertically upwards. With reference to the forces shown, explain what he must do to jump, and why he then moves upwards.

....

....

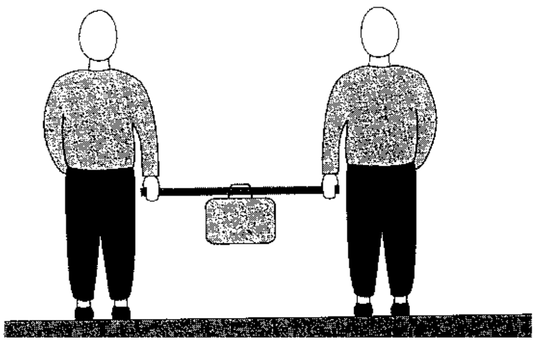
....

....

....

(3)
(Total 9 marks)

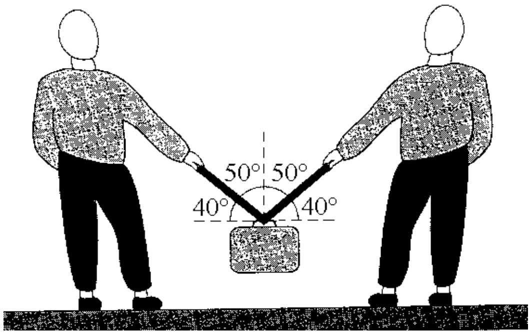
95. Two campers have to carry a heavy container of water between them. One way to make this easier is to pass a pole through the handle as shown.



The container weighs 400 N and the weight of the pole may be neglected. What force must each person apply?

(1)

An alternative method is for each person to hold a rope tied to the handle as shown below.



In the space below draw a free-body force diagram for the container when held by the ropes.

(2)

The weight of the container is 400 N and the two ropes are at 40° to the horizontal. Show that the force each rope applies to the container is about 300 N.

....

....

....

....

Force = ...

(3)

Suggest **two** reasons why the first method of carrying the container is easier.

....

....

....

....

(2)

Two campers using the rope method find that the container keeps bumping on the ground. A bystander suggests that they move further apart so that the ropes are more nearly horizontal. Explain why this would not be a sensible solution to the problem.

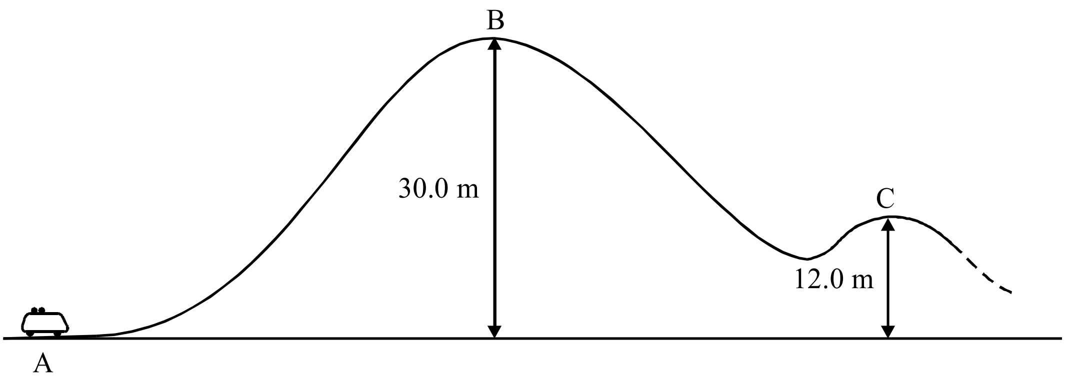
....

....

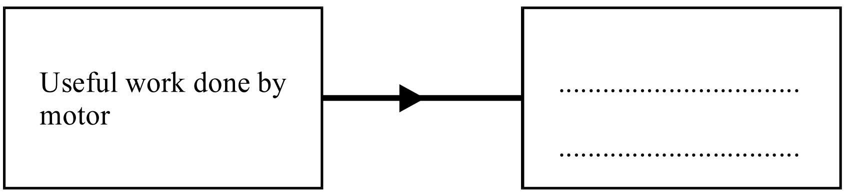
....

(1)
(Total 9 marks)

96. The diagram shows part of a roller coaster ride. **In practice, friction and air resistance will have a significant effect on the motion of the vehicle, but you should ignore them throughout this question**.



The vehicle starts from rest at A and is hauled up to B by a motor. It takes 15.0 S to reach B, at which point its speed is negligible. Complete the box in the diagram below, which expresses the conservation of energy for the journey from A to B.



(1)

The mass of the vehicle and the passengers is 3400 kg. Calculate

(i) the useful work done by the motor.

....

....

Work done = ...

(ii) the power output of the motor.

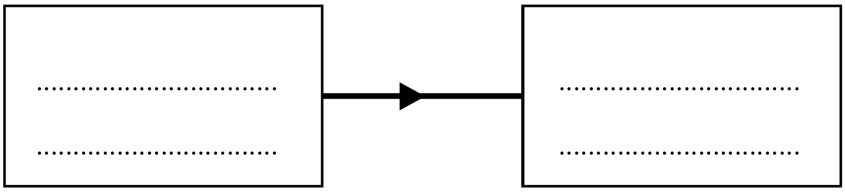
....

....

Power = ...

(4)

At point B the motor is switched off and the vehicle moves under gravity for the rest of the ride. Describe the overall energy conversion which occurs as it travels from B to C.



(1)

Calculate the speed of the vehicle at point C.

....

....

....

Speed = ...

(3)

On another occasion there are fewer passengers in the vehicle; hence its total mass is less than before. Its speed is again negligible at B. State with a reason how, if at all, you would expect the speed at C to differ from your previous answer.

....

....

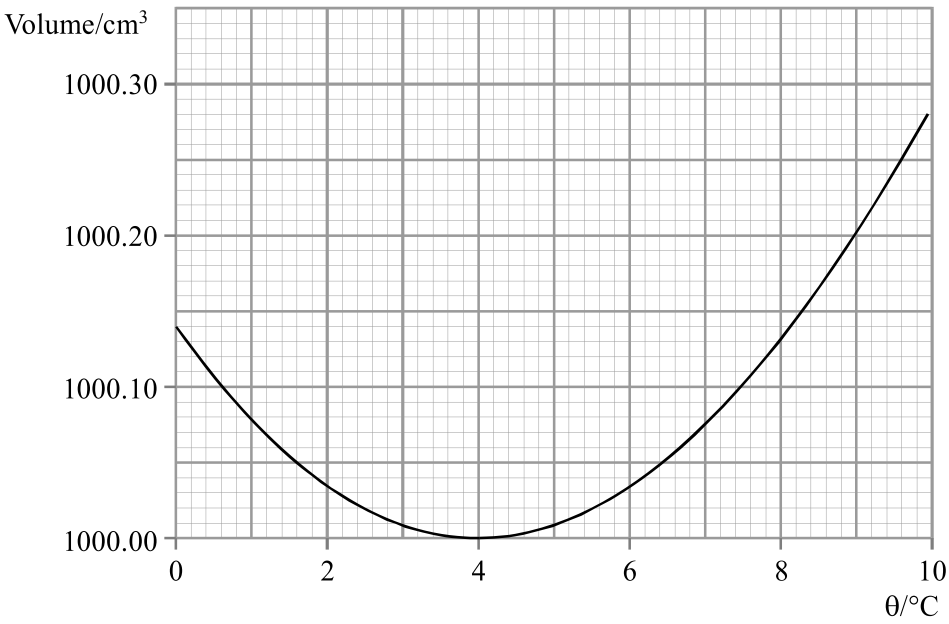
....

....

....

(2)
(Total 11 marks)

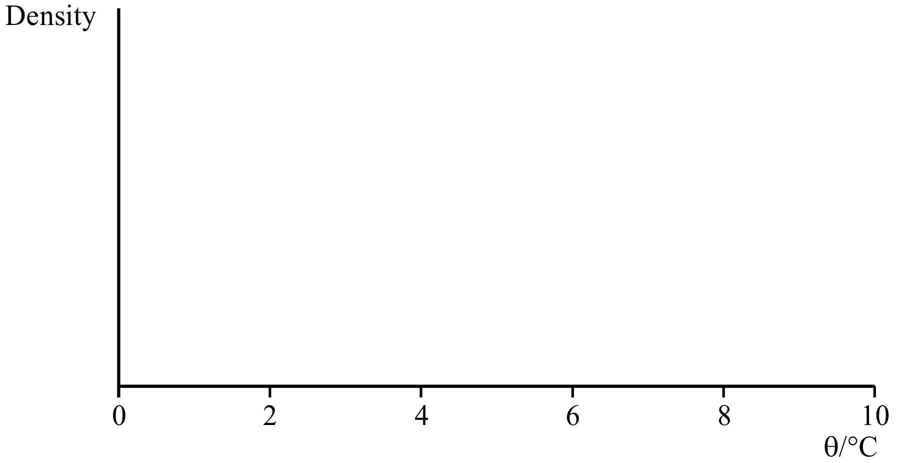
97. The graph shows how the volume of 1.000 kg of water varies with temperature.



State the temperature at which the density of water is a maximum.

....

Using the axes below, sketch a graph of how the density of water varies with temperature between 0 °C and 10 °C.



(3)

Suggest how you could demonstrate that the volume of water when heated from 0 °C to 10 °C behaves in the manner indicated by the graph. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

(4)
(Total 7 marks)

98. A student measured the background radiation in a laboratory at 4.0 Bq. State **two** sources of background radiation.

....

....

(2)

Sodium-22 decays by beta-plus radiation to neon.

Complete the nuclear equation ensuring that each symbol has the appropriate nucleon and proton number.

$$^{22}_{11}\text{Na} \rightarrow \quad \text{Ne} \quad + $$

Write down another possible isotope of sodium.

Na

(3)

Sodium-22 has a half-life of 2.6 years.

Determine the decay constant of sodium-22 in s^{-1}.

....

....

Decay constant = ...s^{-1}.

A sample of common salt (sodium chloride) is contaminated with sodium-22. The activity of a spoonful is found to be 2.5 Bq. How many nuclei of sodium-22 does the spoonful contain?

....

....

Number of nuclei = ...

(4)

Explain whether your answer suggests that the salt is **heavily** contaminated.

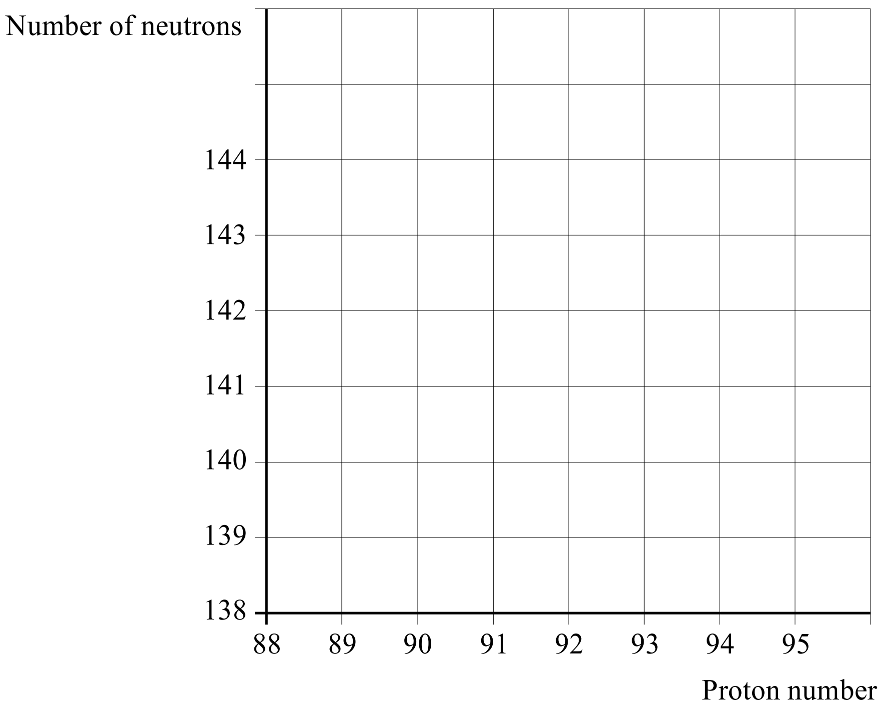
....

....

....

(1)
(Total 10 marks)

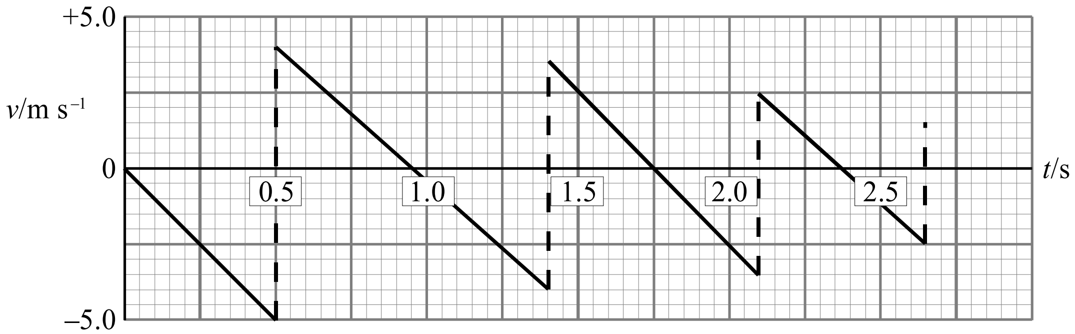
99. Protactinium, Pa, decays to uranium $^{234}_{92}U$ by emitting a beta-minus particle. The uranium produced is itself radioactive and decays by alpha emission to thorium, Th.



Mark and label the position of $^{234}_{92}U$. Draw lines on the grid showing both the beta-minus and the alpha decays. Label your lines α and β.

(Total 4 marks)

100. The diagram shows a velocity-time graph for a ball bouncing vertically on a hard surface. The ball was dropped at $t = 0$ s.



At what time does the graph show the ball in contact with the ground for the third time?

....

(1)

The downward sloping lines on the graph are straight and parallel with each other. Why?

....

....

....

(2)

Show that the height from which the ball was dropped is about 1.2 m.

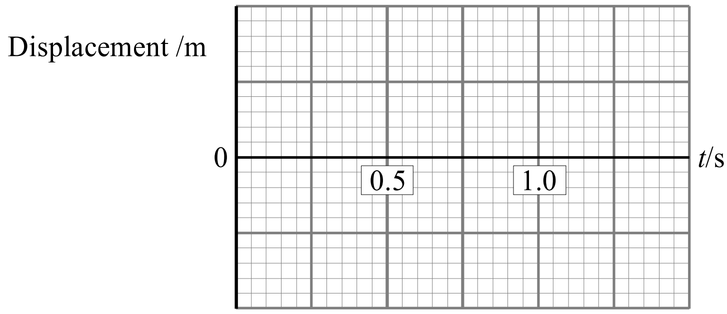
....

....

....

(2)

Sketch a displacement-time curve on the axes below for the first second of the motion.



(3)

What is the displacement of the ball when it finally comes to rest?

....

(1)
(Total 9 marks)

101. An athlete of mass 55.0 kg runs up a flight of stairs of vertical height 3.60 m in 1.80 s.

Calculate the gain in gravitational potential energy of the athlete in doing this.

....

....

....

Gain in g.p.e. =………………………………………………..

Calculate the power that this athlete develops in doing this.

....

....

Power =……………………………………………………

(4)

One way of comparing athletes of different sizes is to compare their power-to-weight ratios. Find a unit for the power-to-weight ratio in terms of SI base units.

....

....

....

....

(2)

Calculate the athlete's power-to-weight ratio.

....

....

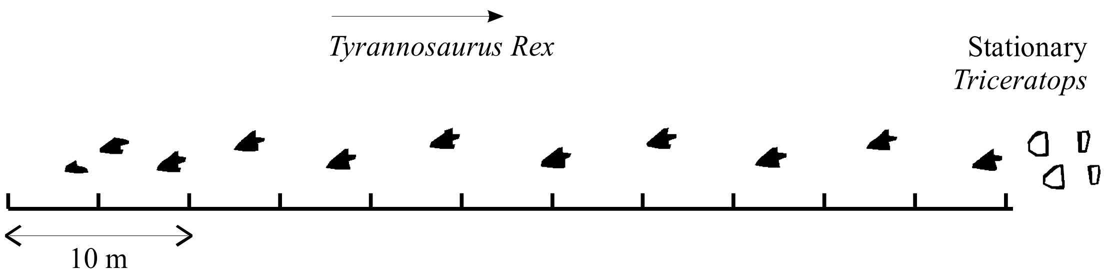
Power-to-weight ratio =……………………………………………………

(2)
(Total 8 marks)

102.

Palaeontologists are able to deduce much about the behaviour of dinosaurs from the study of fossilised footprints.

The tracks below show the path of a *Tyrannosaurus Rex* as it attacks a stationary *Triceratops*.



The time between footprints is 0.62 s. Show that the maximum speed of the *Tyrannosaurus Rex* is about 10 m s^{-1}.

....

....

....

(2)

Tyrannosaurus Rex is believed to have attacked its prey by charging and locking its jaws on the prey. *Tyrannosaurus Rex* would be at its maximum speed when it hit the stationary prey.

This *Tyrannosaurus Rex* has a mass of 7000 kg. Calculate its momentum just before it hits the *Triceratops*.

....

....

Momentum =...

(2)

Triceratops has a mass of 5000 kg. Calculate their combined speed immediately after the collision.

....

....

....

....

Combined speed =...

(3)

The skull of *Tyrannosaurus Rex* is heavily reinforced to withstand the force produced in such a collision.

Calculate the force exerted on the *Tyrannosaurus Rex* if the time taken to reach their combined speed after the collision is 0.30 s.

....

....

....

Force =...

(3)

(Total 10 marks)

103. State in words how to calculate the work done by a varying force.

....

....

....

(2)

Under what circumstances is the work done by a force negative?

....

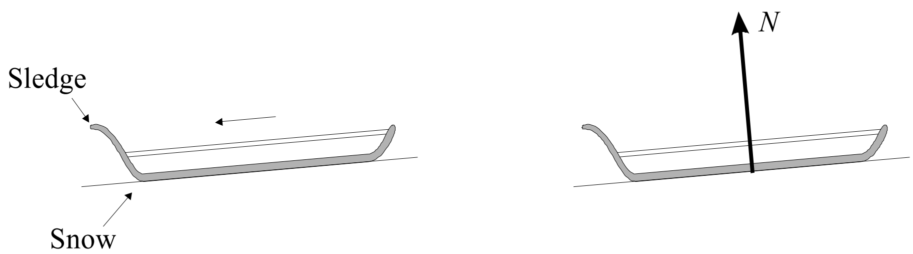
What happens to the kinetic energy of the body on which the force acts in such circumstances?

....

....

(2)

A runaway sledge slides down a slope at a constant speed. One force is shown on the free-body diagram of the sledge. It is the normal contact push of the snow on the sledge.



Add to the free-body diagram to show the other two forces acting on the sledge. Name each force and state what is producing it.

....

....

(3)

The sledge slides 15 m down the slope at a constant speed. The force N = 40 N.

What is the resultant force acting on the sledge?

....

What is the work done by the force N?

....

(2)
(Total 9 marks)

104. State the principle of moments.

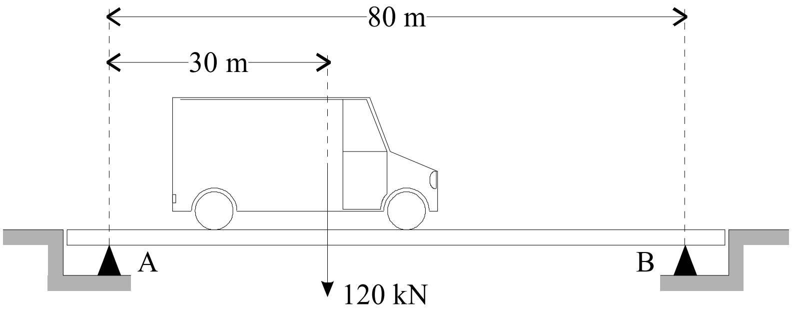
....

....

....

(2)

The diagram shows a lorry of weight 120 kN on a bridge.



Calculate the additional upward force at each of the bridge supports caused by the lorry.

....

....

Upward force at A =…………………………………………………

....

....

Upward force at B =…………………………………………………

(4)
(Total 6 marks)

105. Name *two* sources of natural background radiation.

1 ……………………………………………………………………………………....

2 ....…………………………………………………………………………………....

(2)

Caesium-137 is a by-product of nuclear fission within a nuclear reactor. The nuclear equation below describes the production of $^{137}_{55}Cs$. Complete the two boxes.

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{137}_{55}Cs + \boxed{^{95}Rb} + \boxed{_{0}^{1}n}$$

(2)

The half-life of caesium-137 is 30 years. When the fuel rods are removed from a nuclear reactor core, the total activity of the caesium-137 is 6.4×10^{15} Bq.

Explain the phrase *the activity of caesium-137 is* 6.4×10^{15} *Bq*.

....

....

....

....

(2)

After how many half-lives will this activity have fallen to 2.5×10^{13} Bq? Explain your working.

....

....

....

Number of half-lives = ……………………………………………………

(2)

Comment on the problems of storage of the fuel rods over this time period and beyond.

....

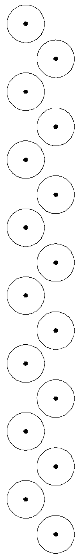
....

....

....

(2)
(Total 10 marks)

106. In 1909 Geiger and Marsden carried out an important experiment to investigate alpha particle scattering. Alpha particles were directed towards a thin gold sheet and detectors were used to observe the distribution of scattered alpha particles.



The black dots in the diagram represent the nuclei of gold atoms. Add to the diagram to illustrate what happened in this experiment.

(3)

Explain why this experiment led to the conclusion that an atom was composed mainly of space, with a very small positive nucleus.

....

....

....

....

....

....

(3)

Here are some order of magnitude values for lengths:

10^{-21} m, 10^{-18} m, 10^{-15} m, 10^{-12} m, 10^{-9} m, 10^{-6} m, 10^{-3} m.

Choose from these an approximate value for

(i) the diameter of a gold atom ....

(ii) the diameter of a gold nucleus ....

(2)

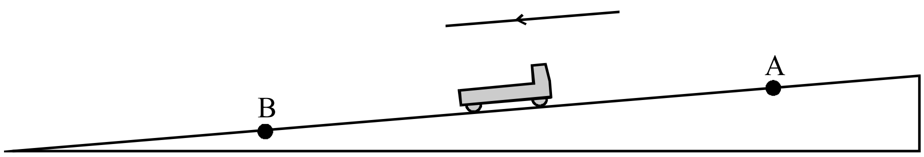
(Total 8 marks)

107. Complete the following equations by writing the correct physical quantities, in words, on the dotted lines.

volume = $\dfrac{\text{mass}}{\text{...}}$
average velocity = $\dfrac{\text{...}}{\text{time}}$
$\dfrac{\text{weight}}{\text{mass}}$ = ...
decay constant = $\dfrac{\text{activity}}{\text{...}}$

(Total 4 marks)

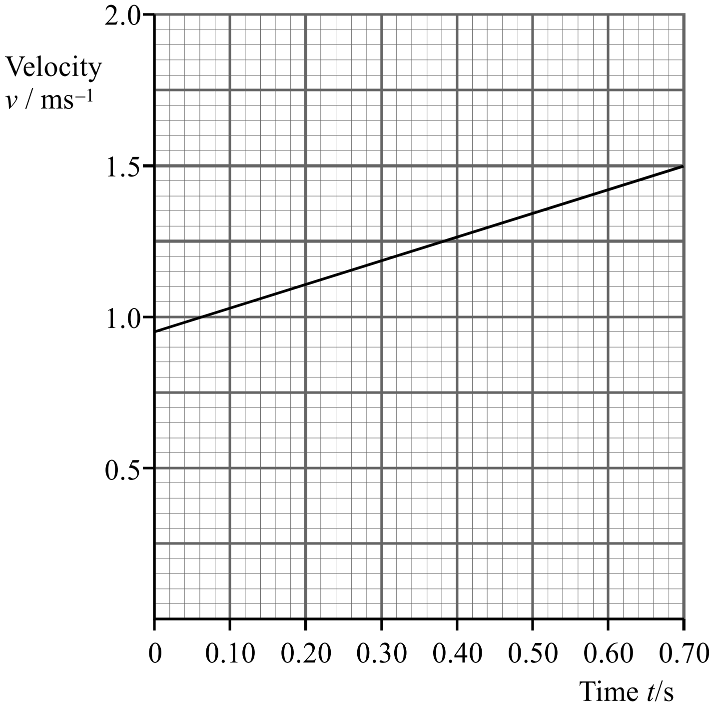
108. The diagram below shows a trolley running down a slope.



Complete the diagram to show an experimental arrangement you could use to determine how the trolley's position varies with time.

(2)

The data is used to produce a velocity-time graph for the trolley. Below is the graph for the motion from point A to point B. Time is taken to be zero as the trolley passes A, and the trolley passes B 0.70 s later.



The motion shown on the graph can be described by the equation $v = u + at$. Use information from the graph to determine values for u and a.

u = ...

....

a = ...

....

(3)

Determine the distance AB.

....

....

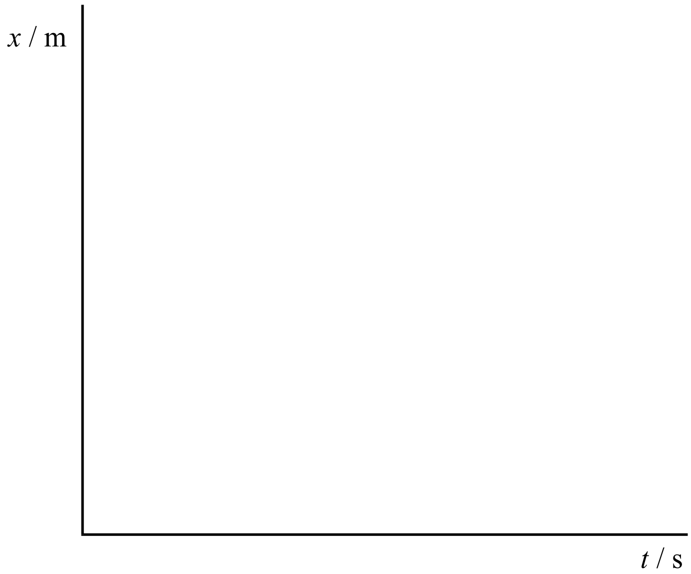
....

....

AB = ...

(3)

On the axes below sketch a graph to show how the displacement x of the trolley from point A varies with time t. Add a scale to each axis.



(3)
(Total 11 marks)

109. When the jet engines on an aircraft are started, fuel is burned and the exhaust gases emerge from the back of the engines at high speed. With reference to Newton's second and third laws of motion, explain why the aircraft accelerates forward. You may be awarded a mark for the clarity of your answer.

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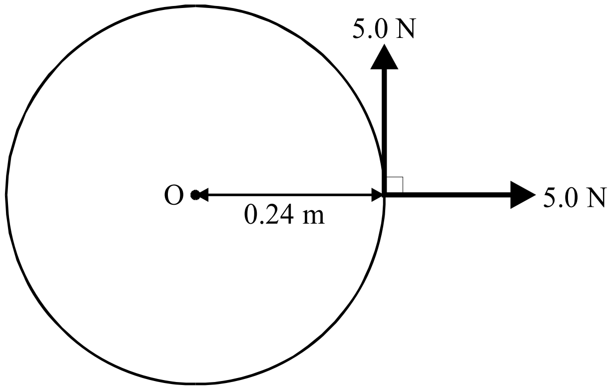
(Total 4 marks)

110. A disk has a radius of 0.24 m. Two 5.0 N forces act on the disk as shown.



What is the resultant moment about O?

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....

Find the magnitude and direction of the resultant force on the disk.

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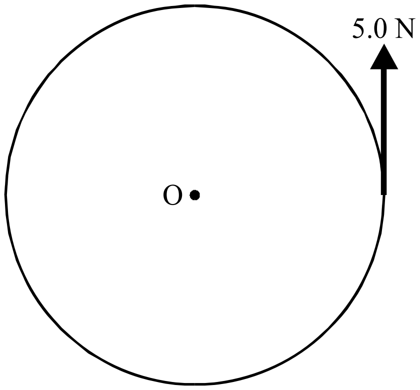
....

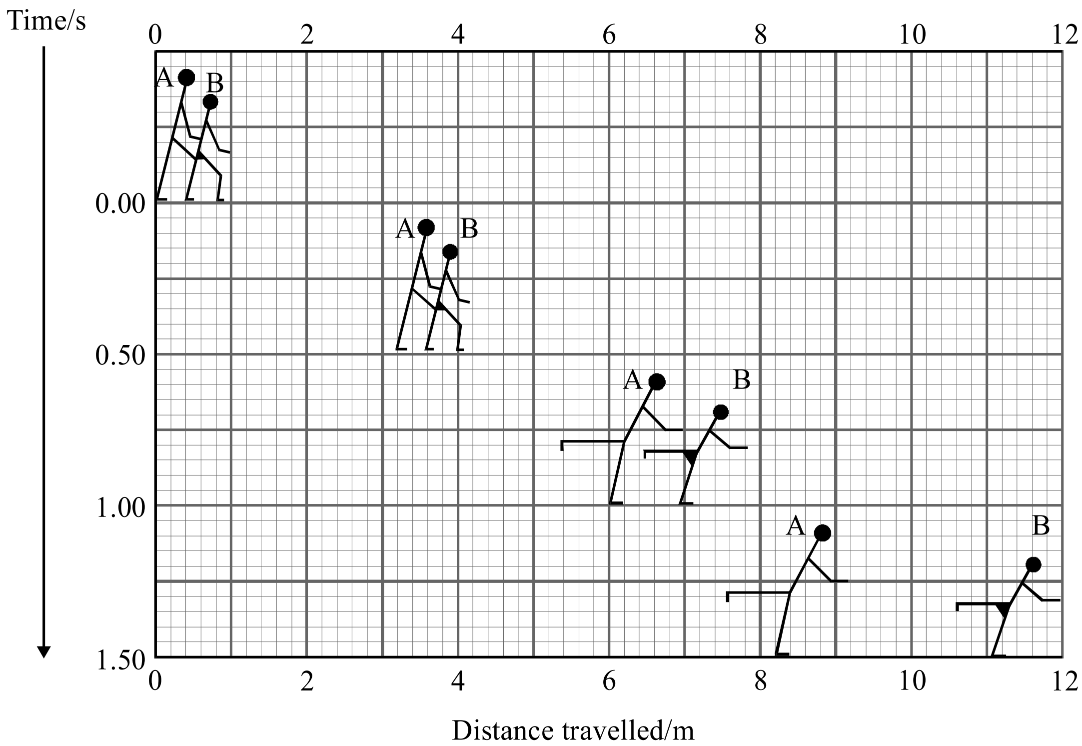
(6)

The two 5.0 N forces are now positioned in such a way that the resultant force on the disk becomes zero whilst the resultant moment about O remains the same as before. The diagram below shows one of the forces. Add an arrow to show the new position and direction of the other force.



(2)
(Total 8 marks)

111. The diagram shows the positions of two ice skaters at intervals of 0.60 s.



Up to 0.50 s, skater A and his partner B are gliding together across the ice. Between 0.50 s and 1.00 s, A pushes B away from him in the direction of travel. After 1.00 s, they continue to glide separately across the ice.

Determine the speed of the skaters before they separate.

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....

....

Initial speed =..

(2)

The masses of the skaters A and B are 75 kg and 55 kg respectively. Use these figures, together with information from the diagram, to show that momentum is approximately conserved when they separate.

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(5)

Why should momentum be approximately conserved in this situation?

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(1)

Without further calculation, explain whether you would expect the total kinetic energy of the skaters to increase, decrease or remain the same when they separate.

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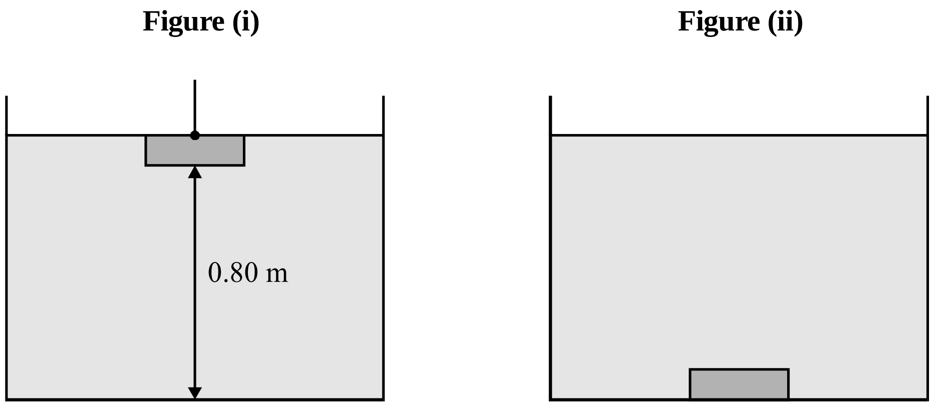
(2)
(Total 10 marks)

112. A granite block is suspended at rest just below the surface of water in a tank (Figure i). The block is now released and falls 0.80 m to the bottom (Figure ii).



The volume of the block is 3.0×10^{-3} m^3, and the density of granite is 2700 kg m^{-3}. Calculate the gravitational potential energy lost by the block as it falls.

....

....

....

g.p.e. = ...

(3)

Although the water level has not changed, the water has gained gravitational potential energy. Explain why.

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(1)

The gravitational potential energy gained by the water is less than that lost by the granite block. Explain this.

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(2)
(Total 6 marks)

113. Samples of two different isotopes of iron have been prepared. Compare the compositions of their nuclei.

....

....

The samples have the same chemical properties. Suggest a physical property which would differ between them.

....

(3)

Tritium (hydrogen-3) is an emitter of beta particles. Complete the nuclear equation for this decay.

$$\mathrm{H} \rightarrow \quad \mathrm{He} \quad + \quad \beta$$

(3)

Describe how you would verify experimentally that tritium emits only beta particles.

....

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(4)
(Total 10 marks)

114. A radioactive source contains barium-140. The initial activity of the source is 6.4×10^8 Bq. Its decay constant is 0.053 day^{-1}.

Calculate the half-life in days of barium-140.

....

....

....

Half-life = ... days

Calculate the initial number of barium-140 nuclei present in the source.

....

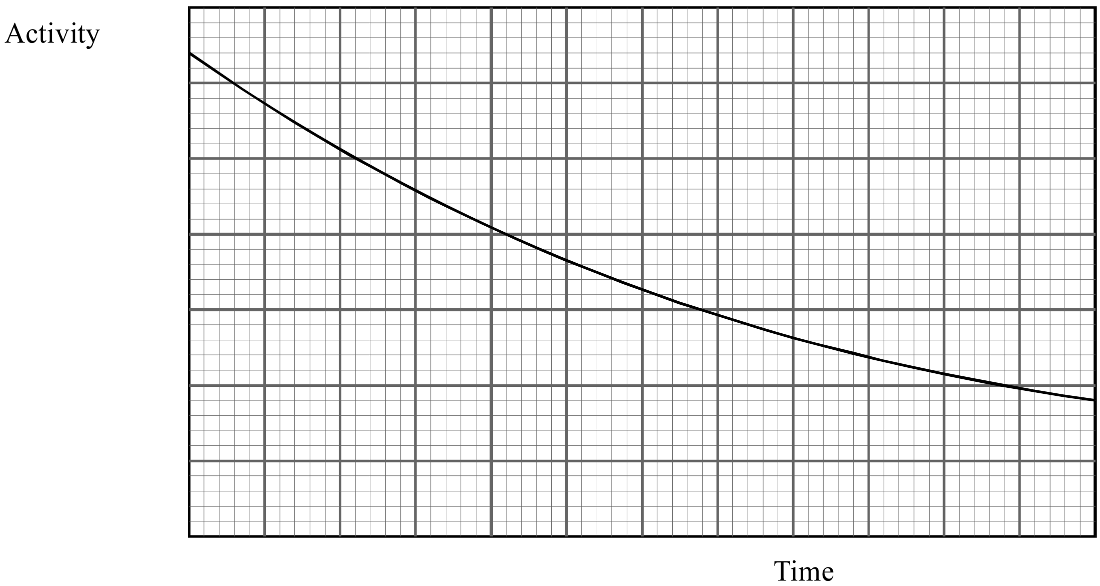
....

....

Number of nuclei = ...

(4)

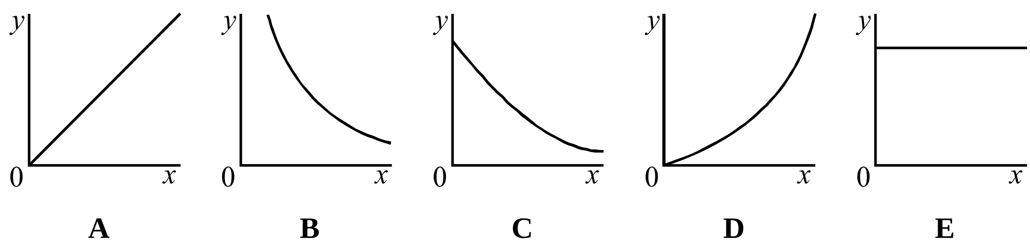
The graph below represents radioactive decay. Add a suitable scale to each axis, so that the graph correctly represents the decay of this barium source.



A radium-226 source has the same initial activity as the barium-140 source. Its half-life is 1600 years. On the same axes sketch a graph to show how the activity of the radium source would vary over the same period.

(3)
(Total 7 marks)

115. Five graphs, A – E, are shown below.



Write the appropriate letter in the table below to indicate which graph is obtained when the quantities described below are plotted on the *y* and *x* axes.

Variable on *y* axis	**Variable on x axis**	**Graph**
Activity of a radioactive source	Time	
Increase in gravitational potential energy of a body	Vertical height body is raised	
Acceleration produced by a constant force	Mass of body being accelerated	
Half-life of a radioactive source	Number of nuclei present in the source	

(Total 4 marks)

116. State the composition of an alpha particle.

....

(1)

When an alpha particle passes through matter, it may ionise atoms. Explain what **ionise** means.

....

....

(1)

An alpha particle from a certain radioactive source has a kinetic energy of 8.2×10^{-13} J. Using the information below, estimate how long it would take this alpha particle to travel a distance equal to the diameter of an atom.

Mass of alpha particle $= 6.6 \times 10^{-27}$ kg
Diameter of atom $= 1.0 \times 10^{-10}$ m

....

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Time = ...

(3)

A beta particle from a different radioactive source has the same kinetic energy as the alpha particle. Explain qualitatively how the speed of this beta particle would compare with the speed of the alpha particle.

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(2)

Beta particles are many times less effective at ionising atoms than alpha particles.
Suggest a reason for this.

....

....

(1)
(Total 8 marks)

117. The **work done by a force,** and the **moment of a force about a point,** are both defined as the product of the force and a distance. Explain the essential difference between the two definitions.

....

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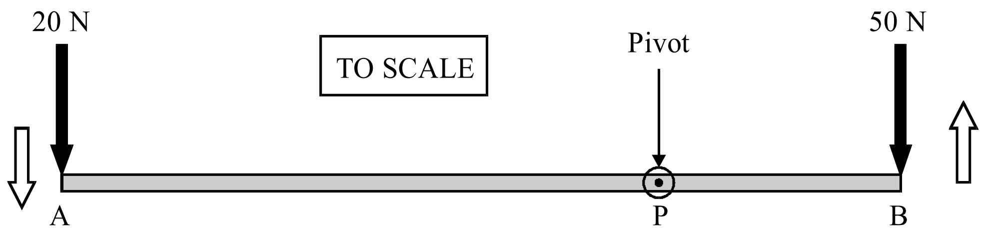
(2)

The diagram below shows, full size, a rigid lever AB pivote**d at P**. **The weight of the lever can be neglected**. **A 20 N force applied at A is balancing a 50 N** load applied at B.



By means of suitable measurements on the diagram, show that the principle of moments is obeyed.

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(2)

End A of the lever moves vertically down 6.0×10^{-3} m. Using the principle of conservation of energy, or otherwise, calculate the distance the load at B is raised.

....

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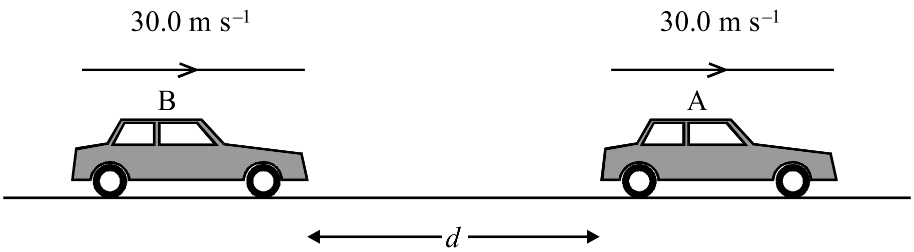
Distance = ...

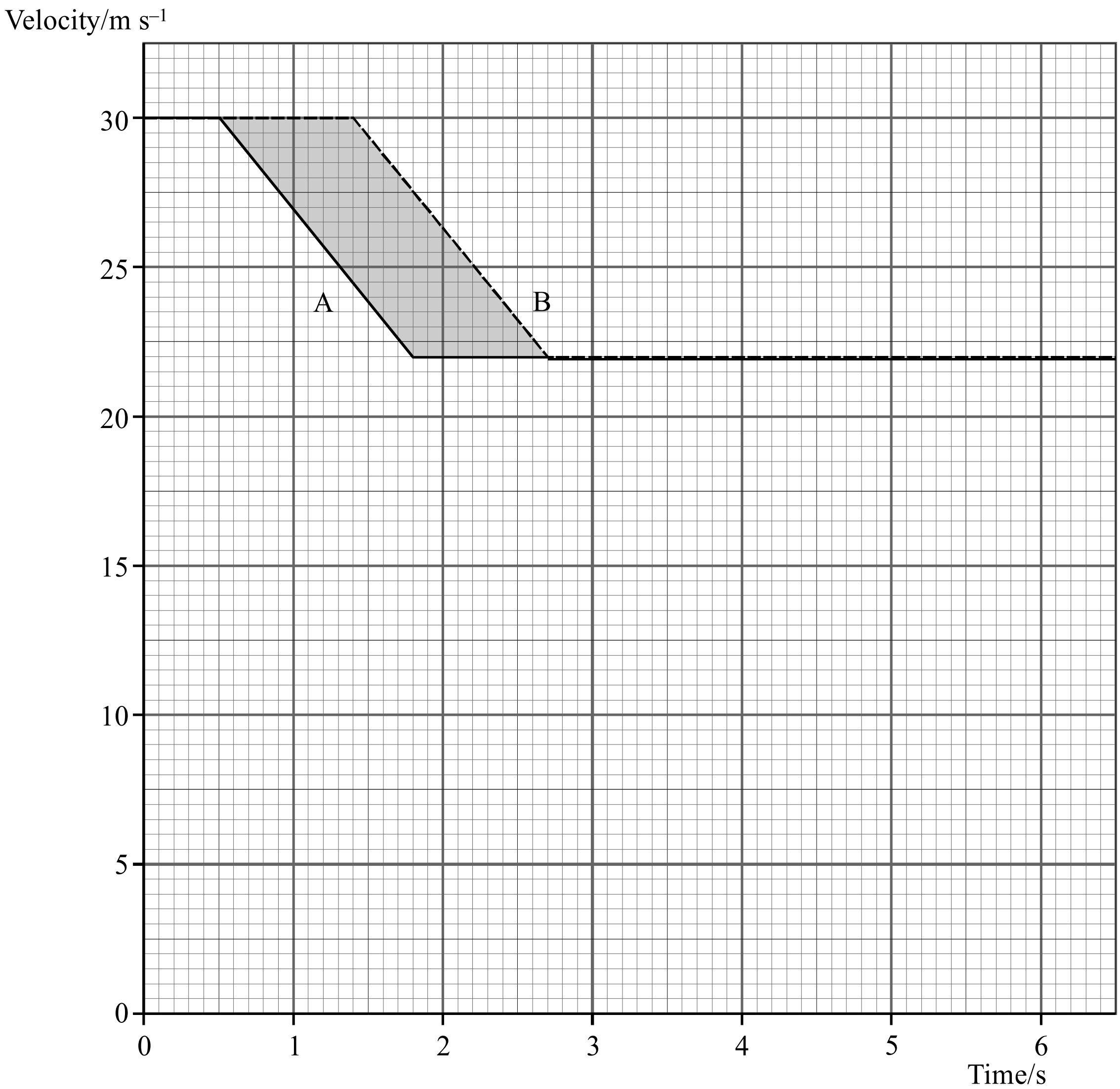
(3)
(Total 7 marks)

118. Two cars, A and B, are travelling along the outside lane of a motorway at a speed of 30.0 m s^{-1}. They are a distance d apart.



The driver of car A sees a slower vehicle move out in front of him, and brakes hard until his speed has fallen to 22.0 m s^{-1}. The driver of car B sees car A brake and, after a reaction time of 0.900 s, brakes with the same constant deceleration as A.

The diagram below shows velocity-time graphs for car A (solid line) and car B (broken line).



Find the deceleration of the cars whilst they are braking.

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....

Deceleration = ...

(3)

What does the area under a velocity-time graph represent?

....

(1)

Determine the shaded area.

....

....

....

Area = ...

(2)

State the minimum value of the initial separation *d* if the cars are not to collide.
Explain how you arrived at your answer.

....

....

....

(2)

Suppose that, instead of only slowing down to 22.0 m s^{-1}, the cars had to stop. Add lines to the grid above to show the velocity–time graphs in this case. (Assume that the cars come to rest with the same constant deceleration as before.)

(1)

Explain why a collision is now more likely.

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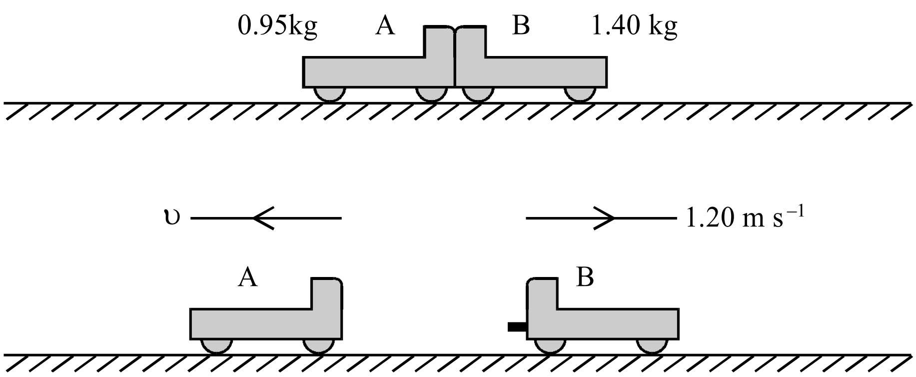
(2)
(Total 11 marks)

119. The diagram shows an experiment with two trolleys.



Initially the trolleys are at rest, in contact, on a horizontal bench. A spring-loaded piston is then released in one trolley, pushing the trolleys apart.

Describe an experimental technique by which you could determine accurately the speeds of the trolleys after they separate.

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(3)

State the total momentum of the trolleys as they move apart, and explain your answer.

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(2)

The masses of A and B are 0.95 kg and 1.40 kg respectively. B moves off at 1.20 m s^{-1}.
Calculate the speed υ of A.

....

....

....

....

Speed ....

(3)
(Total 8 marks)

120. A door which cannot be opened by pushing steadily on it can often be kicked open. By considering what happens to the foot as it hits the door, explain why the kick is more effective. You should refer to Newton's second and third laws of motion in your answer. You may be awarded a mark for the clarity of your answer.

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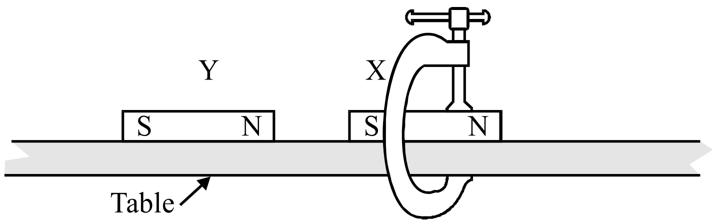
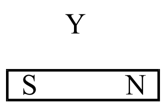
(Total 4 marks)

121. A magnet X is clamped to a frictionless table. A second magnet Y is brought close to X and then released.



Add labelled forces to the free-body diagram below for magnet Y to show the forces acting on it just after it is released.



(3)

According to Newton's third law, each of the forces in your diagram is paired with another force. Write down one of these other forces, stating its direction and the body it acts upon.

....

....

....

(2)
(Total 5 marks)

122. A school physics department has a cobalt-60 gamma ray source. Its half-life is several years. As a project, a student decides to try to measure this half-life. She sets up a GM tube close to the source and determines the count produced by the source in a 10 minute period. One year later she repeats the measurement.

Explain **two** precautions, other than safety precautions, which the student should take in her measurements in order to produce a reliable value for the half-life.

....

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....

(3)

The student then calculates the count she would expect to get in a 10 minute period if she repeated her measurement annually. Some of her results are shown in the table below.

Time/year	**Count in 10 minute period**
0	17 602
1	15 489
2	13 630
3	
4	10 554
5	9287
6	8172
7	7191

Calculate the ratio of the count after one year to the initial count.

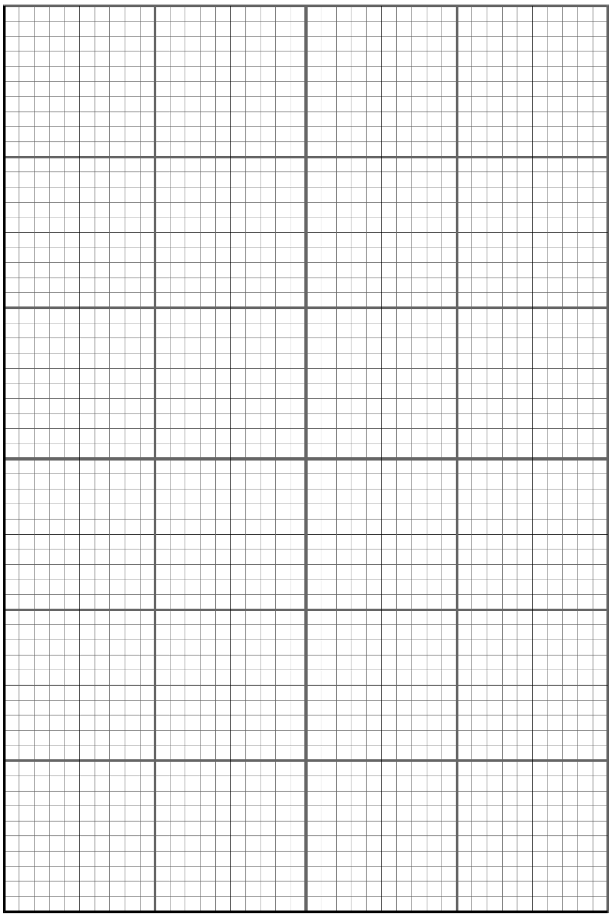
Ratio = ...

(1)

Complete the table to show the count you would expect for year 3.

(1)

On the axes below, plot a graph of count against time.



Use your graph to determine a value for the half-life of cobalt-60.

....

Half-life = ...

(4)
(Total 9 marks)

123. Below are the symbols for some nuclei of the element tin.

$^{111}_{50}\text{Sn}$ $^{112}_{50}\text{Sn}$ $^{113}_{50}\text{Sn}$ $^{114}_{50}\text{Sn}$ $^{115}_{50}\text{Sn}$

What name is given to different nuclei of this type?

....

(1)

$^{111}_{50}\text{Sn}$ decays by beta-plus emission into indium (In). Write a balanced nuclear equation for this decay.

....

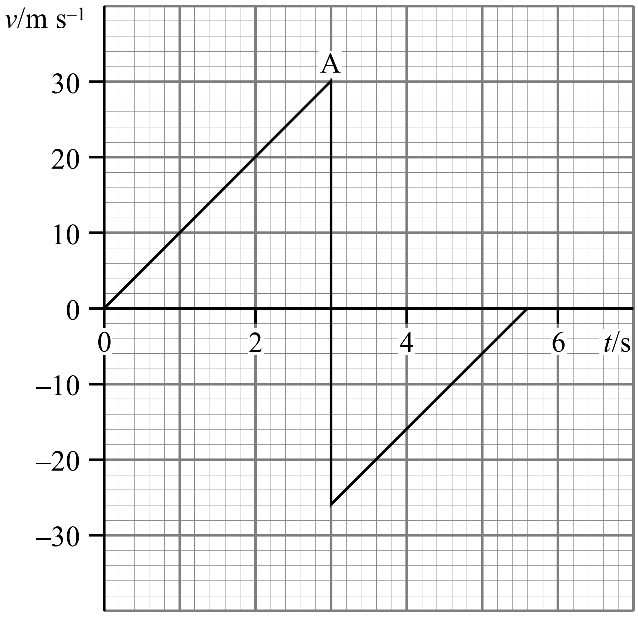
(2)

Which nucleus in the list is likely to produce the densest material?

....

(1)
(Total 4 marks)

124. A ball is dropped from a high window onto a concrete floor. The velocity–time graph for part of its motion is shown.



Calculate the gradient from the origin to A.

....

....

Gradient = ...

Comment on the significance of your answer.

....

(3)

What happened to the ball at point A?

....

(1)

Calculate the height of the window above the ground.

....

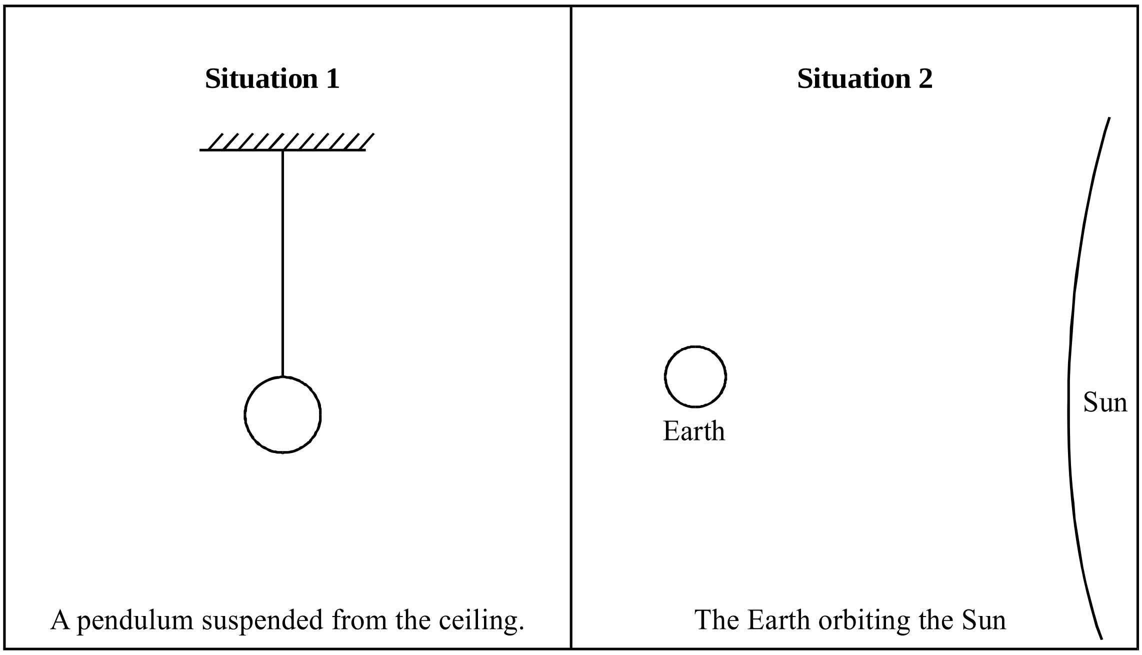
....

....

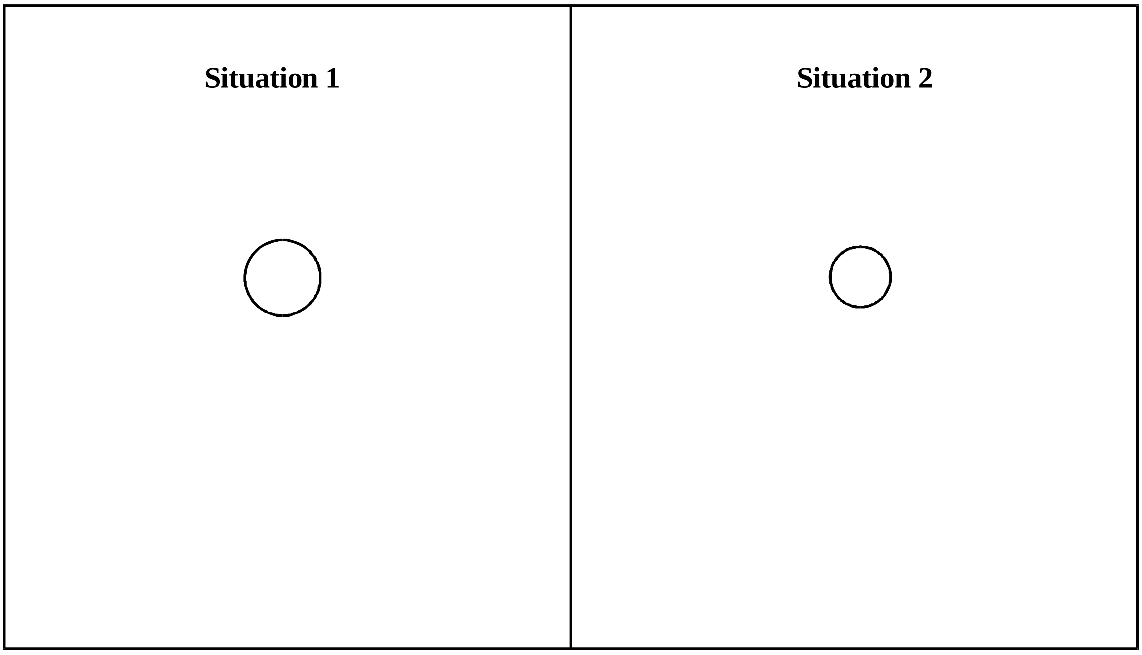
Height = ...

(3)
(Total 7 marks)

125. The diagrams show two situations in which forces act.



Complete labelled free-body force diagrams for the pendulum bob in situation 1 and for the Earth in situation 2.



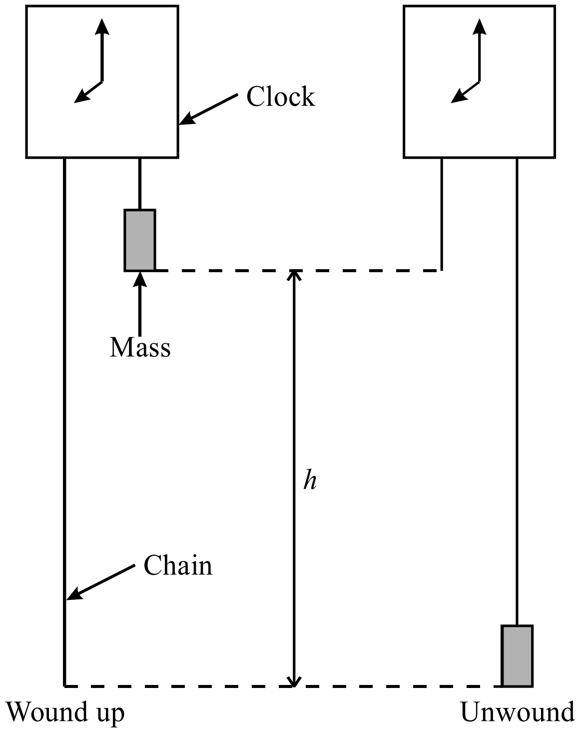
(3)

In the table below, write in the left-hand column each of the forces you have shown. Then complete the right-hand column.

Force	Newton’s third law pair, noting its direction and the body on which it acts

(3)
(Total 6 marks)

126. A “grandfather” clock is a type of clock where the energy needed to provide the movement of the hands comes from a falling mass.



To wind up the clock, the mass has to be raised a distance *h*.

In one such clock, the mass is a steel cylinder of diameter 0.060 m and height 0.17 m. Show that its mass is approximately 4 kg.
(The density of steel is 7.8×10^3 kg m^{-3}.)

....

....

....

(3)

The distance fallen by the mass is 1.1 m. Calculate the change in its gravitational potential energy.

....

....

Change in G. P. E. = ...

(2)

The clock has to be wound up once per week. Calculate the average power output of the falling mass.

....

....

Power = ...

(3)
(Total 8 marks)

127. In the context of the lever, Archimedes is recorded as saying

"Give me a long enough lever and I will move the Earth."

Explain in terms of the principle of moments the point Archimedes was making.

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(2)

Comment on how practical Archimedes' suggestion really is.

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(2)
(Total 4 marks)

128. (a) State Newton's second law of motion.

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(2)

Describe how you could demonstrate experimentally that the acceleration of a trolley is proportional to the resultant force which acts on it.

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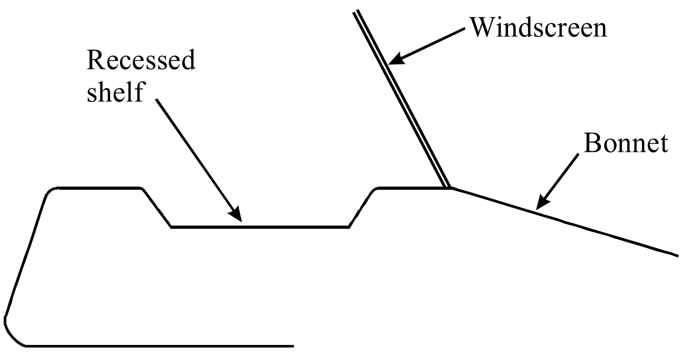
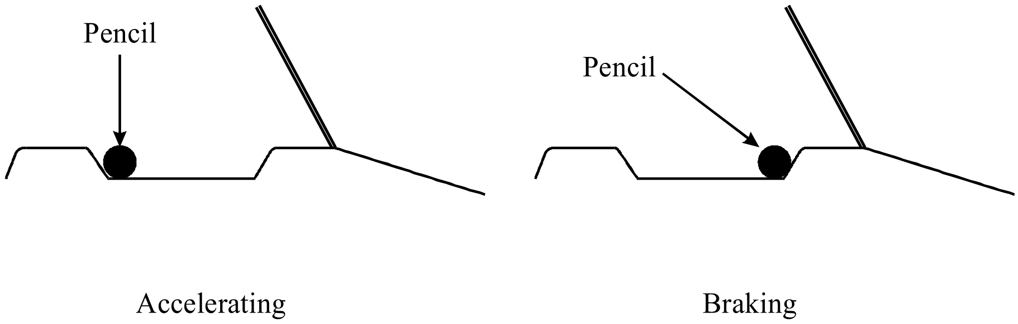
(5)

(b) Behind the windscreen of some cars there is a shelf, which is horizontal, but recessed to stop objects from falling off.



A pencil has been left on the shelf. Whenever the car accelerates forwards, the pencil is against the rear edge of the shelf. Whenever the car is braking the pencil is against the front edge.



Explain these observations. You may be awarded a mark for the clarity of your answer.

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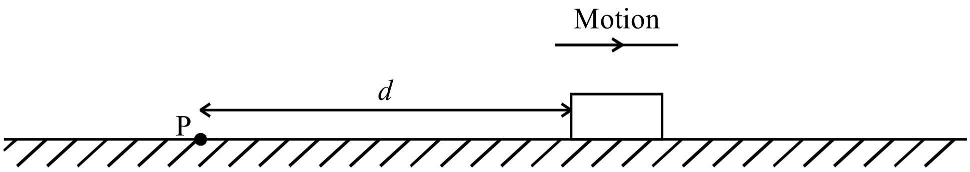
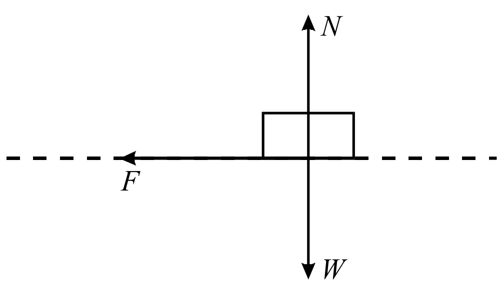
(5)
(Total 12 marks)

129. A block is projected from a point P across a rough, horizontal surface.



The block slows down under the influence of a constant frictional force F and eventually comes to rest. Below is a free-body force diagram for the block whilst it is moving.



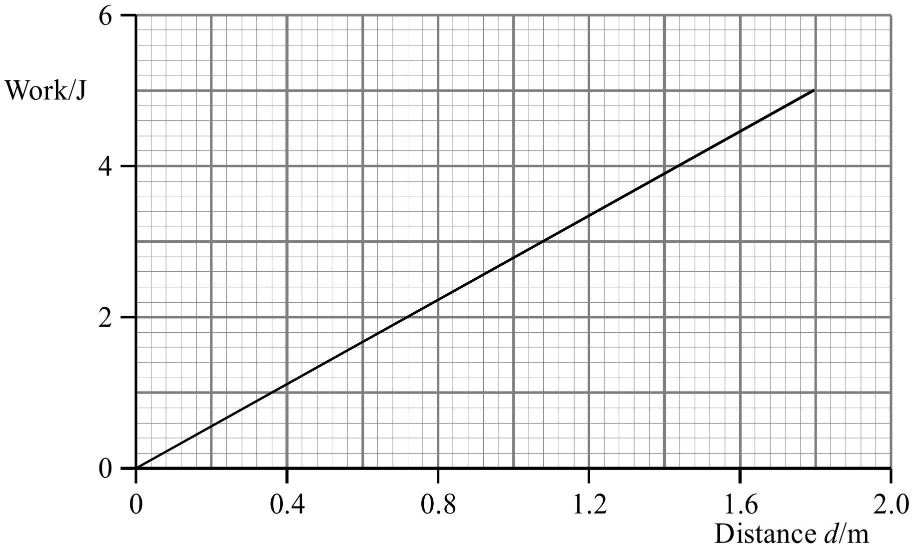
State, with a reason, the amount of work done by each of the forces *W* and *N* as the block moves across the surface.

....

....

(2)

The sliding block does work against friction. The graph shows how the total work done varies with the distance *d* which the block has travelled from the projection point P.



Use the graph to determine the force *F*.

....

....

....

F = ...

(2)

The block comes to rest 1.80 m from P. Add a line to the graph above to show how the kinetic energy of the block varied during the motion.

(2)

The mass of the block was 0.820 kg. Calculate the speed with which it was projected from P.

....

....

....

Speed = ...

(2)

Suppose that, instead of a constant friction force, the block had been brought to rest by a drag force (air resistance) which depends on speed. On the axes below sketch a graph to show qualitatively how you would expect the total work done against air resistance to vary with the distance *d*.

(1)

Explain the shape of your graph.

....

....

(1)
(Total 10 marks)

130. How many neutrons does the nucleus of $^{14}_{6}C$ contain?

....

Carbon-14 has a half-life of 5600 years. Calculate the decay constant of carbon-14.

....

....

Decay constant = ...

(3)

A sample of 14g of carbon-14 contains 6.0×10^{23} nuclei.

How many nuclei are there in 7.0×10^{-9} g of carbon-14?

....

....

Number of nuclei = ...

Hence calculate the activity of 7.0×10^{-9} g of carbon-14.

....

....

....

Activity = ...

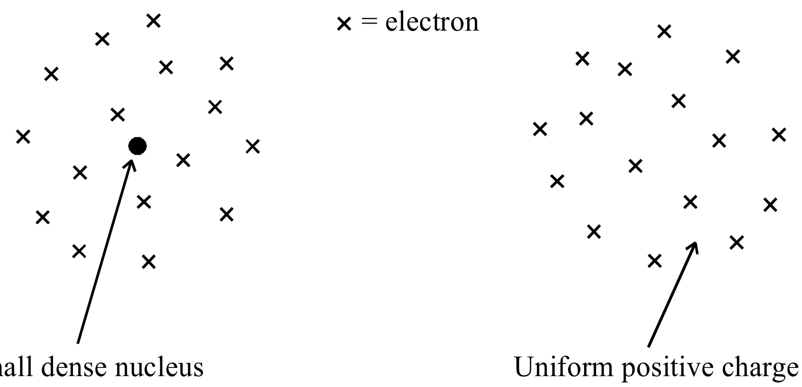
(3)

Carbon-14 is a beta-minus emitter and its decay product is a nucleus of nitrogen, N. Write down a nuclear equation demonstrating this decay.

....

(2)
(Total 8 marks)

131. Two possible structures of the atom were proposed in the early 1900s.They were the Rutherford and "plum pudding" models, as shown.



Rutherford model: a small dense nucleus surrounded by electrons

Plum pudding model: electrons embedded in a region of uniform positive charge

Geiger and Marsden scattered alpha particles off gold atoms. Outline the evidence from this experiment that supported Rutherford's model.

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(3)

Suggest what Geiger and Marsden would have observed if the “plum pudding” model had been correct.

....

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Explain your answer.

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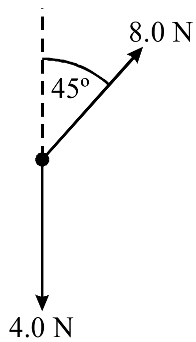
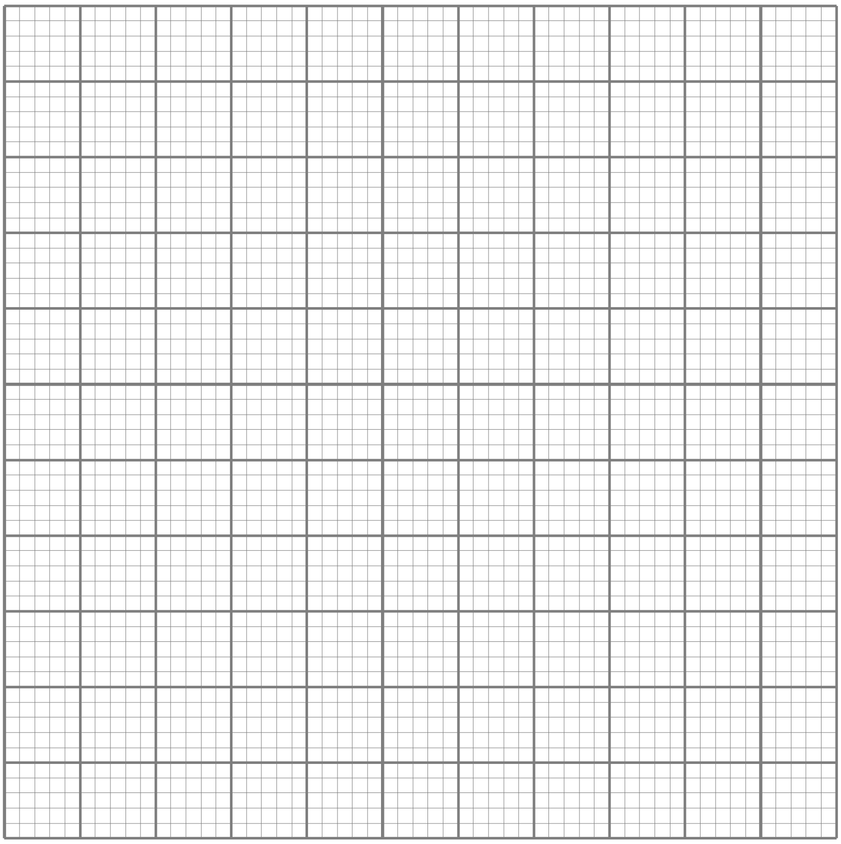
(2)
(Total 5 marks)

132. The diagram shows two forces acting on a body.



On the grid below draw a scale diagram to determine the resultant force acting on the body. Use a scale of 1 cm to 1 N.



State the magnitude of the resultant force.

Force = ...

(4)

What name is given to physical quantities which add by the same rule as forces?

....

Name **two** other examples of such physical quantities.

....

....

(2)
(Total 6 marks)

133. The acceleration of free fall *g* can be measured by timing an object falling from rest through a known distance. Explain one advantage and one disadvantage of making this distance as large as possible.

Advantages: ....

....

....

Disadvantages: ....

....

....

(2)

In a typical laboratory measurement of g, a steel sphere is dropped through a distance of the order of one metre. With the help of a labelled diagram, describe and explain an experimental method of measuring the time it takes the sphere to fall.

....

....

....

....

....

....

(4)

At any given place, the weight of a body is proportional to its mass. Explain how measurements of g support this statement.

....

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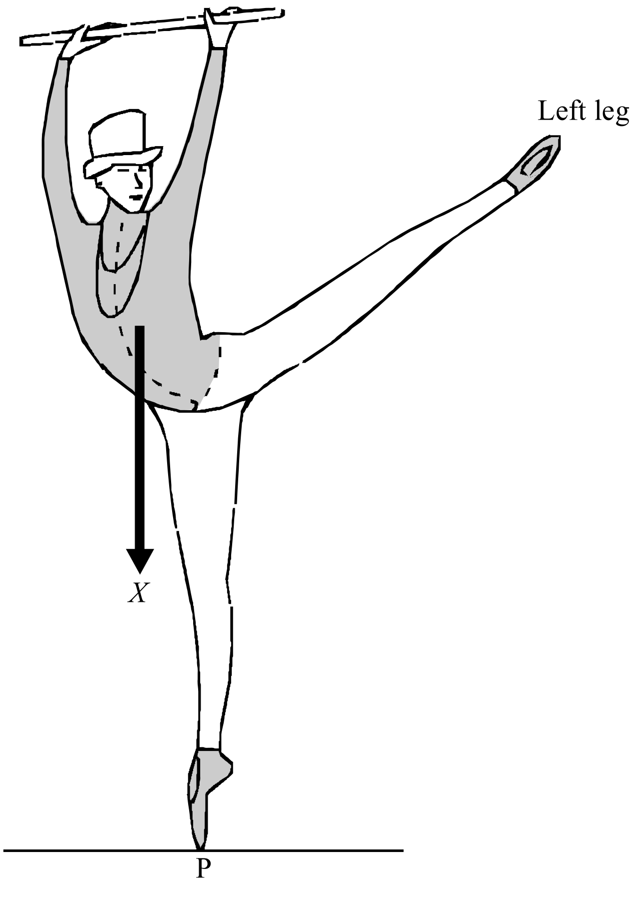
....

(2)
(Total 8 marks)

134. The diagram shows a ballet dancer balancing on the point P of her right foot, with her left leg extended.



The arrow labelled X represents the weight of the whole of her body apart from her legs.

Add a second arrow to the diagram to represent the weight of her extended left leg.
Label this arrow Y.

Add a third arrow, labelled Z, to represent the weight of her right leg.

(2)

With reference to the relative sizes and positions of these forces, explain how this situation illustrates the principle of moments. You may be awarded a mark for the clarity of your answer.

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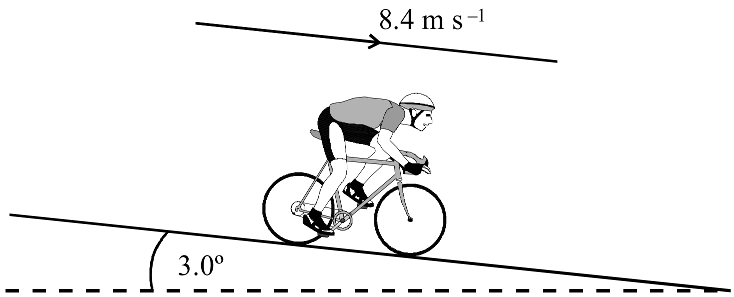
(5)
(Total 7 marks)

135. A cyclist is free-wheeling down a long slope which is at 3.0° to the horizontal. He is travelling, without pedalling, at a constant speed of 8.4 m s^{-1}.



The combined mass of the cyclist and bicycle is 90 kg. Calculate the gravitational potential energy (g.p.e.) lost per second.

....

....

....

....

G.p.e. lost per second = ...

(3)

What happens to this lost g.p.e.?

....

.... **(1)**

At the bottom of the slope the cyclist turns round and pedals back up at the same steady speed of 8.4 m s^{-1}. Give an estimate of the rate at which the cyclist does work as he climbs the hill.

....

....

....

Rate of working = ...

(2)
(Total 6 marks)

136. Define **momentum** and state its unit.

Definition: ....

Unit: .... **(2)**

A stationary nucleus of thorium-226 decays by alpha particle emission into radium.
The equation for the decay is:

$$^{226}_{90}\mathrm{Th} \rightarrow \, ^{222}_{88}\mathrm{Ra} + \, ^{4}_{2}\mathrm{He}$$

State the value of the momentum of the thorium nucleus before the decay .... **(1)**

After the decay, both the alpha particle and the radium nucleus are moving.

Which has the greater speed? Justify your answer.

....

....

....

....

What can be said about the directions of travel of the two particles?

....

....

(3)
(Total 6 marks)

137. Indium-115 (symbol In, proton number 49) decays by beta-minus emission to tin (symbol Sn). Write down a nuclear equation representing this decay.

....

(2)

Indium-115 has a half-life of 4.4×10^{14} years. Calculate its decay constant.

....

....

....

Decay constant = ...

(2)

A radioactive source contains 2.3×10^{21} nuclei of indium-115. Calculate the activity of this source in becquerels.

....

....

....

....

Activity = ... Bq

State how this activity compares with a normal background count rate.

....

(3)
(Total 7 marks)

138. A Physics department has an old radium source which is thought to emit alpha, beta and gamma radiation. A student performs some experimental tests to find out whether this is correct. She uses a metre rule, a I mm thick sheet of aluminium, a 5 mm thick sheet of aluminium and a suitable Geiger-Müller tube with a ratemeter. Her results are as follows:

Test number	Procedure	Observations on ratemeter
1	The source is held very close to the GM tube.	Count rate is high.
2	The source is moved a few centimetres away from the GM tube.	Count rate suddenly drops.
3	With the source 20 cm from the GM tube, 1 mm of aluminium is inserted between them.	Count rate drops significantly.
4	With source still 20 cm from the GM tube, 5 mm of aluminium is inserted between them.	Count rate is still well above background.

Which test(s) lead to the conclusion that each of alpha, beta and gamma radiation is emitted by the source? Justify your answers.

Alpha:

....

....

Beta:

....

....

Gamma:

....

....

(Total 4 marks)

139. Alpha particles and electrons have each been used in scattering experiments to probe the structure of matter.

Complete the table below.

	Alpha scattering	Deep inelastic scattering
Target	....	....

(2)

What conclusions can be drawn from

(i) alpha scattering experiments

....

....

....

....

(ii) deep inelastic scattering experiments?

....

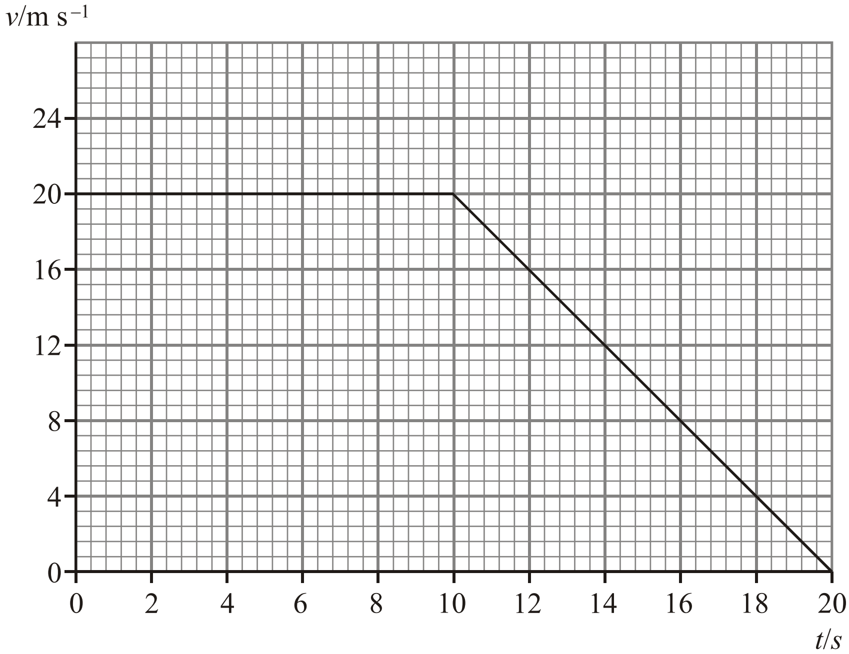
....

....

....

(4)
(Total 6 marks)

140. The graph shows the variation of velocity with time for a body moving in a straight line.



Calculate

(i) the total distance travelled,

....

....

Distance = ...

(ii) the average speed over the 20 seconds.

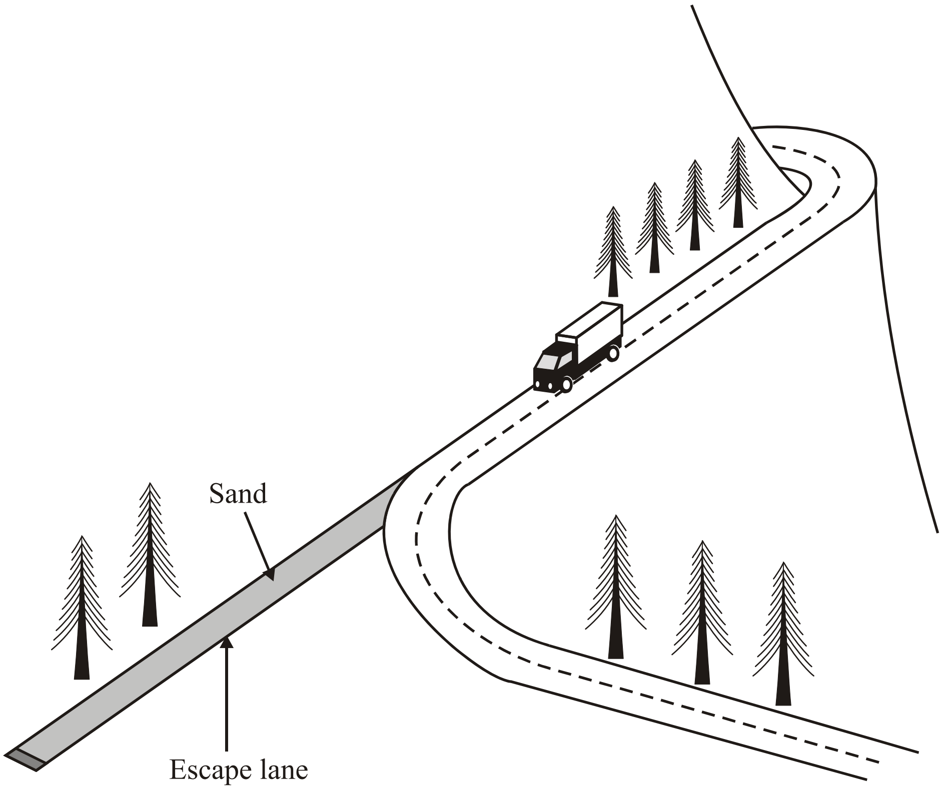
....

....

Average speed = ...

(Total 4 marks)

141. A lorry is travelling at 25 m s^{-1} down a mountain road when the driver discovers that the brakes have failed. She notices that an escape lane covered with sand is ahead and stops her lorry by steering it on to the sand.



The lorry is brought to a halt in 40 m.   Calculate the average deceleration of the lorry.

....

....

....

Average deceleration =...........................

(3)

Suggest how the depth of the sand affects the stopping distance.   Justify your answer.

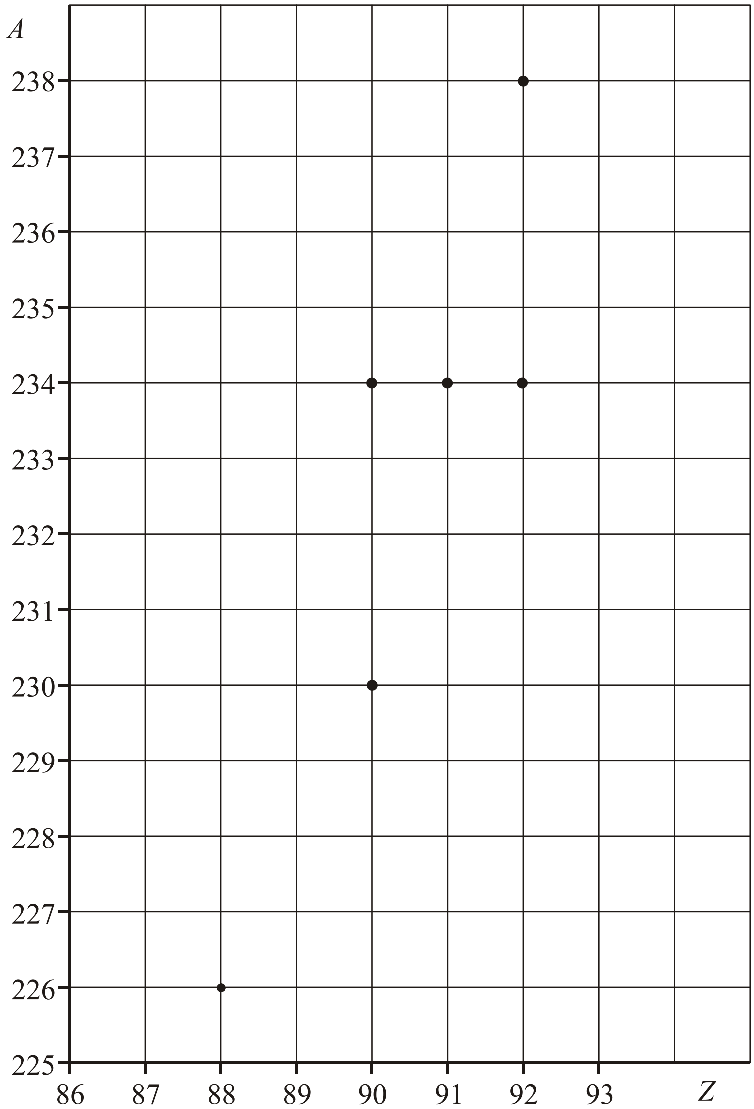
....

....

....

(1)
(Total 4 marks)

142. The nucleon number *A* and proton number *Z* for six different nuclides are shown on the grid.



Explain the term isotope.

....

....

(1)

On the grid, circle two nuclides that are isotopes of the same element.

(1)

Draw an arrow labelled α showing one of the nuclides decaying by alpha emission into one of the other nuclides.

Draw an arrow labelled β showing one of the nuclides decaying by beta-minus decay into one of the other nuclides.

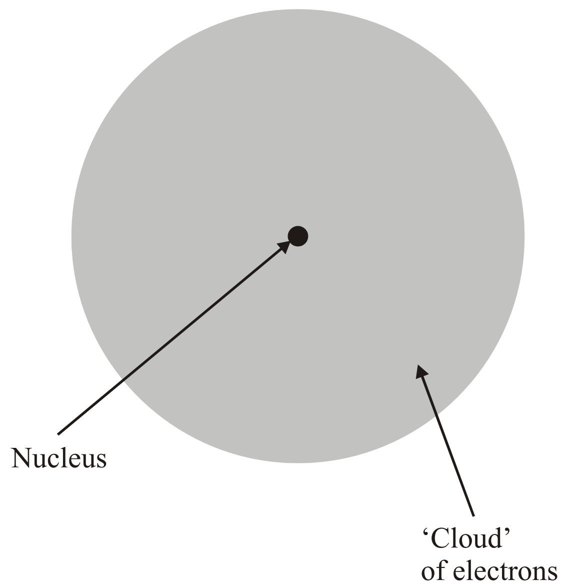
Use information from the grid to help you complete a nuclear equation for this beta-minus emission.

$$Y \quad \rightarrow \quad X \quad + \quad \beta$$

[Y and X represent the nuclei.]

(5)
(Total 7 marks)

143. The nuclear atom may be represented as in the diagram.



Explain how the results of the alpha particle scattering experiment verify the nuclear model of the atom. You may be awarded a mark for the clarify of your answer.

....

....

....

....

....

....

....

....

....

....

(Total 5 marks)

144. Determine the resultant force on the object below.

....

(1)

What can be deduced about the motion of an object

(i) when the resultant force on it is zero,

....

....

(ii) when the resultant force on it is vertically upwards,

....

....

(iii) when the resultant force on it is in the opposite direction to its motion?

....

....

(3)

Newton's third law of motion is sometimes stated in the form: "To every action there is an equal and opposite reaction". A student argues that, in that case, the resultant force on an object must always be zero and so it can never be moved. Explain what is wrong with the student's argument.

....

....

....

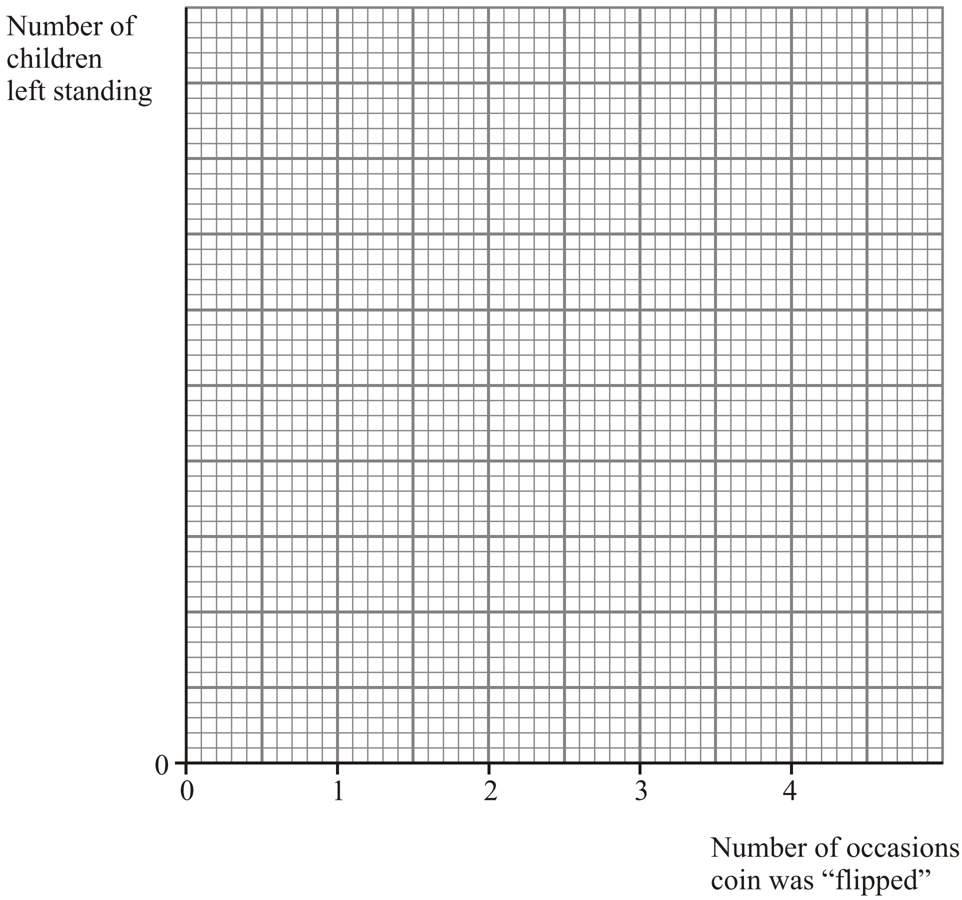
....

(2)
(Total 6 marks)

145. A physics student asked a large group of children to stand up and perform a simple experiment to model radioactive decay. Each child flipped a coin. Those who flipped a "head" sat down.

The children left standing again flipped a coin and those who flipped a "head" sat down. This process was repeated twice more.

There were initially 192 children standing. Plot on the axes below the expected graph of the results. Add a scale to the *y*-axis.



(3)

Radioactive decay is a **random** process. Explain what this means.

....

....

(1)

In what way is the experiment a model of a random process?

....

....

(1)

What is meant by the **half-life** of a radioisotope?

....

....

(1)

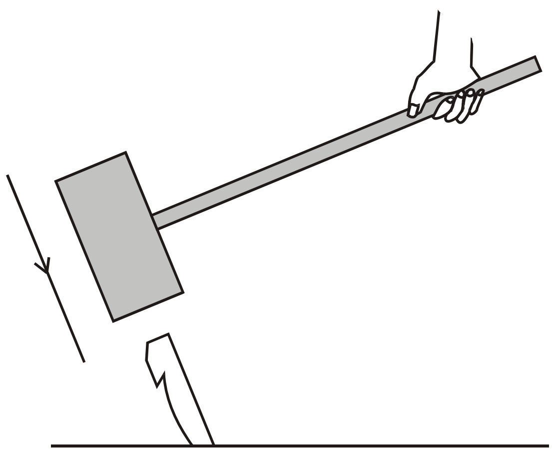
Does the model illustrate half-life? Justify your answer.

....

....

(1)
(Total 7 marks)

146. A wooden mallet is being used to hammer a tent peg into hard ground.



The head of the mallet is a cylinder of diameter 0.100 m and length 0.196 m. The density of the wood is 750 kg m^{-3}. Show that the mass of the head is approximately 1.2 kg.

....

....

....

....

(3)

The head strikes the tent peg as shown at a speed of 4.20 m s^{-1} and rebounds at 0.58 m s^{-1}. Calculate the magnitude of its momentum change in the collision.

....

....

....

Momentum change = ...

(3)

The head is in contact with the peg for 0.012 s. Estimate the average force exerted on the peg by the head during this period.

....

....

Average force = ...

(2)

Give a reason why your value for the force will only be approximate.

....

....

(1)

With reference to your calculations above, discuss whether a mallet with a rubber head of the same mass would be more or less effective for hammering in tent pegs.

....

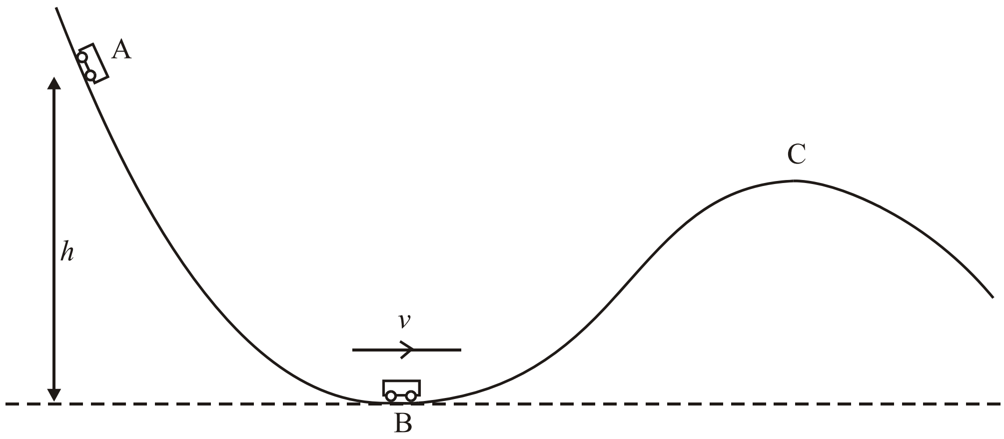
....

....

....

(2)
(Total 11 marks)

147. The diagram shows a small vehicle which is free to move in a vertical plane along a curved track.



The vehicle of mass *m* is released from rest from point A. It runs down to point B, a distance *h* vertically below A. Its speed at point B is *v*.

Write down expressions for

(i) the gravitational potential energy lost by the vehicle as it runs from A to B,

....

(ii) the kinetic energy of the vehicle at B.

....

(1)

Hence derive an expression for the speed *v*.

....

....

....

(2)

State one assumption you have made in your derivation.

....

....

(1)

Would you expect the vehicle to pass point C? Explain your answer.

....

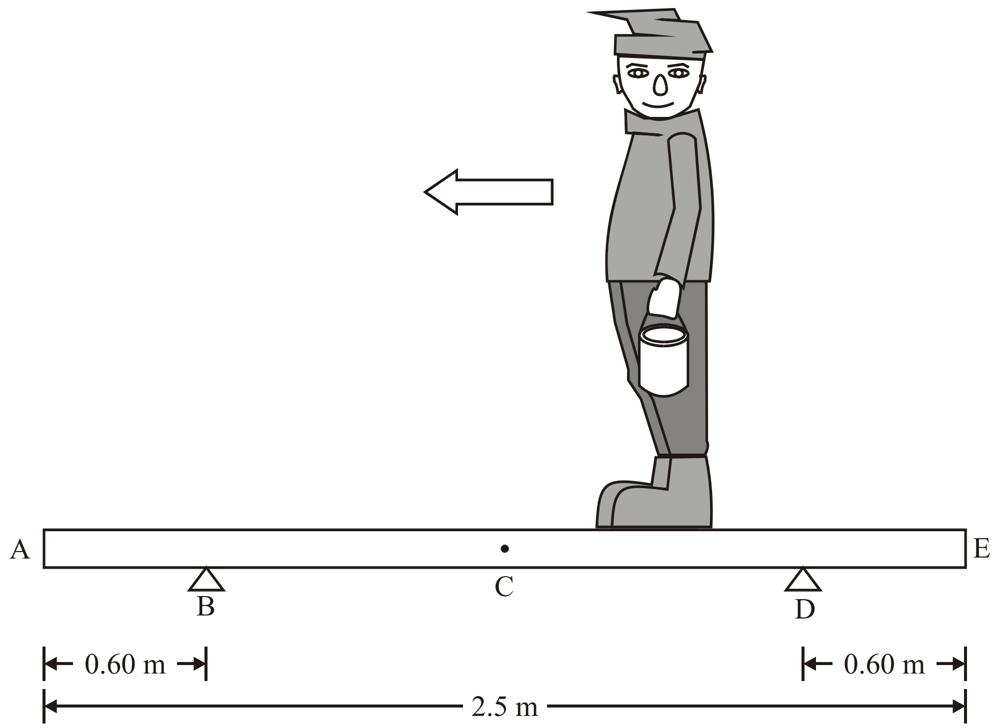
....

....

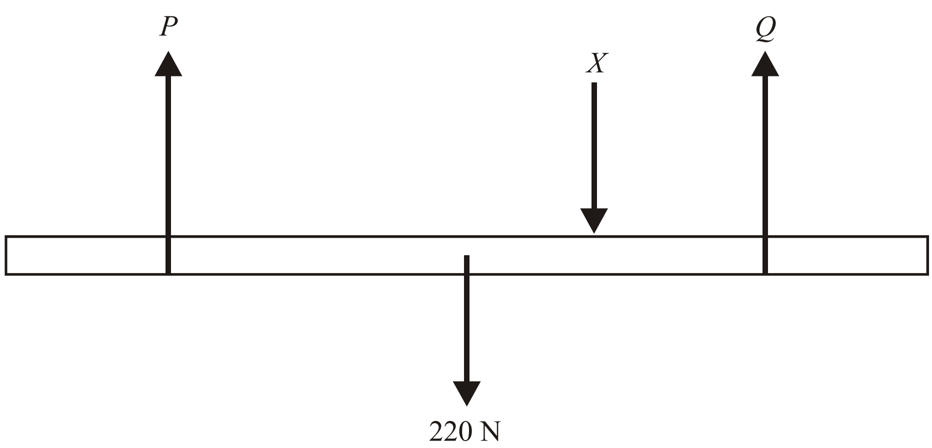
....

(2)
(Total 6 marks)

148. The diagram shows a painter standing on a uniform plank AE which rests on two moveable supports, B and D. The weight of the plank is 220 N. The length of the plank is 2.5 m.



The free-body force diagram of the plank is shown. (X is the push of the painter on the plank.)



The total weight of the painter and paint tin is 760 N. Calculate the total mass of the painter and paint tin.

....

Mass = ...

(1)

The painter walks towards end A of the plank, still holding the paint tin.

(i) The magnitude of force *Q* decreases. Explain why.

....

....

....

(2)

(ii) What happens to the plank and the painter if he passes the point where *Q* becomes zero?

....

Calculate the distance *l* of the painter from A when *Q* becomes zero.

....

....

....

l = ...

(4)

Explain how the value of *l* would change if the painter had a smaller mass.

....

....

....

....

....

How could the painter avoid force *Q* reaching zero, no matter where he stands?

....

....

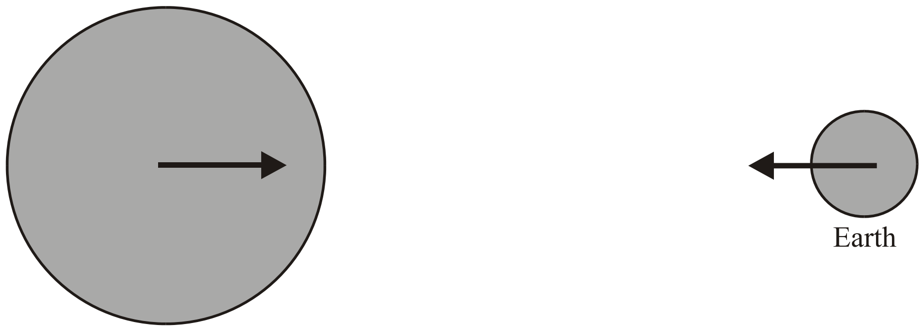
(3)
(Total 10 marks)

149. Complete the table below by giving **one** example of each type of force.

Type of force	Example
Gravitational	
Electromagnetic	
Nuclear	

(3)

The diagram shows forces acting on the Sun and the Earth. These forces form a Newton's third law pair.



State three properties of these forces which are necessary for them to be a Newton's third law pair.

1. ……………………………………………………………………………………….

2. ……………………………………………………………………………………….

3. ……………………………………………………………………………………….

(3)
(Total 6 marks)

150. A man is pushing a shopping trolley at a speed of 1.10 m s^{-1} along a horizontal surface. There is a constant frictional force opposing the motion. The man stops suddenly, letting go of the trolley, which rolls on for a distance of 1.96 m before coming to rest. Show that the deceleration of the trolley is approximately 0.3 m s^{-2}.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(3)

The total mass of the trolley and its contents is 28.0 kg. Calculate the frictional force opposing its motion.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Frictional force = ...

(2)

Calculate the power needed to push the trolley at a steady speed of 1.10 m s^{-1}.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Power = ……………………………………

(2)

The man catches up with the trolley. Calculate the steady force he must now apply to it to accelerate it from rest to 1.10 m s^{-1} in 0.900 s.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

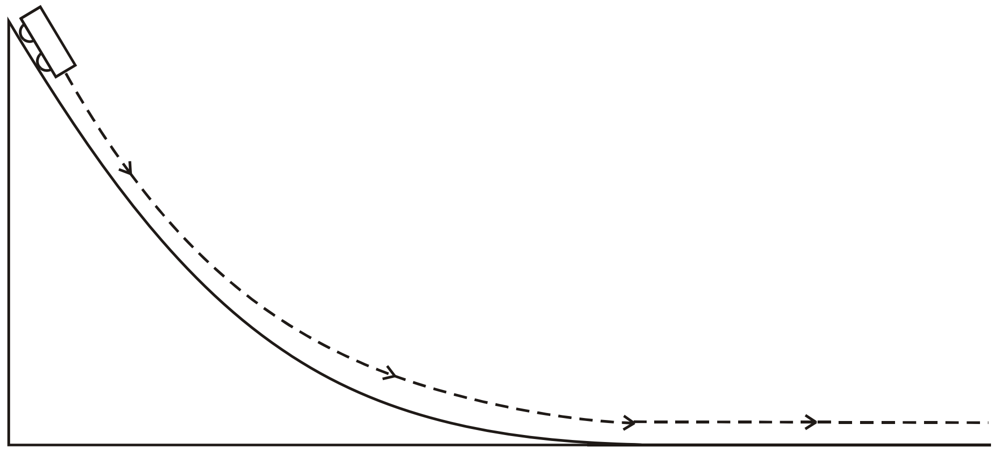
…………………………………………………………………………………………………

Force = ……………………………………

(3)

(Total 10 marks)

151. A Physics teacher is demonstrating conservation of energy. She sets up a curved runway and releases an initially stationary trolley from the top.



She tells the class that, as the trolley runs down the slope, its gravitational potential energy is converted into kinetic energy. Explain why this is only approximately true.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

(1)

Describe an experiment she could perform to find out what percentage of the gravitational potential energy lost is actually converted to kinetic energy. Your answer should include:

(i) any additional apparatus required (add this to the diagram opposite),

(ii) how the apparatus is used,

(iii) how the results are analysed.

……………………………………………………………………………………………………

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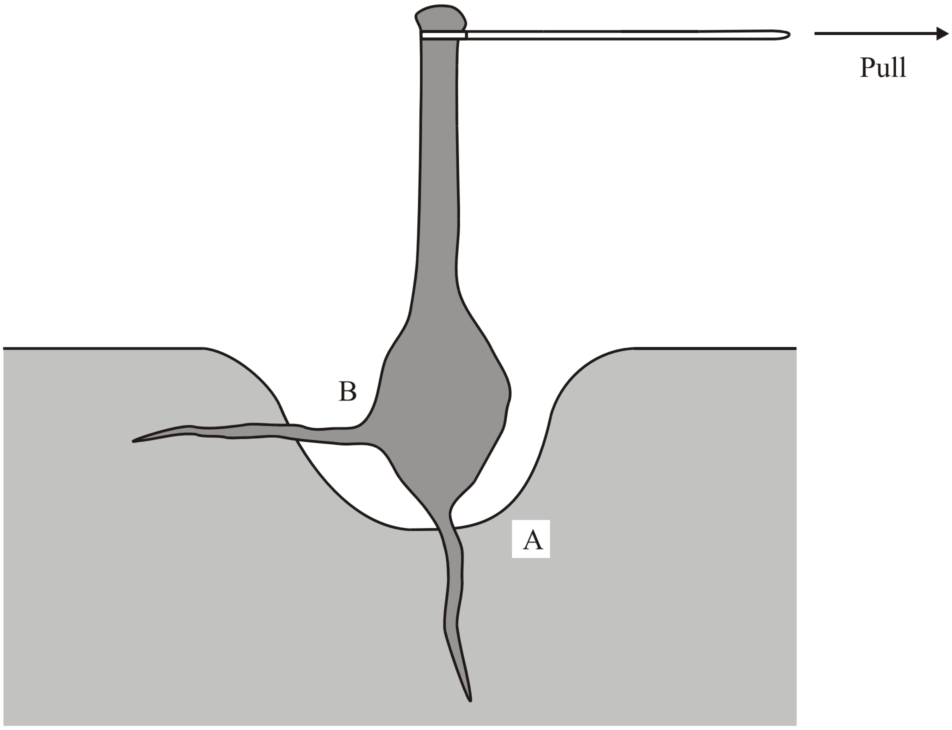
……………………………………………………………………………………………………

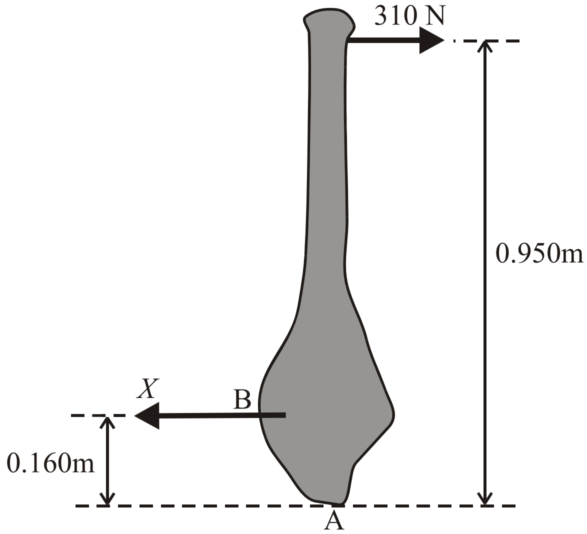
(6)
(Total 7 marks)

152. A gardener is trying to remove a tree stump. He has dug away the soil around it, but it is still anchored by a vertical root at A and a horizontal root at B.



The gardener pulls horizontally on the top of the stump with a force of 310 N, but it does not move.

Below is a diagram showing some of the horizontal forces on the stump. Force *X* is the tension in the root at B.



One horizontal force is missing from the diagram. Add an arrow to represent this force and label it *Y*.

(1)

Using the principle of moments, determine force *X*. (You should ignore the vertical forces on the tree stump.)

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

X = ...

(2)

Explain why, in this moments calculation, it is reasonable to ignore the vertical forces on the stump.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

(1)

Calculate force *Y*.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Y = ...

(2)

If a tree stump is to be removed, it is a mistake to cut it off very close to the ground first. Using the concept of moments, explain why.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

(2)
(Total 8 marks)

153. A model truck A of mass 1.2 kg is travelling due west with a speed of 0.90 m s^{-1}. A second truck B of mass 4.0 kg is travelling due east towards A with a speed of 0.35 m s^{-1}.

Calculate the magnitude of the total momentum of the trucks.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Total momentum = ...

(2)

The trucks collide and stick together. Determine their velocity after the collision.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Velocity = ...

(3)
(Total 5 marks)

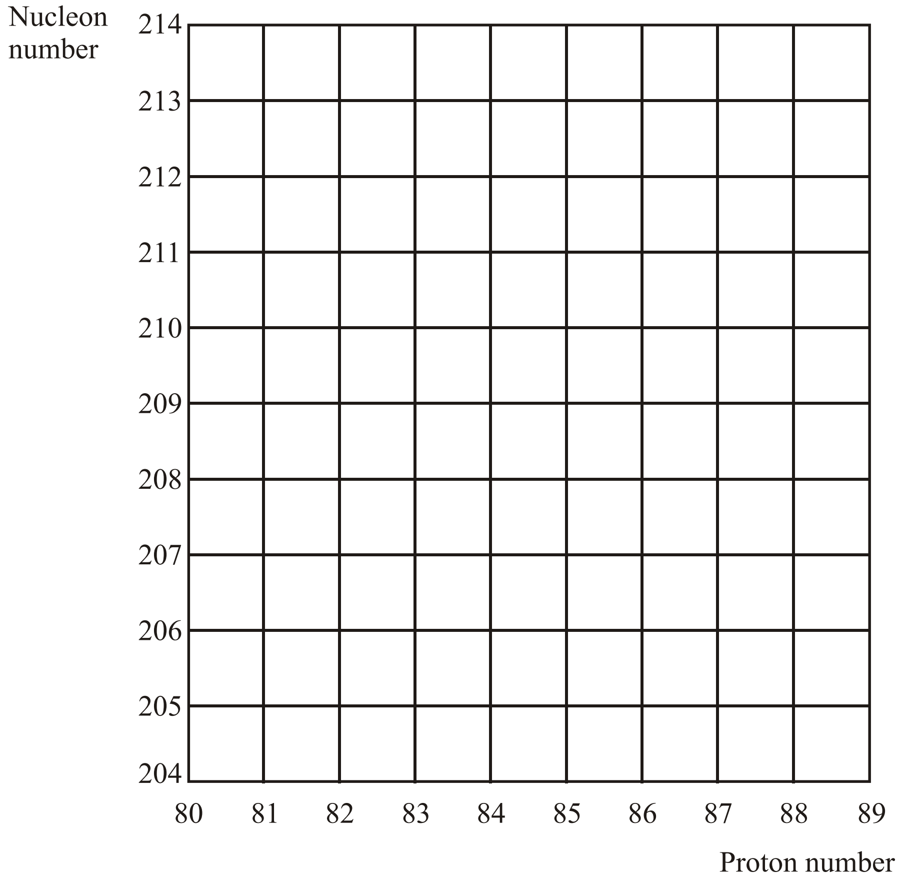
154. What are isotopes?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

(1)

A nucleus of an isotope of polonium (symbol Po) has 84 protons and 126 neutrons. Mark the position of this nucleus on the grid below, and label it Po.



This isotope of polonium decays by alpha particle emission into an element X. Starting from Po, add a line to the grid to represent this decay.

(3)

This isotope of polonium is thought to emit **only** alpha radiation. Describe how you could check this experimentally.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

(3)
(Total 7 marks)

155. The **range** of nuclear radiation in matter depends on how strongly the radiation **ionises** matter. Explain the meanings of the terms in bold type.

range ....

……………………………………………………………………………………………………

ionises ....

....

(2)

State and explain the qualitative relationship between range and ionising ability.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

(2)

Beta radiation from a certain source can be stopped completely by a sheet of aluminium 3.0 mm thick. Calculate the mass of a square sheet of aluminium of this thickness measuring 1.0 m × 1.0 m.

(Density of aluminium = 2.7×10^{3} kg m^{-3})

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Mass = ...

(2)

To a fair approximation, the ability of any sheet of material to stop beta radiation depends only on the mass per square metre of a sheet of the material. Estimate the thickness of lead sheet needed to stop the same beta radiation completely.

(Density of lead = 11.3×10^{3} kg m^{-3})

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Thickness = ...

(2)
(Total 8 marks)

156. In the Rutherford scattering experiment, fast-moving alpha particles were fired at a thin gold foil. What observations from this experiment suggested that the atom has a small, massive nucleus?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

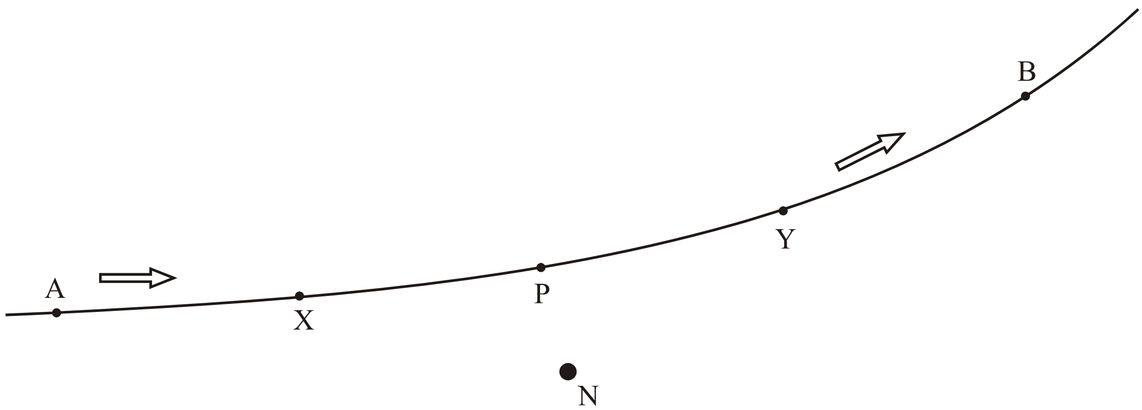
…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(2)

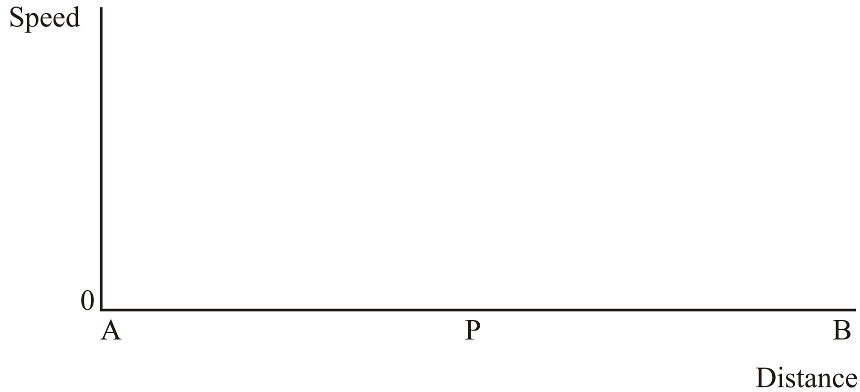
The diagram shows the path followed by one alpha particle which passes close to a gold nucleus N.



Add arrows to the diagram at points X and Y to show the direction of the force on the alpha particle when it is at each of these points.

(1)

The speed of the alpha particle was the same at points A and B. On the axes below, sketch a graph showing how the speed would vary with distance along the path from A to B.



(2)

With reference to the forces you added to the previous diagram, explain the shape of the graph.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

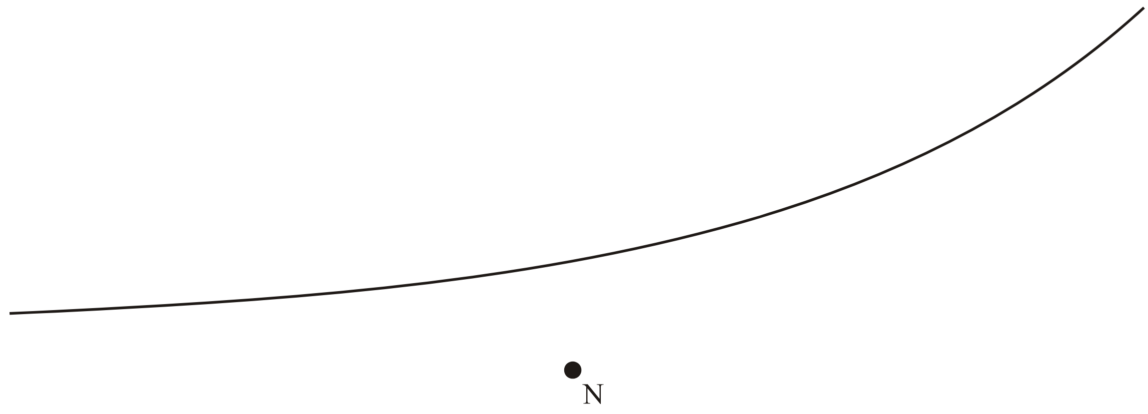
…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(2)

The diagram below shows the path of the alpha particle again.



Add a line to this diagram to show the path which would be followed by an alpha particle which was travelling initially along the same line as before, but more slowly.

(1)

The evidence for a small, massive nucleus from Rutherford scattering might have been less convincing if the alpha particles used had been of lower energy. Suggest how the observations would have changed if lower energy alpha particles had been used.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

(1)
(Total 9 marks)

157. Listed below are six physical quantities:

energy   force   moment   momentum   power   velocity

Select from this list the quantity or quantities fitting each description below. You may use each quantity once, more than once or not at all. A quantity which can be measured in newton second (N s).

……………………………………………………………………………………………………

A quantity which equals the rate of change of another quantity in the list.

……………………………………………………………………………………………………

A quantity which equals the product of two other quantities in the list.

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

A quantity with base units kg m^2 s^{-3}.

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

Two quantities which have the same base units.

1 ....

2 ....

(Total 5 marks)

158. A neutron of mass 1.7×10^{-27} kg travelling at 2.96×10^{7} m s^{-1} collides with a stationary nucleus of nitrogen of mass 23.3×10^{-27} kg. Calculate the magnitude of the momentum of the neutron before it collides with the nucleus of nitrogen.

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

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

Momentum of neutron = ...

(2)

Given that the neutron 'sticks' to the original nucleus after the collision, calculate the speed of the new heavier nucleus of nitrogen.

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

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

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

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

Speed = ...

(3)

An elastic collision is one where kinetic energy is conserved. Make suitable calculations to determine whether this collision is elastic.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

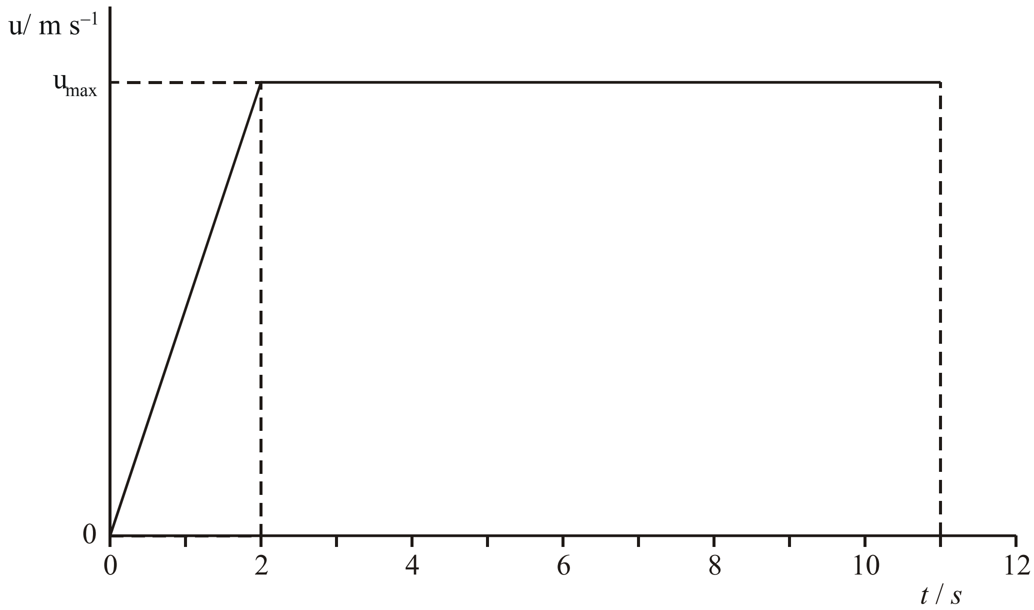
…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(3)
(Total 8 marks)

159. An athlete runs a 100 m race. The idealised graph below shows how the athlete's velocity *v* changes with time *t* for a 100 m sprint.



By considering the area under the graph, calculate the maximum velocity v_{max} of the athlete.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Maximum velocity = ...

(3)

Using the axes below, sketch a graph showing how the acceleration of this athlete changes with time during this race. Mark any significant values on the axes.

(4)
(Total 7 marks)

160. The nucleus of a radioisotope of carbon (C) contains 6 protons and 8 neutrons. Write down a nuclear equation for the decay of this isotope by beta minus emission to nitrogen (N).

$$\rightarrow$$

(3)

The diameter of a carbon nucleus is approximately 10^n m.

Suggest a value for *n*. ....

(1)

The mass of the carbon nucleus is 2×10^{-26} kg. Estimate its density.

………………………………………………………………………………………….

………………………………………………………………………………………….

………………………………………………………………………………………….

………………………………………………………………………………………….

Density = ...

(3)

Comment on your value, relating it to the density of an everyday material.

……………………………………………………………………………………………….

……………………………………………………………………………………………….

(2)
(Total 9 marks)

161. A smoke detector contains a small radioactive source. A typical source contains 1.2×10^{-8} g of americium-241, which has a half-life of 432 years. Show that the decay constant of americium-241 is approximately 5×10^{-11} s^{-1}.

……………………………………………………………………………………………….

……………………………………………………………………………………………….

……………………………………………………………………………………………….

(2)

Calculate the number of nuclei in 1.2×10^{-8} g of americium-241, given that 241 g contains 6.0×10^{23} nuclei.

……………………………………………………………………………………………….

……………………………………………………………………………………………….

Number of nuclei = ...

(1)

Hence calculate the activity of 1.2×10^{-8} g of americium-241.

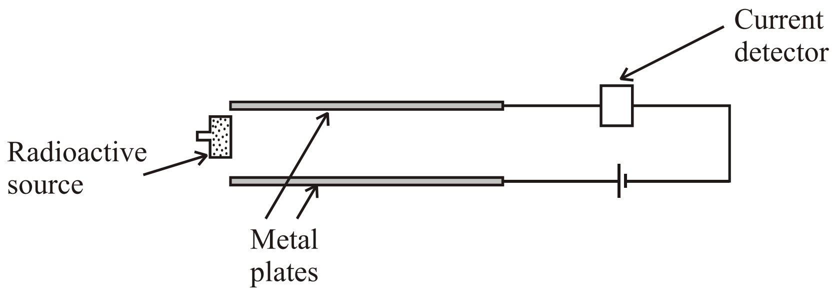
……………………………………………………………………………………………….

……………………………………………………………………………………………….

Activity = ...

(2)

The diagram below shows the principle of the smoke detector.



Radiation from the source ionises the air between the plates, and a small current is detected. If smoke enters the detector, the ions 'stick' to the smoke particles, reducing the current and triggering an alarm.

Americium-241 is an alpha emitter. Explain why an alpha emitter is a suitable source for this apparatus.

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(2)

Discuss other features of this americium sample which make it a suitable source for the smoke detector.

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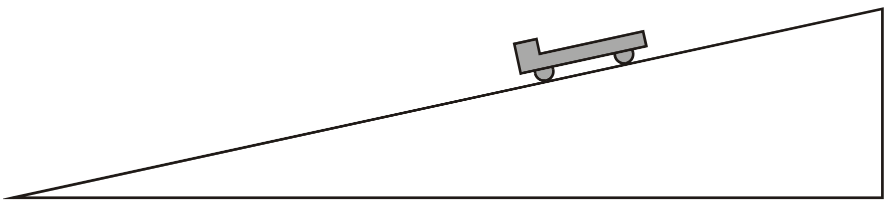
(3)
(Total 10 marks)

162. A trolley is released from rest at the top of an inclined plane.



A student claims that the acceleration of the trolley should be uniform. Describe how you could test this claim experimentally. Your answer should include

(i) any additional apparatus required (add this to the diagram above),

(ii) how the apparatus is used,

(iii) how the results are analysed.

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(6)

With reference to the forces involved, explain why the student expected the acceleration to be constant.

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(2)

Explain whether you would expect the acceleration to remain constant if the slope were much longer so that the trolley reached a high speed.

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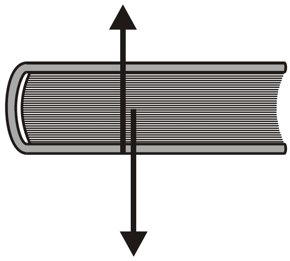
(1)
(Total 9 marks)

163. A book is resting on a table. A student draws a correct free-body force diagram for the book as shown below.



The student makes the incorrect statement that "The forces labelled above make a Newton third law pair; therefore the book is in equilibrium". Criticise this statement.

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(3)

Each of the forces shown in the diagram has a ‘pair’ force related to it by Newton’s third law. Complete the table below.

Force	Type of force	Direction of Newton 3rd law ‘pair’ force	Body ‘pair’ force acts upon
Weight			
Push of table	Electromagnetic		

(4)
(Total 7 marks)

164. A car is travelling along a horizontal road. The driver applies the brakes and the car comes to rest. Describe the principal energy transformation which occurs as the car comes to rest.

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

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

(1)

On another occasion, the same car is travelling with the same speed, but down a hill. The driver applies the brakes, which produce the same average braking force as before. With reference to the energy transformations which occur, explain why the braking distance will be greater on the hill than on the horizontal road. You may be awarded a mark for the clarity of your answer.

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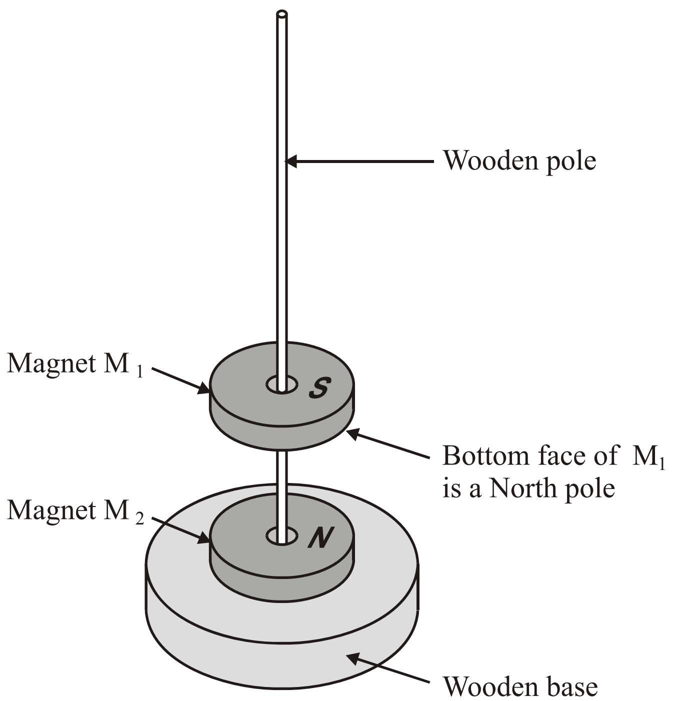
(4)
(Total 5 marks)

165. Complete the table to show the missing physical quantity for each unit.

Unit	Physical quantity
m s^{-1}	Velocity
m s^{-2}	
kg m^{-3}	
N m	
kg m s^{-1}	
N m s^{-1}	

(Total 5 marks)

166. The diagram shows two magnets, M_1 and M_2, on a wooden stand. Their faces are magnetised as shown so that the magnets repel each other.



(a) Draw a fully labelled free-body force diagram for the magnet M_1 in the space below.

(2)

(b) The table gives the three forces acting on the magnet M_2. For each force on M_2 there is a corresponding force known as its 'Newton's third law pair'. In each case state

(i) the body on which this corresponding force acts,

(ii) the direction of this corresponding force.

Force on M_2	Body on which corresponding force acts	Direction of the corresponding force
Contact		
Magnetic		
Weight		

(6)
(Total 8 marks)

167. (a) State the principle of moments.

....

....

(2)

(b) A metal bar has dimensions width 1.2 cm, thickness 0.60 cm and length 200 cm. The metal has a density of 8.0 g cm^{-3}.

(i) Show that the weight of the bar is about 11 N.

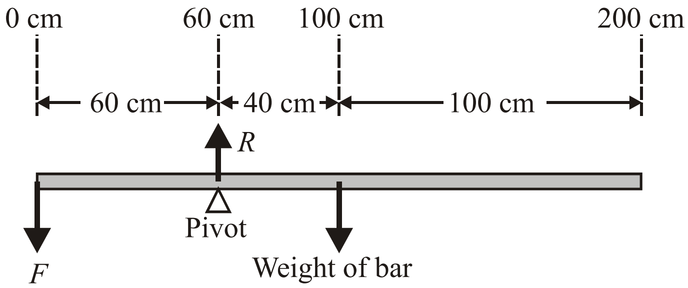
....

....

....

(3)

The bar is placed on a pivot and kept in equilibrium by the forces shown.



(ii) Use the principle of moments to calculate the force *F*.

....

....

....

Force *F* = ...

(2)

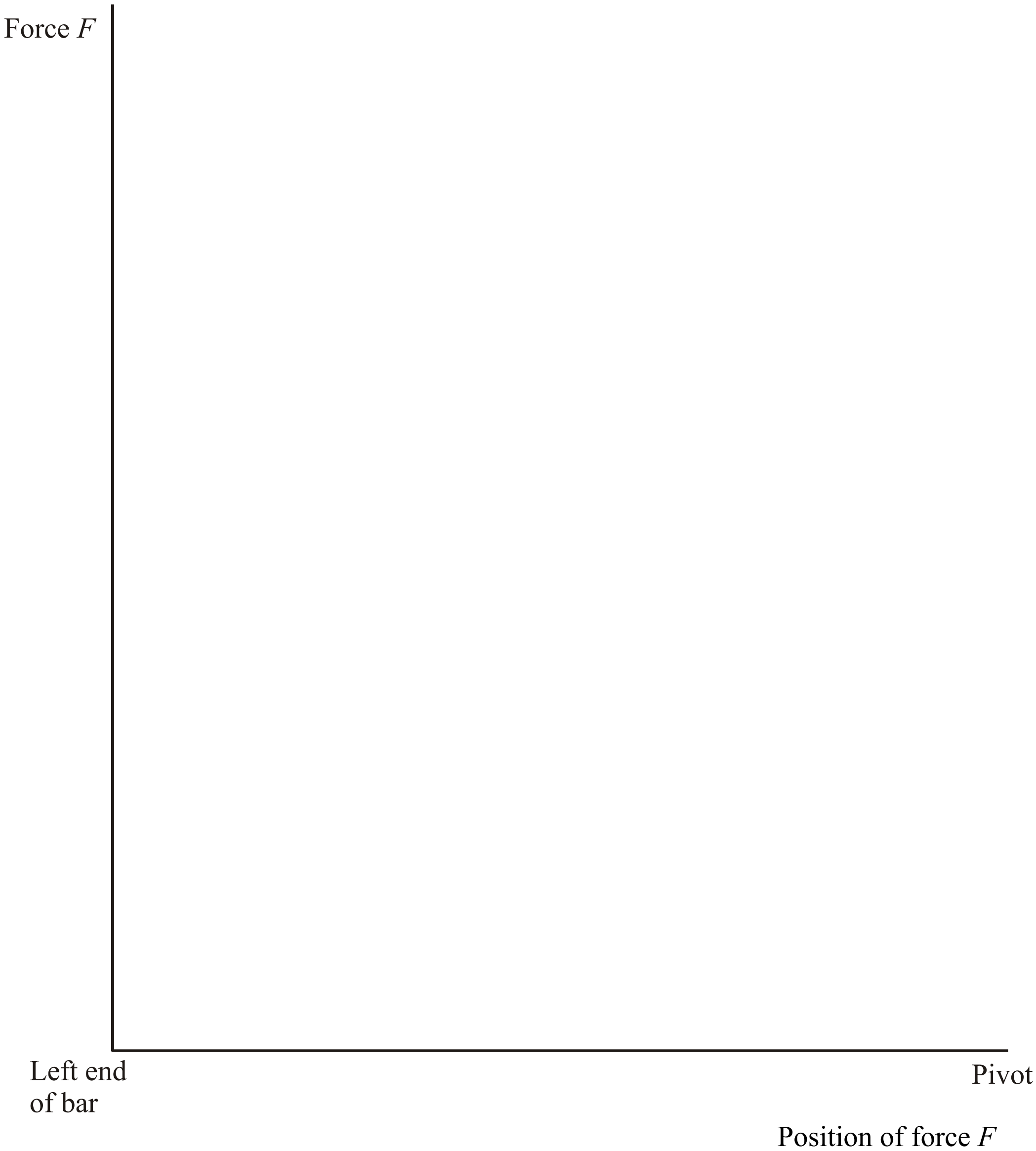
(iii) Calculate the force *R*.

....

Force *R* = ...

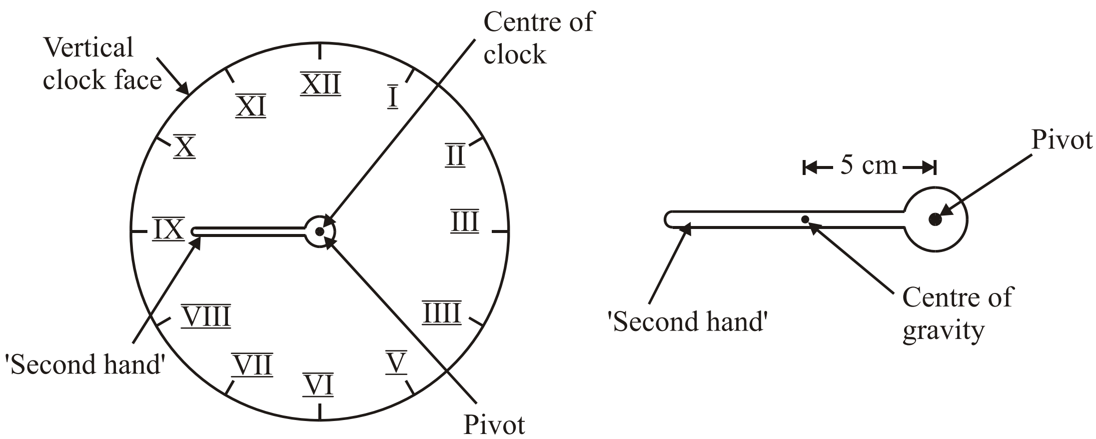
(1)

(iv) The force F is moved towards the pivot. On the axes below sketch how the force F must vary to keep the bar in equilibrium.



(2)
(Total 10 marks)

168. The diagram shows the 'second hand' of a clock whose face is vertical. This hand rotates once every 60 s.



This 'second hand' has a mass of 1.0×10^{-4} kg. Its centre of gravity is 5.0 cm from the pivot as shown on the diagram.

(a) Calculate the moment of the 'second hand' about the pivot when at the position shown above.

....

....

....

Moment = ...

(2)

(b) The clock mechanism lifts the 'second hand' during the next second.

Show that the work done against the gravitational force by the mechanism during this second is approximately 5×10^{-6} J.

....

....

....

....

....

....

(3)

(c) The work done against gravitational force when the 'second hand' moves in the second immediately before the XII position is much smaller than 5×10^{-6} J. Explain why.

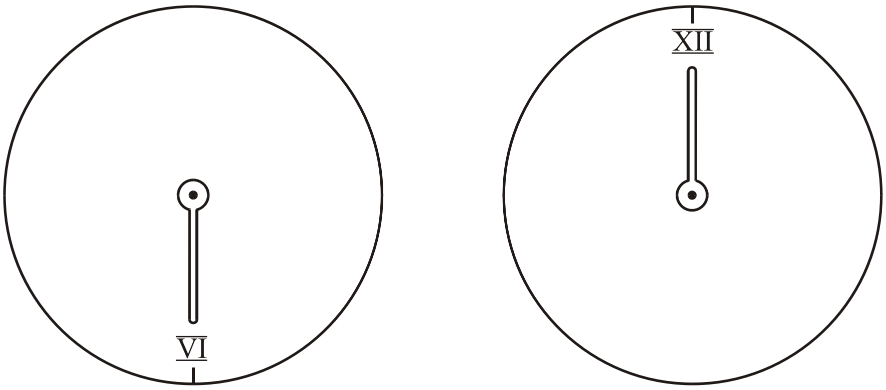
....

....

(1)

(d) Calculate the average power needed to move the 'second hand' from the VI position (Figure 1) to the XII position (Figure 2). Neglect any work done against forces other than the gravitational force.

Figure 1 **Figure 2**



....

....

....

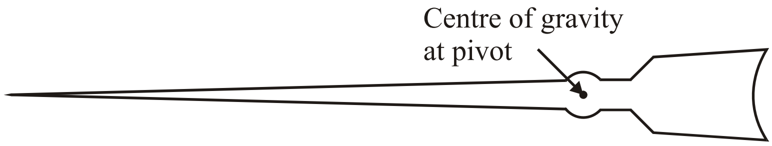
....

....

Average power = ...

(2)

(e) The diagram below shows a different design for the ‘second hand’.



Explain why this design would require less power.

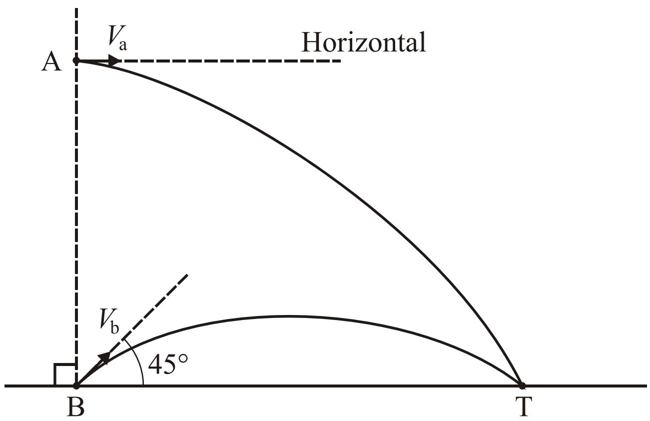
....

....

....

(2)
(Total 10 marks)

169. A student is investigating projectiles. He fires two small identical balls, A and B, simultaneously. Their trajectories are shown in the sketch below. The balls land at the same instant at the target, T.



(a) The initial velocity of ball A is V_a and that of ball B is V_b. Explain why the magnitude of V_b must be greater than that of V_a.

....

....

(b) The paths AT and BT have different lengths. However, balls A and B take the same time to reach the target T. Explain how this is possible. You may be awarded a mark for the clarity of your answer.

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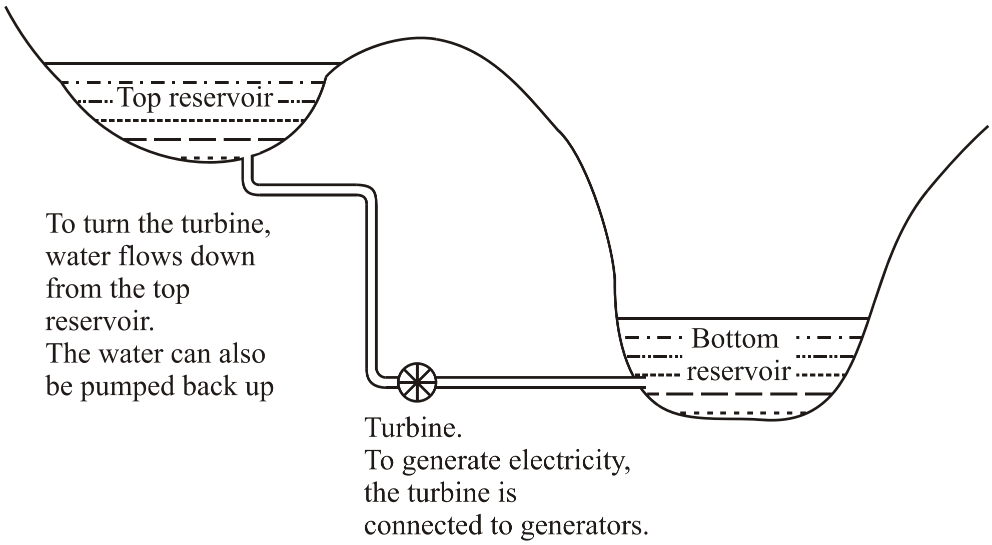
(Total 5 marks)

170. A certain power station generates electricity from falling water. The diagram shows a simplified sketch of the system.



(a) (i) In what form is the energy of the water initially stored?

....

(ii) What energy form is this transformed into in order to drive the turbine?

....

(1)

(b) State the principal of conservation of energy.

....

....

....

(2)

(c) The force of the water at the turbine is 3.5×10^8 N and the output power generated is 1.7×10^9 W. Use this data to calculate the minimum speed at which the water must enter the turbine.

....

....

(2)

(d) Explain why, in practice, the speed at which the water enters the turbine is much greater than this.

....

....

(1)

(e) When working at this output power, 390 m^3 of water flows through the turbine each second. The top reservoir holds 7.0×10^6 m^3 of water. For how long will electricity be generated?

....

....

....

Time = ...

(1)

(f) This power station is used at peak periods, after which the water is pumped back to the top reservoir. The water has to be raised by 500 m. How much work is done to return all the water to the top reservoir?

(The density of water is 1000 kg m^{-3}.)

....

....

....

....

....

Work done = ...

(3)
(Total 10 marks)

171. The first artificially produced isotope was the isotope phosphorus $^{30}_{15}P$. This was formed by bombarding aluminium Al with *α*-particles.

(a) (i) Complete the equation to show the missing nucleon and proton numbers:

$$^{\cdots\cdots}_{\cdots\cdots}Al + ^{\cdots\cdots}_{\cdots\cdots}\alpha \rightarrow ^{30}_{15}P + ^{1}_{0}n$$

(2)

(ii) $^{30}_{15}P$ decays to a stable isotope of silicon $^{30}_{14}Si$ by the emission of a further particle, X. Complete the following equation to show the missing nucleon and proton numbers:

$$^{30}_{15}P \rightarrow ^{30}_{14}Si + ^{\cdots\cdots}_{\cdots\cdots}X$$

Suggest what the particle X is.

....

(2)

(b) The half-life of the radioactive isotope of phosphorus $^{30}_{15}P$ is 195 seconds. Give the meanings of the terms **half-life** and **isotope**.

Half-life ....

....

Isotope ....

....

(3)

(c) Atoms which emit *α*- or *β*-particles usually emit γ-rays as well. Explain why this occurs.

....

....

....

....

....
(1)
(Total 8 marks)

172. When electrons are fired at nucleons many of the electrons are scattered.

When the electrons have low energy, the scattering is elastic.

However, when the electrons have sufficiently high energy, deep inelastic scattering occurs.

(a) What is meant by **inelastic** in this situation?

....

....
(1)

(b) What is revealed about the structure of the nucleon by deep inelastic scattering?

....

....
(1)

(c) What quantity is conserved during both elastic and inelastic scattering?

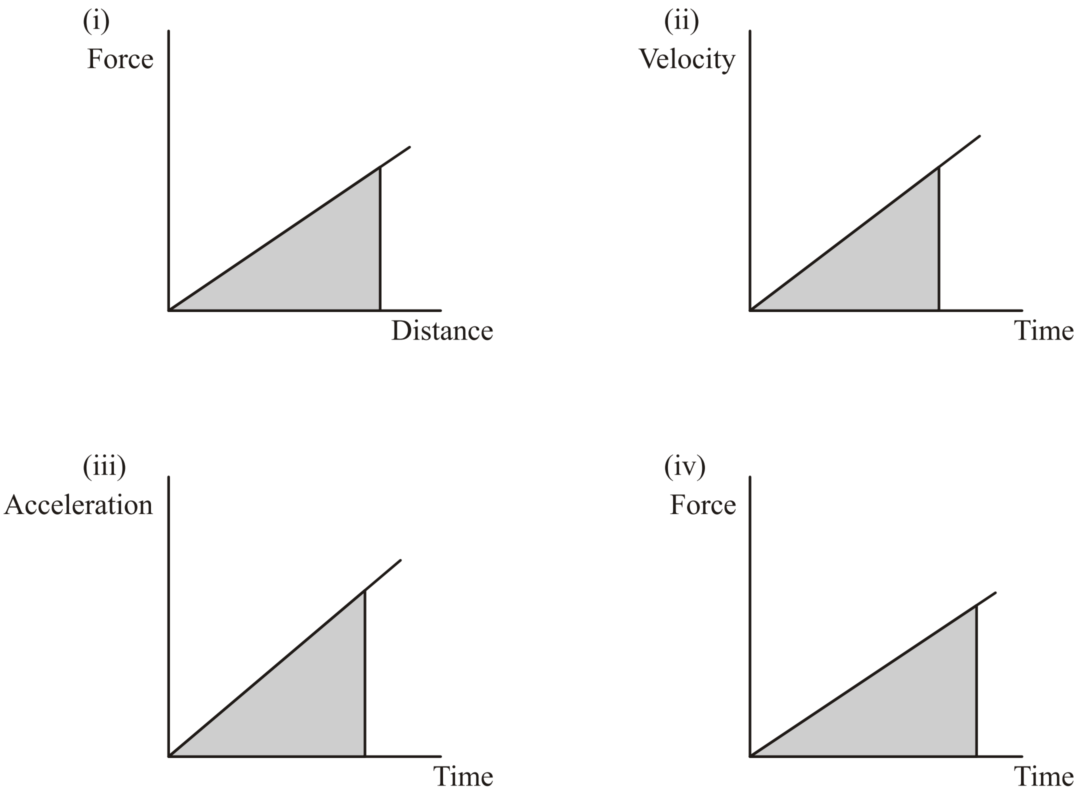
....
(1)

(d) Historically, physicists found that electrons of low energy could not be used to find out information about the nucleus of neutral atoms. Suggest why.

....

....
(1)
(Total 4 marks)

173. Name the physical quantity represented by the area under each of the following graphs. Give your answers in the table below.



Graph	Physical quantity represented by area under graph
(i)	
(ii)	
(iii)	
(iv)	

(Total 4 marks)

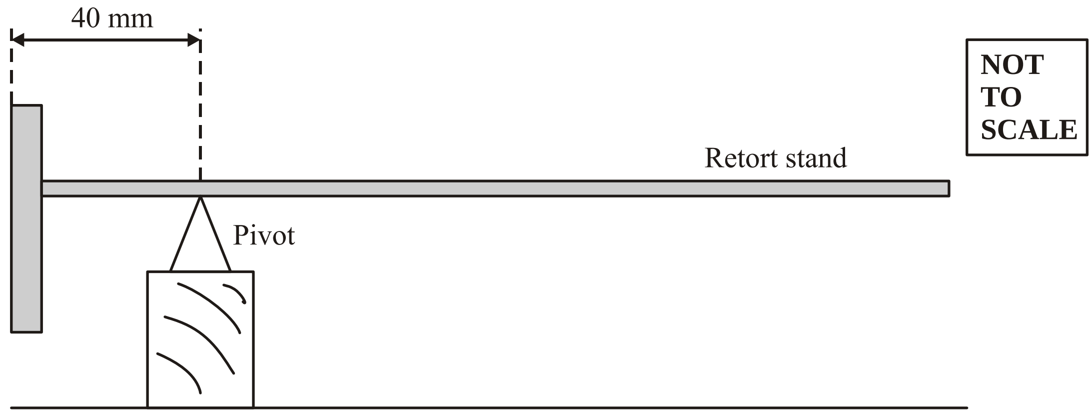
174. (a) State the **principle of moments.**

....

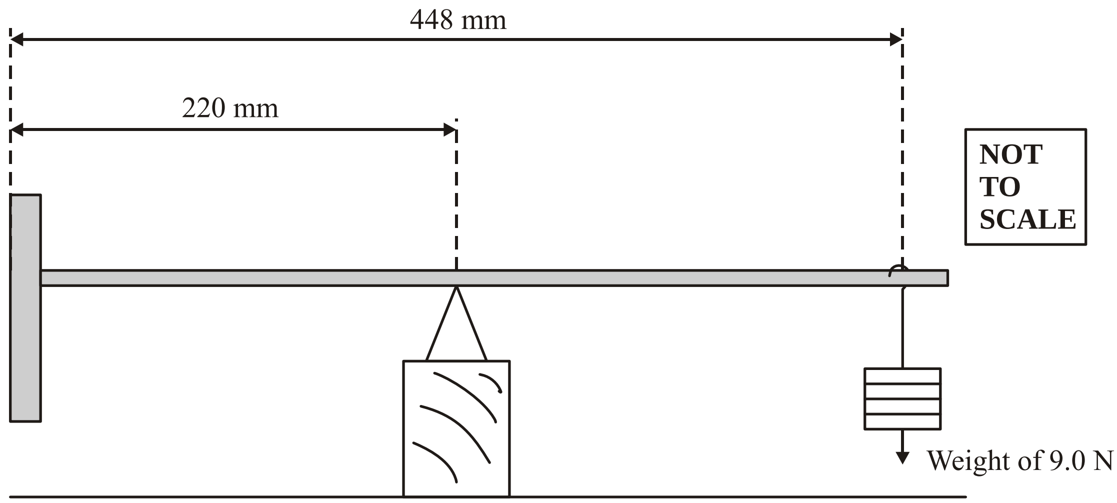
....

(2)

(b) The diagram below shows a retort stand balanced on a pivot to find the point through which its weight acts. It balances when the pivot is 40 mm from the base.



(i) The weight of this retort stand can be found using a known weight. The diagram below shows the retort stand balanced from a different point by a weight of 9.0 N. It balances when the pivot is 220 mm from the base and the 9.0 N weight is 448 mm from the base.



Show that the weight of the retort stand is about 11 N.

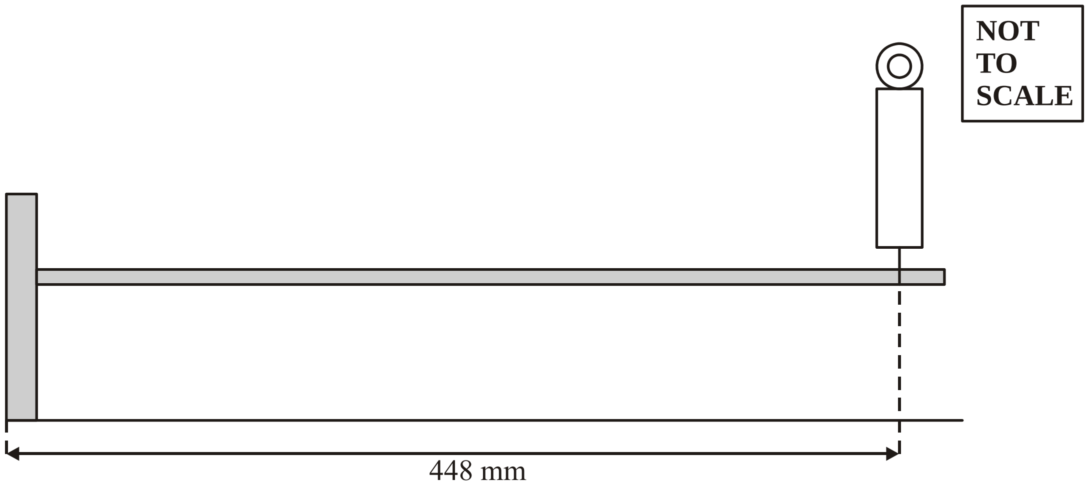
....

....

....

(2)

(ii) Another method to find the weight of the retort stand is shown below. The retort stand is balanced on its base and supported horizontally by a Newtonmeter. The meter is calibrated in 0.1 N divisions and can read up to 10 N.



Calculate the value you would expect the Newtonmeter to read.

....

....

....

....

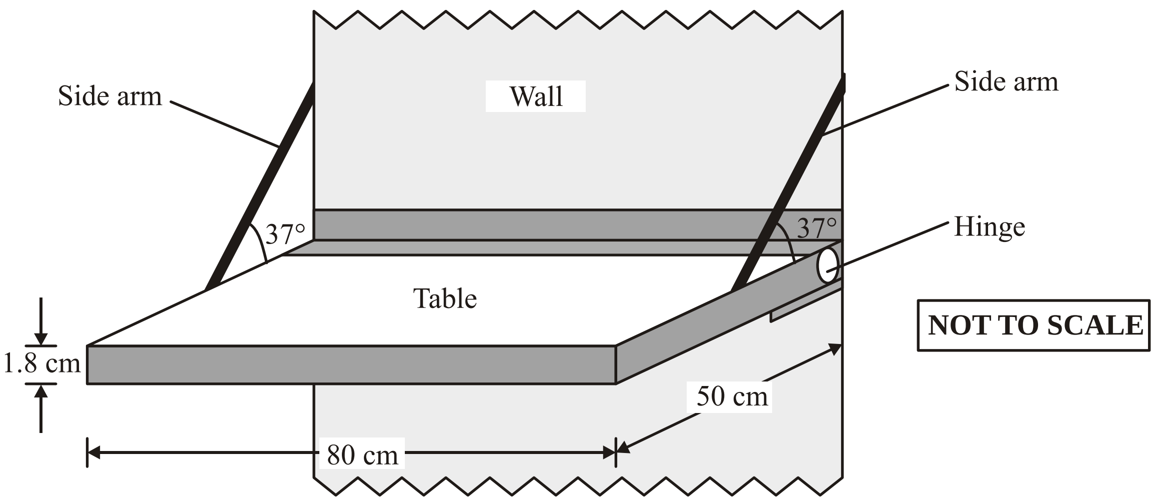
(2)

Hence determine the normal contact force acting on the base of the retort stand.

....

(1)
(Total 7 marks)

175. (a) The diagram below shows a drop-down table attached to a wall. The table is supported horizontally by two side arms attached to the mid-points of the sides of the table.



The table surface is 80 cm long, 50 cm deep and 1.8 cm thick. It is made from wood of density 0.70 g cm^{-3}. Show that its weight is about 50 N.

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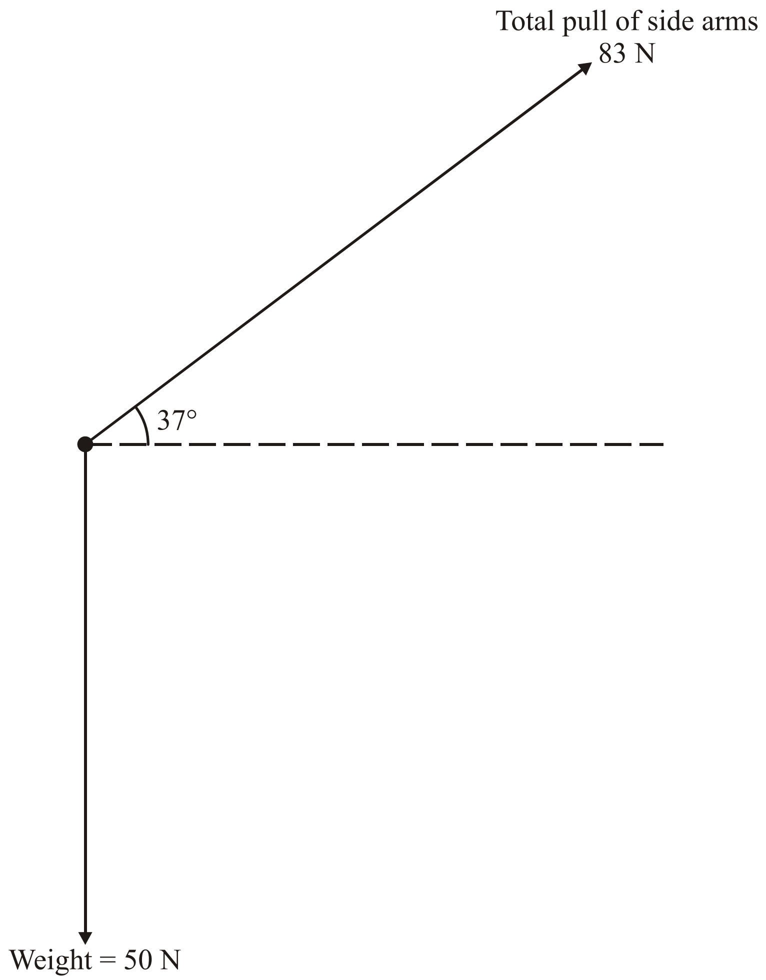
(3)

(b) The free-body force diagram below shows two of the three forces acting on the table top.



(i) Calculate the horizontal and vertical components of the 83 N force.

Horizontal component: ....

....

Vertical component: ....

....

(2)

(ii) Add appropriately labelled arrows to the free-body force diagram to show these components.

(1)

(iii) Hence find the magnitude of the horizontal force that the hinge applies to the table top and state its direction.

....

....

(1)
(Total 7 marks)

176. (a) A car of mass m is travelling in a straight line along a horizontal road at a speed u when the driver applies the brakes. They exert a constant force F on the car to bring the car to rest after a distance d.

(i) Write down expressions for the initial kinetic energy of the car and the work done by the brakes in bringing the car to rest.

Kinetic energy ....

Work done ....

(1)

(ii) Show that the base units for your expressions for kinetic energy and work done are the same.

....

....

....

....

....

(2)

(b) A car is travelling at 13.4 m s^{-1}. The driver applies the brakes to decelerate the car at 6.5 m s^{-2}. Show that the car travels about 14 m before coming to rest.

....

....

....

....

....

....

(3)

(c) On another occasion, the same car is travelling at twice the speed. The driver again applies the brakes and the car decelerates at 6.5 m s^{-2}. The car travels just over 55 m before coming to rest. Explain why the braking distance has more than doubled. You may be awarded a mark for the clarity of your answer.

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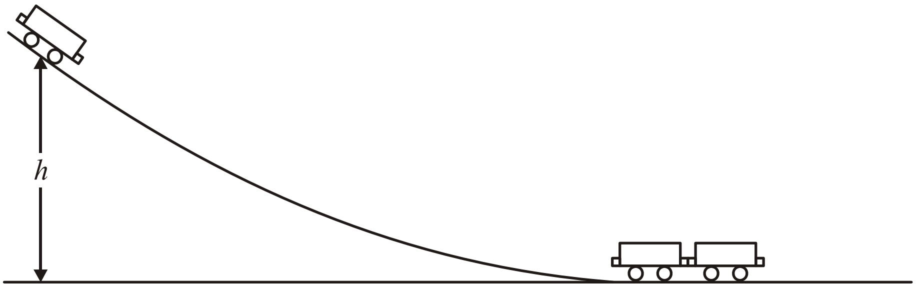
(4)
(Total 10 marks)

177. (a) A toy truck of mass 80 g is released from a height *h* and rolls down a slope as shown below.



What would the height *h* have to be for the truck to reach a speed of 4.0 m s^{-1} at the bottom of the slope? You may assume that any friction at its axles is negligible.

....

....

....

....

....

....

Height = ...

(3)

(b) On reaching the bottom, it joins magnetically to two stationary trucks, identical to the first, and the trucks all move off together.

(i) State the law of conservation of linear momentum.

....

....

....

....

....

(2)

(ii) Use this law to calculate the speed of the trucks immediately after the collision.

....

....

....

....

....

Speed = ...

(2)

(c) One of the stationary trucks has a total frictional force of 0.12 N at its axles. How much time does it take for the three trucks to stop moving if this is the only frictional force acting?

....

....

....

....

....

....

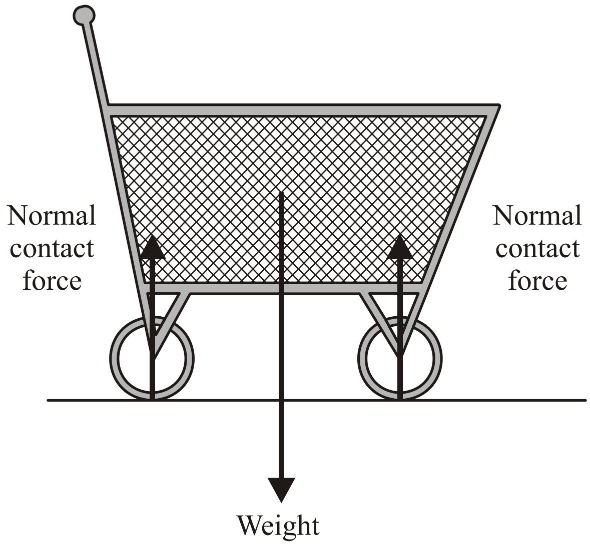
....

....

Time = ...

(3)
(Total 10 marks)

178. (a) The diagram below shows the forces acting on a shopping trolley at rest.



(i) State Newton's first law of motion.

....

....

....

....

(1)

(ii) In everyday situations, it does seem that a force is needed to keep an object, for example the shopping trolley, moving at constant speed in a straight line. Explain why.

....

....

....

(1)

(iii) The vertical forces acting on the trolley are in equilibrium. Explain what **equilibrium** means.

....

....

....

(1)

(b) (i) The weight of the trolley is one of a Newton's third law force pair. Identify what the other force in this pair acts upon and what type of force it is.

....

....

....

....

(2)

(ii) Give two reasons why the two normal contact forces do **not** form a Newton's third law pair.

1 ....

....

2 ....

....

(2)
(Total 7 marks)

179. (a) Name two sources of background radiation.

1 ....

2 ....

(2)

(b) (i) A student is doing an experiment using radioactive material. She uses a counter to record the total count. Her teacher points out that she has forgotten to measure the background count rate. Describe the procedure the student should follow. You must mention any additional equipment she might need to use.

....

....

....

....

....

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....

(4)

(ii) Why might it have been unnecessary to measure the background count rate?

....

....

(1)
(Total 7 marks)

180. (a) (i) Carbon has two important isotopes, ${}^{12}_{6}C$ and ${}^{14}_{6}C$. Carbon-14 is unstable but carbon-12 is stable.

What is meant by saying that carbon-12 is stable?

....

....

(1)

(ii) Carbon-14 is formed in the atmosphere when a particle ${}^{1}_{0}X$ collides with an atom of nitrogen.

Complete the equation to show the missing nucleon and proton numbers:

$${}^{14}_{7}N + {}^{1}_{0}X \rightarrow {}^{14}_{6}C + {}^{\cdots\cdots}_{\cdots\cdots}Y$$

(1)

(iii) Identify the particles X and Y.

X = ... Y = ...

(2)

(b) (i) The half-life of carbon-14 is 5568 years. Show that the decay constant of carbon-14 is about 4×10^{-12} s^{-1}. (You may assume 1 year = 3.2×10^{7} s.)

....

....

....

....

(2)

(ii) A sample of carbon-14 has an activity of 16 counts min^{-1}. Calculate the number of nuclei of carbon-14 in this sample.

....

....

....

....

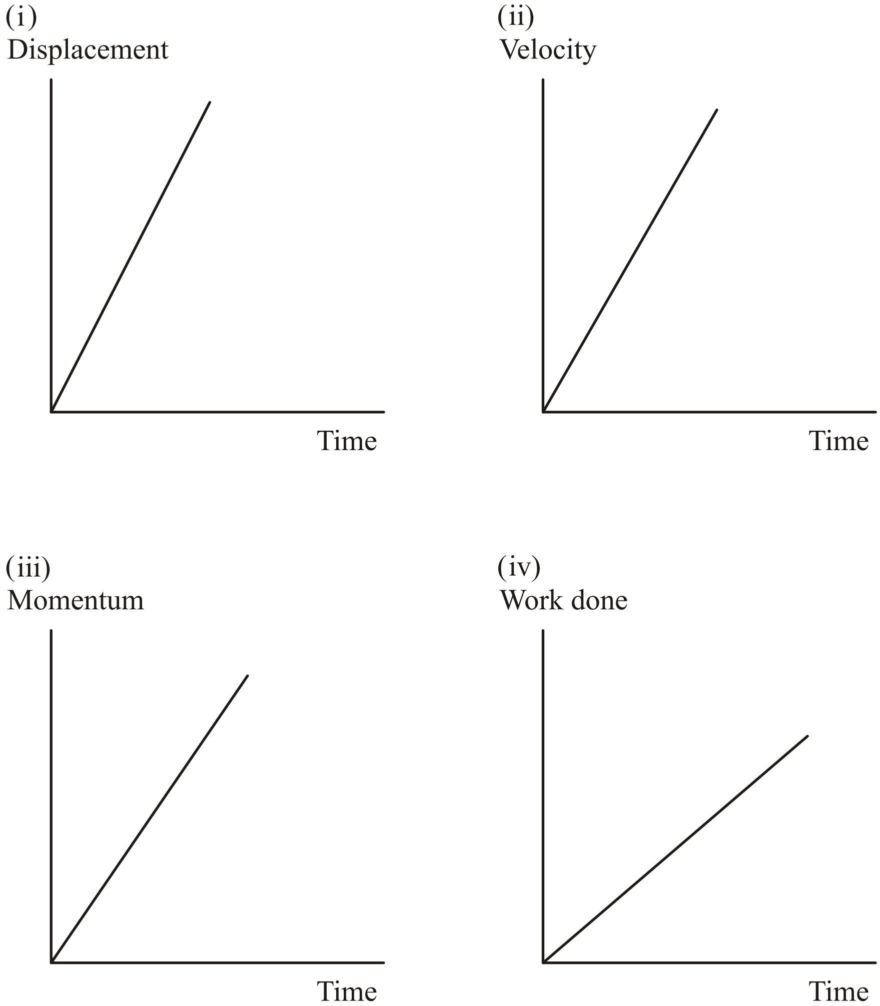
....

Number of nuclei = ...

(2)

(Total 8 marks)

181. What physical quantity does the gradient of each of the following graphs represent? Give your answers in the table below the graphs.



Graph	Physical quantity represented by the gradient
(i)	
(ii)	
(iii)	
(iv)	

(Total 4 marks)

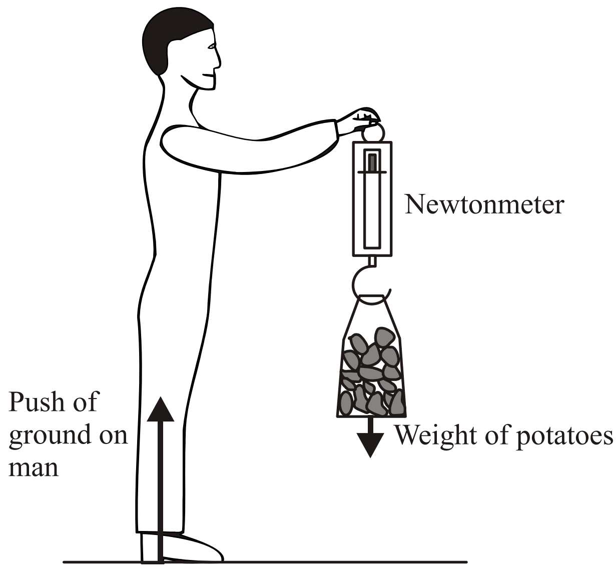
182. (a) Complete the following statement of Newton's third law of motion.

"If body A exerts a force on body B, then body B ....

...."

(2)

(b) A man checks the weight of a bag of potatoes with a newtonmeter. Two of the forces acting are shown in the diagram.



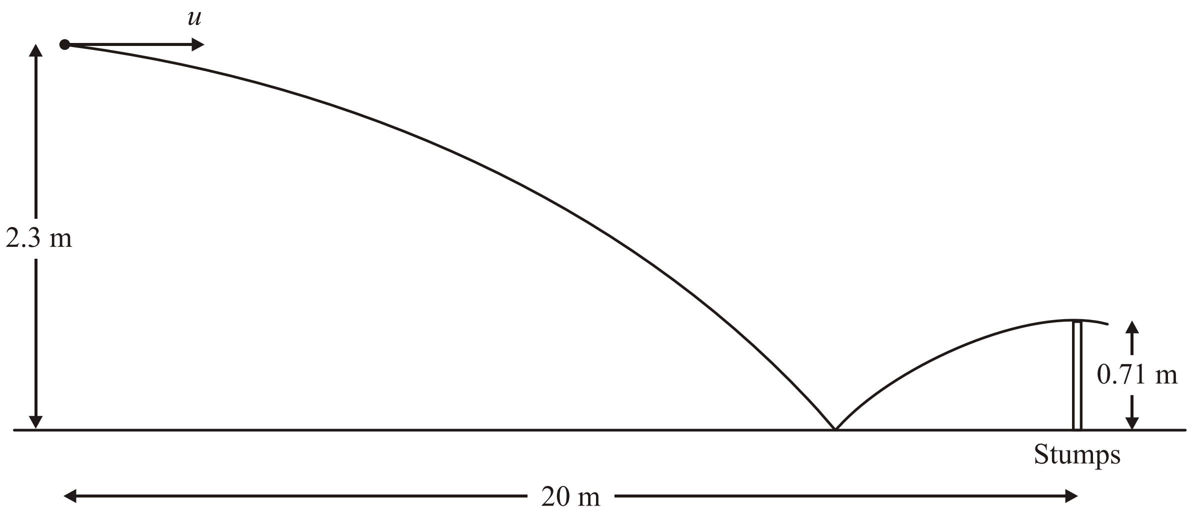
The table below gives these forces. For each force there is a corresponding force, the 'Newton's third law pair force'. In each case state

- the body that the Newton's third law pair force acts upon
- the type of force (one has been done for you)
- the direction of the Newton's third law pair force.

Force	Body the Newton's third law pair force acts upon	Type of force	Direction of the Newton's third law pair force
Weight of potatoes			
Push of ground on man		Normal contact force	

(3)
(Total 5 marks)

183. A cricketer bowls a ball from a height of 2.3 m. The ball leaves the hand horizontally with a velocity *u*. After bouncing once, it passes just over the stumps at the top of its bounce. The stumps are 0.71 m high and are situated 20 m from where the bowler releases the ball.



(a) Show that from the moment it is released, the ball takes about 0.7 s to fall 2.3 m.

....

....

....

....

....

....

(2)

(b) How long does it take the ball to rise 0.71 m after bouncing?

....

....

....

....

....

....

Time = ……………………………………

(3)

(c) Use your answers to parts (a) and (b) to calculate the initial horizontal velocity u of the ball. You may assume that the horizontal velocity has remained constant.

....

....

....

....

Velocity = ……………………………………

(2)

(d) In reality the horizontal velocity would not be constant. State one reason why.

....

....

(1)
(Total 8 marks)

184. (a) State Newton's second law of motion in terms of momentum.

....

....

....

....

(2)

(b) A wind blows steadily against a tree. The area of the tree perpendicular to the direction of the wind is 10 m^2 and the velocity of the wind is 20 m s^{-1}.

(i) Show that the mass of air hitting the tree each second is about 250 kg. (Density of air is 1.23 kg m^{-3}.)

....

....

....

....

(2)

(ii) Calculate the momentum of this mass of air when it is moving at 20 m s^{-1}.

....

....

Momentum = ……………………………………

(iii) Assuming that all the air is stopped by the tree, state the magnitude of the force exerted on the tree by the wind.

....

Force = ...

(2)
(Total 6 marks)

185. (a) State the principle of moments.

....

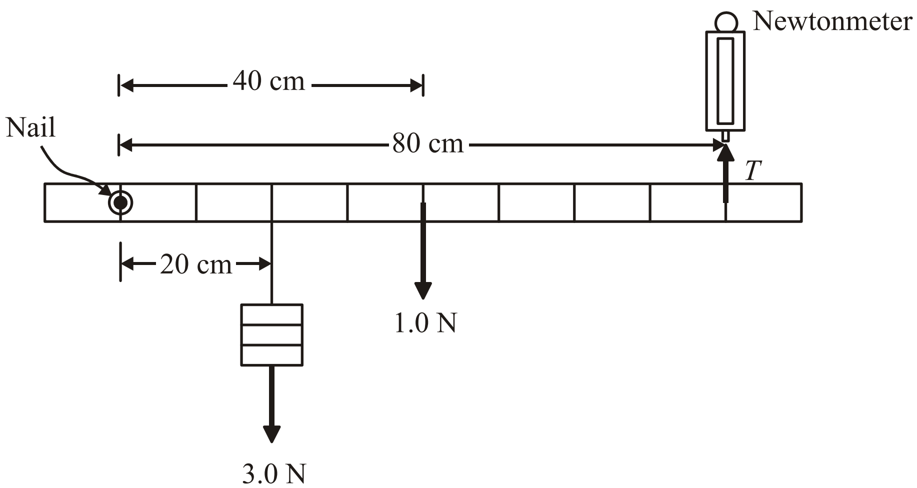
....

....

....

(2)

(b) A metre rule of weight 1.0 N is pivoted on a nail passing through a hole drilled at the 10 cm mark. A weight of 3.0 N is suspended at the 30 cm mark. A newtonmeter supports the rule at the 90 cm mark so that it is horizontal.



(i) Use the principle of moments to calculate the magnitude of force *T* needed to keep the rule horizontal.

....

....

....

Force *T* = ...

(2)

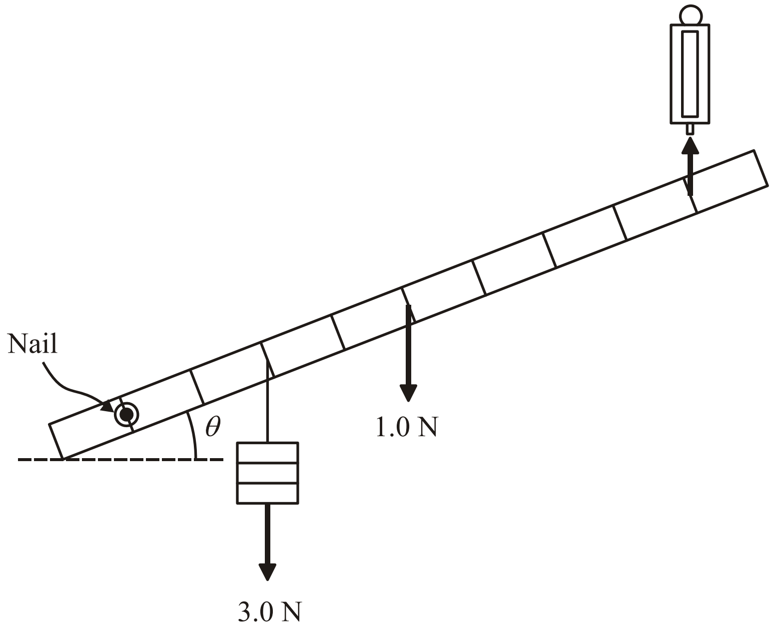
(ii) The nail exerts a force on the rule. Determine the size and direction of this force.

....

....

(2)

(iii) The newtonmeter is raised until the rule makes an angle θ with the horizontal.



Without doing any further calculations, compare the magnitude of the force provided by the newtonmeter in this new position with the force T when the rule was horizontal. Explain your answer.

....

....

....

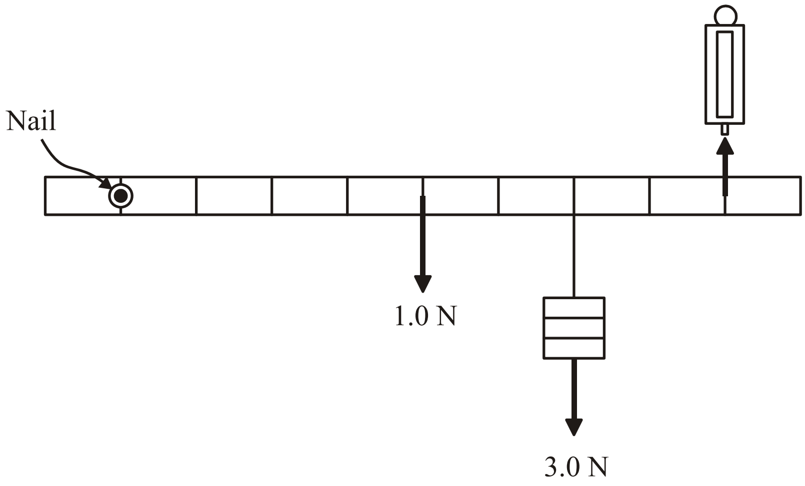
....

....

....

(2)

(iv) With the rule horizontal, the 3.0N weight is placed in the new position shown.



Without doing any further calculations, explain what happens to the force exerted by the newtonmeter. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

....

(4)
(Total 12 marks)

186. A weightlifter raised a bar of mass of 110 kg through a height of 2.22 m. The bar was then dropped and fell freely to the floor.

(i) Show that the work done in raising the bar was about 2400 J.

....

....

....

(2)

(ii) It took 3.0 s to raise the bar. Calculate the average power used.

....

....

....

Power = ...

(2)

(iii) State the principle of conservation of energy.

....

....

....

(2)

(iv) Describe how the principle of conservation of energy applies to

(1) lifting the bar,

(2) the bar **falling** to the floor. Do not include the impact with the floor.

(1) ....

....

....

(2) ....

....

....

....

(3)

(v) Calculate the speed of the bar at the instant it reaches the floor.

....

....

....

....

Speed = ...

(3)
(Total 12 marks)

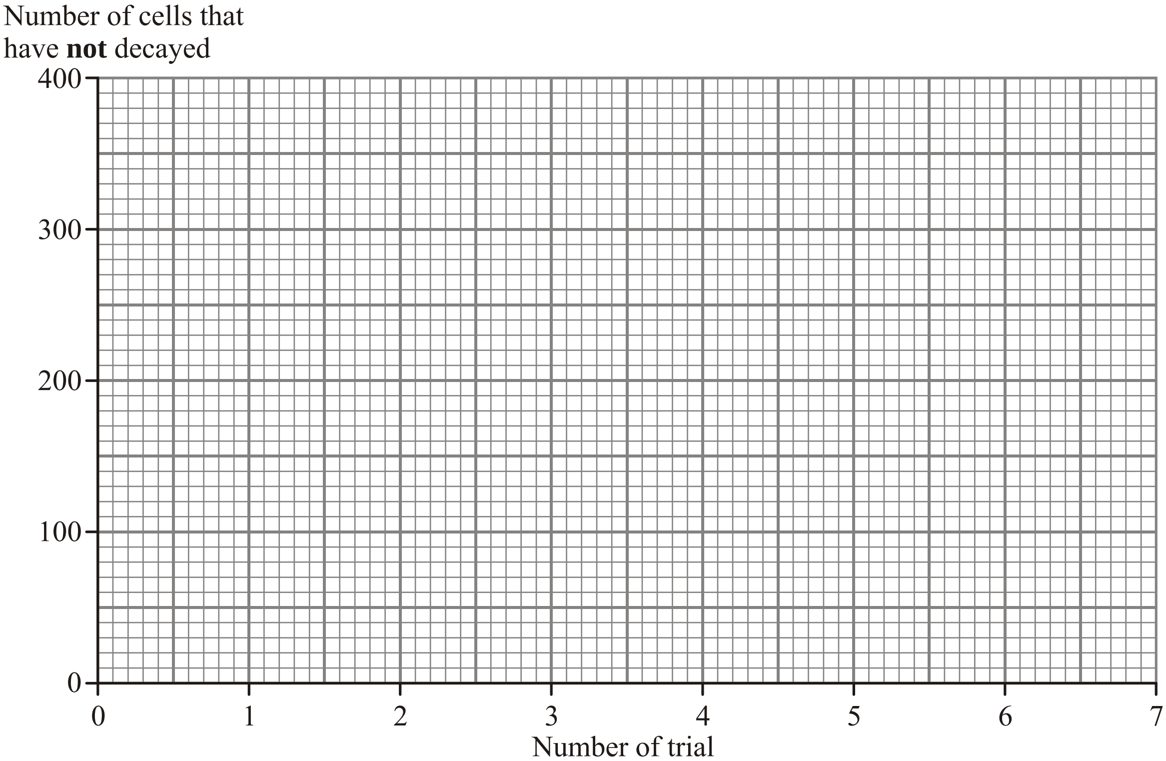
187. A student uses a computer program to model radioactive decay. The program draws a grid of 300 cells on the computer screen.

A letter can be generated at random in each cell. If a vowel (a, e, i, o, u) is generated, the cell is considered to have 'decayed' and is not available for the next trial of the decay process.

The table shows the number of the trial along with the number of cells which have **not** decayed.

Number of trial	Number of cells that have **not** decayed
0	300
1	242
2	196
3	158
4	128
5	103
6	83

(i) On the grid below, plot these data and draw the line of best fit through your points.



(2)

(ii) What is meant by the term **half-life** of a radioactive nuclide?

....

....

....

(iii) Use your graph to find the 'half-life' in terms of the number of trials of this computer model of radioactive decay.

....

....

....

....

....

....

Half-life = ...trials

(3)

(iv) In what way is this model **similar** to radioactive decay?

....

....

....

(1)

(v) In what way is this model **different** from radioactive decay?

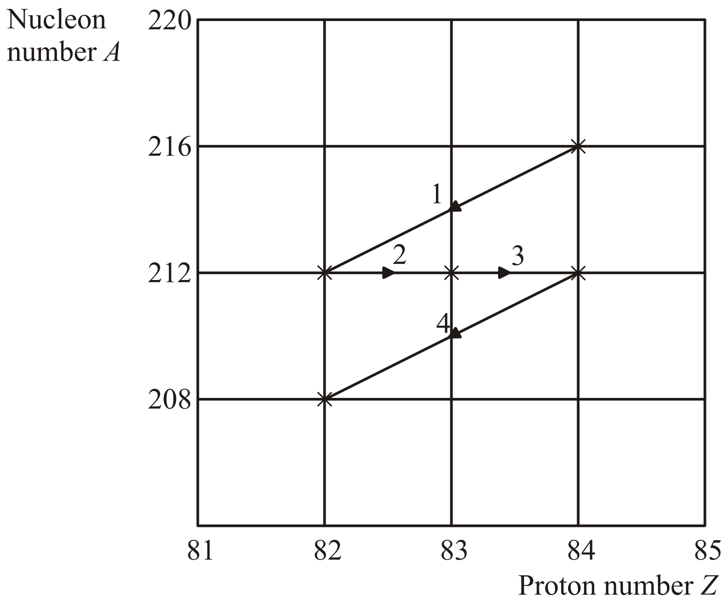
....

....

....

(1)
(Total 7 marks)

188. The final four stages of the naturally occurring thorium-232 decay series are shown. The series ends with a stable isotope of lead, $^{208}_{82}Pb$.



(i) What are isotopes?

....

....

....

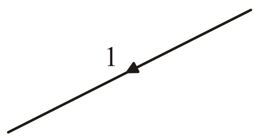
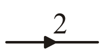
(2)

(ii) Write down the symbol for the unstable isotope of lead which is part of the series shown.

....

(1)

(iii) Complete the table to show the missing information.

Decay path	Change of *A*	Change of *Z*	Type of decay
			
			

(3)
(Total 6 marks)