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:

$v = u + at$

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

$v^2 = + 2ax$

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	$\Delta W = \frac{1}{2}F\Delta x$ (provided Hooke's law holds)

Oscillations and waves

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

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

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

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

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

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

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

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

Quantum phenomena

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

Thermal physics

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

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

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 $= kA\frac{\Delta T}{\Delta x}$

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

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 $= \frac{\mu_0 I}{2\pi r}$

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

Flux $\Phi = BA$

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

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

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

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

Mathematics

$\sin(90° - \theta) = \cos\theta$

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

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

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

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

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

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

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

coulomb force length mole newton temperature interval

(2)

Define the volt.

....

....

(2)

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

....

....

....

(3)

Explain the difference between scalar and vector quantities.

....

....

....

(2)

Is potential difference a scalar or vector quantity?

....

(1)
(Total 10 marks)

3. Explain how a body moving at constant speed can be accelerating.

....

....

....

....

....

(3)

The Moon moves in a circular orbit around the Earth. The Earth provides the force which causes the Moon to accelerate. In what direction does this force act?

....

(1)

There is a force which forms a Newton's third law pair with this force on the Moon.
On what body does this force act and in what direction?

....

....

(2)
(Total 6 marks)

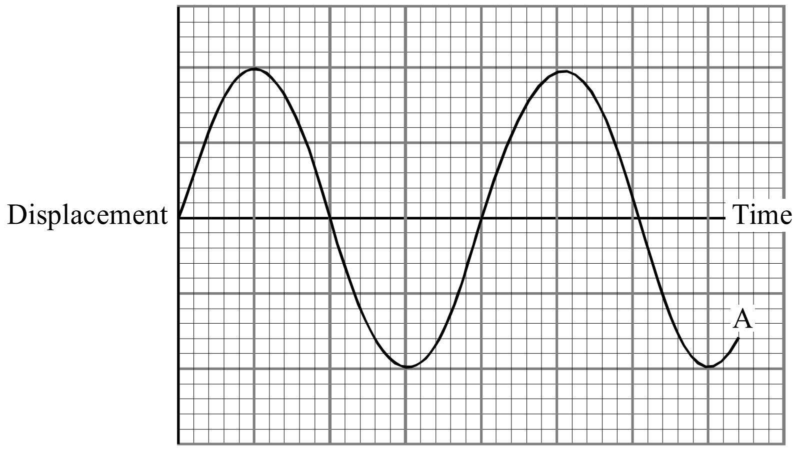
4. Define simple harmonic motion.

....

....

(2)

The curve labelled A shows how the displacement of a body executing simple harmonic motion varies with time.



Add the following to the graph:

(i) A curve labelled B showing how the acceleration of the same body varies with time over the same time period.

(ii) A curve labelled C showing how the velocity of the same body varies with time over the same time period.

(4)

Which pair of curves illustrates the definition of simple harmonic motion?

....

Explain your answer.

....

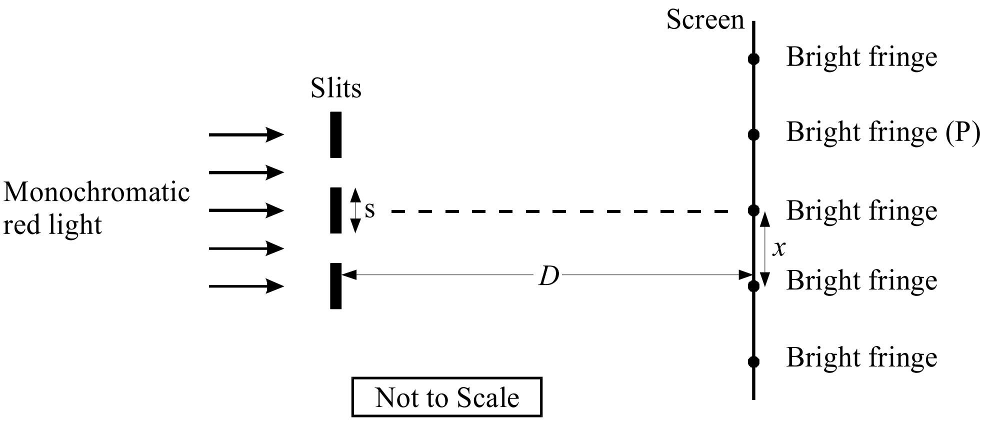
....

....

....

(3)
(Total 9 marks)

5. The diagram shows an arrangement to produce interference fringes by Young's two slits method.



State suitable values for *s* and *D* if clearly observable fringes are to be produced.

s ....

D ....

Explain how the bright fringe labelled P is formed.

....

....

....

....

(4)

What would be the effect on the fringe width *x* of

(i) increasing the slit separation *s*,

....

(ii) illuminating the slits with blue light?

....

(2)

To obtain an interference pattern the light from the two slits must be coherent. What is meant by the term *coherent?*

....

....

(1)
(Total 7 marks)

6. (a) The following equation describes the release of electrons from a metal surface illuminated by electromagnetic radiation.

$$hf = k.e._{max} + \phi$$

Explain briefly what you understand by each of the terms in the equation.

hf ....

....

$k.e._{max}$ ....

....

ϕ ....

....

(3)

(b) Calculate the momentum p of an electron travelling in a vacuum at 5% of the speed of light.

....

....

....

p = ...

(3)

What is the de Broglie wavelength of electrons travelling at this speed?

....

....

....

λ = ...

(2)

Why are electrons of this wavelength useful for studying the structure of molecules?

....

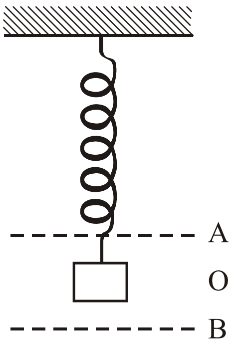
....

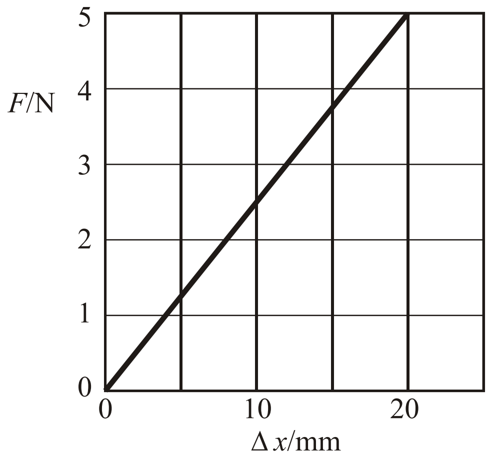
....

(2)
(Total 10 marks)

-

7. The diagram below shows a mass of 0.51 kg suspended at the lower end of a spring. The graph shows how the tension, F, in the spring varies with the extension, Δx, of the spring.





Use the graph to find a value for the spring constant k.

....

....

k = ...

(2)

The mass, originally at point O, is set into small vertical oscillations between the points A and B. Choose A, B or O to complete the following sentences.

The speed of the mass is a maximum when the mass is at ....

The velocity and acceleration are both in the same direction when the

mass is moving from ...... to...... .

(2)

Calculate the period of oscillation T of the mass.

....

....

Period of oscillation T = ...

(2)

What energy transformations take place while the mass moves from B to O?

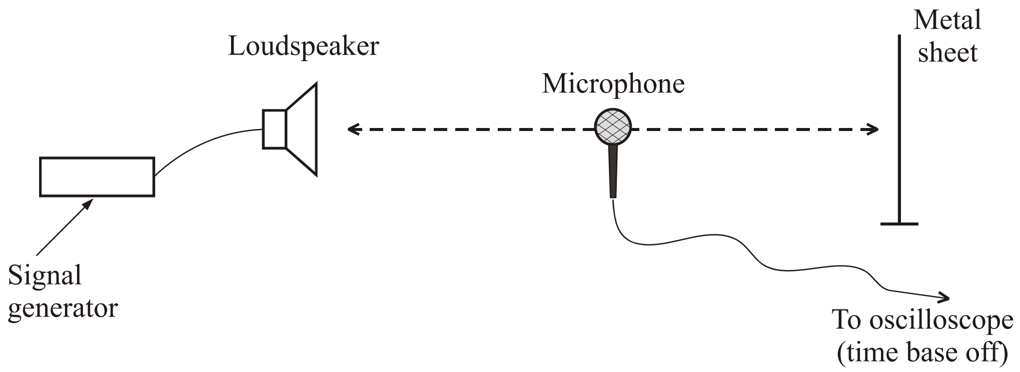
....

....

....

(2)
(Total 8 marks)

8. The diagram below shows a loudspeaker which sends a note of constant frequency towards a vertical metal sheet. As the microphone is moved between the loudspeaker and the metal sheet the amplitude of the vertical trace on the oscilloscope continually changes several times between maximum and minimum values. This shows that a stationary wave has been set up in the space between the loudspeaker and the metal sheet.



How has the stationary wave been produced?

....

....

....

(2)

State how the stationary wave pattern changes when the frequency of the signal generator is doubled. Explain your answer.

....

....

....

(2)

What measurements would you take, and how would you use them, to calculate the speed of sound in air?

....

....

....

....

....

(4)

Suggest why the minima detected near the sheet are much smaller than those detected near the loudspeaker.

....

....

....

(2)
(Total 10 marks)

9. A 60 W light bulb converts electrical energy to visible light with an efficiency of 8%. Calculate the visible light intensity 2 m away from the light bulb.

....

....

....

Intensity = ...

(3)

The average energy of the photons emitted by the light bulb in the visible region is 2 eV. Calculate the number of these photons received per square metre per second at this distance from the light bulb.

....

....

....

Number of photons = ...m^{-2} s^{-1}

(2)
(Total 5 marks)

10. (a) Describe briefly how you would demonstrate in a school laboratory that different elements can be identified by means of their optical spectra

....

....

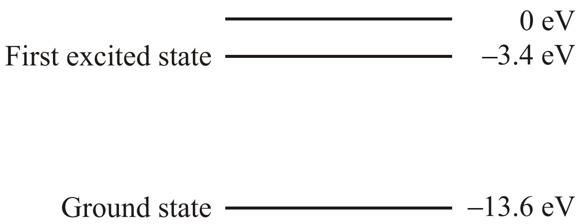
....

....

....

(3)

(b) The diagram below is a simplified energy level diagram for atomic hydrogen.



A free electron with kinetic energy 12 eV collides with an atom of hydrogen and causes is to be raised to its first excited state.

Calculate the kinetic energy of the free electron (in eV) after the collision.

....

....

Kinetic energy = ...

Calculate the wavelength of the photon emitted when the atom returns to its ground state.

....

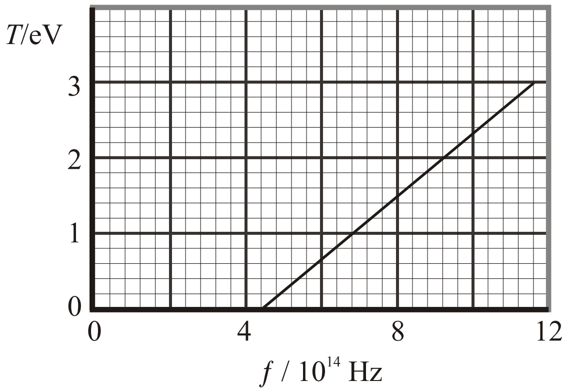
....

....

Wavelength = ...

(4)
(Total 7 marks)

11. The graph shows how the maximum kinetic energy T of photoelectrons emitted from the surface of sodium metal varies with the frequency f of the incident radiation.



Why are no photoelectrons emitted at frequencies below 4.4×10^{14} Hz?

....

....

(1)

Calculate the work function Ø of sodium in eV.

....

....

....

Work function = ...

(3)

Explain how the graph supports the photoelectric equation $hf = T + Ø$

....

....

....

(2)

How could the graph be used to find a value for the Planck constant?

....

....

(1)

Add a line to the graph to show the maximum kinetic energy of the photoelectrons emitted from a metal which has a greater work function than sodium.

(2)
(Total 9 marks)

12. A simple pendulum has a period of 2.0 s and oscillates with an amplitude of 10 cm.
What is the frequency of the oscillations?

....

Frequency = ...

(1)

At what point of the swing is the speed of the pendulum bob a maximum?

....

Calculate this maximum speed.

....

....

....

Maximum speed = ...

(3)

At what points of the swing is the acceleration of the pendulum bob a maximum?

....

Calculate this acceleration.

....

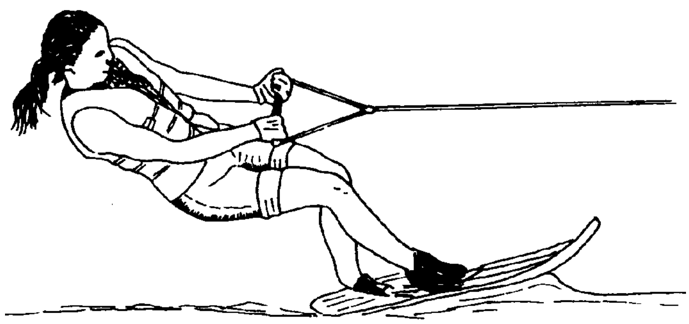
....

....

Maximum acceleration = ...

(3)
(Total 7 marks)

13. 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)

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

....

....

....

....

(2)

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

....

....

....

....

....

(1)

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

....

....

(2)

15. A satellite orbits the Earth once every 120 minutes. Calculate the satellite's angular speed.

....

....

....

....

angular speed = ...

(2)

Draw a free-body force diagram for the satellite.

(1)

The satellite is in a state of free fall. What is meant by the term *free fall?* How can the height of the satellite stay constant if the satellite is in free fall?

....

....

....

....

....

(3)
(Total 6 marks)

16. A student was studying the motion of a simple pendulum the time period of which was given by $T = 2\pi\ (l/g)^{½}$.

He measured T for values of l given by

l/m = 0.10, 0.40, 0.70, 0.70, 1.00

and plotted a graph of T against $\sqrt{l}$ in order to deduce a value for g, the free-fall acceleration. Explain why these values for l are poorly chosen.

....

....

....

(1)

How would the student obtain a value of g from the gradient of the graph?

....

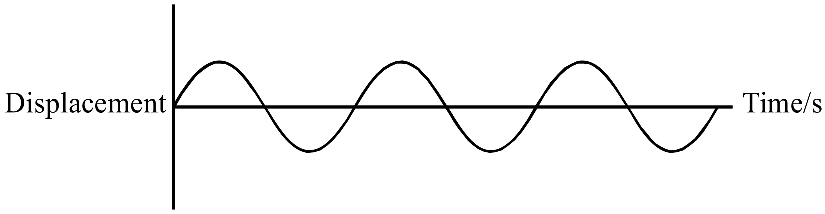
....

....

....

(2)

The graph below shows three cycles of oscillation for an undamped pendulum of length 1.00 m.

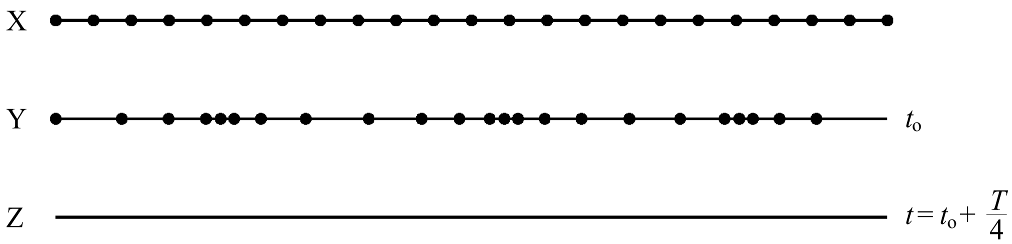


Add magnitudes to the time axis and on the same axes show three cycles for the same pendulum when its motion is lightly air damped.

(4)
(Total 7 marks)

17. Sound travels by means of longitudinal waves in air and solids. A progressive sound wave of wavelength λ and frequency f passes through a solid from left to right. The diagram × below represents the equilibrium position of a line of atoms in the solid.

Diagram Y represents the positions of the same atoms at a time $t = t_0$.



Explain why the wave is longitudinal.

....

....

(1)

On diagram Y label

(i) two compressions (C),

(ii) two rare factions (R),

(iii) the wavelength λ of the wave.

(3)

The period of the wave is T.   Give a relationship between λ, T and the speed of the wave in the solid.

....

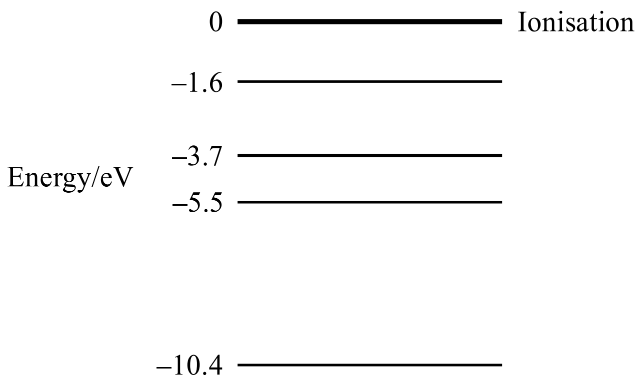
....

(1)

Along the line Z mark in the positions of the two compressions and the two rare factions at a time t given by $t = t_0 + T/4$.

(2)
(Total 7 marks)

18. The diagram shows some of the outer energy levels of the mercury atom.



Calculate the ionisation energy in joules for an electron in the -10.4 eV level.

....

....

Ionisation energy = ...

(2)

An electron has been excited to the -1.6 eV energy level.   Show on the diagram all the possible ways it can return to the -10.4 eV level.

(3)

Which change in energy levels will give rise to a yellowish line (λ = 600 nm) in the mercury spectrum?

....

....

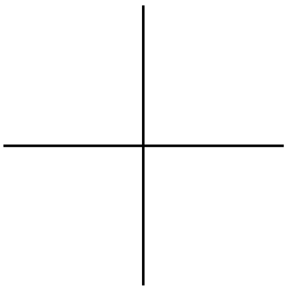
....

....

....

(4)
(Total 9 marks)

19. A body oscillates with simple harmonic motion. On the axes below sketch a graph to show how the acceleration of the body varies with its displacement.



(2)

How could the graph be used to determine *T*, the period of oscillation of the body?

....

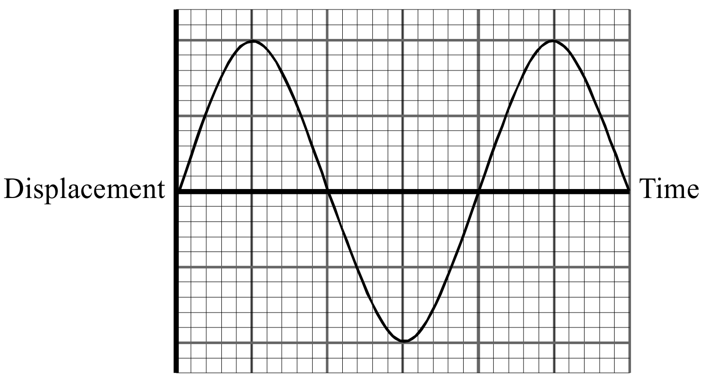
....

....

....

(2)

A displacement-time graph from simple harmonic motion is drawn below.



The movement of tides can be regarded as simple harmonic, with a period of approximately 12 hours.

On a uniformly sloping beach, the distance along the sand between the high water mark and the low water mark is 50 m. A family builds a sand castle 10m below the high water mark while the tide is on its way out. Low tide is at 2.00 p.m.

On the graph

(i) label points L and H, showing the displacements at low tide and the next high tide,

(ii) draw a line parallel to the time axis showing the location of the sand castle,

(iii) add the times of low and high tide.

(3)

Calculate the time at which the rising tide reaches the sand castle.

....

....

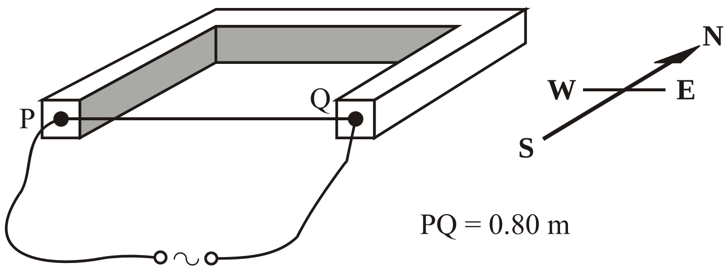
....

....

Time ....

(3)
(Total 10 marks)

20. A thin copper wire PQ, 0.80 m long, is fixed at its ends. It is connected as shown to a variable frequency alternating current supply and set perpendicular to the Earth's magnetic field.



(a) When there is a current from P to Q the wire experiences a force. Draw a diagram showing the resultant magnetic field lines near the wire as viewed from the West. (You should represent the wire PQ as ⊗.)

Explain what is meant by a neutral point.

(4)

(b) The wire PQ experiences a maximum force of 0.10×10^{-3} N at a place where the Earth's magnetic field is 50×10^{-6} T. Calculate the maximum value of the current and its r.m.s. value.

(4)

(c) A strong U-shaped (horseshoe) magnet is now placed so that the mid-point of the wire PQ lies between its poles. The frequency of the a.c. supply is varied from a low value up to 50 Hz, keeping the current constant in amplitude. The wire PQ is seen to vibrate slightly at all frequencies and to vibrate violently at 40 Hz.

(i) Explain carefully why the wire vibrates and why the amplitude of the vibrations varies as the frequency changes.

(3)

(ii) Calculate the speed of transverse mechanical waves along the wire PQ.

(3)

(iii) Describe the effect on the wire of gradually increasing the frequency of the a.c. supply up to 150 Hz.

(2)
(Total 16 marks)

21. A stone on a string is whirled in a vertical circle of radius 80 cm at a constant angular speed of 16 radians per second.

Calculate the speed of the stone along its circular path.

....

....

....

Speed = ...

(2)

Calculate its centripetal acceleration when the string is horizontal.

....

....

....

Acceleration = ...

(2)

Calculate the resultant acceleration of the stone at the same point.

....

....

....

Resultant acceleration = ...

(3)

Explain why the string is most likely to break when the stone is nearest the ground.

....

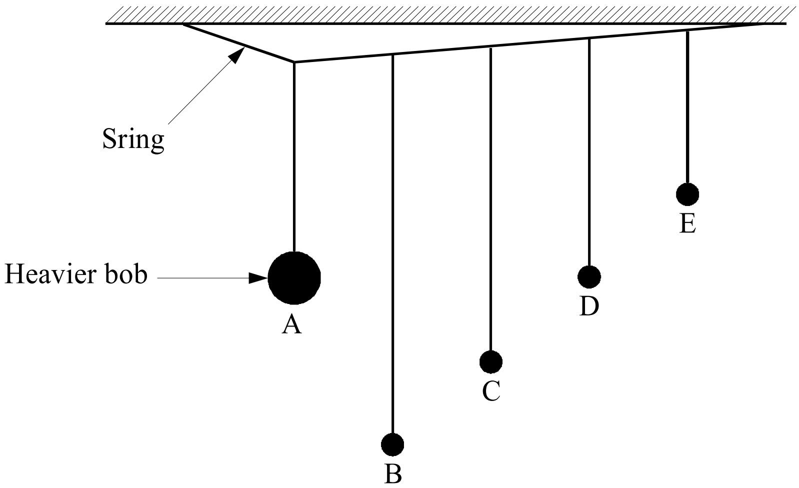
....

....

....

(2)
(Total 9 marks)

22. The diagram shows five pendulums, all suspended from the same string. Pendulum A is displaced by a few centimetres and then released so that it oscillates in a direction perpendicular to the plane of the paper.



By completing the table below, describe the motion of the pendulums over the next few minutes.

	Frequency compared to frequency of A	**Amplitude**
A	Constant	
B		
C		
D		
E		

(5)

State what is meant by the term *resonance*. How is resonance demonstrated by this experiment?

....

....

....

....

....

(3)
(Total 8 marks)

23. (a) A radio source of frequency 95 MHz is set up in front of a metal plate. The distance from the plate is adjusted until a standing wave is produced in the space between them. The distance between any node and an adjacent antinode is found to be 0.8 m.

Calculate the wavelength of the wave.

....

....

Wavelength = ...

Calculate the speed of the radio wave.

....

....

Speed = ...

What does this suggest about the nature of radiowaves?

....

....

(5)

(b) The minimum intensity that can be detected by a given radio receiver is 2.2×10^{-5} W m^{-2}.

Calculate the maximum distance that the receiver can be from a 10 kW transmitter so that it is *just* able to detect the signal.

....

....

....

....

Maximum distance = ...

(3)
(Total 8 marks)

24. Explain what is meant by the term *wave-particle duality.*

....

....

....

....

....

....

(3)

Calculate the de Broglie wavelength of a snooker ball of mass 0.06 kg travelling at a speed of 2 m s^{-1}

....

....

Wavelength = ...

(2)

Comment on your answer.

....

....

(1)
(Total 6 marks)

25. Read the passage carefully and then answer the questions at the end.

Atmospheric Electricity
Lightning was probably the cause of the first fire observed by humans and today it still leads to

danger and costly damage. It is now known that most lightning strokes bring negative charge to ground and that thunderstorm electric fields cause positive charges to be released from pointed objects near the ground.

Worldwide thunderstorm activity is responsible for maintaining a small negative charge on the surface of the Earth. An equal quantity of positive charge in the atmosphere leads to a typical potential difference of 300 kV between the Earth's surface and a conducting ionospheric layer at about 60 km. The resulting, fair-weather, electric field decreases with height because of the increasing conductivity of the air. Across the lowest metre there is a voltage difference of about 100 V.

Early estimates of global activity have still to be improved upon by satellite surveillance. The 2000 thunderstorms estimated to be active at any one time each produce an average current of 1 A bringing negative charge to ground. The resulting fair-weather field thus causes a leakage current of around 2000 A in the reverse direction, so the charge flows are in equilibrium. The charge on the Earth and the fair-weather field are too small to cause us problems in everyday life. With an average current per storm of only 1 A, there is no scope for tapping into thunderstorms as an energy source.

The long range sensing of lightning depends on detecting the radio waves which lightning produces. Different frequency bands are chosen for different distances. The very high frequency (VHF) band at 30-300 MHz can only be used up to about 100 km because the Earth's curvature defines a radio horizon. Greater ranges, of several thousand kilometres, are achieved in the very low frequency (VLF) band at frequencies of 10-16 kHz. These signals bounce with little attenuation within the radio duct formed between the Earth and ionospheric layers at heights of 50-70 km.

A further system senses radio waves in the extremely low frequency (ELF) band around 1 kHz. ELF waves are diffracted in the region between the Earth's surface and the ionosphere and propagate up to several hundred kilometres. Horizontally polarised ELF waves do not propagate to any significant extent, hence this system avoids the polarisation error of conventional direction-finding systems.

(a) Explain the meaning of the following terms as used in the passage:

(i) to ground (paragraph 1),

(ii) leakage current (paragraph 3),

(iii) horizontally polarised (paragraph 5).

(5)

(b) What is the electric field strength at the Earth's surface?

Calculate the average electric field strength between the Earth's surface and the conducting ionospheric layer.

Sketch a graph to show the variation of the Earth's fair-weather electric field with distance above the Earth's surface to a height of 60 km.

(7)

(c) The power associated with a lightning stroke is extremely large. Explain why *there is no scope for tapping into thunderstorms as an energy source* (paragraph 3).

(3)

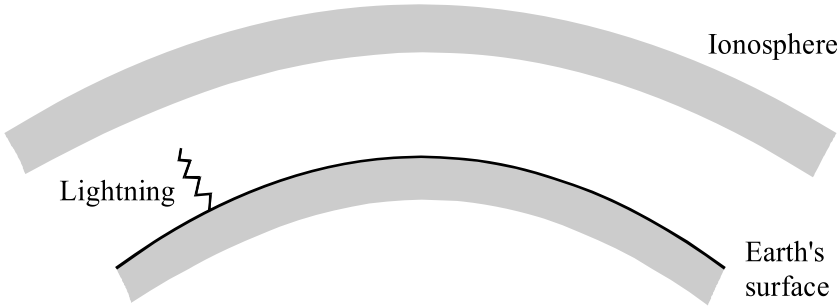
(d) Show that a total charge of 5×10^5 C spread uniformly over the Earth will produce an electric field of just over 100 V m^{-1} at the Earth's surface. Take the radius of the Earth to be 6400 km.

Draw a diagram to show the direction of this fair-weather field.

Suggest a problem which might arise if the charge on the Earth were very much larger.

(6)

(e) The diagram shows a lightning stroke close to the surface of the Earth.



Copy the diagram and add rays to it to illustrate the propagation of radio waves in the VLF band.

On a second copy of the diagram add wavefronts to illustrate the propagation of radio waves in the ELF band.

Explain with the aid of a diagram the meaning of the term *radio horizon* used in paragraph 4 with reference to VHF radio waves.

(7)

(f) List the frequency ranges of VHF, VLF and ELF radio waves.

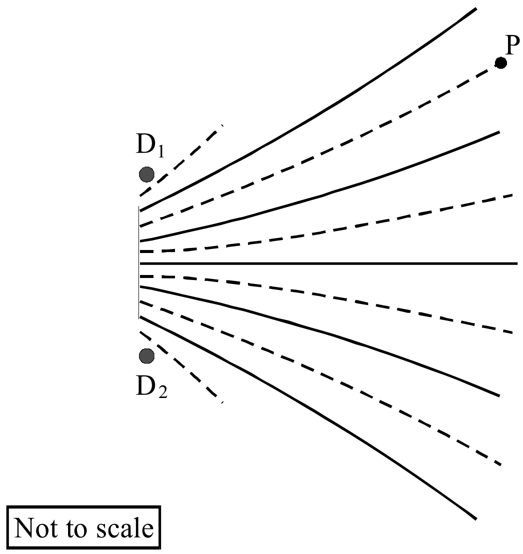
Calculate the wavelength of

(i) a typical VHF signal,

(ii) an ELF signal.

(4)
(Total 32 marks)

26. (a) The diagram represents an interference pattern produced on the surface of water in a ripple tank when two dippers D_1 and D_2 are vibrating in phase. The full lines indicate regions of maximum disturbance, the dashed lines regions where the water surface is undisturbed.



(i) Explain how waves from D_1 and D_2 can produce zero displacement at P at all times.

(2)

(ii) The wavelength of the ripples is 3.0 cm. If the distance from P to D_1 is 46.5 cm, what is the distance from P to D_2? Give your reasoning.

(3)

(iii) A student says that a stationary wave pattern exists along the line joining D_1 and D_2. Explain what is meant by a stationary wave pattern. Deduce the separation of the dippers.

(4)

(b) The dippers are driven up and down at 50 Hz using short solenoids connected to a low voltage a.c. supply. The dipper itself is a short magnet supported by a copper spring.

(i) Describe the type of motion followed by the dipper. Explain how it is forced to move in this way.

(4)

(ii) The amplitude of the dipper's motion is 0.75 mm. Calculate the maximum speed of the dipper.

(3)
(Total 16 marks)

27. 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)

28. State the period of the Earth about the Sun.

....

Use this value to calculate the angular speed of the earth about the Sun in rad s^{-1}.

....

....

Angular speed = ...

(2)

The mass of the Earth is 5.98×10^{24} kg and its average distance from the Sun is 1.50×10^{11} m. Calculate the centripetal force acting on the Earth.

....

....

....

Centripetal force = ...

(2)

What provides this centripetal force?

....

....

(1)
(Total 5 marks)

29. What is meant by *simple harmonic motion*?

....

....

....

....

(2)

Calculate the length of a simple pendulum with a period of 2.0 s.

....

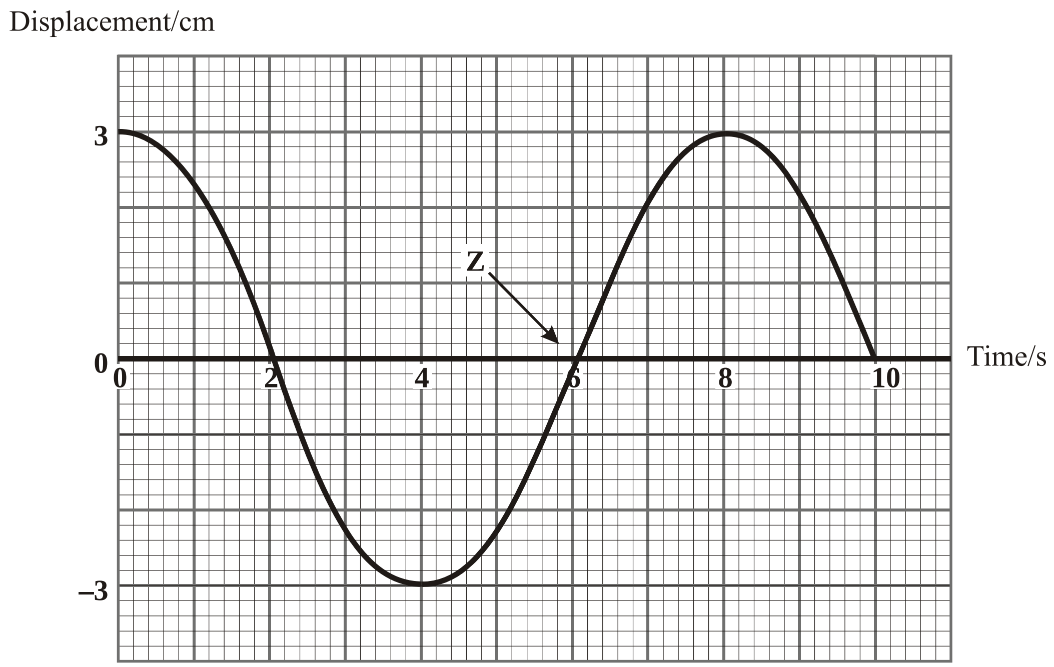
....

....

Length = ...

(2)

The graph shows the variation of displacement with time for a particle moving with simple harmonic motion.



What is the amplitude of the oscillation?

....

(1)

Estimate the speed of the particle at the point labelled Z.

....

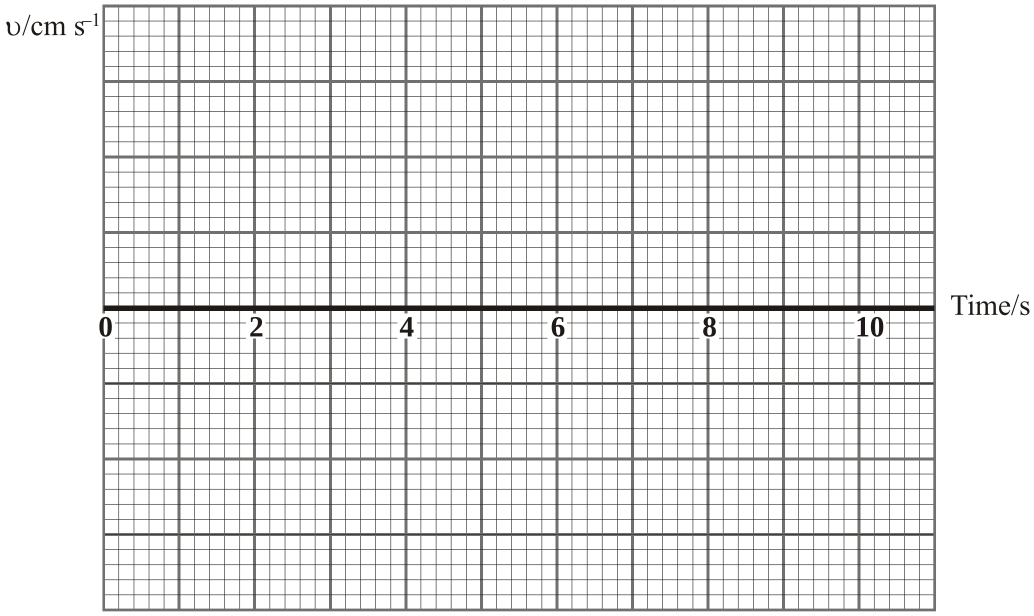
....

....

Speed = ...

(2)

Draw on the axes below a graph of the variation of velocity υ with time for this particle over the same period of time. Add a scale to the velocity axis.



(2)
(Total 9 marks)

30. The photograph shows the interference pattern produced when monochromatic light falls on a pair of slits 0.5 mm apart. The pattern was produced on a screen 1.5 m from the slits.

The photograph has been magnified by a factor of × 3. Use the photograph to obtain a value for the fringe spacing.

....

....

(2)

Calculate the wavelength of the light used.

....

....

....

Wavelength = ...

(2)

Mark with an X on the photograph the fringe or fringes where light from one slit has travelled a distance of two wavelengths further than the light from the other slit.

Explain why the fringes near the centre of the photograph are clearer than those near the edges of the photograph.

....

....

....

....

(4)

In the space below sketch the pattern which would be obtained on the screen if one of the slits were covered up. Label the bright and the dark regions.
(An accurate scale diagram is **not** expected.)

(2)

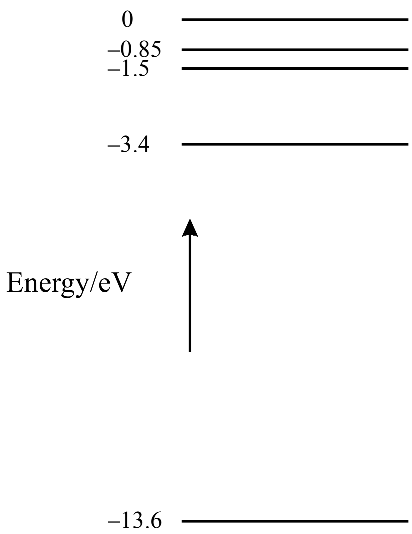
What additional measurement would you need in order to draw an accurate diagram for this case?

....

....

(1)
(Total 11 marks)

31. The diagram shows some of the energy levels for atomic hydrogen.



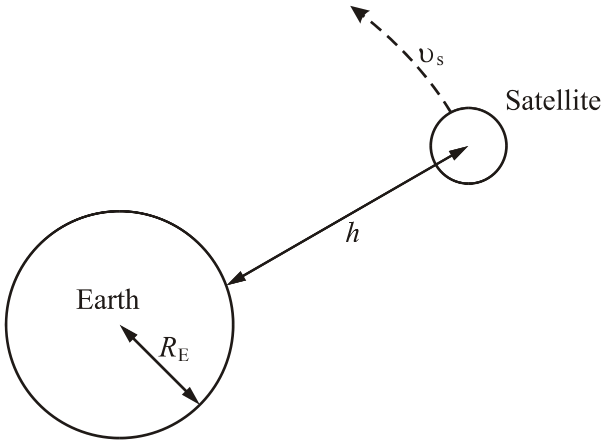
For each of the statements below, indicate whether the statement is true (✓) or false (✗).

Statement	**True/False**
The single electron of a hydrogen atom normally occupies the –13.6 eV energy level.	
An electron of energy 10 eV colliding with a hydrogen atom in its ground state could have an energy of 0.2 eV after the collision.	
An electron moving from the –3.4 eV to the –0.85 eV level gives out a photon of energy 2.55 eV.	
Light of wavelength 650 nm has sufficient energy to excite an electron from the –3.4 eV to the –1.5 eV energy level.	

Use this space for any calculations.

(4)
(Total 4 marks)

32. 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.

....

....

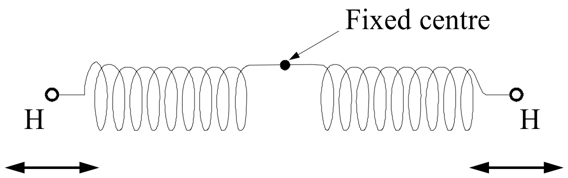
....

....

....

(2)
(Total 10 marks)

33. One simple model of the hydrogen molecule assumes that it is composed of two oscillating hydrogen atoms joined by two springs as shown in the diagram.



If the spring constant of each spring is 1.13×10^3 N m^{-1}, and the mass of a hydrogen atom is 1.67×10^{-27} kg, show that the frequency of oscillation of a hydrogen atom is 1.31×10^{14} Hz.

....

....

....

....

(2)

Using this spring model, discuss why light of wavelength 2.29×10^{-6} m would be strongly absorbed by the hydrogen molecule.

....

....

....

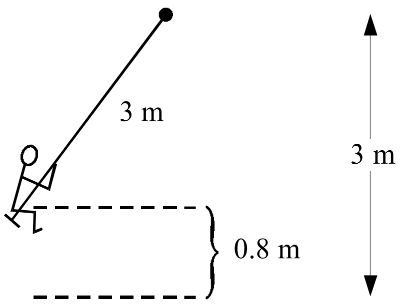
....

....

....

(4)
(Total 6 marks)

34. A child of mass 21 kg sits on a swing of length 3.0 m and swings through a vertical height of 0.80 m.



Calculate the speed of the child at a moment when the child is moving through the lowest position.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(2)

Calculate the force exerted on the child by the seat of the swing at a moment when the child is moving through the lowest position.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Force = ……………………………

(3)

Explain why, as the amplitude of the motion increases, children may lose touch with the seat of the swing.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

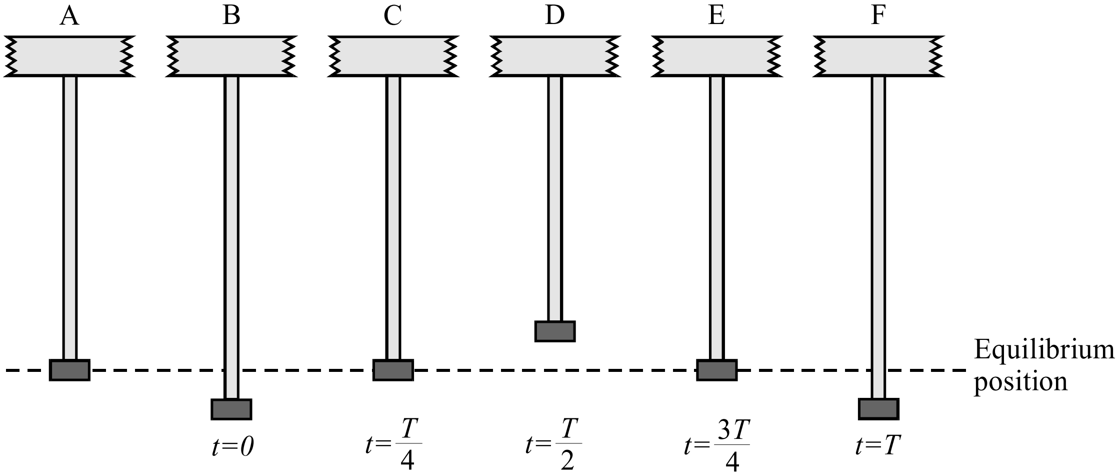
…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(2)
(Total 7 marks)

35. Diagram A shows a mass suspended by an elastic cord. The mass is pulled downwards by a small amount and then released so that it performs simple harmonic oscillations of period *T*. Diagrams B–F show the positions of the mass at various times during a single oscillation.



Complete the table below to describe the displacement, acceleration and velocity of the mass at the stages B–F, selecting appropriate symbols from the following list:

maximum and positive → +

maximum and negative → –

zero → 0

Use the convention that *downward* displacements, accelerations and velocities are positve.

(4)

In the sport of bungee jumping, one end of an elastic rope is attached to bridge and the other end to a person. The person then jumps from the bridge and performs simple harmonic oscillations on the end of the rope.

People are bungee jumping from a bridge 50 m above a river. A jumper has a mass of 80 kg and is using an elastic rope of unstretched length 30 m. On the first fall the rope stretches so that at the bottom of the fall the jumper is just a few millimetres above the water.

Calculate the decrease in gravitational potential energy of the bungee jumper on the first fall.

....

....

Change in g.p.e. = ...

(2)

What has happened to this energy?

....

(1)

Calculate the force constant k, the force required to stretch the elastic rope by 1 m.

....

....

....

Force constant k = ...

(3)

Hence calculate T, the period of oscillation of the bungee jumper.

....

....

Period T = ...

(2)
(Total 12 marks)

36. (a) A student is given a ripple tank in which plane waves can be generated.

Outline how the student could measure the wave speed v, the frequency f and the wavelength λ of the waves.

....

....

....

....

....

(6)

(b) The speed υ of ocean waves in deep water is given by the relationship

$$\upsilon = \sqrt{\frac{g\lambda}{2\pi}}$$

where g is the acceleration of free fall and λ is the wavelength of the waves.

Derive an expression for T, the period of the waves, in terms of g and λ.

....

....

....

(3)

Calculate the value of T when the wavelength of the waves is 8.0 m.

....

....

T = ...

(1)
(Total 10 marks)

37. Explain the term *plane polarised wave.*

....

....

....

....

(2)

Describe an experiment using light or microwaves which tests whether or not the waves are plane polarised.

....

....

....

....

....

(2)

For each of the statements below, indicate whether the statement is true (√) or false (**X**).

Statement	**True/False**
The speed of sound in air is less than the speed of sound in water.	
Since sound waves are longitudinal they cannot be diffracted.	
Sound waves transmit pressure but not energy.	
A sound wave of frequency 436 Hz travelling at 331 ms^{-1} has a wavelength of 75 cm ± 1 cm	

(4)
(Total 8 marks)

38. Experiments on the photoelectric effect show that

- the kinetic energy of photoelectrons released depends upon the frequency of the incident light and not on its intensity,
- light below a certain threshold frequency cannot release photoelectrons.

How do these conclusions support a particle theory but not a wave theory of light?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

(6)

Calculate the threshold wavelength for a metal surface which has a work function of 6.2 eV.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

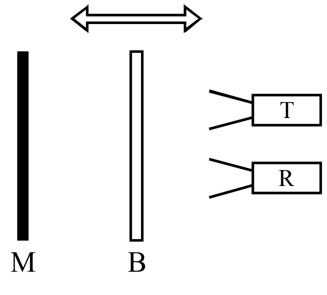
Threshold wavelength = ………………………………………….

To which part of the electromagnetic spectrum does this wavelength belong?

…………………………………………………………………………………………

(4)
(Total 10 marks)

39. (a) A microwave transmitter T and a suitable receiver R are placed side by side as shown. A movable sheet of hardboard B and a fixed metal sheet M are set perpendicular to the microwave beam. The hardboard sheet reflects 30% of the microwaves incident on it.



(i) When B is moved backwards and forwards, the reading on R is high for some positions of B and for other positions it is low. Explain these observations.

(ii) It is found that when B is moved 140 mm towards T and R, the reading on R goes from a high reading through nine high readings and then to a final high reading. Calculate the wavelength of these microwaves.

(6)

(iii) The speed at which B is moving can be found by measuring the frequency of the high-low readings for microwaves of known wavelength.

Describe another way of measuring the average speed of B when it moves through a metre in about two seconds.

Discuss any possible errors in your measurements. (Assume that any instruments you use are accurately calibrated.)

(5)

(b) It is difficult to explain the experiment in (*a*)(i) using the photon model for microwaves.

(i) In what way does the photon model make the experiment difficult to explain?

(ii) Calculate the energy of photons of wavelength 30 mm and express this energy in electronvolts.

(iii) How does the value you have calculate compare to the energy of a typical photon of visible radiation (light)?

(5)
(Total 16 marks)

40. 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)

41. Complete the diagram below to show the different regions of the electromagnetic spectrum.

Radio waves	

(2)

State *four* differences between radio waves and sound waves.

1. ………………………………………………………………………………………

2. ………………………………………………………………………………………

3. ………………………………………………………………………………………

4. ………………………………………………………………………………………

(4)

Two radio stations broadcast at frequencies of 198 kHz and 95.8 MHz. Which station broadcasts at the longer wavelength?

………………………………………………………………………………………

Why do obstacles such as buildings and hills present less of a problem for the reception of the signal from the station transmitting at the longer wavelength?

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

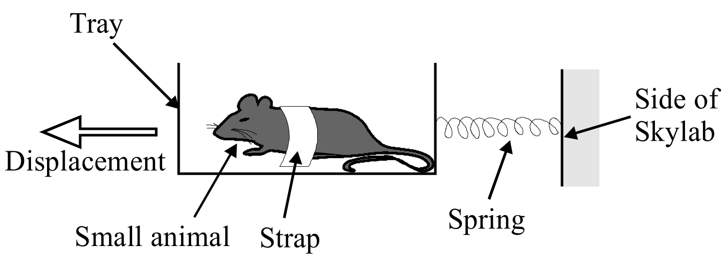
………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

(3)
(Total 9 marks)

42. The diagram shows a method for determining the mass of small animals orbiting the Earth in Skylab. The animal is securely strapped into a tray attached to the end of a spring. The tray will oscillate with simple harmonic motion when displaced as shown in the diagram and released.



Define *simple harmonic motion*.

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

(2)

The tray shown above has a mass of 0.400 kg. When it contains a mass of 1.00 kg, it oscillates with a period of 1.22 s.

Calculate the spring constant *k*.

....

....

....

....

k = ...

(3)

The 1.00 kg mass is removed and a small animal is now strapped into the tray. The new period of oscillation is 1.48 s. Calculate the mass of the animal.

....

....

....

Mass = ...

(2)

The Skylab astronauts suggest that the calibration experiment with the 1.00 kg mass could have been carried out on Earth before take off. If a similar experiment were conducted on Earth would the time period be greater than, less than, or equal to 1.22 s? Explain your answer.

....

....

....

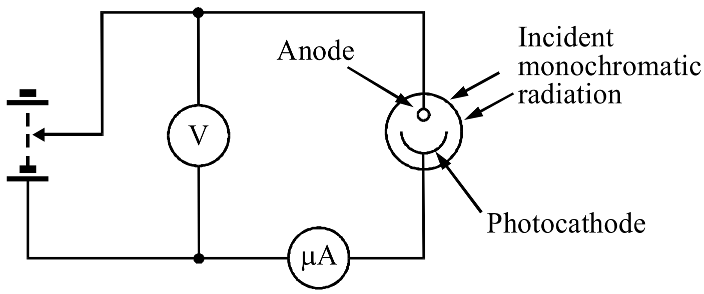
....

....

....

(3)
(Total 10 marks)

43. The diagram shows monochromatic light falling on a photocell.



As the reverse potential difference between the anode and cathode is increased, the current measured by the microammeter decreases. When the potential difference reaches a value V_s, called the stopping potential, the current is zero.

Explain these observations.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

(5)

What would be the effect on the stopping potential of

(i) increasing only the intensity of the incident radiation,

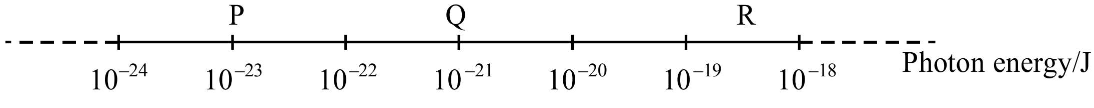
……..…………………………………………………………………………

(ii) increasing only the frequency of the incident radiation?

……..…………………………………………………………………………

(2)
(Total 7 marks)

44. The diagram shows a range of photon energies which could be used to describe part of the electromagnetic spectrum.



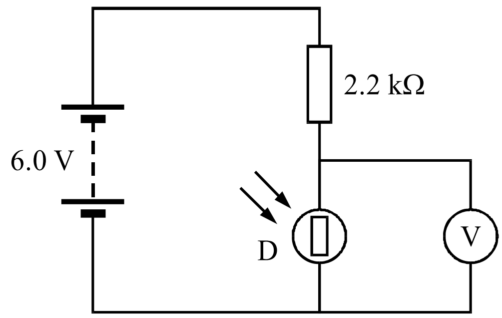
(a) Use information from the data sheet to identify the region of the spectrum labelled P. Name the regions labelled by Q and by R.

(4)

(b) Outline an experiment which would enable you to determine the wavelength of electromagnetic waves of wavelength about 30mm. Explain how the wavelength is calculated from the measurements you take.

(5)

(c) A beam of light is incident on a detector D whose resistance varies with the intensity of the light. The detector is connected in an electrical circuit as shown.



(i) At high illumination, the voltmeter registers 1.2 V. What is then the resistance of D? State any assumption you make.

(4)

(ii) At low illumination, the voltmeter registers 6.0 V, the same as it would record if connected directly across the cells.

What would you now do, using ordinary laboratory apparatus other than an ohmmeter, to find the resistance of D? Explain your answer.

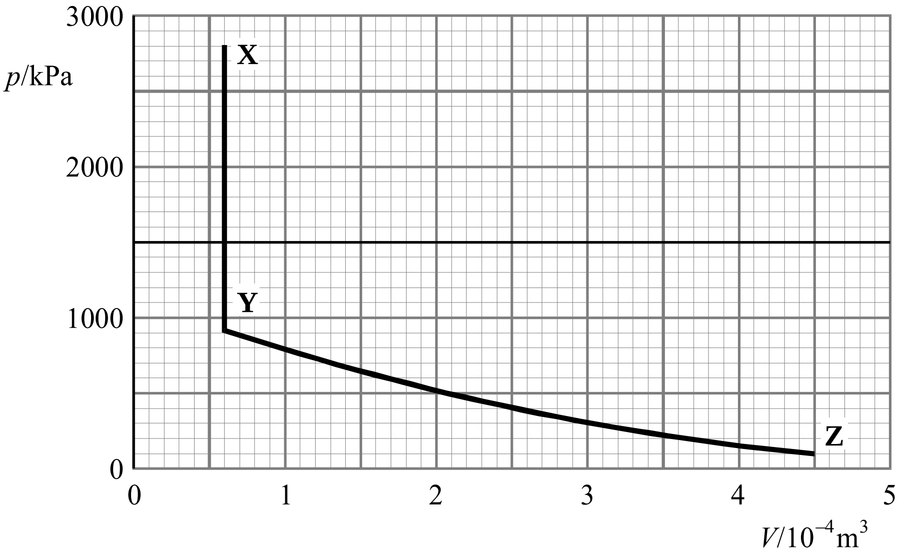
(3)
(Total 16 marks)

45. (a) Draw a labelled diagram of the apparatus you would use to demonstrate that the pressure *P* of an ideal gas is proportional to its absolute temperature *T*.

Do not describe the experiment, but state any precautions you would take during the measurements of *P* and *T*.

(5)

(b) In the cylinder of an ordinary petrol engine, air at atmospheric pressure is mixed with a little petrol vapour. The mixture, which behaves like an ideal gas, is then compressed. A spark ignites the mixture which causes it to be heated at a constant volume. The power stroke of the piston then follows. The *p–V* graph shows two of these three processes.



(i) The area beneath the curved part of the graph is 150 Pa m^3. It represents the work done in compressing the gas. Show that the unit is equivalent to the joule.

(ii) If the temperature of the air-vapour mixture at Y is 640K, calculate the temperature in the cylinder at X. State any assumption you have made.

(6)

(c) Assume that the piston in a petrol engine moves with simple harmonic motion of amplitude 40 mm. Calculate the maximum acceleration of the piston when the engine is rotating at 8000 revolutions per minute.

The piston is connected to another part of the engine by a rod which is pulled and pushed as the piston moves inside the cylinder. Explain why the material from which the rod is made has to be carefully chosen.

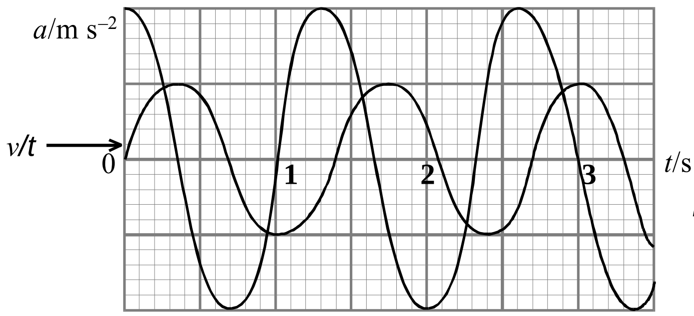
(5)
(Total 16 marks)

46. The following statements apply to a body orbiting a planet at constant speed and at constant height. Indicate whether each statement is true (√) or false (**x**).

Statement	True/False
The body is travelling at constant velocity.	
The body is in equilibrium because the centripetal force is equal and opposite to the weight.	
The only force acting on the body is its weight.	
The body's acceleration towards the planet equals the gravitational field strength at the position of the body.	

(Total 4)

47. A body performs simple harmonic oscillations. The graph shows how the acceleration of the body varies with time.



[if inverted, ✓ ✗]

State the frequency of the oscillations.

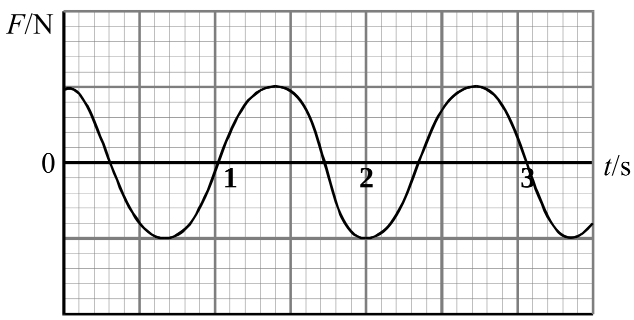
....

(1)

Add to the graph above a curve showing how the *velocity* of the same body varies with time over the same period.

(2)

On the grid below, sketch a graph to show how the *force* acting on the same body varies with time over the same period.



[if inverted, ✓ ✗]

(2)

A mass m attached to a spring of force constant k oscillates with a period of 1.2 s. Calculate the period of oscillation for a mass $2m$ attached to a spring of force constant $4k$.

....

....

....

Period of oscillation = ...

(2)
(Total 7 marks)

48. Describe an experiment using microwaves to produce and detect a two-slit interference pattern.

....

....

....

....

....

....

....

(4)

Suggest an appropriate slit separation for this experiment.

....

(1)

How could this experiment be used to obtain a value for the wavelength of the microwaves?

....

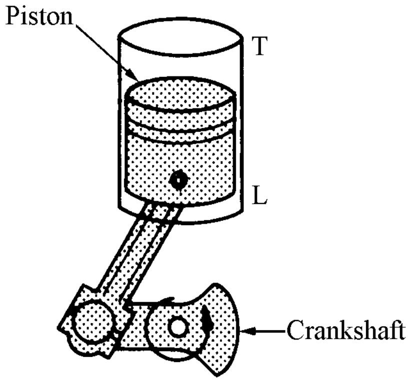
....

....

....

(3)
(Total 8 marks)

49. The diagram shows one piston of an internal combustion engine.



As the crankshaft rotates through 360°, the top of the piston moves from L to T and back to L. The distance LT is 8.6 cm and the crankshaft rotates at 6000 revolutions per minute.

Calculate the frequency of oscillation *f* of the piston.

....

f =..

(1)

State the amplitude of this oscillation.

....

(1)

The oscillations of the piston are approximately simple harmonic. Calculate the maximum acceleration of the piston.

....

....

....

Acceleration = ...

At which position(s) in the movement of the piston will this acceleration be zero?

....

(3)

Suggest why the motion of the piston *is not* perfectly simple harmonic.

....

(1)
(Total 6 marks)

50. (a) In an oscilloscope, *N* electrons each of charge *e* hit the screen each second. Each electron is accelerated by a potential difference *V*.

(i) Write down an expression for the total energy of the electrons reaching the screen each second.

(ii) The power of the elctron beam is 2.4W. When the oscilloscope is first switched on the spot on the glass screen is found to rise in temperature by 85 K during the first 20 s.

The specific heat capacity of glass is 730 J kg $^{-1}$K^{-1}. Calculate the mass of glass heated by the electron beam. State two assumptions you have made in your calculation.

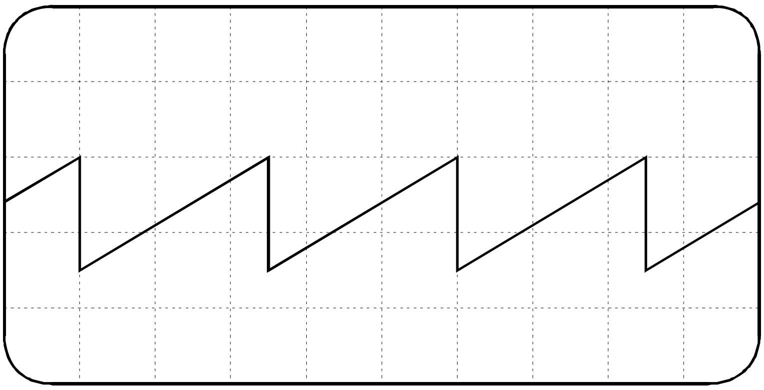
(7)

(b) Outline how, in principle, you would measure the specific heat capacity of glass. You may use a lump of glass of any convenient shape in your experiment.

What difficulties might lead to errors?

(5)

(c) The oscilloscope is now used to investigate the 'saw-toothed' signal from a signal generator. The trace show is obtained.



The Y-gain control is set at 0.2 volts per division and the time-based control at 100 microseconds per division.

(i) Calculate the frequency of the saw-toothed signal.

(ii) What is the rate of rise of the signal voltage during each cycle?

(4)
(Total 16)

51. 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.

....

....

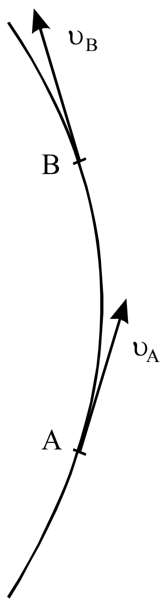
....

....

....

(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.

....

....

....

....

....

....

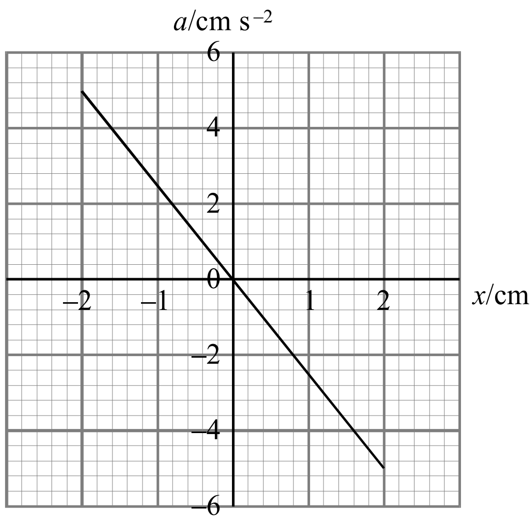
(3)
(Total 8 marks)

52. 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)

53. The graph shows the variation of acceleration *a* with displacement *x* for a body oscillating with simple harmonic motion.



Calculate the period of oscillation of the body.

..............................……...

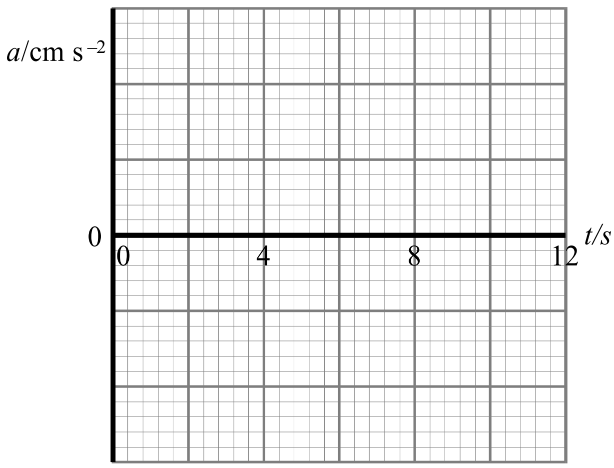
..............................……...

Period of oscillation =..

(2)

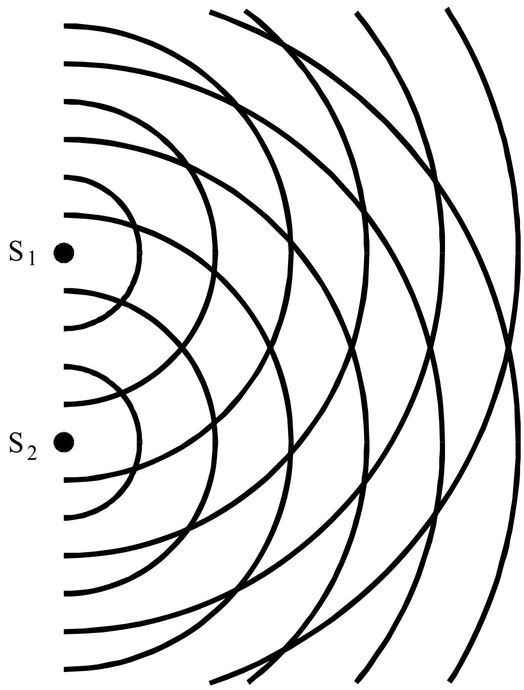
At time t = 0 the body is momentarily at rest.

On the axes below, sketch a graph to show how acceleration of the body varies with time. Add a scale to the acceleration axis.



(4)
(Total 6 marks)

54. The diagram shows wavefronts spreading out from two identical sources, S_1 and S_2.



Describe how such a pattern could be produced and observed using a ripple tank.

....

....

....

....

....

(5)

On the diagram draw the following:

(i) a line labelled A joining points where the waves from S_1 and S_2 have travelled equal distances,

(ii) a line labelled B joining points where the waves from S_1 have travelled one wavelength further than the waves from S_2,

(iii) a line labelled C joining points where the waves from S_2 have travelled half a wavelength further than the waves from S_1.

(4)

Complete each of the sentences below by selecting an appropriate term from the following:

increase
decrease
stay the same

If only the separation of the sources were increased, the angle between lines A

and B would..

If only the wavelength of the waves were increased, the angle between lines A

and B would..

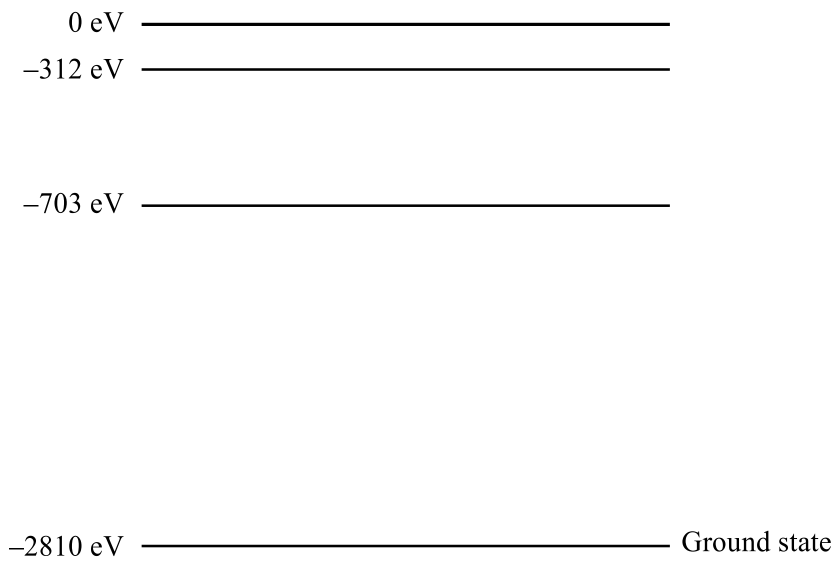
If only the depth of the water in the ripple tank were increased, the angle between lines A

and B would...

(3)
(Total 12 marks)

55. A muon is a particle which has the *same charge* as an electron but its *mass* is 207 times the mass of an electron.

An unusual atom similar to hydrogen has been created, consisting of a muon orbiting a single proton. An energy level diagram for this atom is shown.



State the ionisation energy of this atom.

....

Calculate the maximum possible wavelength of a photon which, when absorbed, would be able to ionise this atom.

....

....

....

....

Maximum wavelength =...

To which part of the electromagnetic spectrum does this photon belong?

....

(5)

Calculate the de Broglie wavelength of a muon travelling at 11% of the speed of light.

....

....

....

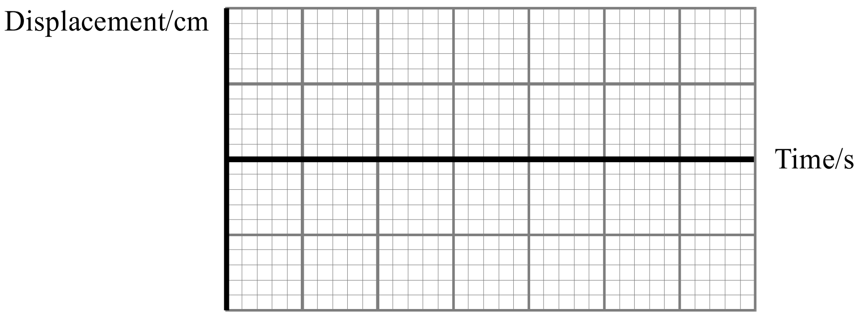
....

Wavelength =..

(3)
(Total 8 marks)

56. A sewing machine needle moves vertically with simple harmonic motion. The difference between the highest and lowest positions of the point of the needle is 3.6 cm. The needle completes 20 stitches per second.

On the grid below sketch a displacement–time graph for the point of the sewing machine needle. Show at least one complete cycle and add a scale to both axes.



(3)

Calculate the maximum speed of the needle.

....

....

....

Maximum speed = ...

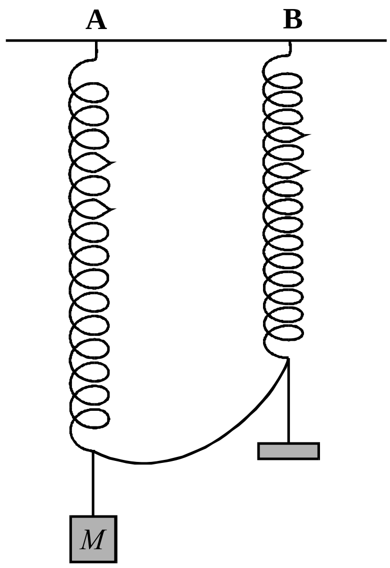
(2)

On your graph mark with an M two places where the needle moves with this maximum speed.

(1)
(Total 6 marks)

57. An experiment which demonstrates forced vibrations is described below.

Two identical springs are suspended from a rigid support. Spring A carries a mass *M* kg while spring B carries a hanger to which slotted masses can be added. The mass of the hanger is much less than *M*. The springs are linked by a loosely hanging chain.



Mass *M* is displaced and performs vertical oscillations only. After a few seconds the hanger on spring B is observed to be oscillating vertically with a very small amplitude.

The experiment is repeated several times with an extra mass added to the hanger on spring B each time, until the total mass on B is 2*M* kg.

Describe and explain the changes to the oscillations of both springs as the mass on B is increased.

....

....

....

....

....

....

....

....

....

....

(Total 6 marks)

58. Calculate the period T of a simple pendulum of length 24.9 m.

T =……….........……...............

The pendulum is displaced by 3.25 m and allowed to swing freely. Use the equation

maximum speed = 2π × *frequency* × *amplitude*

to calculate the maximum speed of the pendulum.

....

....

Maximum speed =……….........……...............

Calculate the maximum acceleration of the pendulum.

....

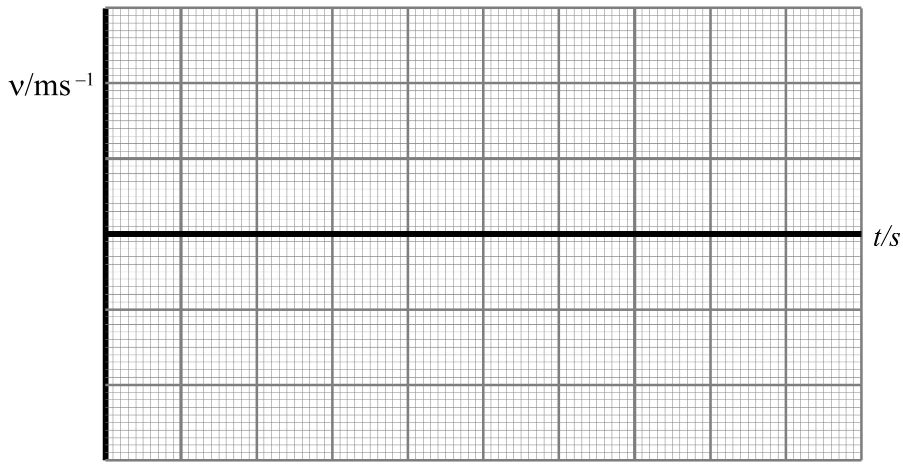
....

Maximum acceleration = ……….........……...............

(5)

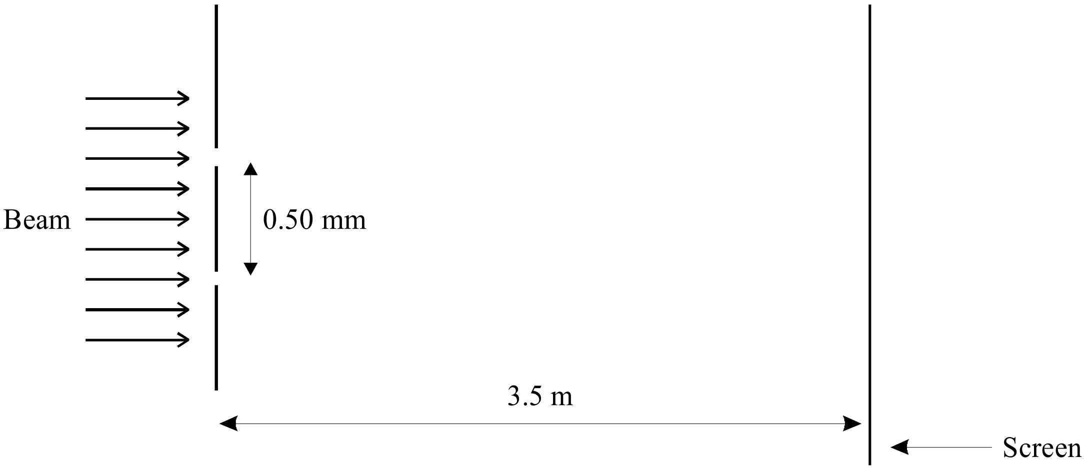
…………………………………………………………………………………………

Sketch two graphs showing how the velocity and the acceleration of the pendulum vary with time.
Each graph should show *two* complete cycles and should start at the same moment in time.
Add scales to the axes of both graphs.



(5)
(Total 10 marks)

59. A laser beam of wavelength 690 nm is directed normally at parallel slits as shown below.



Calculate the fringe spacing at the screen.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

Fringe spacing =………..........……................

Sketch the pattern which would be observed on the screen.

(4)

This laser beam is replaced by one with a wavelength of 460 nm. Describe how the appearance of the fringes would change.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(2)

The two laser beams are now directed simultaneously at the slits. Which fringes exactly overlap?

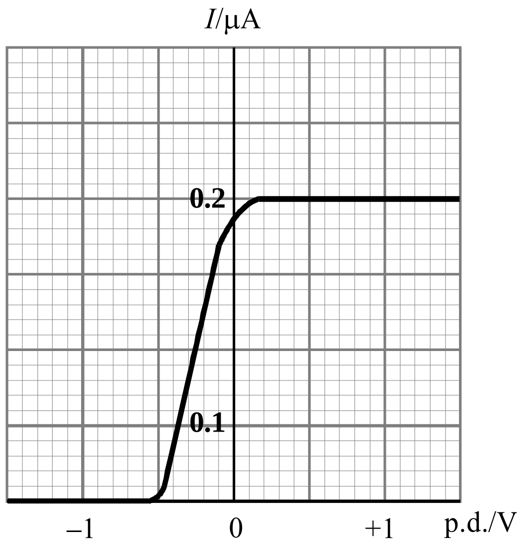
…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(2)
(Total 8 marks)

60. Monochromatic light of constant intensity falls on a photocell. The graph shows how the current in the photocell varies with the potential difference applied across it.



The frequency of the incident light is 6.0×10^{14} Hz. Use the graph to estimate the work function of the metal which forms the cathode of the photocell.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Work function = ……….........……................

(3)

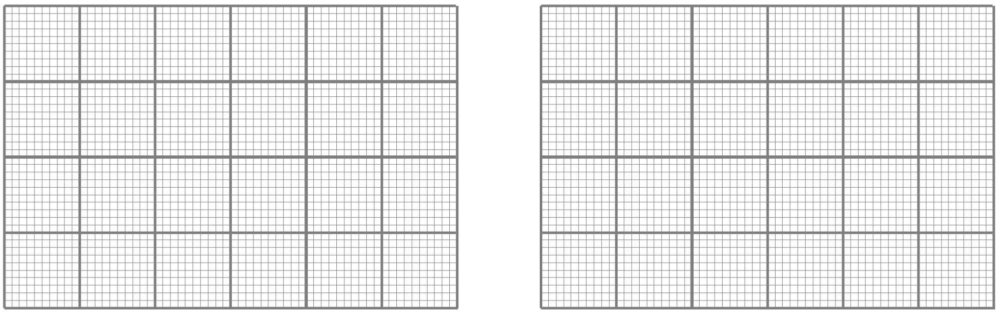
Add to the axes above the graph obtained when only the intensity of the light is increased. Label this graph A.

Add to the axes above the graph obtained when only the frequency of the light is increased. Label this graph B.

(4)
(Total 7 marks)

61. A mass moves with simple harmonic motion. The displacement x of the mass varies with time t according to the relationship $x = x_0 \sin 2\pi ft$.

On the grids provided sketch two graphs, one showing the variation of acceleration of this mass with time, the other showing the variation of acceleration with displacement.

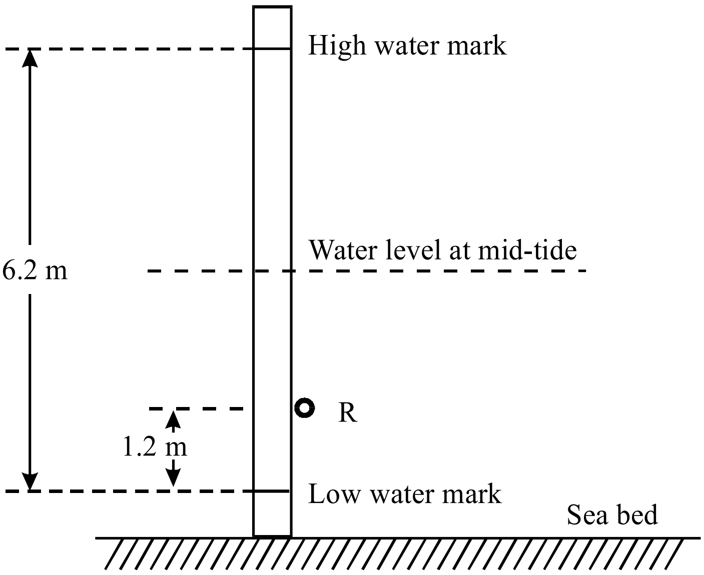


Acceleration – time graph

Acceleration – displacement graph

(4)

The movement of the tides may be assumed to be simple harmonic with a period approximately equal to 12 hours. The diagram shows a vertical wooden pole fixed firmly to the sea bed. A ring is attached to the pole at point R.



What is the amplitude of this tide?

……………………………………………………………………………………………

High tide on a particular day is at 9 a.m. State the times of the next mid-tide and the next low tide.

Next mid-tide: ……….........……..............…………………………………………………..

Next low tide: ……….........……..............…………………………………………………..

(3)

Calculate the time at which the falling water level reaches the ring R.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Time =……….........……...............

(4)
(Total 11 marks)

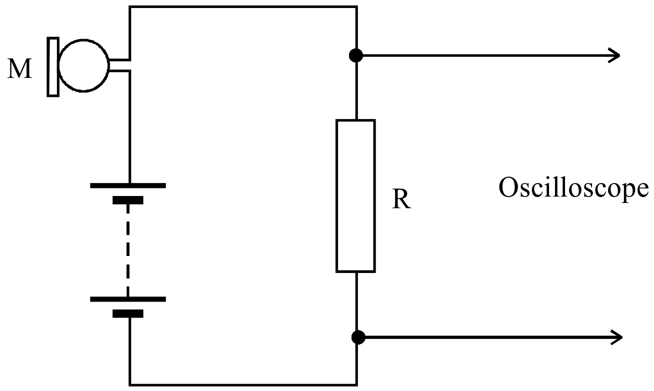
62. (a) Explain why sound waves cannot be plane polarised. How are sound waves in air usually generated?

The speed of sound in air c is related to the pressure p and density ρ of the air by the equation $c = (\gamma p/p)^{\frac{1}{2}}$ where γ is a dimensionless constant.

Show that the equation is homogeneous with respect to units.

(6)

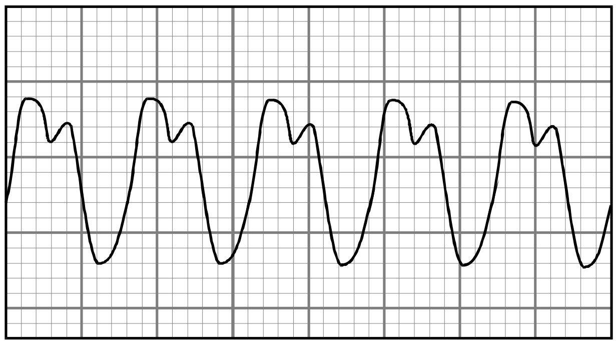
(b) In one type of microphone loosely packed carbon granules respond to changes of pressure produced by sound waves. When the granules are compressed the resistance of the microphone decreases. Such a microphone M is connected in a circuit as shown.



(i) Explain how the potential difference across the resistor R changes when the pressure at the microphone increases.

(2)

For a particular incident sound, the trace on the oscilloscope is as shown.



(ii) The settings on the oscilloscope are 0.20mV cm^{-1} and 250 μs cm^{-1}. Determine the frequency of the sound and the amplitude of the voltage change across the resistor R.

(5)

(iii) The trace shows that the sound is the result of the superposition of two waves. Describe an experiment which demonstrates the superposition of waves of wavelength about 30 mm, i.e. microwaves or water ripples.

(3)
(Total 16 marks)

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

....

....

(1)

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

....

....

....

....

....

(3)

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

....

....

(1)
(Total 5 marks)

64. Fill in the gaps in the sentences below.

A body oscillates with simple harmonic motion when the resultant force F acting on it and its

displacement x are related by the expression ....

The acceleration of such a body is always directed ....

The acceleration of the body is a maximum when its displacement is..............................

and its velocity is .... when its displacement is zero.

(4)

A mass of 0.08 kg suspended from a vertical spring oscillates with a period of 1.5 s. Calculate the force constant of the spring.

....

....

....

....

Force constant = ...

(2)
(Total 6 marks)

65. Under what circumstances could two progressive waves produce a stationary (standing) wave?

....

....

....

....

(2)

Describe with the aid of a diagram an experiment using microwaves to produce stationary (standing) waves.

....

....

....

How would you show that a stationary wave had been produced?

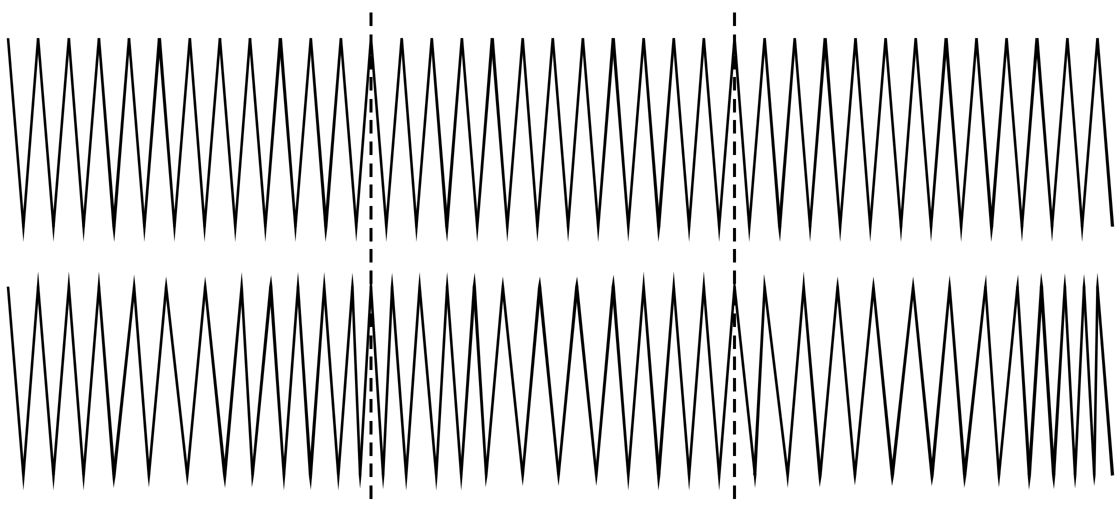
....

....

....

(3)
(Total 5 marks)

66. The diagram shows part of a stretched slinky spring and the same section of the spring when a longitudinal wave is travelling along it.



The dotted vertical lines show the positions of two coils which at this moment are undisplaced.

Mark on the lower diagram a compression C and a rarefaction R

Measure the wavelength of the wave

Wavelength ....

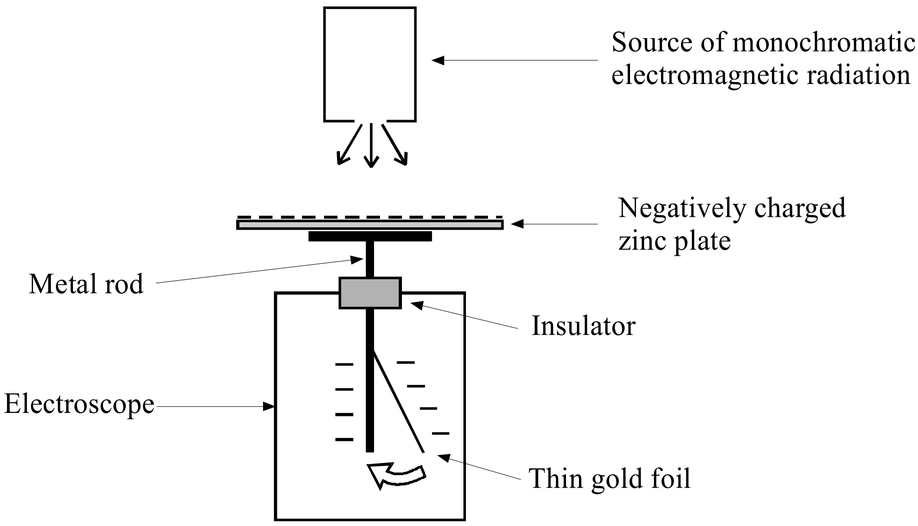
Mark on the lower diagram a coil with maximum displacement, M.

Measure the amplitude of the wave, i.e. the displacement of coil M.

Amplitude ....

(Total 4 marks)

67. The diagram shows apparatus which can be used to demonstrate the photoelectric effect.



The deflection of the thin gold foil is a measure of the charge stored on the zinc plate.

When ultraviolet light is directed towards the zinc plate, the thin gold foil gradually returns to the vertical.

When red light is used the thin gold foil stays in the position shown.

How does the particle theory of light explain these observations?

....

....

....

....

....

....

....

....

....

....

....

....

....
(4)

What would be observed if electromagnetic radiation of greater intensity were used?

Ultraviolet of greater intensity ....

....

Red light of greater intensity ....

....
(2)

What would be observed if the zinc plate and electroscope were positively charged? Explain your answer.

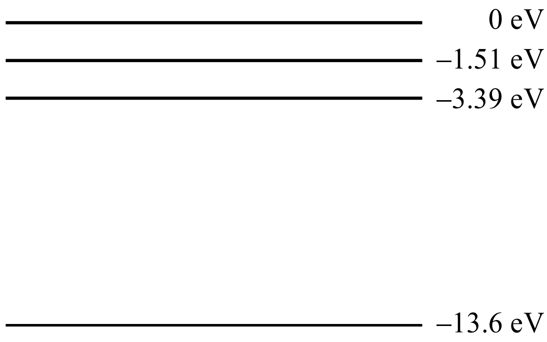
....

....

....

....
(2)
(Total 8 marks)

68. The diagram shows some of the energy levels for atomic hydrogen.



Add arrows to the diagram showing all the single transitions which could ionise the atom.
(2)

Why is the level labelled –13.6eV called the ground state?

....

....

....

(1)

Identify the transition which would result in the emission of light of wavelength 660 nm.

....

....

....

....

Transition = ...

(4)
(Total 7 marks)

69. A mass is suspended from a spring. The mass is then displaced and allowed to oscillate vertically. The amplitude of the oscillations is 6.0mm. The period of the oscillations is 3.2s.

Calculate the maximum acceleration of the mass.

....

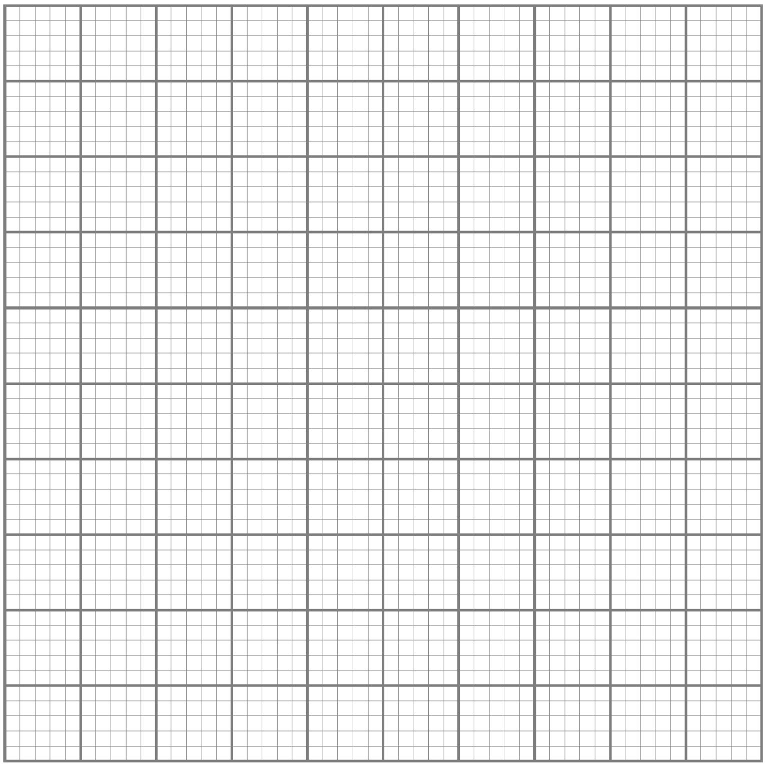
....

....

Maximum acceleration = ...

(3)

Sketch a graph showing how the acceleration of the mass varies with displacement. Add a scale to both axes.



(4)

State and explain *one* reason why the mass may not oscillate with simple harmonic motion.

....

....

....

(2)
(Total 9 marks)

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

....

....

(1)

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

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

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

....

....

....

....

....

....

(3)

Why might the formula still be incorrect?

....

....

(1)
(Total 5 marks)

....

(3)
(Total 5 marks)

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

....

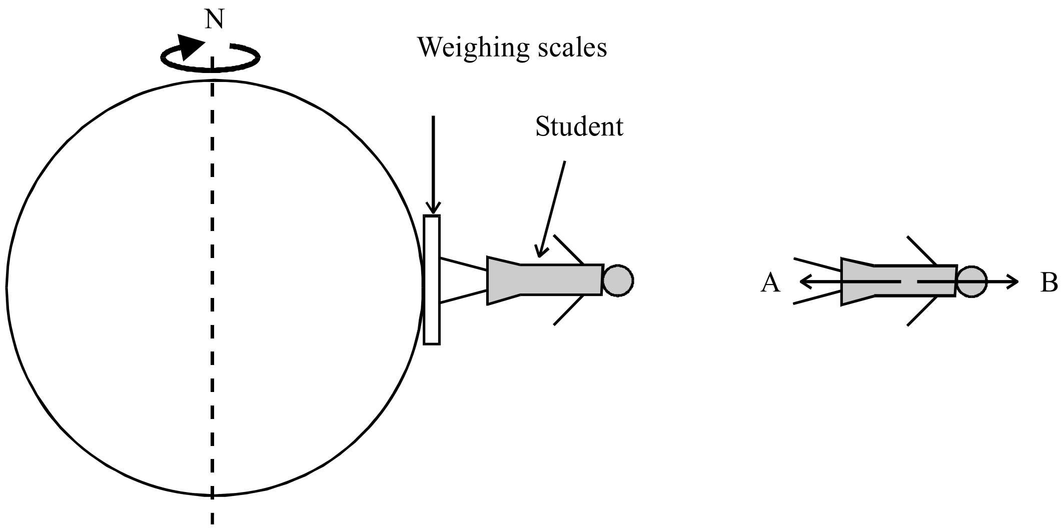
....

....

....

(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)

72. Ultraviolet light of wavelength 12.2 nm is shone on to a metal surface. The work function of the metal is 6.20 eV.

Calculate the maximum kinetic energy of the emitted photoelectrons.

....

....

....

....

Kinetic energy =.................................

Show that the maximum speed of these photoelectrons is approximately 6×10^6 ms^{-1}.

....

....

....

(5)

Calculate the de Broglie wavelength of photoelectrons with this speed.

....

....

....

Wavelength =.......................................

Explain why these photoelectrons would be suitable for studying the crystal structure of a molecular compound.

....

....

....

....

(4)
(Total 9 marks)

73. A motorist notices that when driving along a level road at 95 km h^{-1} the steering wheel vibrates with an amplitude of 6.0 mm. If she speeds up or slows down, the amplitude of the vibrations becomes smaller

Explain why this is an example of resonance.

....

....

....

....

....

(3)

Calculate the maximum acceleration of the steering wheel given that its frequency of vibration is 2.4 Hz.

....

....

....

....

Acceleration =.......................................

(2)
(Total 5 marks)

74. A 60 W filament lamp transfers electrical energy to light with an efficiency of 12%. Calculate the light intensity produced by the lamp at a point 3.5 m from the filament.

....

....

....

....

Intensity =..

(3)

The lamp is observed through a sheet of Polaroid.

Describe and explain the effect of this on the intensity of the light.

....

....

....

....

....

The sheet of Polaroid is now slowly rotated in a plane perpendicular to the direction of propagation of the light. What effect does this have on the intensity of the light?

....

....

(4)
(Total 7 marks)

75. Draw a labelled diagram of the apparatus you would use to produce a two slit interference pattern with light.

State appropriate values for

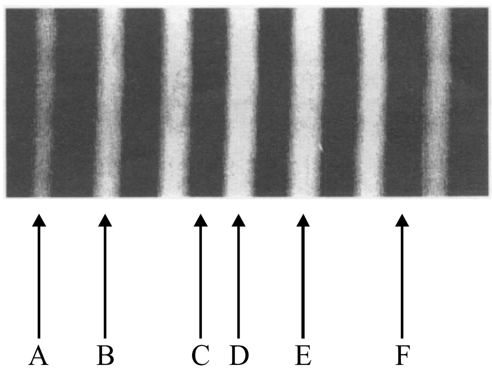
(i) the slit separation

....

(ii) the distance from the slits to the screen.

.... **(3)**

The photograph shows an interference pattern obtained from such an experiment using monochromatic light.



scale 1:1

Determine the fringe width.

....

....

Fringe width =... **(2)**

Complete the following sentences by adding one or more of the letters A-F, shown on the diagram.

Light from the two slits has travelled the same distance at position(s) ....

Light from the two slits is out of phase at position(s) ....

There is a path difference of three wavelengths between light from the two slits at

position(s) .... **(4)**

One of the slits is now covered. Describe how the pattern on the screen changes.

....

....

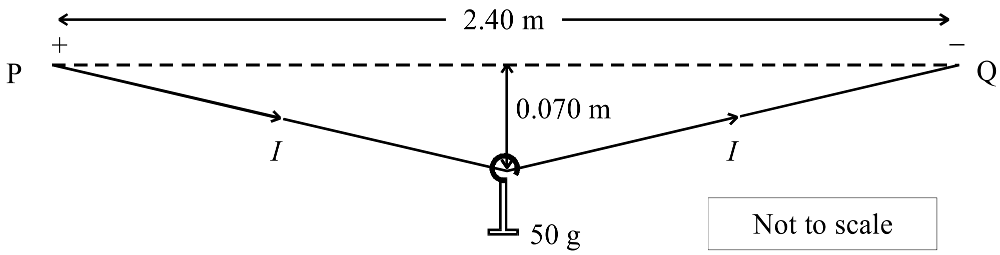
....

....

....

(2)
(Total 11 marks)

76. A student devises a way of measuring electric current by hanging a mass of 50 g on a conducting wire stretched between two points P and Q which are 2.40 m apart. The sag at the centre of the wire varies with the current *I*, as the wire expands because of the heating effect of the current. The sag is 0.070 m when the current is 13 A d.c.



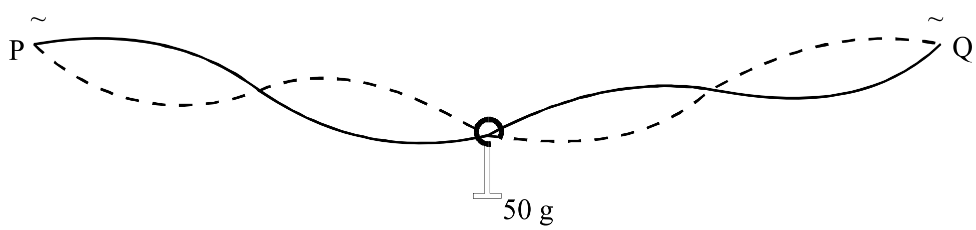
(a) Draw a free-body force diagram for the 50 g mass when the sag is 0.070 m. Hence, or otherwise, determine the tension *T* in the wire.

(5)

(b) Outline how the student could have measured the resistance of the conducting wire at different values of *I* before setting up this experiment.

(3)

(c) The student now connects P and Q to a 50 Hz a.c. supply. When the current is 13 A r.m.s. the wire is found to oscillate as shown.



The student measures the distance between adjacent nodes along the wire to be 606 mm.

(i) What is meant by a current of 13 A r.m.s.?

(ii) Deduce the speed c of transverse waves along the hot wire.

(iii) Suggest why the wire oscillates in this manner.

(6)

(d) The tension in the wire is related to c and the mass per unit length μ of the wire by the expression

$$T = \mu c^2$$

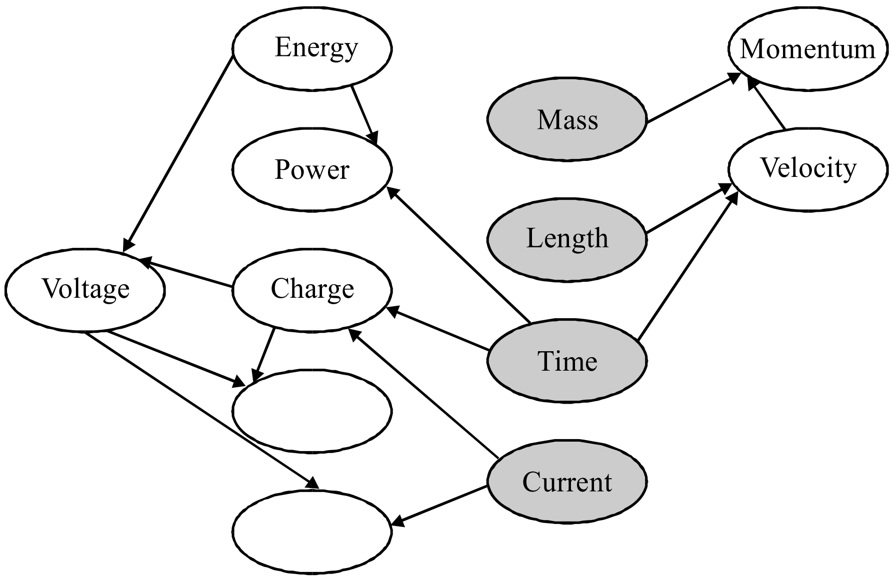
Show that the unit of μc^2 is N.

(2)
(Total 16 marks)

77. 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.

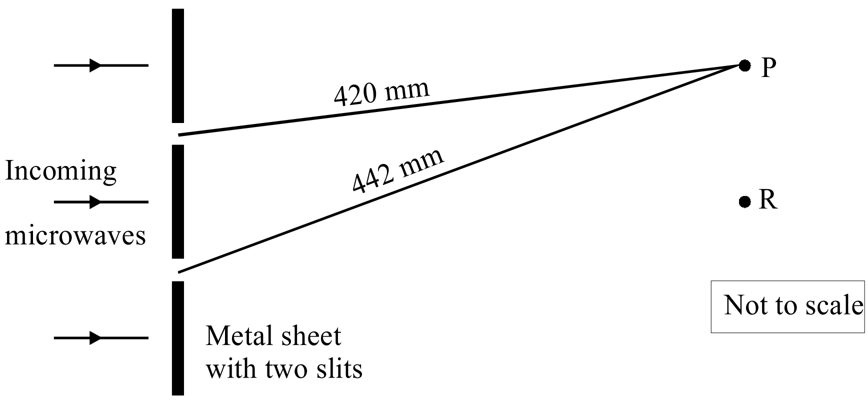
....

....

....

(2)
(Total 4 marks)

78. A beam of microwaves is directed at two slits in a metal sheet. The diagram below shows two adjacent positions P and R where a microwave detector would register maximum readings.



Use the diagram to determine the wavelength of the microwaves.

....

....

Wavelength = ...

Calculate the frequency of the microwaves.

....

....

Frequency = ...

(4)

On the diagram mark with a Q a position where another maximum reading would occur. On the diagram mark with a D a position where a minimum reading would occur.

(2)

In a similar experiment, sound waves were directed at the same metal sheet. The speed of sound is $330 ms^{-1}$ and the frequency of the sound waves was 1100Hz. Explain why a maximum reading would *not* be detected at P in this experiment.

....

....

....

....

(2)
(Total 8 marks)

79. A mass of 16 kg is suspended by a spring of spring constant $k = 3.9 \times 10^3\ N\ m^{-1}$. The mass is displaced downwards and released so that it performs small vertical oscillations.

Calculate the period of the oscillations.

....

....

Period =...

(2)

The amplitude of the motion is 8.4 mm. Calculate the maximum acceleration of the mass.

....

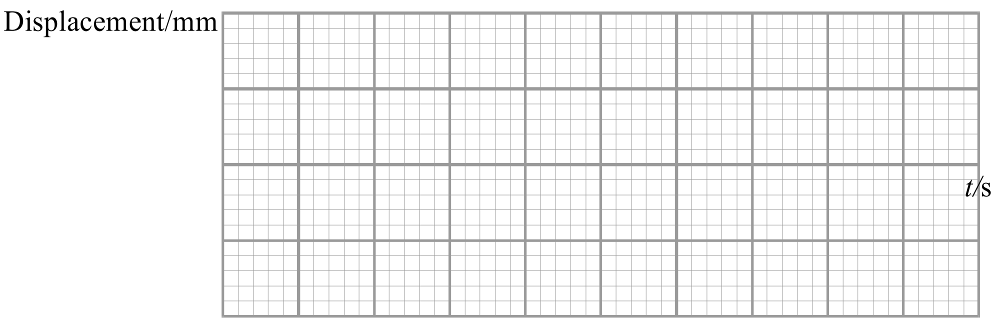
....

....

Maximum acceleration =..

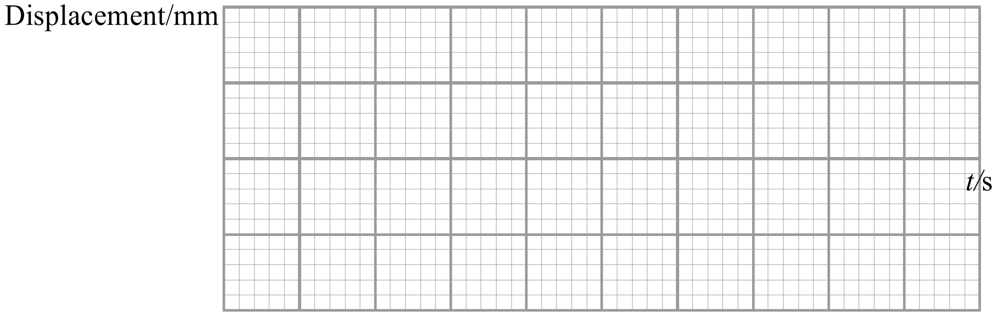
(3)

Sketch a graph showing how the displacement of the mass would vary with time for the first two cycles. Assume that upward displacements are positive. Add scales to both axes.



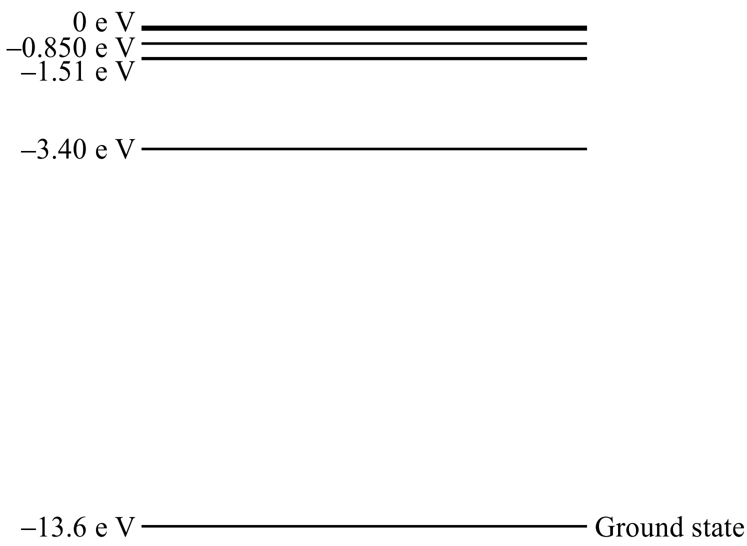
(4)

Sketch on the grid below a displacement-time graph for the same mass if it were moving entirely within motor oil.



(1)
(Total 10 marks)

80. The following is a simplified energy level diagram for atomic hydrogen.



State the ionisation energy of atomic hydrogen.

....

....

Account for the labelling of the energy levels with negative numbers.

....

....

....

....

....

(3)

Calculate the wavelength of the photon emitted when an electron moves from the –1.51 eV energy level to the –3.40 eV energy level.

....

....

....

....

Wavelength = ...

(3)

Describe how you would produce a line spectrum of atomic hydrogen in a laboratory.

....

....

....

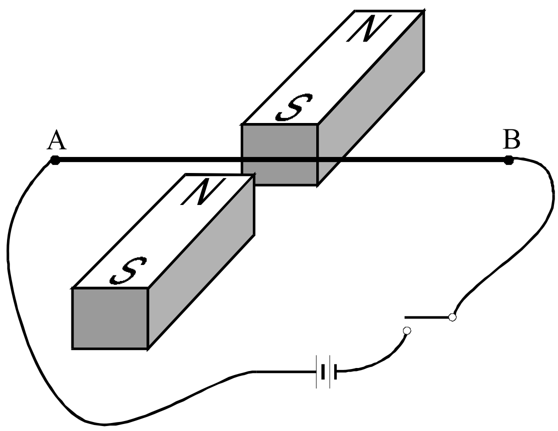
....

(2)

Sketch what you would expect to see.

(1)
(Total 9 marks)

81. A stretched wire AB is held horizontally between the poles of two magnets and is connected to a battery as shown in the diagram.



Show on the diagram the direction of the force on the wire when the switch is closed.

(1)

The battery is replaced by a variable frequency a.c. supply. The wire AB has a natural frequency of 20 Hz.

Describe what is seen when

(i) a very low frequency (less than 1 Hz) is selected,

....

....

(1)

(ii) the frequency is **gradually** increased to 50 Hz.

....

....

....

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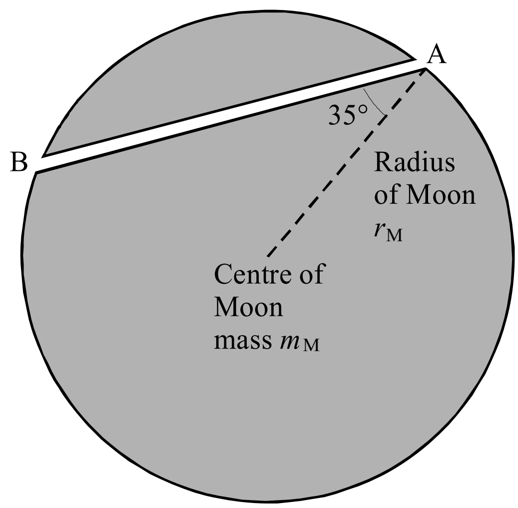
(5)
(Total 7 marks)

82. A futuristic postal system on a colonised Moon might use tunnels bored through the Moon, such as that shown between A and B. There is no air in the tunnels and their sides are frictionless.



It can be shown that a parcel released at A would oscillate with simple harmonic motion between A and B unless it was "collected" at B.

(a) (i) Explain what is meant by *simple harmonic motion.*

(ii) Sketch a graph to show how the velocity of the parcel varies at it moves through the tunnel from A to B.

(4)

(b) The time taken by a parcel to reach B from A is given by

$$t_{AB} = \left(\frac{3\pi}{4\rho_M G}\right)^{\frac{1}{2}}$$

where ρ_M is the mean density of the Moon.

(i) Show that the units of $\rho_M G$ reduce to s^{-2}.

(ii) Calculate t_{AB} to the nearest minute.

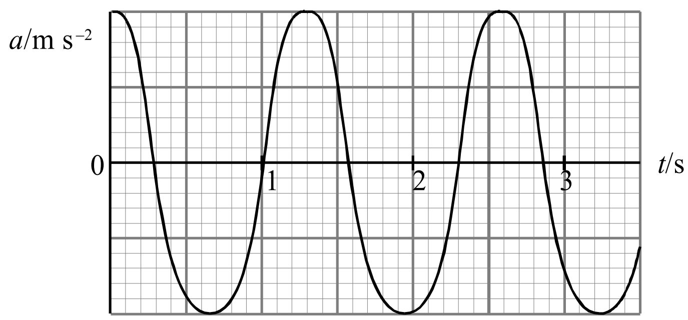
Take the radius of the Moon to be 1.64×10^6 m and its mass to be 7.34×10^{22} kg.

(iii) The equation shows that t_{AB} does not depend on the length of the tunnel.

Explain qualitatively why this appears to be reasonable.

(8)
(Total 12 marks)

83. A body performs simple harmonic oscillations. The graph shows how the acceleration a of the body varies with time t.



State the frequency of the oscillations.

....

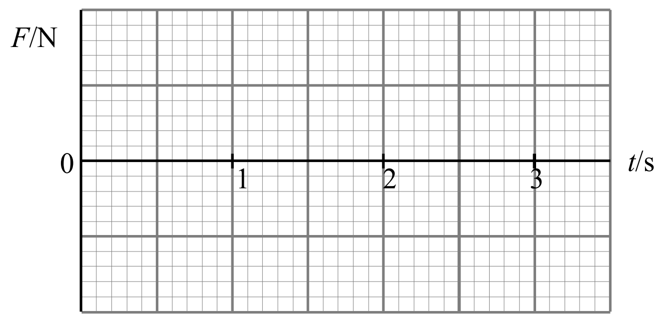
....

(1)

Add to the graph above a curve showing how the *velocity* of the same body varies with time over the same period.

(2)

On the grid below, sketch a graph to show how the *force F* acting on the same body varies with time over the same period.



(2)

A mass m attached to a spring of force constant k oscillates with a period of 1.2 s.
Calculate the period of oscillation for a mass $2m$ attached to a spring of force constant $4k$

....

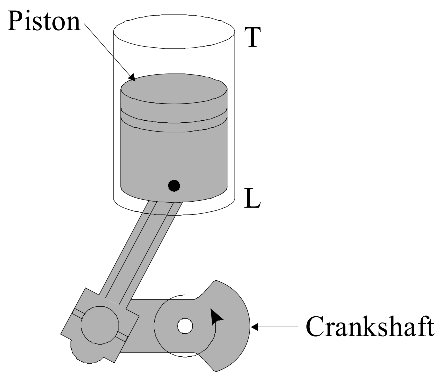
....

....

Period of oscillation =…………………..

(2)
(Total 7 marks)

84. The diagram shows one piston of an internal combustion engine.



As the crankshaft rotates through 360º, the top of the piston moves from L to T and back to L.
The distance LT is 8.6 cm and the crankshaft rotates at 6000 revolutions per minute.

Calculate the frequency of oscillation f of the piston.

....

f =………………………………………..

(1)

State the amplitude of this oscillation.

....

(1)

The oscillations of the piston are approximately simple harmonic. Calculate the maximum acceleration of the piston.

....

....

....

Acceleration =.............................

(2)

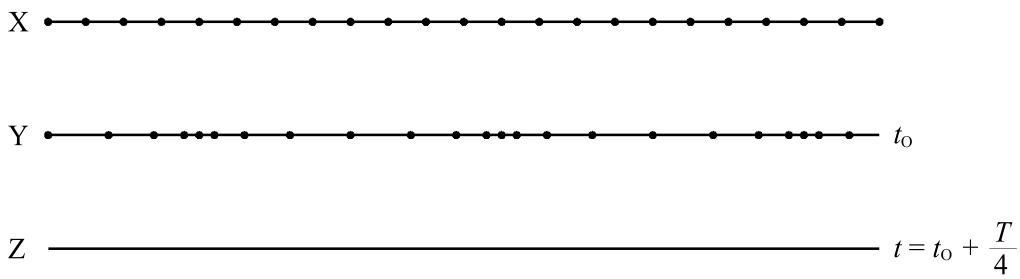
At which position(s) in the movement of the piston will this acceleration be zero?

....

(1)
(Total 5 marks)

85. Sound travels by means of longitudinal waves in air and solids. A progressive sound wave of wavelength λ and frequency f passes through a solid from left to right. In the diagram below line X represents the equilibrium positions of a line of atoms in the solid.

Line Y represents the positions of the same atoms at a time $t = t_0$.



Explain why the wave is longitudinal.

....

....

(1)

On diagram Y label

(i) two compressions (C),
(ii) two rarefactions (R),
(iii) the wavelength λ of the wave.

(3)

The period of the wave is T.

Along the line Z mark in the positions of the two compressions and the two rarefactions at a time t given by $t = t_0 + T/4$.

(2)
(Total 6 marks)

86. Complete the diagram below to show the different regions of the electromagnetic spectrum.

Radio waves		γ-rays

(1)

State *four* differences between radio waves and sound waves.

1 ....

2 ....

3 ....

4 ....

(4)

Two radio stations broadcast at frequencies of 198 kHz and 95.8 MHz. Which station broadcasts at the longer wavelength?

....

Why do obstacles such as buildings and hills present less of a problem for the reception of the signal from the station transmitting at the longer wavelength?

....

....

....

....

....

....

(3)
(Total 8 marks)

87. Draw a labelled diagram of the microwave apparatus you would use to produce and detect a two-slit interference pattern.

(3)

Suggest an appropriate slit separation for this experiment.

....

(1)

How could this experiment be used to obtain a value for the wavelength of the microwaves?

....

....

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....

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(3)
(Total 7 marks)

88. Experiments on the photoelectric effect show that

- the kinetic energy of photoelectrons released depends upon the frequency of the incident light and not on its intensity.

- light below a certain threshold frequency cannot release photoelectrons.

How do these conclusions support a particle theory but not a wave theory of light? You may be awarded a mark for the clarity of your answer.

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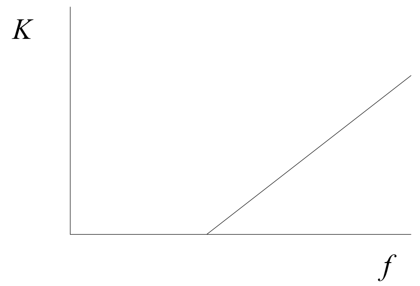
(6)

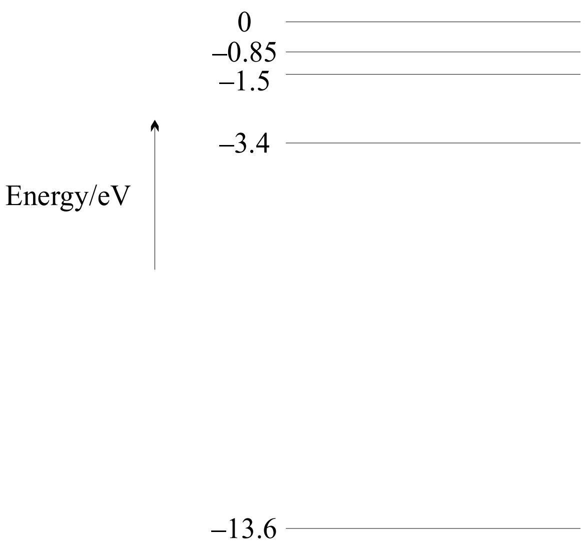
The graph shows how the kinetic energy *K* of emitted photoelectrons from one metal varies with the frequency *f* of the incident light.



Add a second line to the graph showing how *K* will vary with *f* for a second metal which has a *smaller* work function.

(2)
(Total 8 marks)

89. The diagram shows some of the energy levels for atomic hydrogen.



Calculate the ionisation energy in joules for an electron in the –13.6 eV energy level.

....

....

Ionisation energy =……………………...

(1)

Which change in energy levels will give rise to a blue line (λ =490 nm) in the hydrogen spectrum?

....

....

....

....

....

....

(4)

Show this change in energy levels on the diagram.

(1)

The spectrum of white light that has been passed through hot hydrogen gas is observed in the laboratory. The continuous spectrum is seen to have a few dark lines across it. One of these dark lines occurs in the blue region of the spectrum at a wavelength of 490 nm.

Explain the origin of this dark line.

....

....

....

....

(3)

The spectrum of a distant star is observed. It too shows the same pattern of dark lines, but all at longer wavelengths. The line measured at 490 nm in the laboratory occurs at 550 nm in the star's spectrum. What can be deduced about the star?

....

....

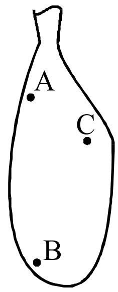
....

....

(3)
(Total 12 marks)

90. A deflated balloon has three points, A, B and C, drawn on its surface. Draw the appearance of the balloon when it is

(i) partially inflated,
(ii) fully inflated.



(2)

The expanding balloon can be used to illustrate *Hubble's law*. Explain how the expanding balloon can be used to illustrate Hubble's law. You may be awarded a mark for the clarity of your answer.

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(5)
(Total 7 marks)

91. Listed below are four types of wave:

microwave sound ultraviolet infrared

From this list, choose the wave which matches each description in the table below, and write it in the space provided. (You may choose a type of wave once, more than once or not at all.)

Description	**Type of wave**
A wave capable of causing photoelectric emission of electrons	
A wave whose vibrations are parallel to the direction of propagation of the wave	
A transverse wave of wavelength 5×10^{-6} m	
The wave of highest frequency	

(Total 4 marks)

92. Neutrons of mass 1.67×10^{-27} kg are travelling at 2.10% of the speed of light. Calculate the de Broglie wavelength for these neutrons.

....

....

....

Wavelength = ...

(3)

Discuss briefly whether neutrons or electrons travelling at this speed would be more suitable for atomic diffraction studies.

....

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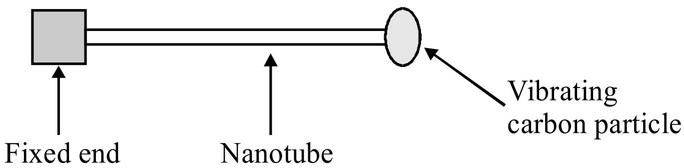
....

(3)
(Total 6 marks)

93. A clever method of "weighing" very small objects such as tiny carbon particles is to attach them to a nanotube. The carbon particle is set into vibration.



In one such experiment, the carbon particle vibrates with maximum amplitude when at a frequency of 970 kHz.

What name is given to the frequency at which an object vibrates with maximum amplitude?

....

(1)

This arrangement can be modelled as a mass on a spring. Calculate the mass of the carbon particle, assuming that the spring constant is 0.81 N m^{-1}.

....

....

....

....

....

Mass = ...

(3)

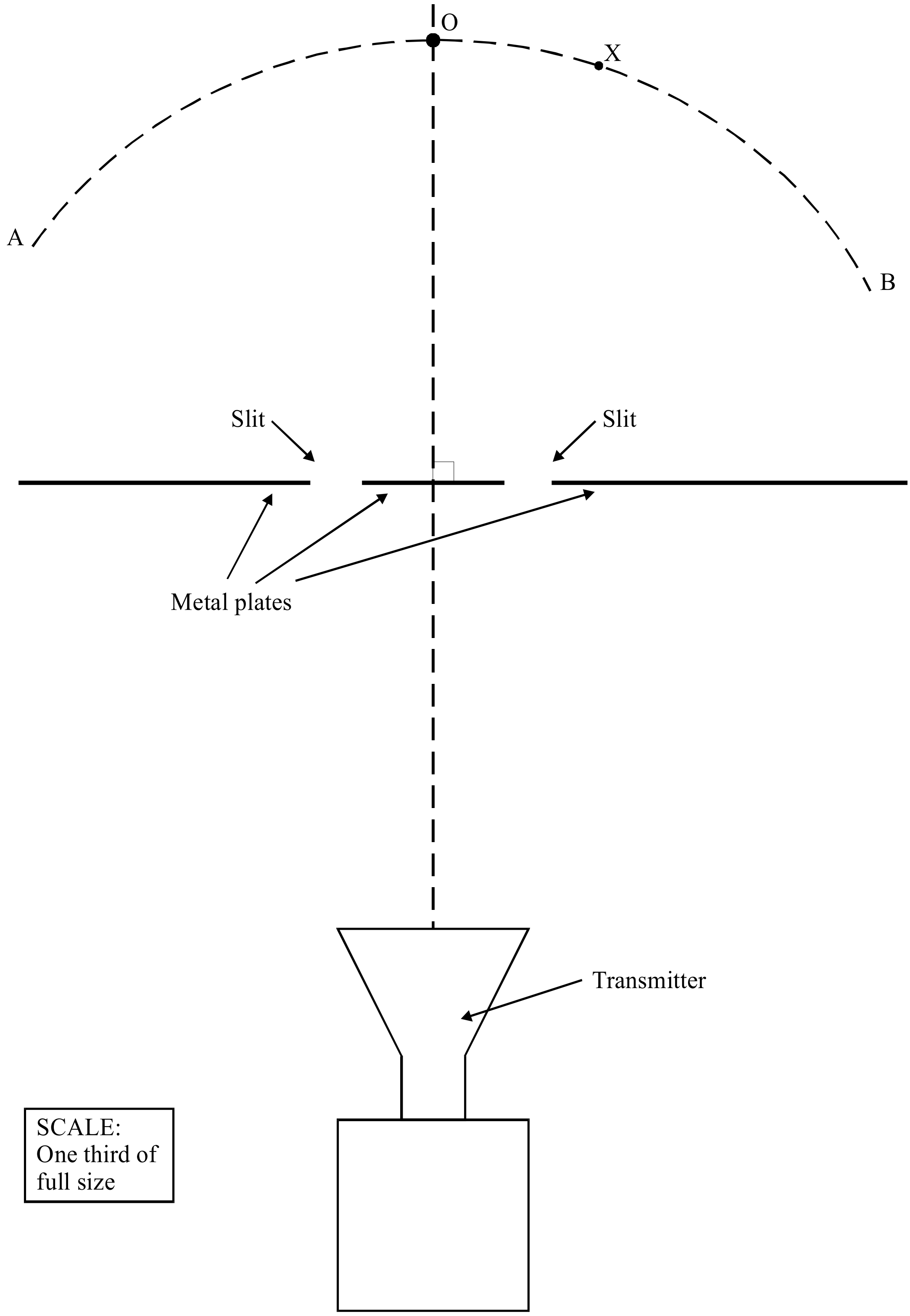
What assumption about the motion of this tiny object has been made?

....

....

(1)
(Total 5 marks)

94. The diagram is a plan view of an experiment to measure the wavelength of microwaves. The diagram is to scale but **one third of full size**.



As a microwave detector is moved around the arc from A to B, alternate maxima and minima of intensity are observed. Explain why.

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(4)

A maximum is observed at point O, and the next maximum at point X. By means of suitable measurements on the diagram determine the wavelength of the microwaves.

....

....

....

....

....

Wavelength = ...

(3)

A teacher demonstrating this experiment finds that, even at the maxima, the wave intensity is small. A student suggests making the slits wider to let more energy through. Explain why this might not be a good idea.

....

....

....

....

(2)

For an interference pattern to be observed between waves from two sources, the sources must be coherent. Explain what is meant by **coherent**, and what makes the two sources in this experiment coherent.

....

....

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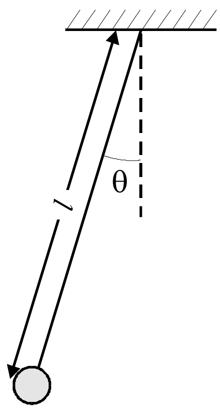
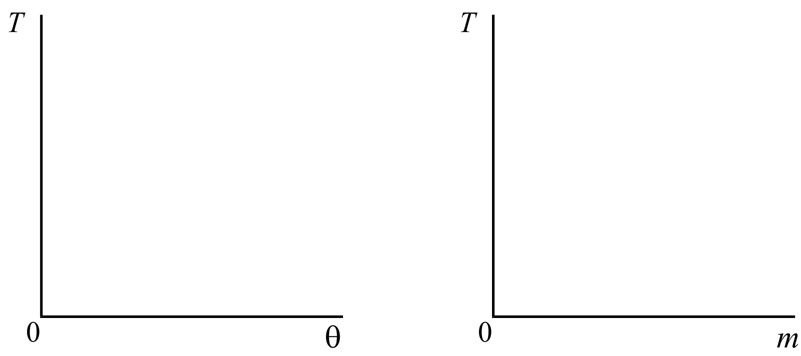
(2)
(Total 11 marks)

95. A simple pendulum of length *l* has a bob of mass *m*.



A student studies the variation of its time period *T* with the angle θ (which is a measure of the amplitude of the motion), the mass *m* and the length *l*.

On the axes below show how *T* varies with θ and with *m*.



(2)

Describe how the student could verify experimentally that $T \propto \sqrt{l}$.

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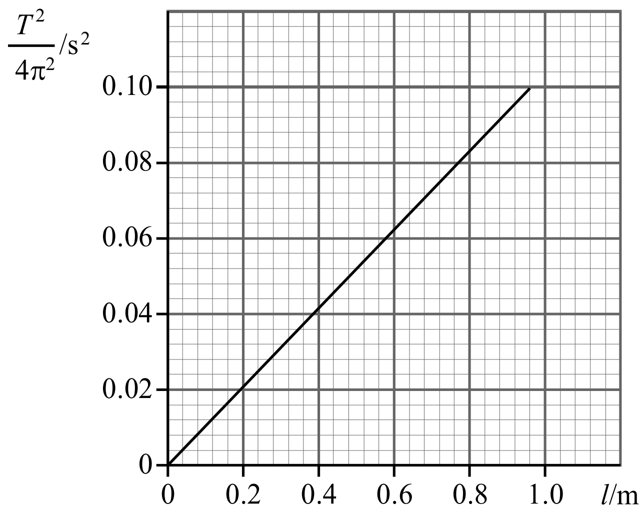
(4)

Below is a graph of $\frac{T^2}{4\pi^2}$ against l.



Calculate the rate of change of $\frac{T^2}{4\pi^2}$ with l.

....

....

Rate of change = ...

Find the rate of change of l with $\frac{T^2}{4\pi^2}$ and comment on your answer.

....

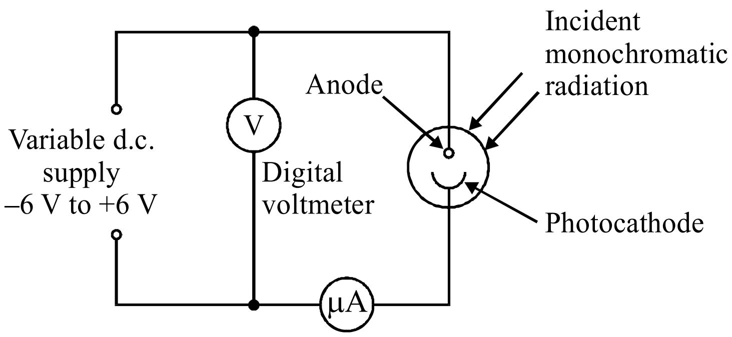
....

....

....

(4)
(Total 10 marks)

96. The diagram shows monochromatic radiation falling on a photocell connected to a circuit.



The incident radiation has a wavelength of 215 mm. The metal surface of the photocathode has a work function of 2.26eV.

Calculate the energy in eV of a photon of the incident radiation.

....

....

....

....

Energy = ... eV

(4)

What is the maximum kinetic energy in eV of the emitted electrons?

....

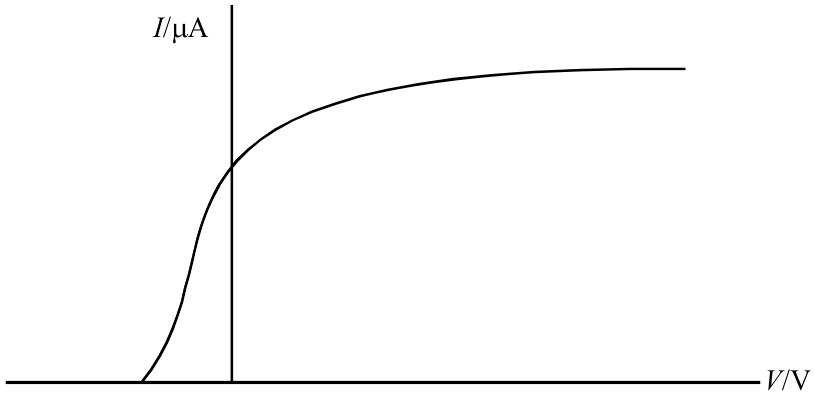
Maximum k.e. = ... eV

Write down the value of the stopping potential.

Stopping potential = ...

(2)

If the wavelength and intensity of the incident radiation is kept constant, a graph of the current I through the photocell against applied p.d. V is as shown.



Mark a letter S on the graph to show the stopping potential.

The photocathode is replaced with one whose metal surface has a greater work function. On the graph above, sketch how I would vary with V given that the wavelength and intensity of the incident radiation remain unchanged.

(3)
(Total 9 marks)

97. A tennis ball connected to a long piece of string is swung around in a horizontal circle above the head of a pupil.

The pupil feels that there is a tension in the string and argues that for equilibrium there must be an outward “centrifugal” force acting on the ball. Criticise his argument and explain why there is a tension in the string.

....

....

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....

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....

....

(5)

The pupil lets go of the string. Draw a free-body force diagram for the ball at the instant after release.

(1)
(Total 6 marks)

98. The Doppler shift may be used in the study of distant galaxies. Explain what is meant by a Doppler shift and how it is used to deduce the motion of distant galaxies. You may be awarded a mark for the clarity of your answer.

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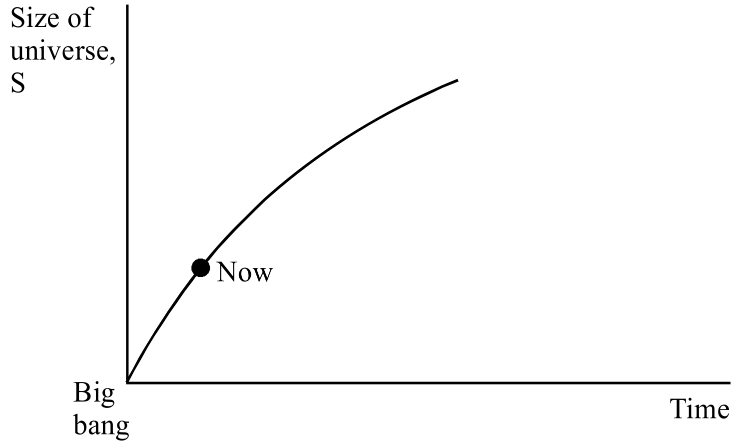
(5)

The graph shows the variation of the size *S* of an open universe against time *t*.



On the same axes, sketch a second graph showing how S varies with t for a closed universe.

(1)

It can be shown that the Universe is closed if its density exceeds a critical value ρ.
This is determined from the Hubble constant H using

$$\rho = kH^2$$

where k is a known constant.

Outline the experimental difficulties in determining ρ accurately.

....

....

....

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....

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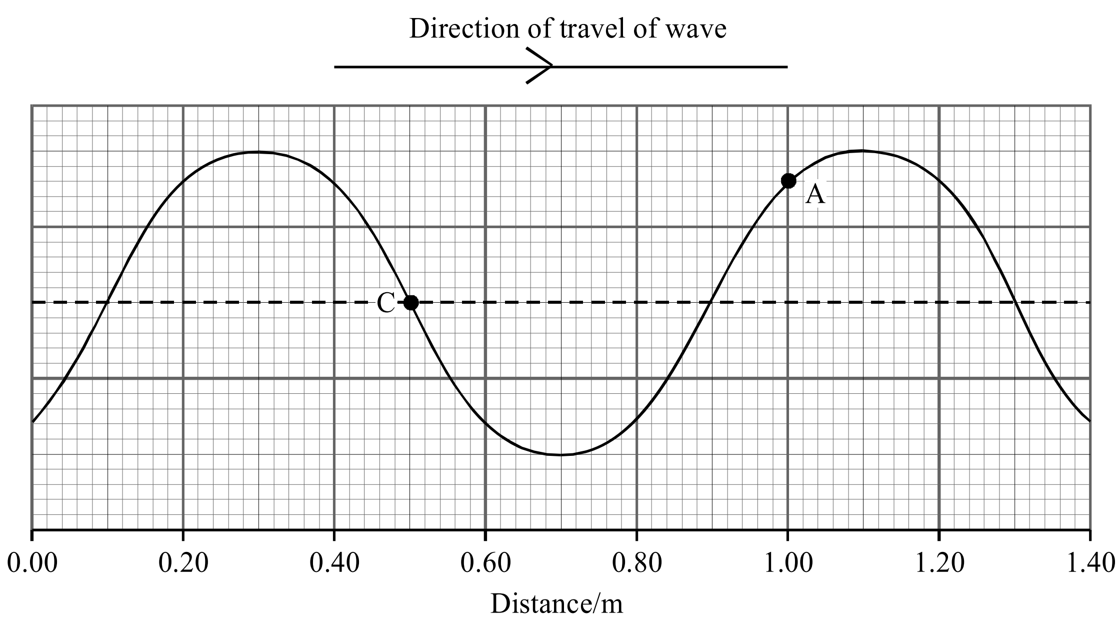
(3)
(Total 9 marks)

99. The diagram shows the shape of a wave on a stretched rope at one instant of time. The wave is travelling to the right.



Determine the wavelength of the wave.

Wavelength = ...

Mark on the diagram a point on the rope whose motion is exactly out of phase with the motion at point A. Label this point X.

Mark on the diagram a point on the rope which is at rest at the instant shown. Label this point Y.

Draw an arrow on the diagram at point C to show the direction in which the rope at C is moving at the instant shown.

(4)

The wave speed is 3.2 m s^{-1}. After how long will the rope next appear exactly the same as in the diagram above?

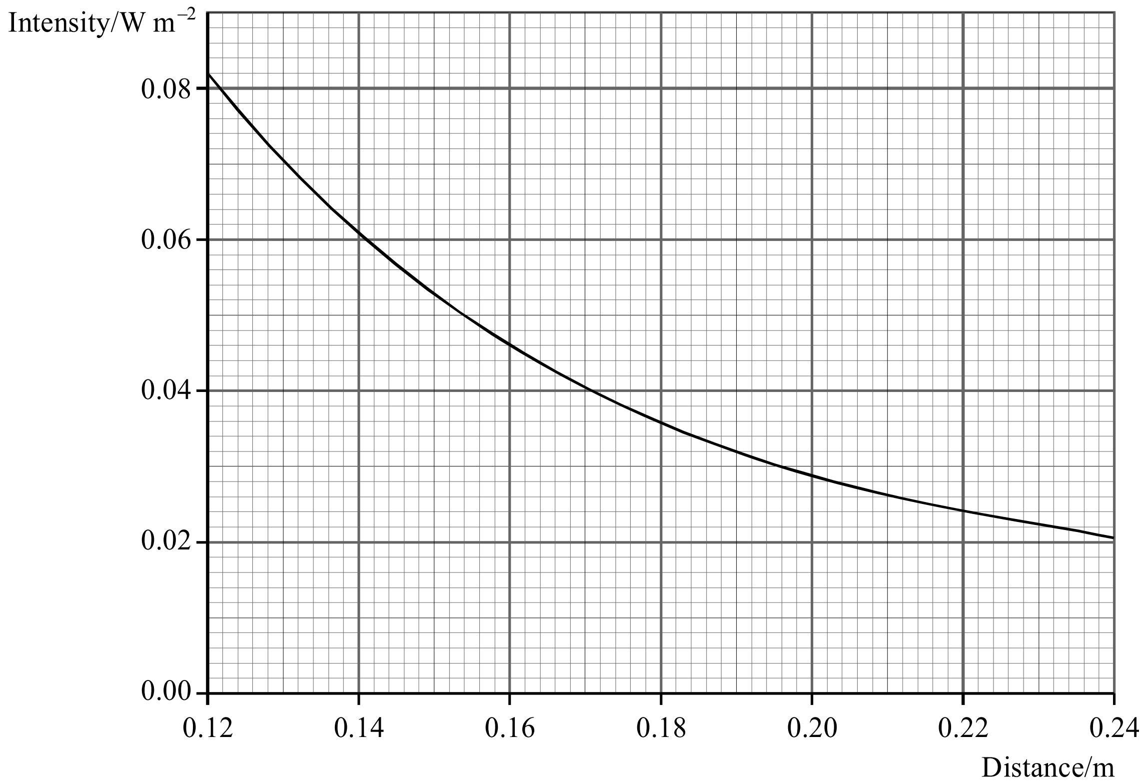
....

....

Time = ...

(2)
(Total 6 marks)

100. The graph shows how the intensity of light from a light-emitting diode (LED) varies with distance from the LED.



Use data from the graph to show that the intensity obeys an inverse square law.

....

....

....

....

....

What does this suggest about the amount of light absorbed by the air?

....

(3)

The light from the LED has a wavelength of 620 nm. Show that the energy of a photon of this light is approximately 3×10^{-19} J.

....

....

....

(2)

A student observes the LED from a distance of 0.20 m. The pupil of her eye has a diameter of 6.0 mm. Calculate the number of photons which enter her eye per second.

....

....

....

....

....

....

....

Number per second = ...

(4)

Explain in terms of photons why the light intensity decreases with increasing distance from the LED.

....

....

....

(1)
(Total 10 marks)

101. Define simple harmonic motion (s.h.m.).

....

....

....

....

(2)

Figure (i) shows a mass performing vertical oscillations on the end of a spring. Figure (ii) is a free-body force diagram for the mass.

Figure (i)

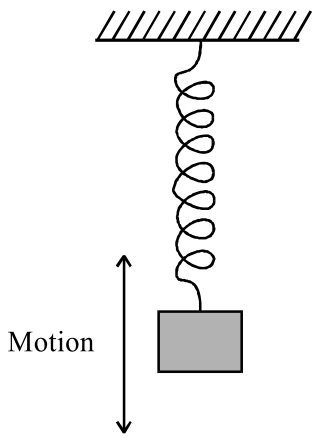
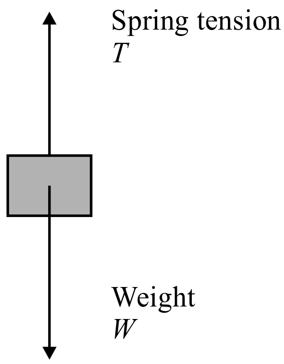


Figure (ii)



The tension T is proportional to the extension of the spring. In the equilibrium position, $T = W$.

With reference to the relative magnitudes of T and W at different points in the motion, explain why the mass oscillates. You may be awarded a mark for the clarity of your answer.

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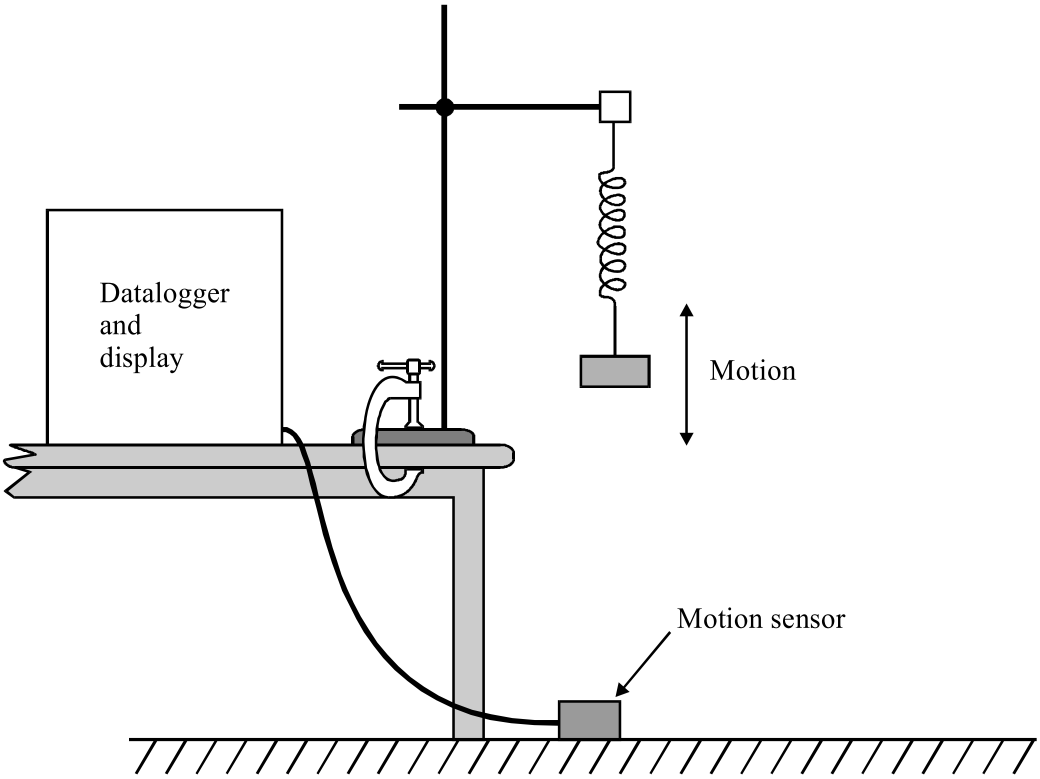
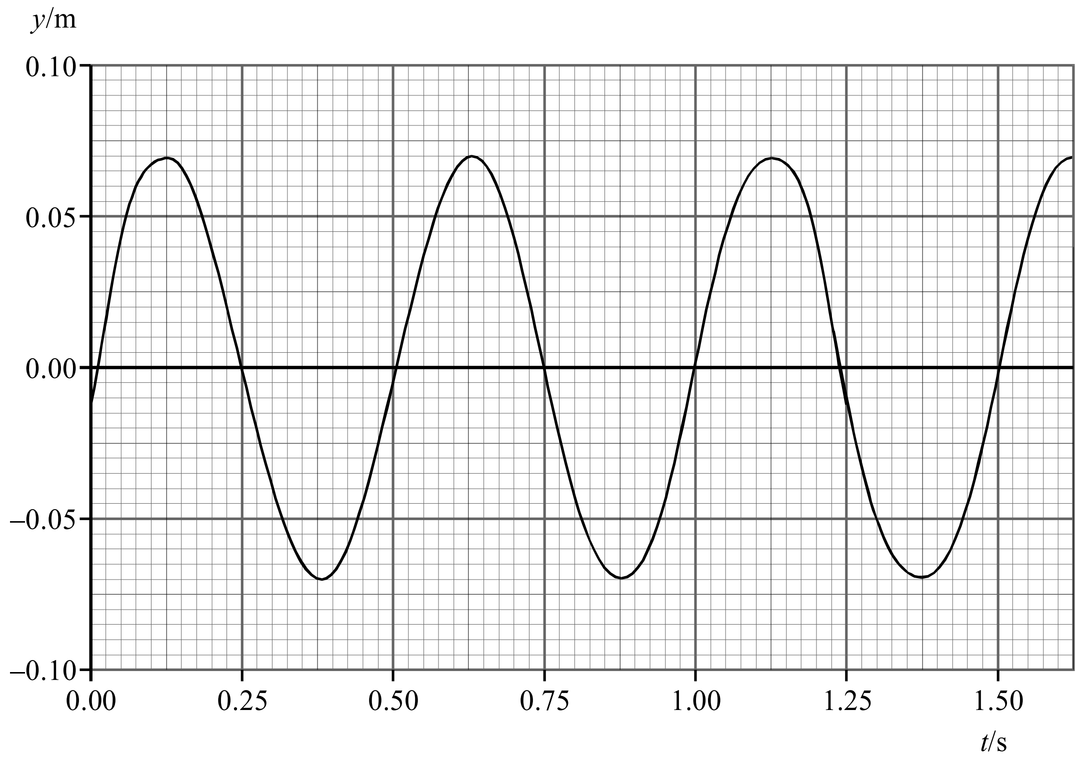
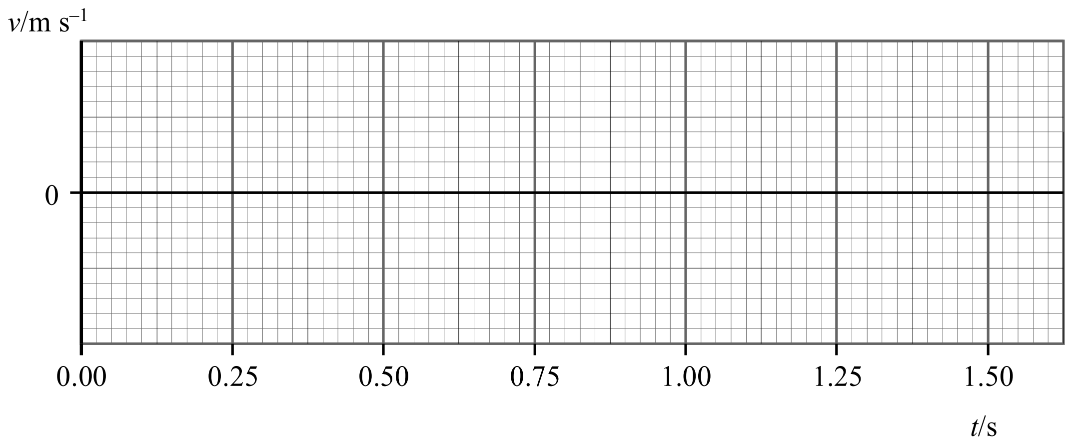
(4)

A datalogger, display and motion sensor are set up to study the motion of the mass. (The motion sensor sends out pulses which enable the datalogger to register the position of the mass.)



The datalogger produces on the display graphs of displacement y and velocity v against time t. The diagram below shows an idealised version of the displacement–time graph. On the lower axes, sketch the velocity–time graph which you would expect to see. (No scale is required on the v axis.)





(2)

Using information from the displacement–time graph, calculate as accurately as possible the maximum velocity of the mass.

....

....

....

....

....

....

Maximum velocity = ...

(4)
(Total 12 marks)

102. Describe how you would demonstrate experimentally that electromagnetic waves can be polarised, using **either** light **or** microwaves. Include a diagram of the apparatus you would use.

....

....

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....

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(4)

What does the experiment tell you about the nature of electromagnetic waves?

....

....

(1)
(Total 5 marks)

103. The electron in a hydrogen atom can be described by a stationary wave which is confined within the atom. This means that its de Broglie wavelength must be similar to the size of the atom, of the order of 10^{-10} m.

Calculate the speed of an electron whose de Broglie wavelength is 1.0×10^{-10} m.

....

....

....

Speed = ...

Calculate the kinetic energy of this electron, in electron volts.

....

....

....

....

Kinetic energy = ... eV

(5)

When β radiation was first discovered, it was suggested that the atomic nucleus must contain electrons. However, it was soon realised that this was impossible because such electrons would possess far too much energy to be bound within the nucleus. Using the ideas of the earlier parts of this question, suggest why an electron confined within the nucleus would have a very high energy.

....

....

....

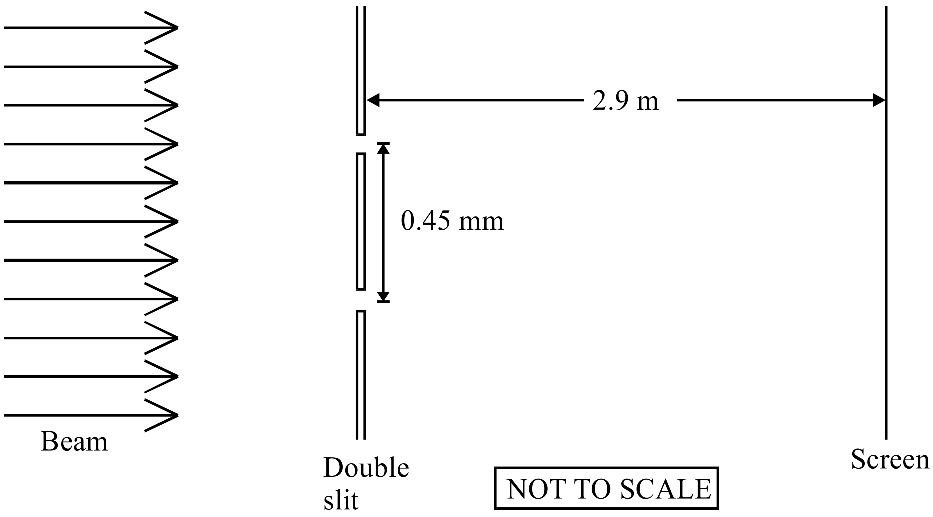
....

....

....

(2)
(Total 7 marks)

104. A laser emits green light of wavelength 540 nm. The beam is directed onto a pair of slits as shown.



The light from the two slits superposes on the screen forming an interference pattern. Calculate the fringe separation.

....

....

....

Fringe separation = ...

(2)

Without any further calculation, state what would happen to the fringe separation if, **separately,**

(i) the slit separation were reduced,

....

(ii) the distance from the slits to the screen were increased,

....

(iii) the laser were replaced with one which emitted red light.

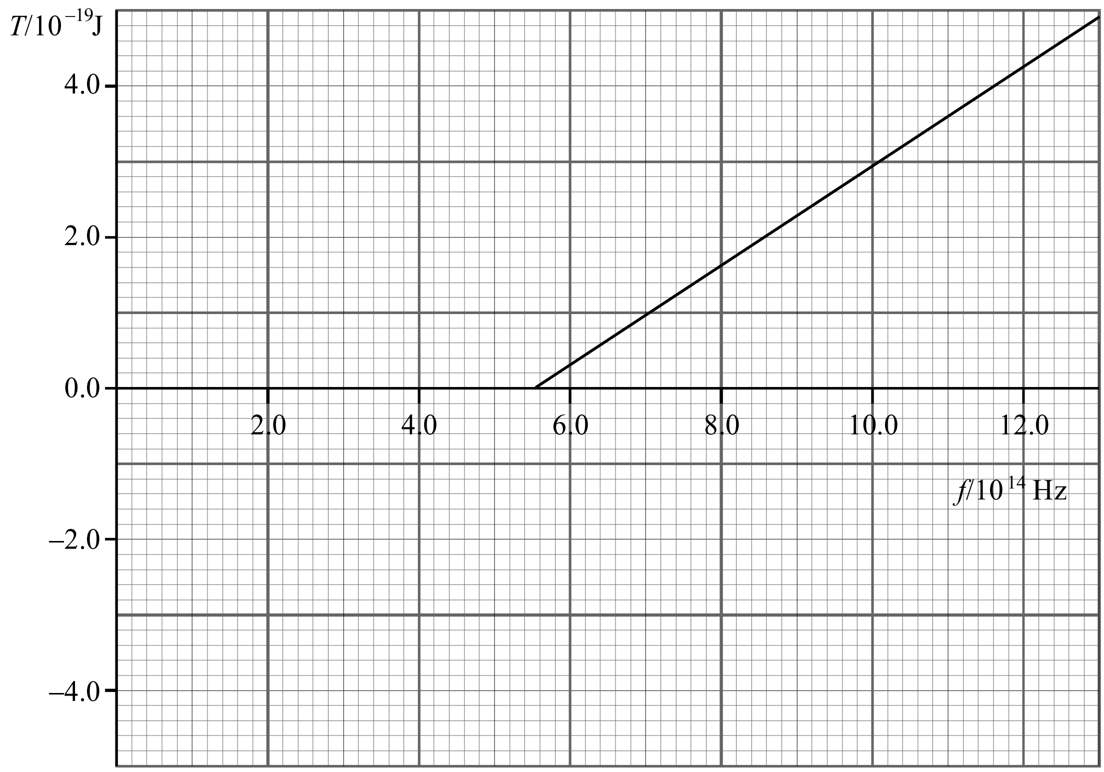
....

(3)

Draw in the space below the diffraction pattern you would observe if **one** of the slits were covered up.

(3)
(Total 8 marks)

105. The graph shows how the maximum kinetic energy T of photoelectrons emitted from the surface of sodium metal varies with the frequency f of the incident electromagnetic radiation.



Use the graph to find a value for the Planck constant.

....

....

....

....

Planck constant = ...

(3)

Use the graph to find the work function ϕ of sodium metal.

....

....

....

Work function = ...

(2)

Calculate the stopping potential when the frequency of the incident radiation is 9.0×10^{14} Hz.

....

....

....

....

Stopping potential = ...

(3)
(Total 8 marks)

106. The table lists three physical quantities.

Physical quantity	**Any commonly used unit**	**Base units**
Activity of a radioactive source		
Angular speed		
The Hubble constant		

In the middle column write down any commonly used unit for each quantity.

In the right-hand column write down the combination of base units which gives the correct unit for each quantity.

(Total 4 marks)

107. Define simple harmonic motion (s.h.m.).

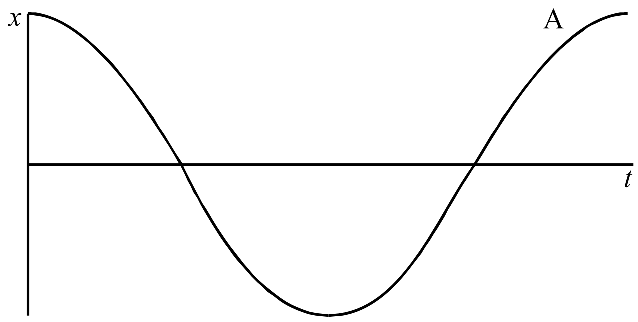
....

....

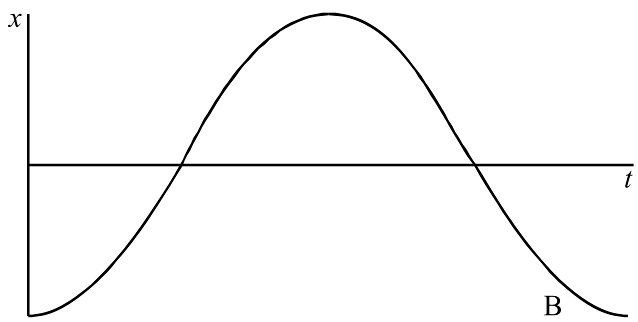
....

(2)

On graph (i), the curve labelled A shows how the displacement *x* of a body executing simple harmonic motion varies with time *t*.
On graph (ii), the curve labelled B shows how the acceleration *a* of this body varies over the same time interval.



Graph (i)



Graph (ii)

Add to **either** graph a curve labelled C showing how the velocity of this body varies over the same time interval.
Which pair of curves illustrates the definition of simple harmonic motion?

....

(3)

A long simple pendulum has a natural frequency of 0.092 Hz. What is the length of this pendulum?

....

....

....

....

....

Length of pendulum = ...

(3)
(Total 8 marks)

108. A space station orbits the Earth once every 91 minutes. Calculate the angular speed of the space station.

....

....

....

Angular speed = ...

(3)

The space station orbit is 210 km above the surface of the Earth, which has a radius of 6370 km. Find the acceleration of the space station.

....

....

....

....

....

....

Acceleration = ...

(3)

A box of mass 4.1 kg is located inside the space station. What is the size and direction of the resultant force acting on the box in the space station?

....

....

....

Resultant force = ...

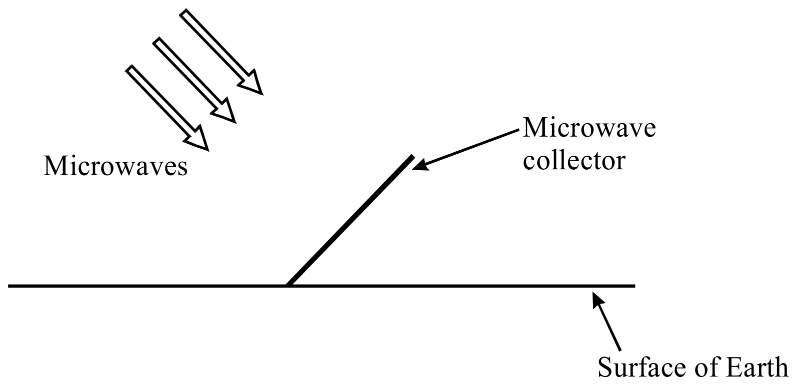
(3)
(Total 9 marks)

109. Radio waves and sound waves are sometimes confused by the general public.
Complete the table to give **three** ways in which they differ.

Radio waves	**Sound waves**

(3)

It is proposed to place a solar power station in orbit around the Earth. The solar power station will convert sunlight to microwave energy. Microwave collectors on Earth will convert the microwaves into electricity.



The solar power station orbits the Earth at a constant distance from the surface of 36 000 km. The total area of the collectors is equivalent to a rectangle with dimensions of 120 m by 250 m.

The collectors are used to generate 600 kW of power. Calculate the intensity of the microwaves at the collectors. State any assumption that you make.

....

....

....

....

Intensity = ...

(3)

Calculate the total power which the orbiting station would have to emit if it transmitted microwaves equally in all directions. State any assumption that you make.

....

....

....

....

....

Power = ...

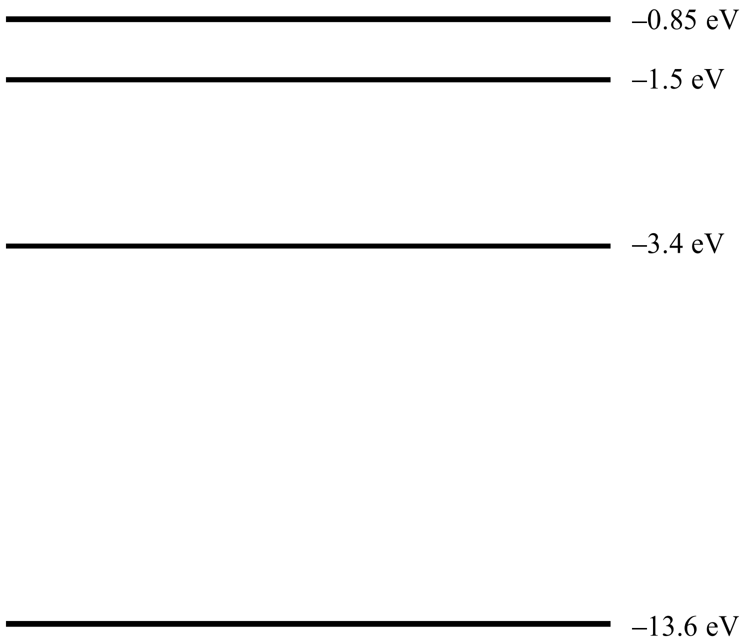
(3)

Suggest a more efficient method of transmitting the microwave energy to the collectors on Earth.

....

(1)
(Total 10 marks)

110. The following diagram shows the lowest four energy levels of atomic hydrogen.



Calculate the ionisation energy in joules for atomic hydrogen.

....

....

Ionisation energy = ... J

(2)

On the diagram above draw

(i) a transition marked with an R which shows a photon **released** with the **longest** wavelength,

(ii) a transition marked with an A which shows a photon **absorbed** with the **shortest** wavelength.

(2)

Describe how you would produce and observe the emission spectrum of hydrogen in the laboratory.

....

....

....

....

What would such a spectrum look like?

....

....

(3)

The 211 mm line of atomic hydrogen is often used in studying stars or galaxies.
To which region of the electromagnetic spectrum does this line belong?

....

(1)

A galaxy is observed with the 211 mm line shifted to a wavelength of 203 mm.
Calculate the speed of this galaxy.

....

....

....

....

....

Speed of galaxy = ...

What else can be deduced about the motion of this galaxy?

....

....

(4)
(Total 12 marks)

111. The photoelectric effect supports a particle theory of light but not a wave theory of light.

State two features of the photoelectric effect which support the particle theory of light but which do not support the wave theory of light. For each feature explain why it supports particle theory and not wave theory.

Feature 1: ....

....

....

Explanation: ....

....

....

....

....

Feature 2: ....

....

....

Explanation: ....

....

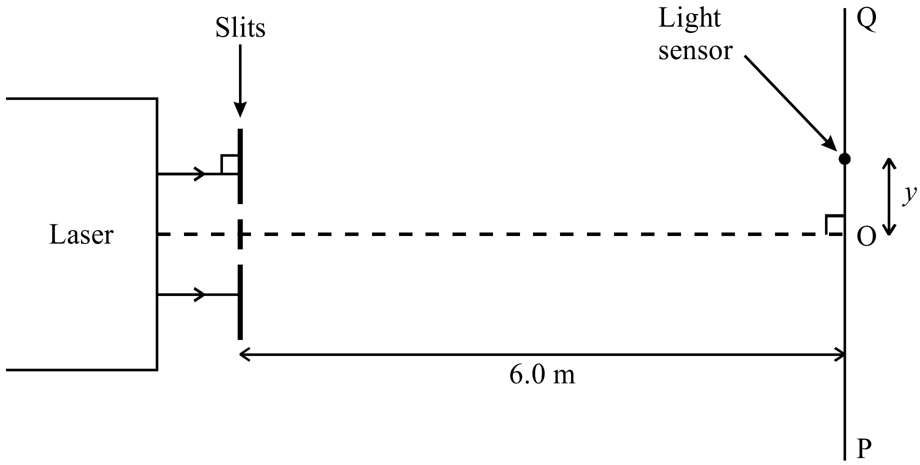
....

....

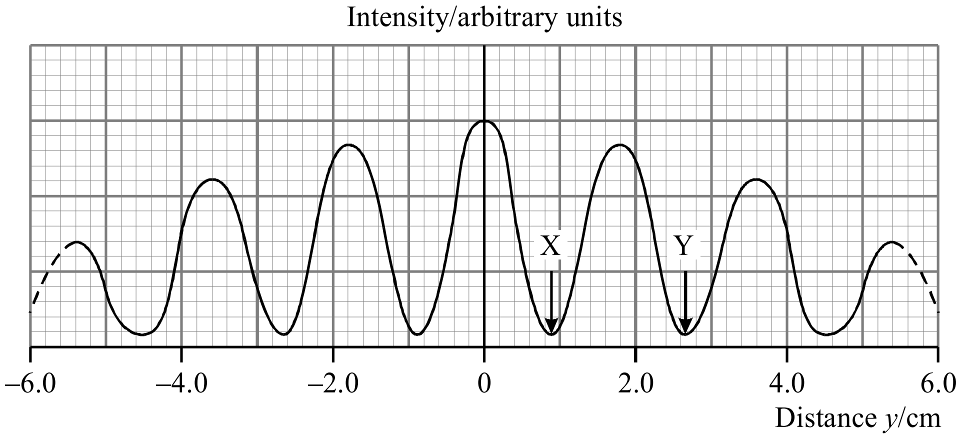
....

(Total 5 marks)

112. The diagram shows, not to scale, an experimental arrangement for studying the transmission of light by a double slit.



Monochromatic light from a laser falls normally on two narrow, closely spaced parallel slits. The intensity of light transmitted is studied by moving a small light sensor along the line PQ, at a perpendicular distance of 6.0 m from the slits. The graph shows how the light intensity varies with distance y from the mid-point O.



Explain with the aid of a diagram why the two light waves from the slits produce a minimum intensity at X.

....

....

....

(2)

Point O is equidistant from the slits. State, in terms of the wavelength A, the path difference between the waves arriving at Y.

Path difference = ...

What is the phase difference, in radians, between the waves arriving at point Y?

....

Phase difference = ... rad.

(2)

The spacing of the slits in the experiment was 0.20 mm. Use this, together with information from the diagrams, to calculate the wavelength of the light.

....

....

....

....

Wavelength = ...

(3)

One of the two slits is now covered up and the experiment is repeated. Add a line to the graph opposite to show how you would expect the light intensity to vary with the distance y.

(2)

(Total 9 marks)

113. Describe with the aid of a diagram how you could produce stationary waves on a string.

....

....

....

....

(3)

Explain how you could use a stationary wave to determine the speed of travelling waves on the string. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

(4)
(Total 7 marks)

114. A metal "slinky" spring can be used as a long solenoid. It is stretched out so that each turn is 1.6 cm from its nearest neighbour. A current of 0.50 A is passed through the coils of the solenoid. Calculate the number of turns per metre in the solenoid.

....

....

Number of turns = ...m^{-1}

(1)

Show that the magnetic field strength in the middle of the solenoid is about 4×10^{-5} T.

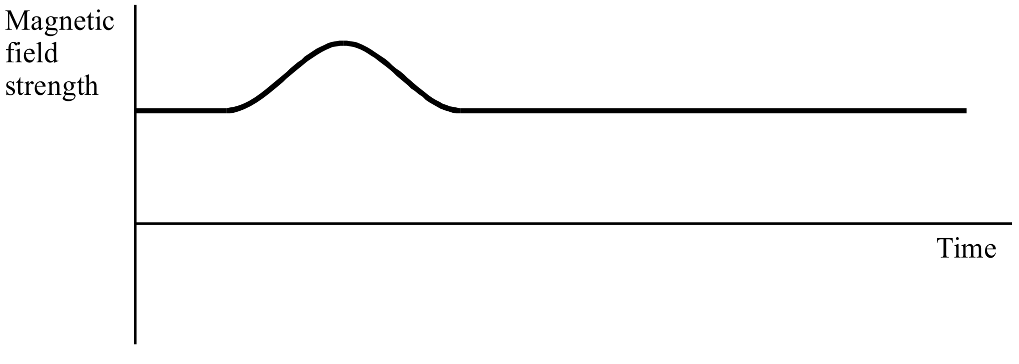
....

....

....

(2)

A longitudinal compression pulse is sent along the solenoid. The resulting changes in the magnetic field strength are detected by a Hall probe fixed inside the solenoid. As the compression pulse passes the Hall probe, the reading changes as follows:



Explain the shape of the graph.

....

....

....

....

(2)

The solenoid is replaced by a heavier one that has an identical number of turns per unit length. A rarefaction pulse is then sent along this heavier solenoid. This pulse travels at a slower speed than the pulse in the first solenoid.

Show on the axes above how the reading on the Hall probe will now vary.

(2)
(Total 7 marks)

115. A satellite S orbits the Earth once every 87 minutes.

Show that its angular speed is approximately 1×10^{-3} radians per second.

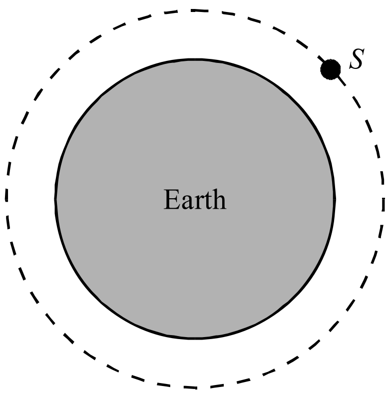
....

....

....

(2)

In the space on the right draw a free-body force diagram for the satellite in the position shown.



(1)

With reference to your free-body force diagram, explain why the satellite is accelerating.

....

....

....

(1)

The radius of the satellite's orbit is 6500 km. Calculate the magnitude of its acceleration.

....

....

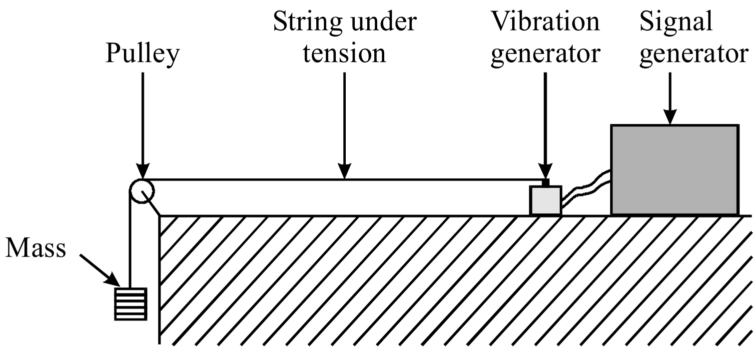
....

....

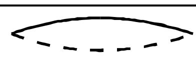
Acceleration = ...

(2)
(Total 6 marks)

116. A piece of string is connected to a variable frequency vibration generator. The fundamental frequency of this system is 60 Hz.



Complete the table to show what would be observed as the frequency is gradually increased from 40 Hz to 180 Hz.

Frequency / Hz	Relative maximum amplitude	Appearance of string
40	low	
60	high	
100		
120		
180		

(7)

How is this phenomenon used to describe the behaviour of the electron in a hydrogen atom? You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

....

(4)
(Total 11 marks)

117. Electrons and photons appear to exhibit either particle or wave behaviour in different situations.

Complete the tables by briefly outlining an observation and its explanation which provide evidence for the particle or wave behaviour in the situation given.

Electrons

Evidence for **particle** behaviour	
Situation	Detecting beta radiation using a GM tube
Observation and explanation	Random clicks are recorded, indicating the arrival of individual β^- particles, i.e. electrons.

Evidence for **wave** behaviour	
Situation	Diffraction of electrons by a crystal
Observation and explanation	

Photons

Evidence for **particle** behaviour	
Situation	Photoelectric effect
Observation and explanation	

Evidence for **wave** behaviour	
Situation	Double slit interference pattern
Observation and explanation	

(Total 6 marks)

118. Calcium has a line spectrum, which includes the spectral line at a wavelength of 393 nm.

Calculate the frequency of this line.

....

....

Frequency = ...

To which region of the electromagnetic spectrum does this line belong?

....

(3)

What is a line spectrum?

....

....

(1)

In cosmology, this calcium line may be used to determine the speed of recession of a distant galaxy.

A galactic cluster in Ursa Major has a recessional velocity of 1.43×10^7 m s^{-1}.
Calculate the wavelength of this calcium line as observed from Earth.

....

....

....

....

....

Wavelength = ...

(3)

Given that this galactic cluster is 1.0×10^9 light years distant, calculate a value for the Hubble constant in s^{-1}.

....

....

....

....

....

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

(4)

Another galactic cluster is 4.0×10^9 light years away from us. Suggest a value for the recessional velocity of this cluster.

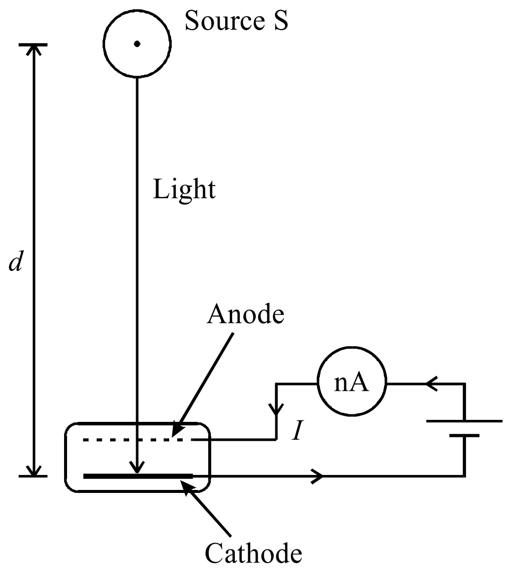
....

....

Velocity = ...

(1)
(Total 12 marks)

119. The diagram shows a small monochromatic light source S positioned at a distance *d* above the cathode of a photocell.



A potential difference is maintained between the anode and the cathode. The light falling on the cathode generates a small current I which is indicated on a very sensitive ammeter.

The size of the current I is directly proportional to the intensity of the light falling on the cathode.

In terms of the waves emitted, what is meant by a monochromatic source?

....

....

(1)

Describe how you could use this apparatus to show that the intensity of the light from the source obeys an inverse square law.

....

....

....

....

....

....

State one important precaution you would need to take to obtain accurate results.

....

....

....

(4)

The cathode of the photocell is made of potassium, which has a work function of 3.6×10^{-19} J. Calculate the maximum wavelength of light which could be used in this experiment.

....

....

....

Maximum wavelength = ...

(3)

(Total 8 marks)

120. The graphs below show how displacement y and velocity v vary with time t for the motion of a mass on a spring.

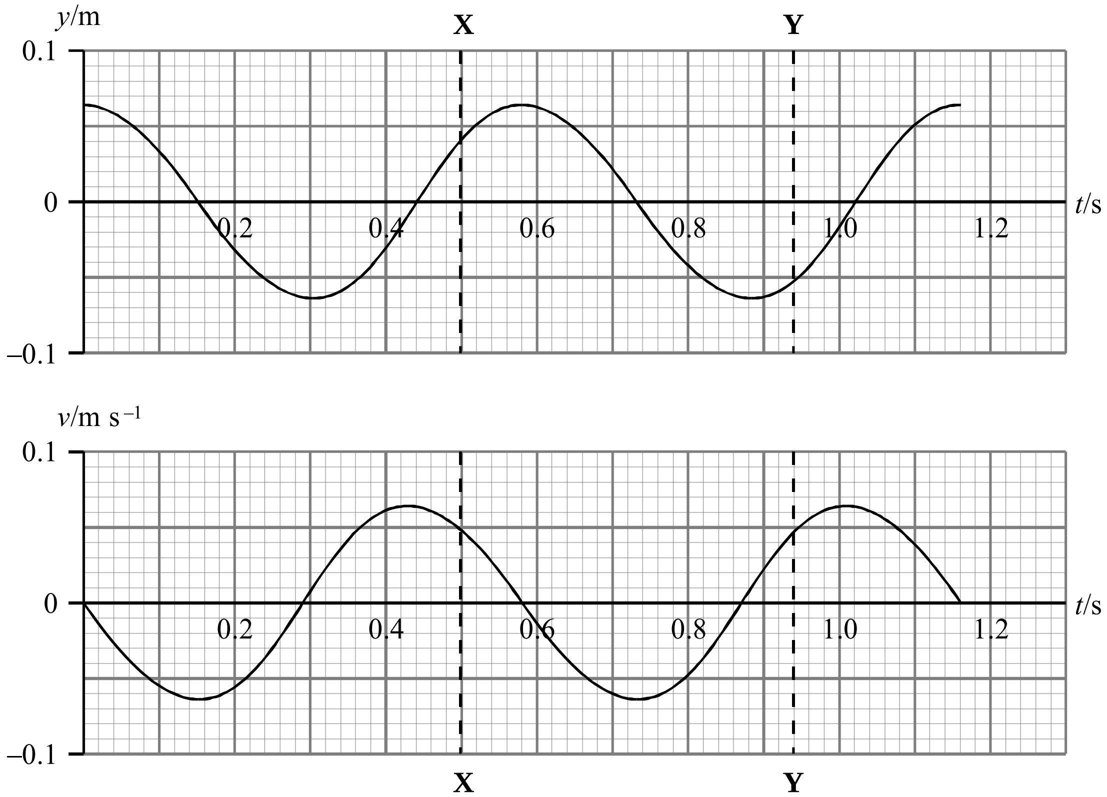
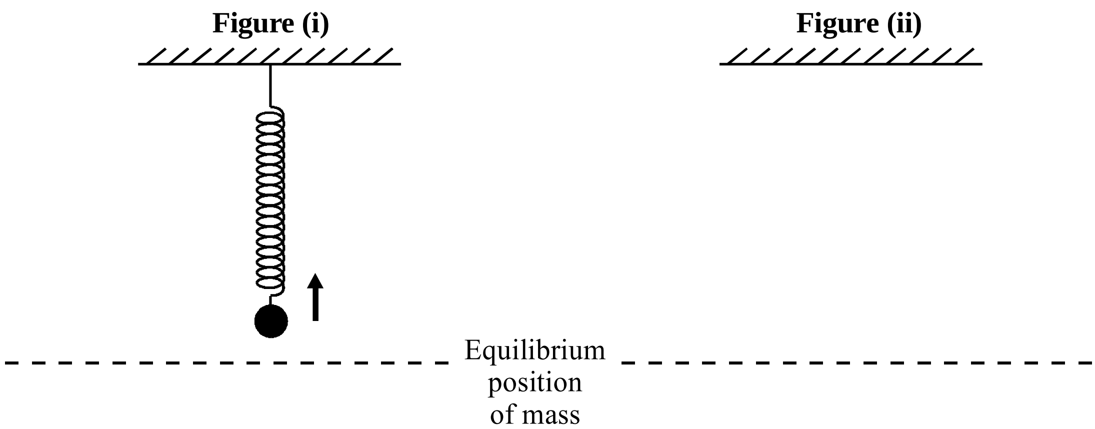


Figure (i) below shows the position and direction of travel of the mass at the instant labelled **X** on the graphs. Complete figure (ii) to show the spring and the position of the mass and its direction of travel at the instant labelled **Y**.



Add arrows labelled "a" to figures (i) and (ii) to show the direction of the acceleration of the mass in each case.

(2)

Using information from the graphs, determine the amplitude of motion, and the value of the spring constant *k* given that the mass is 0.40 kg.

Amplitude = ...

....

....

....

....

....

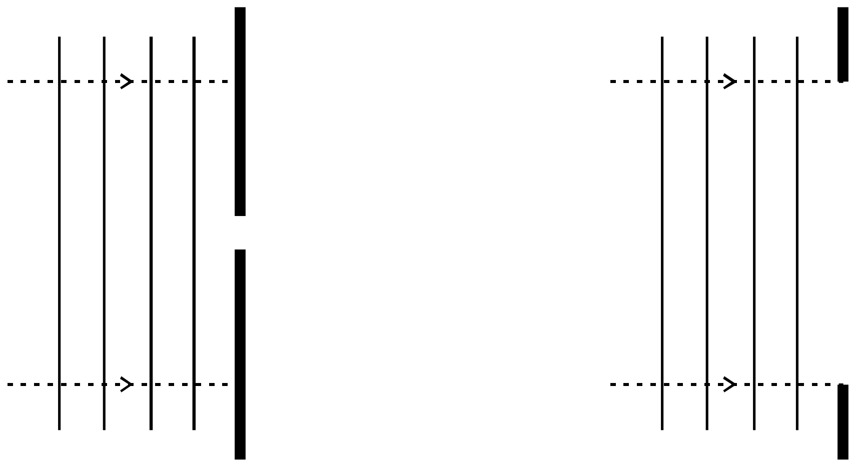
....

Spring constant = ...

(5)

(Total 7 marks)

121. Each of the diagrams below shows a series of wavefronts, one wavelength apart, approaching a gap between two barriers in a ripple tank.



What is a wavefront?

....

....

(1)

Add further wavefronts to each diagram to show what happens as the waves pass through each gap.

(3)

The station BBC Radio 4 broadcasts both on the Long Wave band at 198 kHz and on VHF at approximately 94 MHz. In mountainous parts of the country, reception is better on Long Wave than on VHF. Suggest why.

....

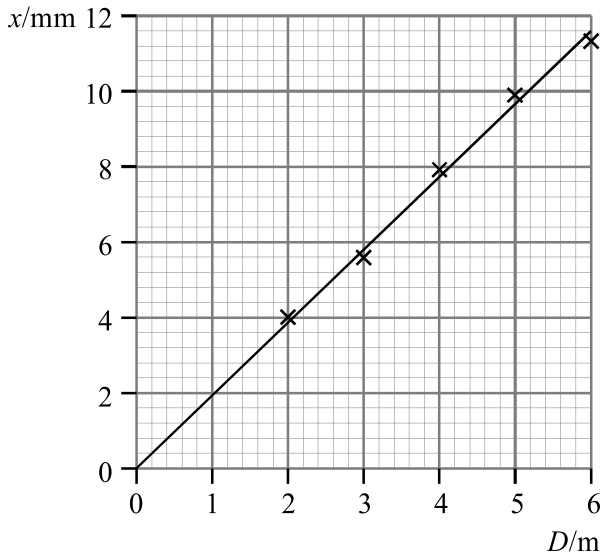
....

....

....

(2)
(Total 6 marks)

122. In an experiment on superposition, light from a laser was incident normally on a double slit, and the interference pattern was observed on a screen situated a distance *D* from the slits. The fringe spacing *x* was measured for a number of different values of *D* and the graph below was plotted.



Determine the gradient of the graph.

....

....

Gradient = ...

(1)

Use your result to find a value for the spacing of the slits, given that the wavelength of the light was 620 nm.

....

....

....

....

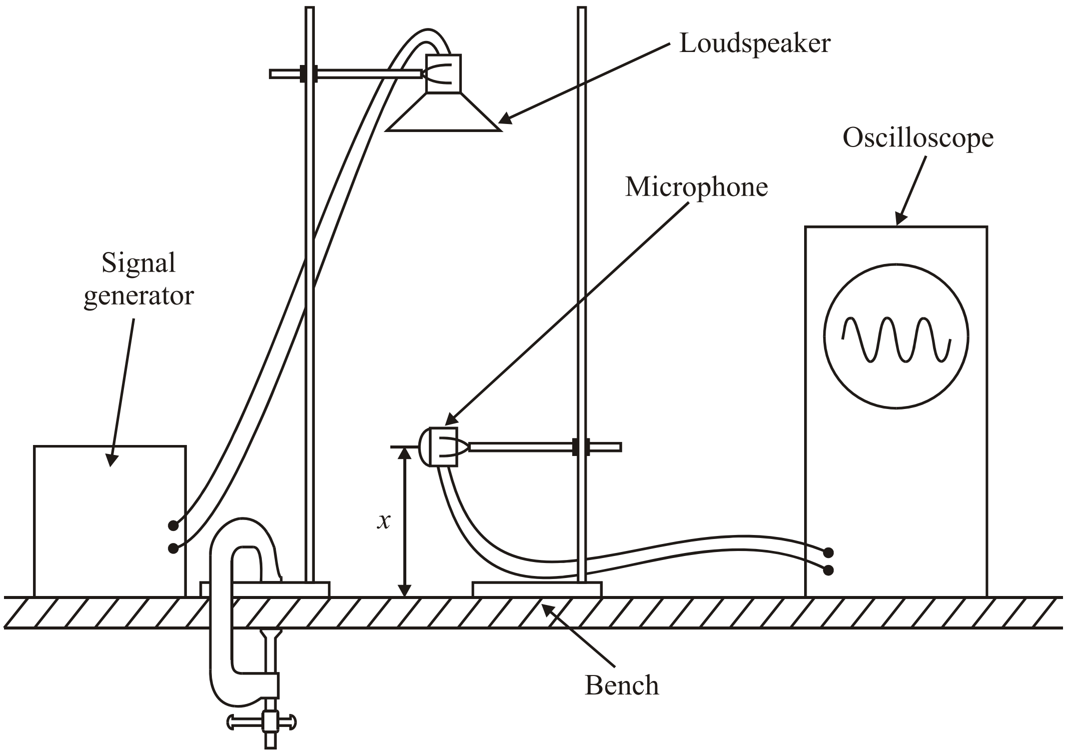
Slit spacing = ...

(2)

Add a second line to the graph to show the results you would expect if the experiment were repeated with the slit spacing doubled.

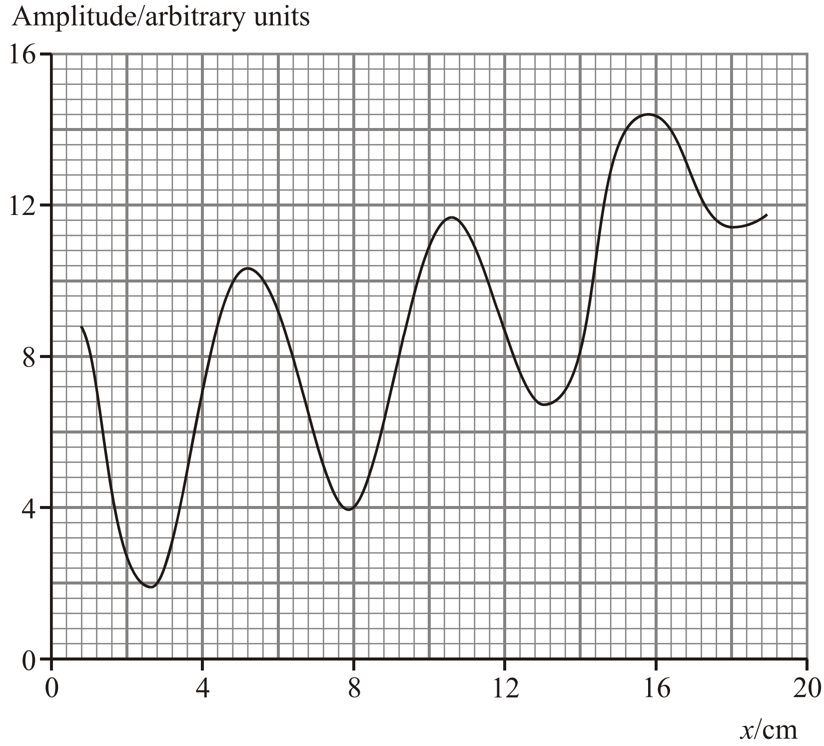
(1)
(Total 4 marks)

123. The diagram shows an experiment with sound waves.



A loudspeaker connected to a signal generator is mounted, pointing downwards, above a horizontal bench. The sound is detected by a microphone connected to an oscilloscope. The height of the trace on the oscilloscope is proportional to the amplitude of the sound waves at the microphone.

When the vertical distance *x* between the microphone and the bench is varied, the amplitude of the sound waves is found to vary as shown on the graph.



Explain why the amplitude of the sound has a number of maxima and minima.
You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

....

....

(5)

The frequency of the sound waves is 3.20 kHz. Use this, together with information from the graph, to determine a value for the speed of sound in air.

....

....

....

....

Speed of sound = ...

(4)

The contrast between the maxima and minima becomes less pronounced as the microphone is raised further from the surface of the bench. Suggest an explanation for this.

....

....

....

....

....

(2)
(Total 11 marks)

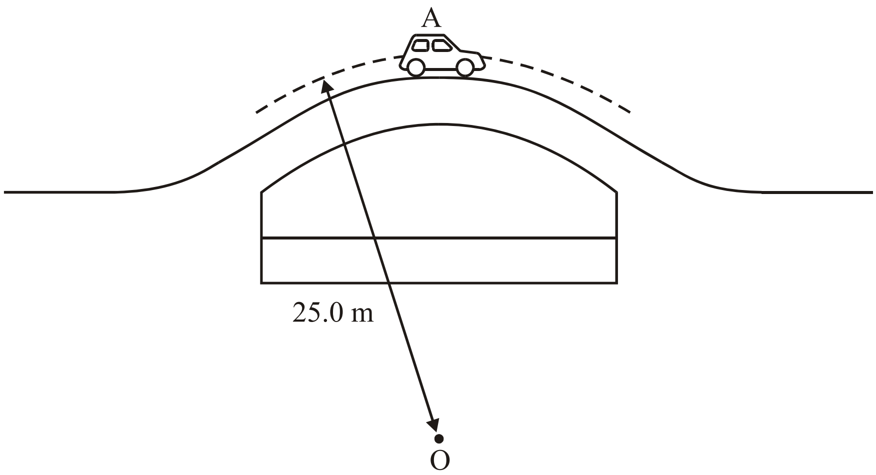
124. A body of mass *m* travelling at constant speed *v* around a circular path of radius *r* must have a resultant force *F* acting upon it. Write down a formula for the magnitude of *F* and state the direction in which it acts.

Formula: ....

Direction: ....

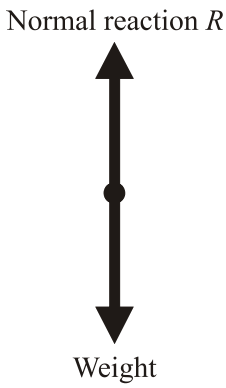
(2)

The diagram shows a car at the highest point A of a hump-backed bridge.



When the car is driven over the bridge it follows part of a vertical circle of radius 25.0 m centred at the point O below the bridge.

Below is a free-body force diagram for the car at point A.



The mass of the car is 925 kg. Calculate the normal reaction force *R*

(i) when the car is parked at rest at A,

....

R = ...

(ii) when the car is passing point A at a speed of 10.0 m s^{-1}.

....

....

....

R = ...

(4)

If the car is driven across the bridge repeatedly, at gradually increasing speeds, it is found that, above a certain critical speed, the car loses contact with the road at A, and "takes off ". Explain why this happens.

....

....

....

....

(1)

Calculate the critical speed for this particular bridge.

....

....

Critical speed = ...

(2)

An object which is in free fall is said to be "apparently weightless". Explain what this means, illustrating your answer with reference to the situation described in this question.

....

....

....

....

(2)
(Total 11 marks)

125. Define simple harmonic motion (s.h.m.).

....

....

....

....

(2)

A mass on a spring is displaced 0.036 m vertically downwards from its equilibrium position. It is then released. As it passes upwards through its equilibrium position a clock is started. The mass takes 7.60 s to perform 20 cycles of its oscillation.

Assuming that the motion is s.h.m., it can be described by the equation

$$x = x_0 \sin 2\pi ft$$

where x is the displacement in the upward direction and t the time since the clock was started. What are the values of x_0 and f in this case?

x_0 = ...

....

....

f = ...

(3)

Use the equation to calculate the displacement when t = 1.00 s.

....

....

x = ...

(1)

In practice, simple harmonic motion is not a perfect model of the motion of the mass, and so the equation above does not predict the displacement correctly. Explain how and why the motion differs from that predicted by the equation.

....

....

....

....

(2)
(Total 8 marks)

126. If an oscillating system is made to perform *forced oscillations* at a frequency close to its *natural frequency*, then *resonance* occurs.

Describe how you could demonstrate qualitatively the meanings of the terms in italics.
Include a diagram of the apparatus you would use.

....

....

....

....

....

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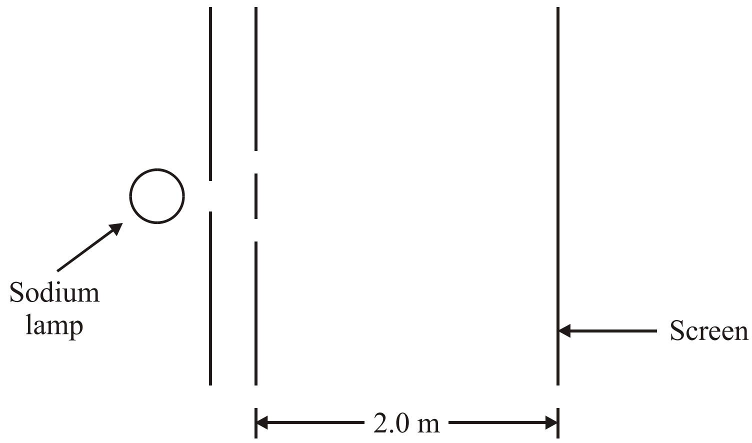
....

(Total 7 marks)

127. The diagram shows, in principle, an experiment which can be used to demonstrate two-slit interference patterns with light.



The sodium lamp emits yellow light of wavelength 589.0 nm. The fringe spacing for this wavelength is 3.9 mm. Calculate the separation between the centres of the slits.

....

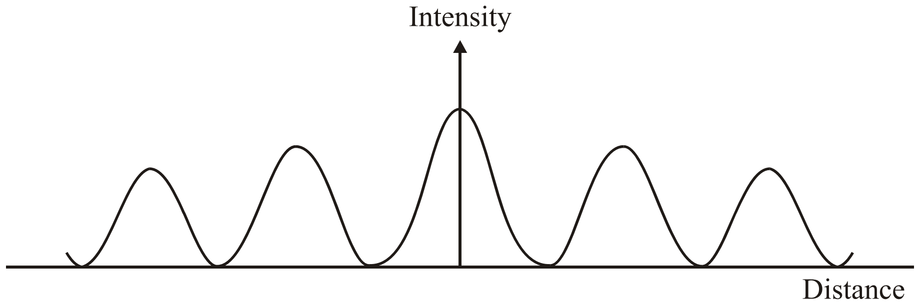
....

....

Separation = ...

(2)

The diagram below shows how the intensity varies with distance across the screen for the central part of the interference pattern produced by light of a single wavelength.



Add a second line to the diagram to show the intensity variation you would expect if the wavelength were increased.

(1)

In addition to the wavelength of 589.0 nm, the sodium lamp also produces light of wavelength 589.6 nm. The two emissions have similar intensities. Explain whether you would expect the presence of these two wavelengths to be a problem in observing a clear interference pattern.

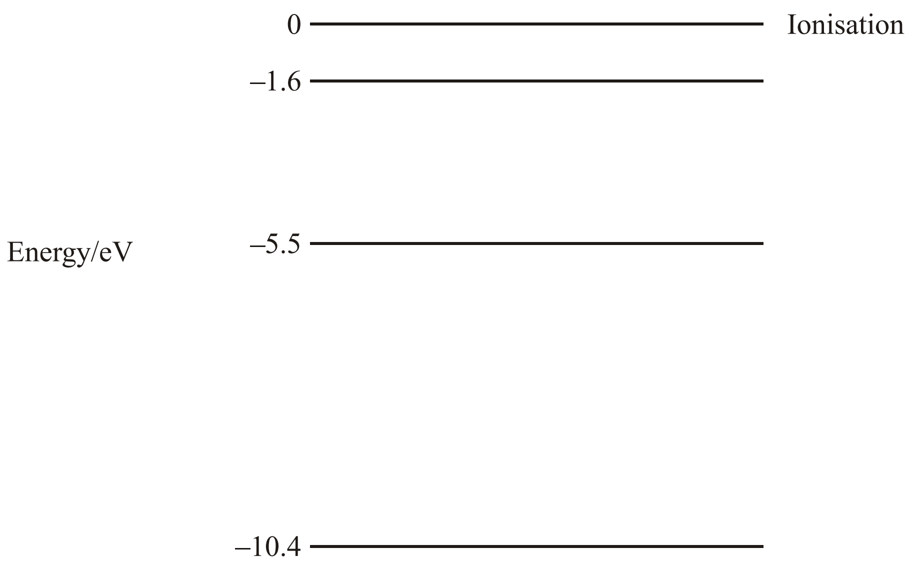
....

....

....

(2)
(Total 5 marks)

128. The diagram shows some of the energy levels of a mercury atom.



Calculate the ionisation energy in joules for an electron in the –10.4 eV level.

....

....

Ionisation energy = ... J

(2)

A proton of kinetic energy 9.2 eV collides with a mercury atom. As a result, an electron in the atom moves from the –10.4 eV level to the –1.6 eV level. What is the kinetic energy in eV of the proton after the collision?

....

....

Kinetic energy = ...

(1)

A transition between which two energy levels in the mercury atom will give rise to an emission line of wavelength 320 nm?

....

....

....

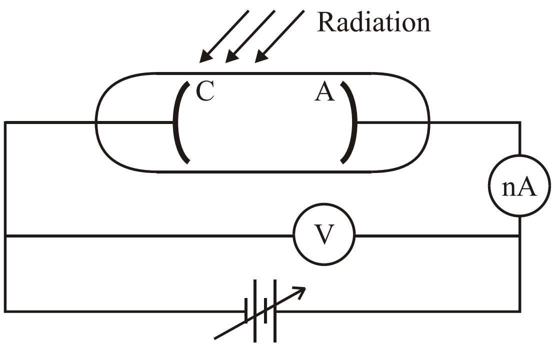
....

....

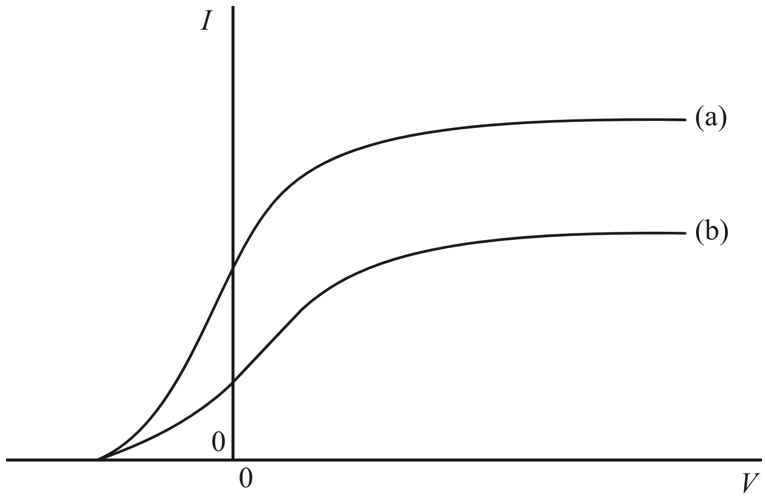
....

(3)
(Total 6 marks)

129. The diagram shows apparatus for an experiment on the photoelectric effect.



Monochromatic radiation strikes the cathode C and photoelectrons are emitted towards the anode A. When a potential difference V is applied, a current I is measured on the very sensitive ammeter. Data can also be obtained with the polarity of the supply reversed. Using this apparatus, graph (a) below was obtained. After making a change to the incident radiation, graph (b) was obtained.



What can be deduced about the incident radiations from

(i) the fact that both curves start from the same point on the negative V axis,

....

....

(ii) the higher final value of the current I in (a) compared to (b)?

....

....

(2)

The cathode is now replaced by one made from a metal with a higher work function. On the same axes, sketch a graph labelled (c) showing what would be observed if the original radiation were used.

(1)

The work function of the metal of the cathode is 7.2×10^{-19} J. Calculate the maximum speed of the photoelectrons emitted when the incident radiation has a frequency of 7.9×10^{15} Hz.

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Maximum speed = ...

(4)
(Total 7 marks)

130. The hydrogen lines in the spectra of almost all galaxies show a red shift. Explain the meaning of a red shift.

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(2)

Explain how this red shift is thought to occur, and what the measurements of galactic red shifts suggest about the Universe.

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(3)
(Total 5 marks)

131. A CD player uses a laser that emits radiation of wavelength 790 nm.

A student suggests setting up this laser to observe a two-slit interference pattern by shining it at a screen through a double slit. Why would the student not be able to see any fringes?

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

(1)

A laser that emits radiation of wavelength 790 nm is directed at a double slit with a suitable detector 1.2 m from the slit. The slit spacing is 0.24 mm. How far apart are the fringes which correspond to maximum readings on the detector?

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Fringe separation = …............................

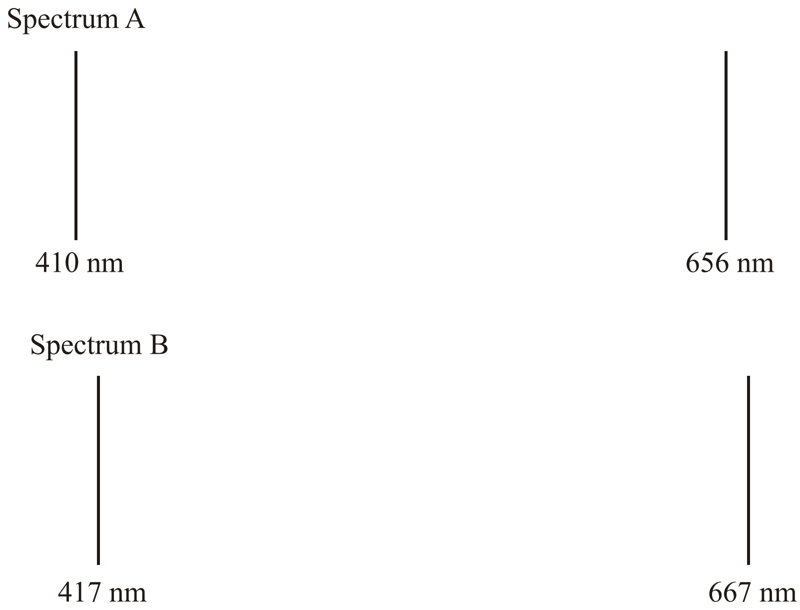
(2)

How could you increase the fringe separation without changing the wavelength of the laser beam?

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

(1)
(Total 4 marks)

132. Spectrum A shows two emission lines of hydrogen obtained in a laboratory; spectrum B shows the same lines as obtained from light from a distant galaxy. Use these spectra to determine the **velocity** of this galaxy. (The diagrams are not to scale.)



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Velocity = ...

(4)

Using a value for the Hubble constant of 1.8×10^{-18} s^{-1}, estimate the distance of this galaxy from Earth.

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Distance = ...

(2)
(Total 6 marks)

133. Neutrons, like electrons, are often used to study crystal structure. A suitable de Broglie wavelength for the neutrons would be about 1 nm.

Explain why the neutrons must have a de Broglie wavelength of this order of magnitude.

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(2)

Given the mass of a neutron as 1.67×10^{-27} kg, calculate the kinetic energy of a neutron which has a de Broglie wavelength of 1.20 nm.

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Kinetic energy = ...

(3)

What is meant by **wave-particle duality**? Illustrate your answer with the example of neutrons. You may be awarded a mark for the clarity of your answer.

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(4)
(Total 9 marks)

134. Describe, with the aid of a diagram, an experiment to demonstrate stationary waves using microwaves.

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(4)

Using the idea of wave superposition, explain what is observed in your experiment.

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(2)

Describe how you could use the experiment to measure the wavelength of microwaves.

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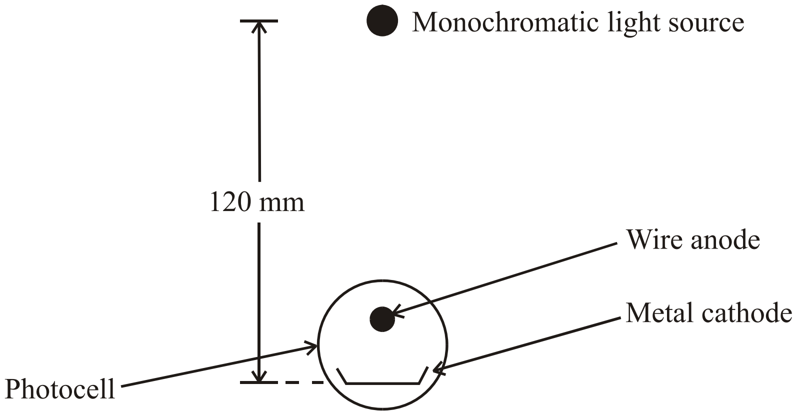
(2)
(Total 8 marks)

135. A monochromatic light source is placed 120 mm above the cathode of a photocell.



The light source consumes 6 W of power and is 15% efficient. Calculate the light intensity at the cathode. State an assumption that you made.

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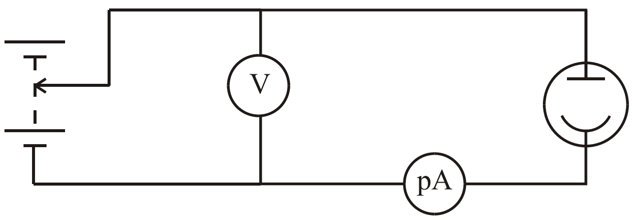
(3)

A potential difference is applied between the cathode and the anode of the photocell and the sensitive ammeter detects the current.



The table below shows the currents which are obtained with this apparatus for two different intensities and two different wavelengths of light, using two different cathode materials. Work function energies are given.

Wavelength of incident radiation /nm	Cathode material	Work function /eV	Photocurrent /A when intensity of incident radiation is	
			$1\ \text{W m}^{-2}$	$5\ \text{W m}^{-2}$
320	Aluminium	4.1	0	0
640	Aluminium	4.1	0	0
320	Lithium	2.3	0.2×10^{-12}	1.0×10^{-12}
640	Lithium	2.3	0	0

Show that the incident photons of λ = 320 nm and λ = 640 nm have energies of approximately 4 eV and 2 eV respectively.

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(4)

Account for the photocurrent readings shown in the table.

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(3)

Calculate the stopping potential for the photoelectrons released by lithium when irradiated by light of wavelength 320 nm.

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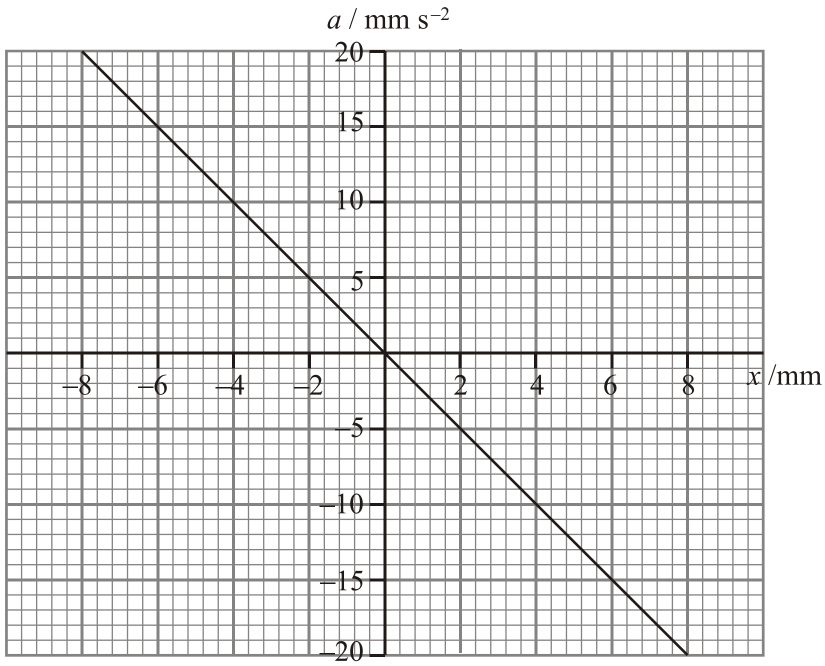
Stopping potential = ...

(2)
(Total 12 marks)

136. The graph shows how the acceleration a varies with displacement x for a particle undergoing simple harmonic motion.



Calculate the gradient of this graph.

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Gradient = ...

Use your value to deduce the frequency for this motion.

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Frequency = ...

(4)

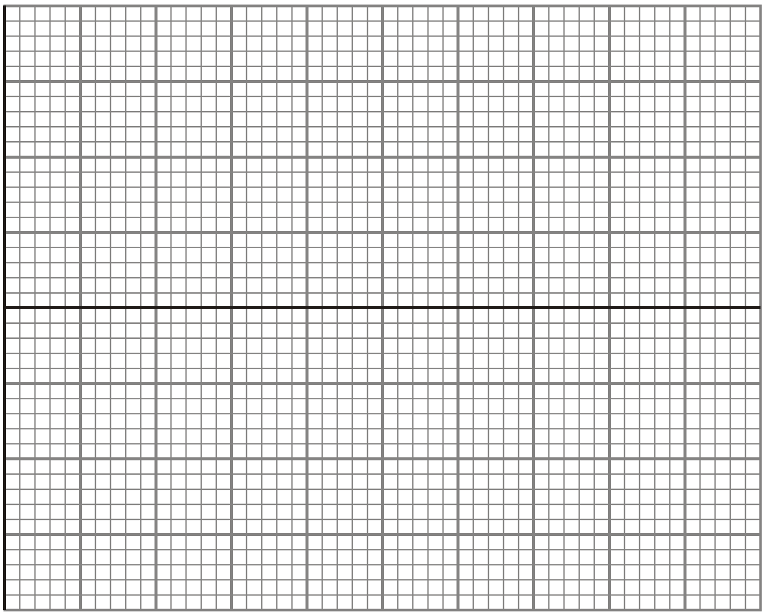
Hence, write down the period of the motion.

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

(1)

On the grid below sketch a graph of acceleration against time for this motion. Assume that the displacement is zero and the velocity is positive at $t = 0$.

Add suitable scales to the axes. Draw at least two complete cycles.



(3)
(Total 8 marks)

137. In a washing machine clothes are placed inside a metal drum with small holes in it. When the wet clothes are spun, the drum rotates at high speed and water escapes through the holes. The drum has a radius of 0.220 m and rotates at 800 revolutions per minute.

Show that the speed of the rim of the drum is approximately 18 m s^{-1}.

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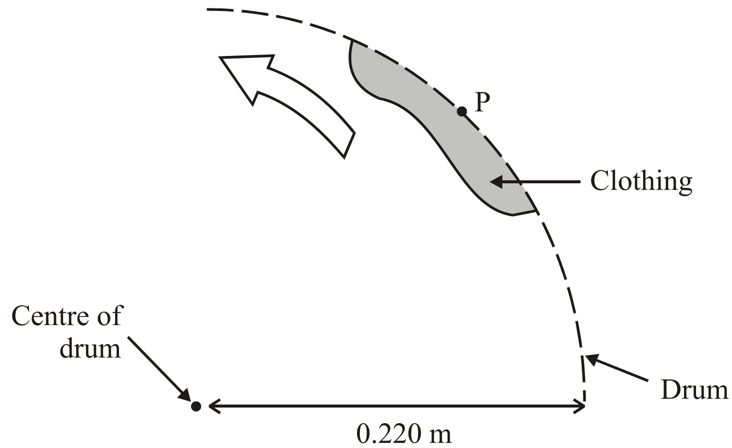
(3)

The diagram shows a piece of clothing in the drum which is spinning anticlockwise.



Estimate the magnitude of the acceleration of this piece of clothing.

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Acceleration = ...

(2)

Add an arrow to the diagram to show the direction of this acceleration. Label the arrow A.

Explain what force produces this acceleration.

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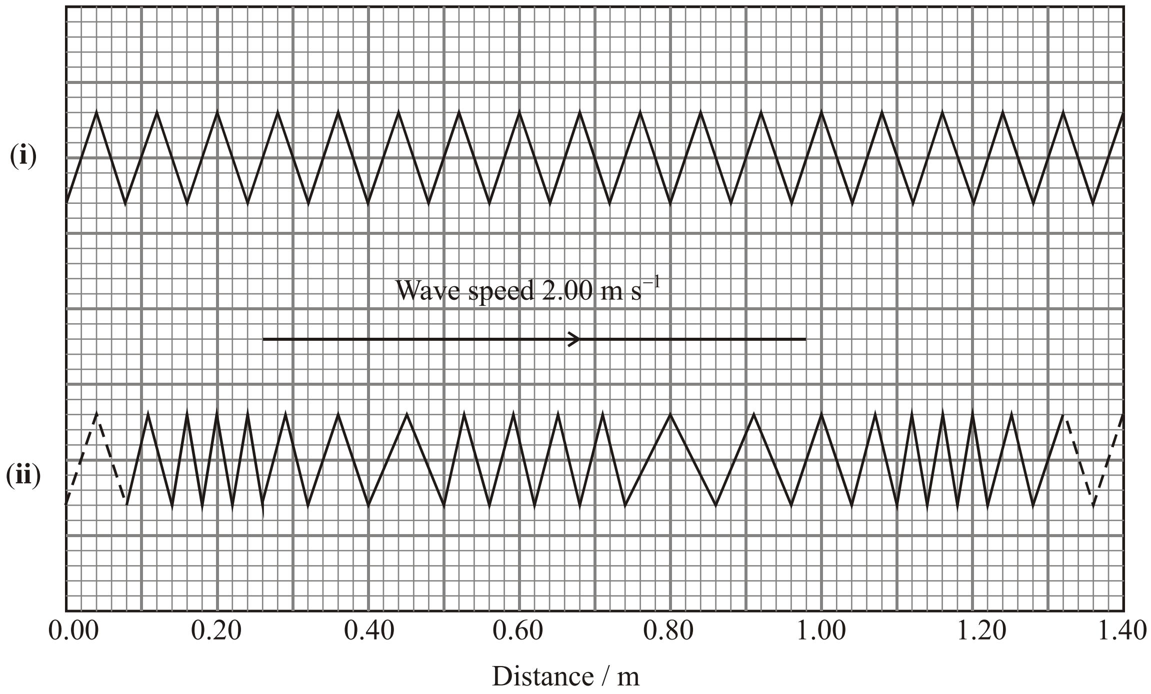
(2)

A drop of water becomes detached from the clothing at point P, which is next to one of the holes in the drum. Draw an arrow on the diagram to show the path which the drop of water now follows. Label this arrow B.

(1)
(Total 8 marks)

138. Diagram (**i**) represents part of a stretched spring. Diagram (**ii**) represents the same section of the spring at one instant of time when a sinusoidal longitudinal wave is travelling along it.



Use the diagram (**ii**) to determine the wavelength of the longitudinal wave.

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

Wavelength = ...

(1)

The wave speed is 2.00 m s^{-1}. Calculate the frequency of this wave.

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

Frequency = ...

(1)

Describe qualitatively the motion of an individual coil of this spring as the longitudinal wave travels along the spring.

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(3)
(Total 5 marks)

139. A body performs simple harmonic motion when its acceleration is proportional to its displacement from a fixed point and is directed towards that point. What additional condition must be satisfied for the oscillations of a pendulum to be simple harmonic?

....

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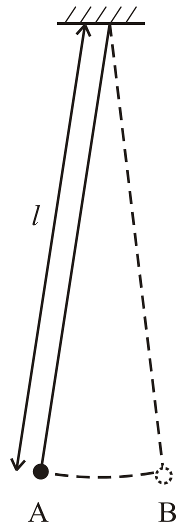
(1)

The diagram shows a long pendulum which is oscillating between points A and B.



The pendulum takes 5.72 s to swing from A to B. Calculate its period *T*.

T = ...

The acceleration due to gravity is 9.81 m s^{-2}. Calculate the length *l* of the pendulum.

....

....

....

l = ...

(3)

(Total 4 marks)

140. To make an object of mass m move at speed υ around a circular path of radius r, a resultant force must act on it. The magnitude of the resultant force is given by $m\upsilon^2/r$.

Explain why a resultant force is required, and state its direction.

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(3)

When vehicles corner on a level road, the resultant force is provided by friction. For a given vehicle and road surface, the friction cannot exceed a certain maximum value. Use these facts, together with the expression for the resultant force, to explain why roads designed for high-speed travel have no sharp bends.

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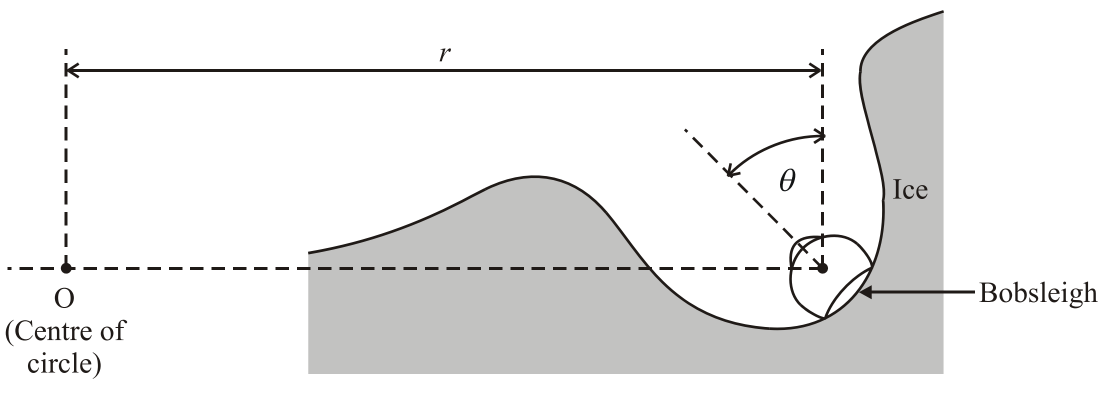
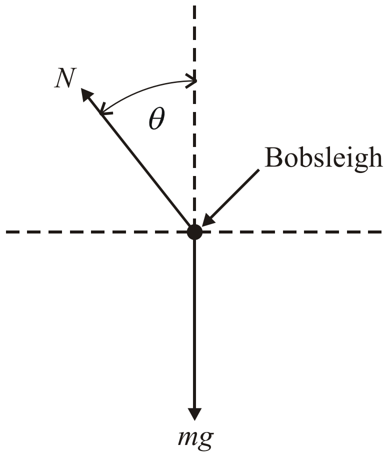
(2)

On a bobsleigh run, the bobsleigh travels along an ice channel with little friction. When cornering, it slides up the side of the channel until the required resultant force is provided.

The diagram shows a head-on view of a bobsleigh travelling at speed υ round a bend which is part of a horizontal circle centred at the point O. The bobsleigh is tilted through an angle θ.



Below is a free-body force diagram for the bobsleigh. Friction is assumed to be negligible.



The normal contact force exerted by the ice on the bobsleigh is *N*, and its weight is *mg*.

Write down an equation expressing the condition for no vertical acceleration.

....

Write down an equation applying Newton's second law horizontally.

....

Hence show that

$$\tan \theta = \frac{v^2}{rg}$$

($\tan \theta = \sin \theta / \cos \theta$)

....

....

....

....

(4)

Calculate the value of angle θ for a bobsleigh travelling at 30.0 m s^{-1} around a bend of radius 20.0 m.

....

....

θ =…..

(1)
(Total 10 marks)

141. You are provided with a double slit whose slit separation is known to be 0.20 mm. Describe how you would use it to measure the wavelength of the light from a monochromatic source. Mention any step you would take to make the measurement as accurate as possible.

You should include a diagram of the experimental arrangement, and state a suitable value for any other important dimension.

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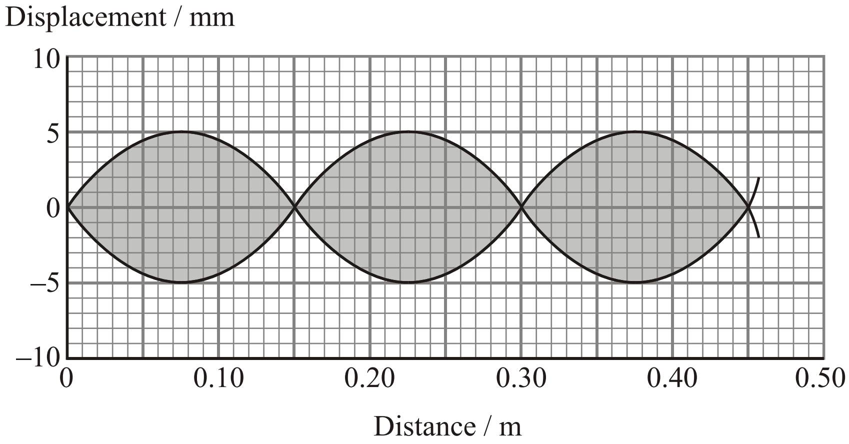
(Total 7 marks)

142. A stationary wave is produced on a stretched string by a vibration generator attached to one end. The graph shows part of the wave. The two full lines represent the extreme positions of the string.



State the wavelength of this wave.

....

(1)

Mark a letter A on the graph to label an antinode.

(1)

The stationary wave is formed by the superposition of two waves travelling along the string in opposite directions. The frequency of the vibrator is 36.0 Hz. Calculate the speed of the travelling waves.

....

....

Wave speed = ...

(2)

State the phase relationship between the two travelling waves at an antinode.

....

(1)

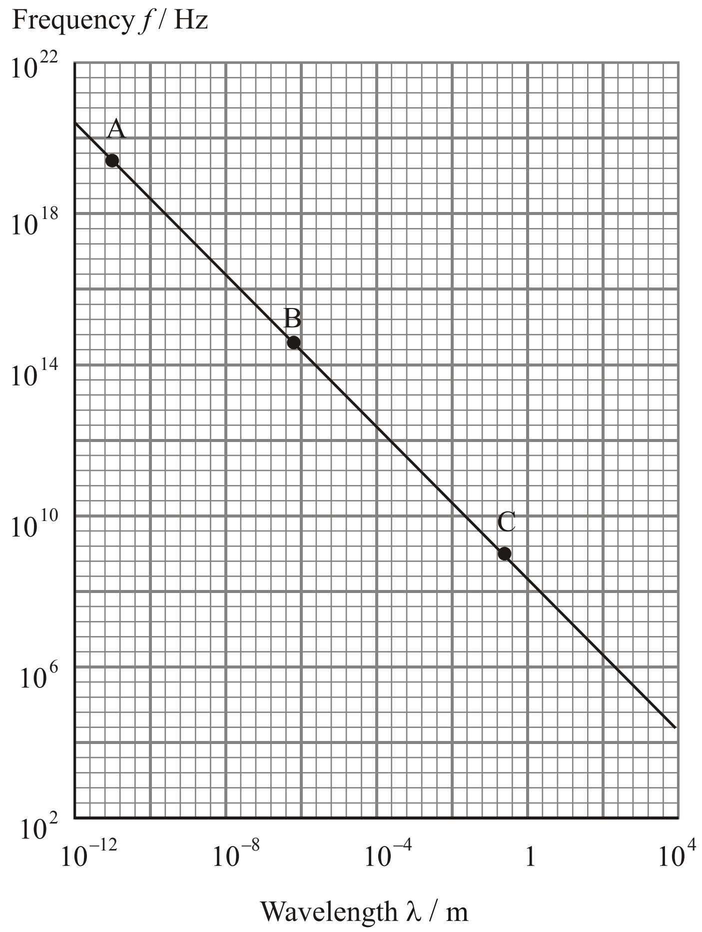
Determine the amplitude of each of the travelling waves.

....

Amplitude = ...

(1)
(Total 6 marks)

143. The graph shows how frequency varies with wavelength for electromagnetic waves in a vacuum. Note that the scales are logarithmic.



Three different waves are labelled by the letters A, B and C on the graph. In the table below, write the appropriate letter to identify each of the waves described.

Description	Letter
Red light	
Waves used for mobile telephone communication	
Radiation capable of ionising matter	

(2)

How does the graph confirm that frequency is inversely proportional to wavelength?

....

....

....

....

(1)

What does this tell us about electromagnetic waves?

....

....

....
(1)
(Total 4 marks)

144. Define the **intensity** of an electromagnetic wave.

....

....
(1)

Two beams of monochromatic electromagnetic radiation, A and B, have equal intensities. Their wavelengths are:

Beam A	300 nm
Beam B	450 nm

In the table below, E denotes the energy of a photon and N denotes the number of photons passing per second through unit area normal to the beam. The subscripts A and B refer to the two beams. In the second column of the table, state the value of each ratio, and in the third column explain your answer.

Ratio	Value	Explanation
E_A / E_B		
N_A / N_B		

(4)

The table below gives the work functions of four metals.

Metal	Work function / eV
Potassium	2.26
Magnesium	3.68
Tungsten	4.49
Iron	4.63

Define the term **work function**.

....

....

(1)

A metal plate made from one of these metals is exposed to beams A and B in turn. Beam A causes electrons to be emitted from the plate, but beam B does not. Calculate the photon energies in each beam and hence deduce from which metal the plate is made.

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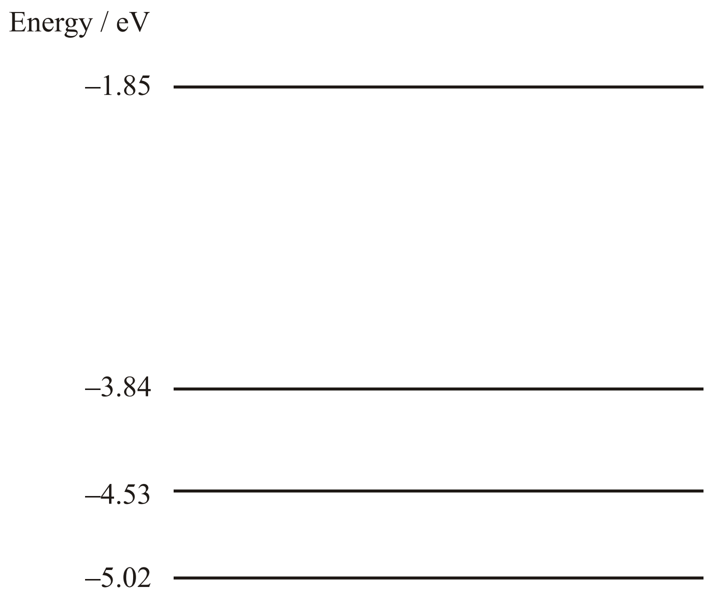
(4)
(Total 10 marks)

145. Four of the energy levels of a lithium atom are shown below.



Draw on the diagram all the possible transitions which the atom could make when going from the –3.84 eV level to the –5.02 eV level.

(2)

Photons of energy 3.17 eV are shone onto atoms in lithium vapour. Mark on the diagram, and label with a T, the transition which could occur.

(1)

One way to study the energy levels of an atom is to scatter electrons from it and measure their kinetic energies before and after the collision. If an electron of kinetic energy 0.92 eV is scattered from a lithium atom which is initially in the –5.02 eV level, the scattered electron can have only two possible kinetic energies.

State these two kinetic energy values, and explain what has happened to the lithium atom in each case. (You should assume that the lithium atom was at rest both before and after the collision.)

Kinetic energy 1 ....

Explanation ....

....

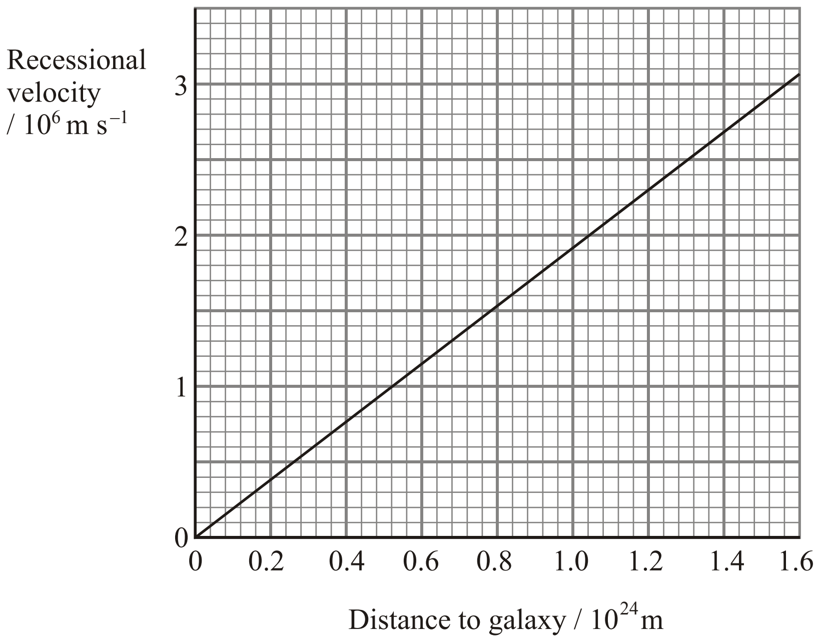
Kinetic energy 2 ....

Explanation ....

....

(4)
(Total 7 marks)

146. (a) The graph shows the best-fit line obtained when recessional velocity is plotted against distance from Earth for a large number of galaxies.



Use this graph to calculate a value for the Hubble constant.

....

....

....

Hubble constant = ...

(2)

A spectral line measured using a laboratory source has a wavelength of 372.7 nm. The same line, measured in light from a distant galaxy, has an apparent wavelength of 410.0 nm. Estimate the distance of this galaxy from Earth.

....

....

....

....

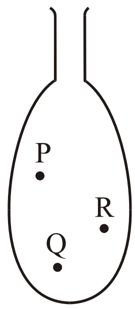
....

....

Distance = ...

(4)

(b) The diagram shows a deflated balloon. It has three dots on its surface, labelled P, Q and R. In the space next to the diagram, draw the balloon as it would appear when fully inflated. Mark the new positions of the three dots.



(2)

Explain how the inflation of the balloon can be used to model the expansion of the Universe. You may be awarded a mark for the clarity of your answer.

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(4)

(Total 12 marks)

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

....

....

....

....

(2)

(b) (i) A girl standing at the equator is in circular motion about the Earth's axis. Calculate the angular speed of the girl.

....

....

....

Angular speed = ...

(2)

(ii) The radius of the Earth is 6400 km. The girl has a mass of 60 kg. Calculate the resultant force on the girl necessary for this circular motion.

....

....

Force = ...

(2)

(iii) If the girl were to stand on weighing scales calibrated in newtons, what reading would they give?

....

....

....

Scale reading = ...

(3)
(Total 9 marks)

148. The table below summarises some features of the electromagnetic spectrum. Complete the table by filling in the missing types of radiation, wavelengths and sources.

Radiation	Typical wavelength	Source
Visible light		Very hot objects
Gamma		
	100 m	High frequency electrical oscillator
	10^{-6} m	

(Total 6 marks)

149. (a) A 100 Wceiling light bulb is 2.5 m above the floor. It is 6.0% efficient at converting electrical energy to visible light. Calculate the visible light intensity at the floor directly beneath the bulb.

....

....

....

....

Intensity = ...

(3)

(b) The number of photons hitting a square metre in one second at this distance from the bulb is 2.4×10^{17}. Find the average energy of the photons in electronvolts.

....

....

....

....

....

Average energy of photons = ...

(3)
(Total 6 marks)

150. A stationary wave of amplitude 4.0 cm is produced by the superposition of two progressive waves that travel in opposite directions.

(a) Define the term **amplitude**.

....

....

(1)

(b) The graph below shows the positions of the stationary wave and of one of the two progressive waves at a particular instant. Apply the principle of superposition to determine the displacement of the other progressive wave at positions A, B and C on the distance axis at this same instant.

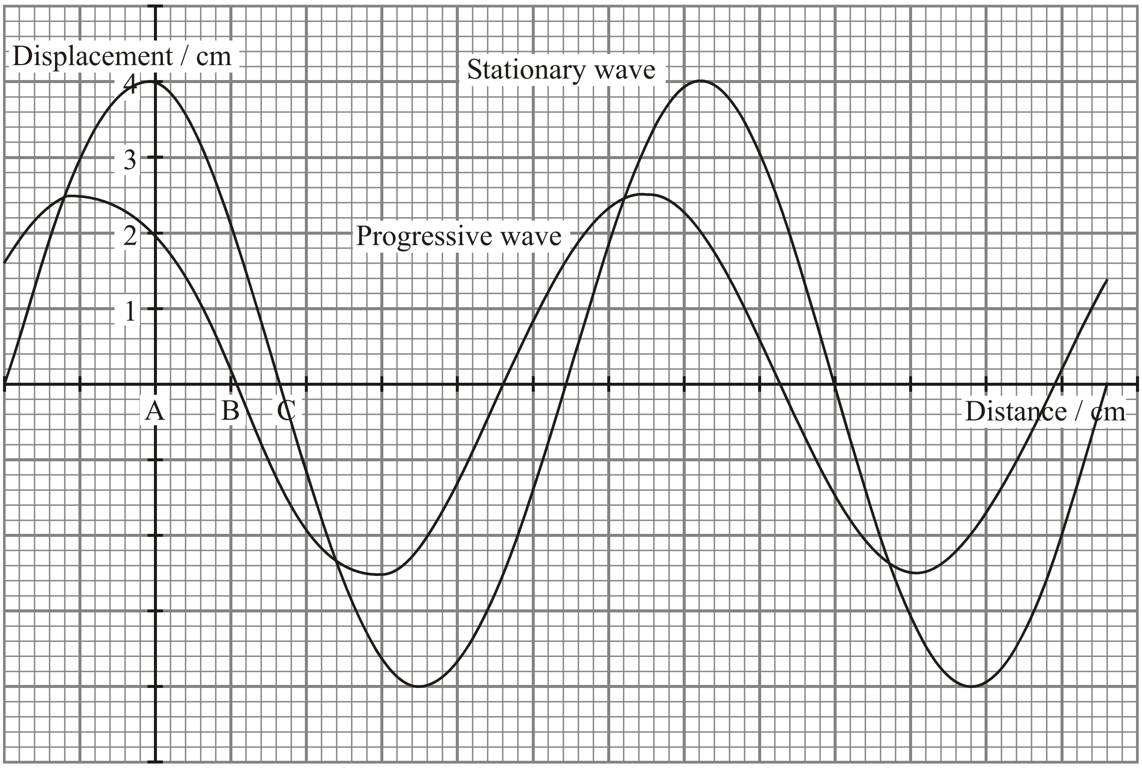
Displacement at A ....

Displacement at B ....

Displacement at C ....

(3)

Plot these displacement values on the graph.
Hence draw one complete wavelength of this progressive wave.



(3)
(Total 7 marks)

151. (a) Explain what is meant by the term **transverse wave.** You may wish to illustrate your answer with the help of a simple diagram.

....

....

....

(3)

(b) State two differences between a stationary wave and a progressive wave.

Difference 1 ....

....

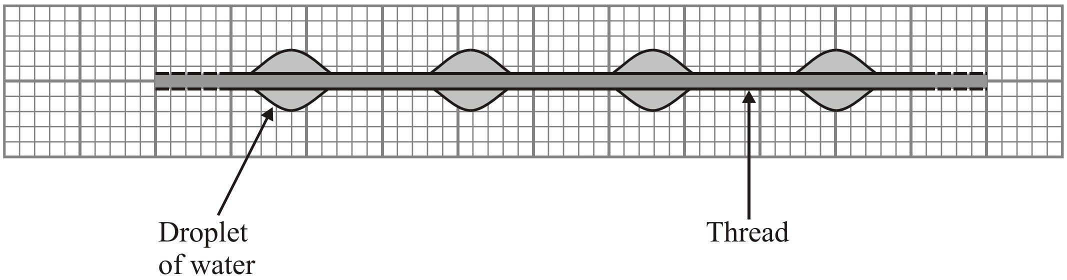
Difference 2 ....

....

(2)

(c) Spiders are almost completely dependent on vibrations transmitted through their webs for receiving information about the location of their prey. The threads of the web are under tension. When the threads are disturbed by trapped prey, progressive transverse waves are transmitted along the sections of thread and stationary waves are formed.

Early in the morning droplets of moisture are seen evenly spaced along the thread when prey has been trapped.



1 cm on diagram represents 0.25 cm of thread

(i) Explain why droplets form only at these points.

....

....

(1)

(ii) The speed of a progressive transverse wave sent by trapped prey along a thread is 9.8 cm s^{-1}. Use the diagram to help you determine the frequency of the stationary wave.

....

....

....

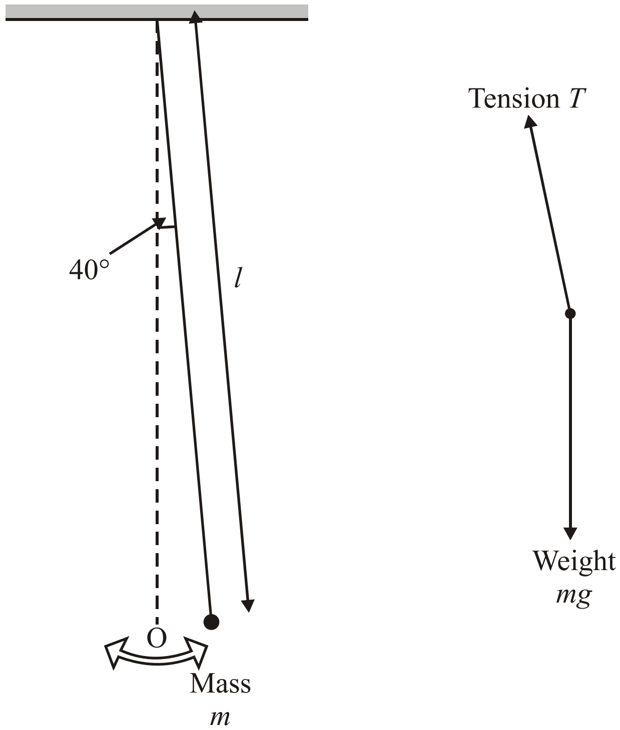
....

Frequency = ...

(4)

(Total 10 marks)

152. A simple pendulum of length l consists of a small mass m attached to the end of a thread. The other end is fixed. The mass is slightly displaced through an angle of 4.0° and then released so that it oscillates along a small arc with centre O.



(a) The free-body force diagram for the oscillating mass at its maximum displacement is drawn alongside.

(i) Add to the free-body force diagram the component of weight that is equal in magnitude to the tension T at this instant. Label it A.

(1)

(ii) Add to the same diagram the component of weight that acts perpendicularly to the line of action of the tension. Label it B.

(1)

(iii) Determine the magnitude of the instantaneous acceleration of the mass.

....

....

Acceleration = ...

(2)

(iv) State the direction of this acceleration.

....

(1)

(b) The period of the pendulum is 4.2 s. When the length l is shortened by 1.0 m the period becomes 3.7 s. Show how this data can be used to determine a value for the acceleration of free fall. You should obtain an appropriate equation and substitute the data, but you are not expected to perform the final calculation.

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(3)
(Total 8 marks)

153. (a) What is meant by the Doppler effect (electromagnetic Doppler effect) when applied to light?

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....

(2)

(b) Edwin Hubble reached a number of conclusions as a result of observations and measurements of red-shift. State two of these conclusions.

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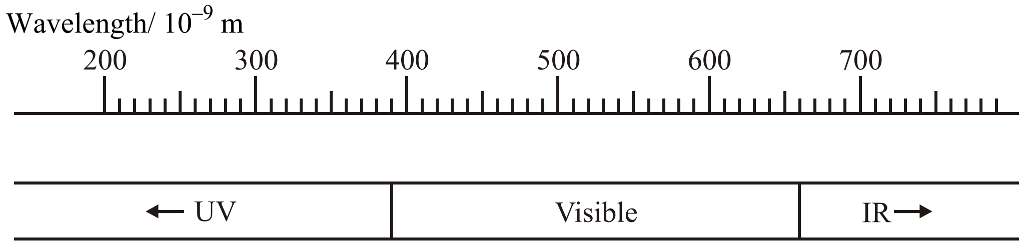
....

(2)

(c) The diagram gives values of wavelength for part of the electromagnetic spectrum.



A very hot distant galaxy emits violet light just at the edge of the visible spectrum. Estimate the maximum velocity the galaxy could have so that visible light could still be detected as it moves away from the Earth.

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(4)

(d) The fate of the Universe is dependent on the average mass-energy density of the Universe. What is meant by the critical density of the Universe?

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(2)
(Total 10 marks)

154. The photoelectric effect supports a particle theory of light but not a wave theory of light.

Below are two features of the photoelectric effect. For each feature explain why it supports the particle theory and not the wave theory.

(a) Feature 1: The emission of photoelectrons from a metal surface can take place instantaneously.

Explanation ....

....

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(2)

(b) Feature 2: Incident light with a frequency below a certain threshold frequency cannot release electrons from a metal surface.

Explanation ....

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(2)
(Total 4 marks)

155. Hubble's law can be represented by the formula $v = Hd$.

(a) State the unit of the Hubble constant H.

....

(1)

(b) Show how the age of the Universe can be estimated by using the above formula. State an assumption that has to be made.

....

....

....

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....

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Assumption: ....

....

....

(4)
(Total 5 marks)

156. (a) What is meant by the principle of superposition of waves?

....

....

....

(2)

(b) (i) A two-slit interference experiment is used to find the wavelength of light from a monochromatic source. Draw a labelled diagram (not to scale) of the experimental arrangement, giving approximate dimensions.

(3)

(ii) Describe what happens to the interference pattern when the source is replaced by one that emits light of a higher frequency.

....

....

(1)

(iii) Describe what is observed if one of the two slits is covered.

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(3)
(Total 9 marks)

157. (a) Define simple harmonic motion.

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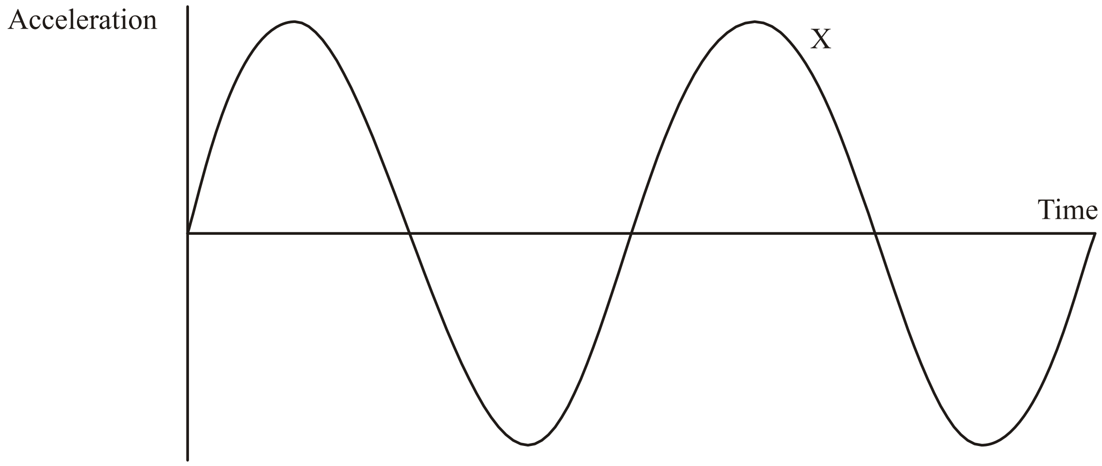
(2)

(b) The curve labelled X shows how the acceleration of a body executing simple harmonic motion varies with time.



Add to the graph

(i) a curve labelled Y showing how the displacement of the same body varies with time over the same time interval,

(ii) a curve labelled Z showing how the velocity of the same body varies with time over the same time interval.

(4)

(c) (i) A mass of 150 g is supported by a spring having a spring constant of 24 N m^{-1}. Show that the frequency of vertical oscillations of the mass is about 2 Hz.

....

....

....

....

(3)

(ii) The amplitude of the oscillations is 30 mm. Calculate the maximum speed of the mass.

....

....

....

Maximum speed = ...

(2)

(Total 11 marks)

158. A microwave generator produces plane polarised electromagnetic waves of wavelength 29 mm.

(a) (i) Calculate the frequency of this radiation.

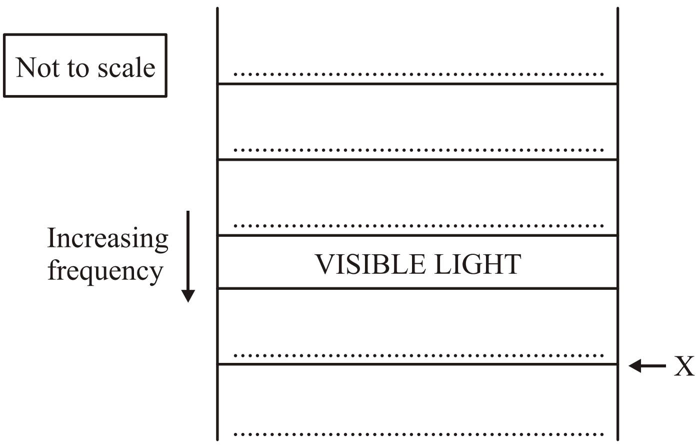
....

....

Frequency = ...

(1)

(ii) Complete the diagram of the electromagnetic spectrum below by adding the names of the parts of the electromagnetic spectrum.



(2)

(iii) State a typical value for the wavelength of radiation at boundary X.

....

(1)

(b) (i) Explain what is meant by 'plane polarised'.

....

....

....

....

(2)

(ii) Describe, with the aid of a diagram, how you would demonstrate that these microwaves were plane polarised.

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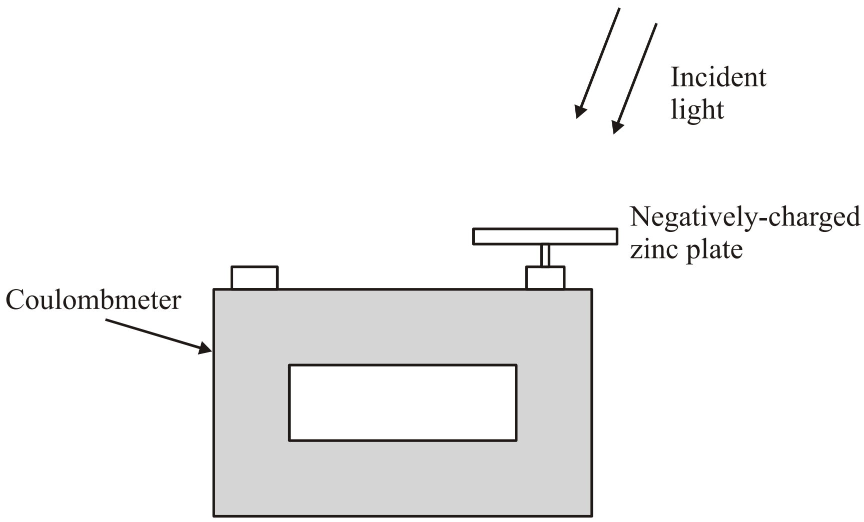
(4)
(Total 10 marks)

159. The diagram shows a coulombmeter (an instrument for measuring charge) set up to demonstrate the photoelectric effect.



The clean zinc plate is negatively charged. When ultraviolet light is shone onto the zinc plate, the plate discharges. The coulombmeter reading gradually falls to zero. When the experiment is repeated with red light the plate does not discharge.

(a) Explain these effects in terms of the particle theory of light. You may be awarded a mark for the clarity of your answer.

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....

(4)

(b) What would happen to the charged plate if

(i) the intensity of the red light were increased

....

....

....

(ii) the intensity of the ultraviolet light were increased?

....

....

....

(2)

(c) Zinc has a work function of 3.6 eV. Calculate the maximum kinetic energy of the photoelectrons when the zinc is illuminated with ultraviolet light of wavelength 250 nm.

....

....

....

....

....

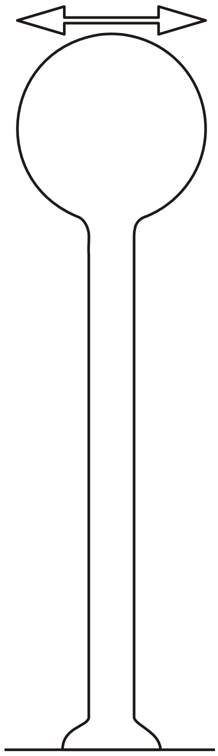
....

Maximum kinetic energy = ………………………

(4)

(Total 10 marks)

160. A water tower consists of a massive tank of water supported on a vertical column. It oscillates sideways with simple harmonic motion when shaken by longitudinal earthquake waves.



Water tower

(a) What is meant by a **longitudinal** wave?

....

....

....

....

(2)

(b) The water tower could collapse when shaken by earthquake waves of a particular frequency. Explain how this could happen.

....

....

....

....

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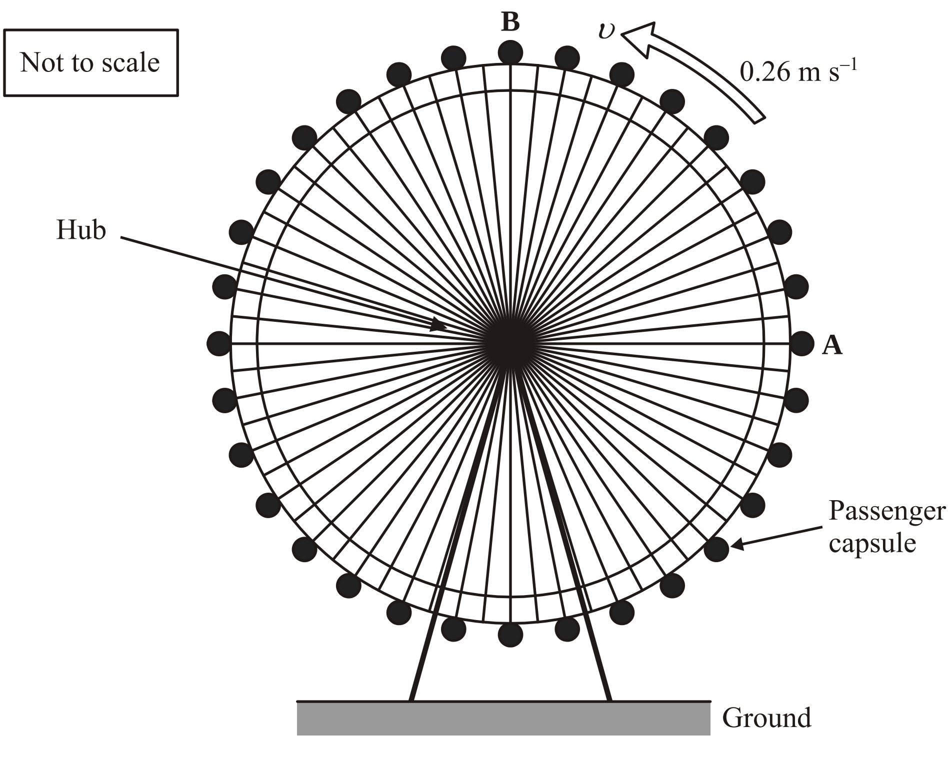
....

....

(3)
(Total 5 marks)

161. The London Eye is a tourist attraction designed to give passengers a panoramic view over London. The giant wheel completes two revolutions in one hour. Each capsule moves with a constant speed of 0.26 m s^{-1} as it follows a circular path.

Figure 1



(a) Calculate the radius of this circular path.

....

....

....

....

Radius = ...

(2)

(b) A man of mass 85 kg follows a circular path of this radius as he rides in a capsule. What is the magnitude and direction of the resultant force acting on the man?

....

....

....

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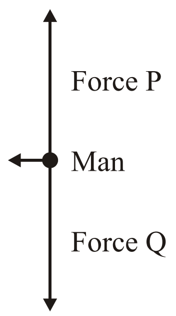
....

....

(3)

(c) Figure 2 shows the free-body force diagram for the man when the capsule is at position **A** as shown in Figure 1.

Figure 2



(i) Name forces P and Q

Force P: ....

Force Q: ....

(2)

(ii) When the man is at position A there is no resultant **vertical** force acting on him. In this position force P = force Q in magnitude. Explain why the man continues his motion in a circle.

....

....

....

(2)

(iii) Explain why force Q must be larger than force P when the capsule is at position B.

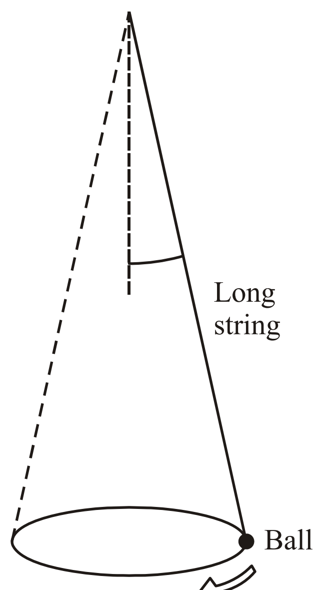
....

....

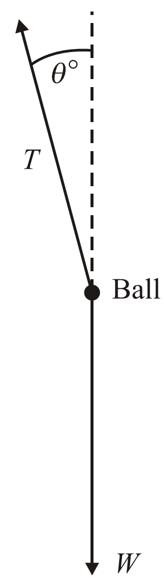
....

(1)
(Total 10 marks)

162. A ball attached to the end of a long string is made to rotate in a horizontal circular path at a constant speed. The forces acting on the ball are its weight, *W,* and the tension, *T*, in the string.



Horizontal
circular path



Free-body force
diagram

With reference to the free-body force diagram, explain how it is possible for the ball to move with constant speed and yet still be accelerating.

....

....

....

....

....

....

....

....

(Total 4 marks)

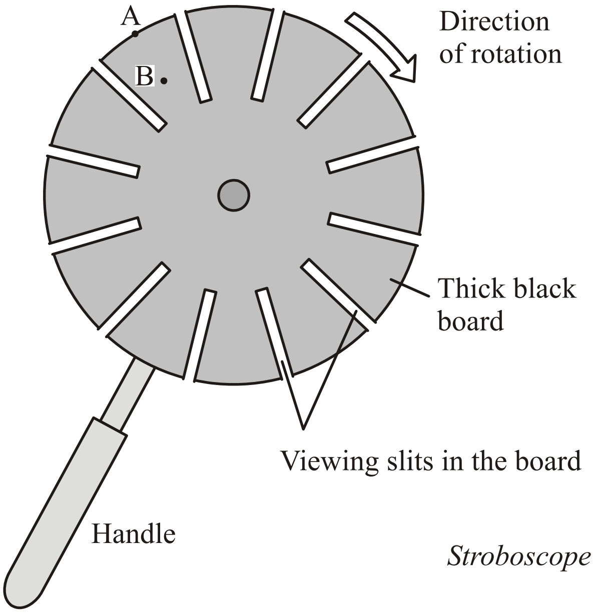
163. (a) Plane progressive wavefronts are produced in a ripple tank. The frequency of the vibrator producing the waves is 50 Hz. Calculate the time interval between successive wavefronts.

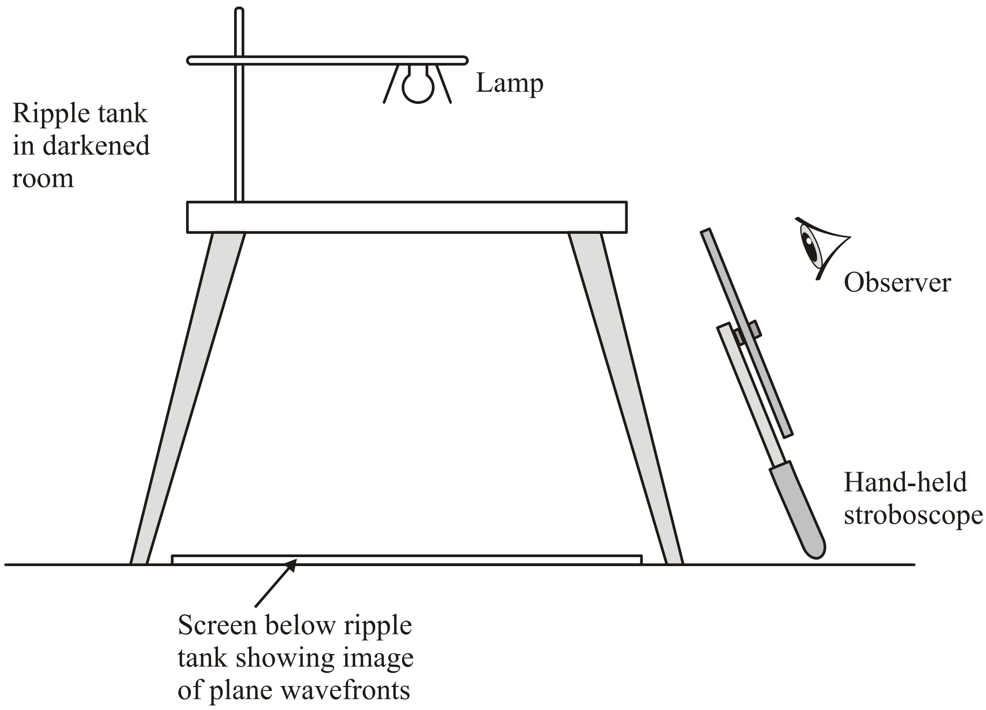
....

Time interval = ...

(1)

(b) The wavefronts are projected onto a white screen directly below the ripple tank. They are viewed through the slits in a stroboscope that is rotated by hand. Diagrams of the stroboscope and the arrangement are shown below.





(i) The angular speed of the stroboscope is gradually increased to the fastest speed at which the wavefronts appear stationary. State the time interval between successive slits at this instant.

....

(1)

(ii) Show that the angular speed, ω_A, of a point A on the rim of the stroboscope at this same instant is approximately 26 rad s^{-1}.

....

....

....

....

(2)

(iii) The radius of the stroboscope is 15 cm. Calculate the velocity, v_A, of A.

....

....

Velocity = ...

(2)

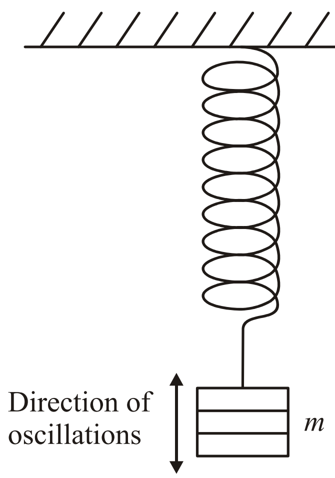
(iv) Point B is 10 cm from the centre of the stroboscope and 5.0 cm from A. State the value of the following ratios.

$\omega_A : \omega_B$ = ...

$v_A : v_B$ = ...

(2)
(Total 8 marks)

164. A spring of negligible mass and spring constant, *k*, has a load of mass, *m*, suspended from it. A student displaces the mass and releases it so that it oscillates vertically.



(a) The student investigates the variation of the time period, T, of the vertical oscillations with m.

Describe how he could verify experimentally that $T \propto \sqrt{m}$. Include any precautions the student should take to make his measurements as accurate as possible. You may be awarded a mark for the clarity of your answer.

....

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(5)

(b) The student calculates the natural frequency of his mass-spring system. Show that for a mass of 400 g and a spring constant of 230 N m^{-1} this frequency is approximately 4 Hz.

....

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....

....

(3)

(c) The student connects the mass-spring system to a vibrator and signal generator to demonstrate resonance. Explain fully, with respect to this system, what is meant by the terms **natural frequency** and **resonance.**

Natural frequency: ....

....

....

....

....

Resonance: ....

....

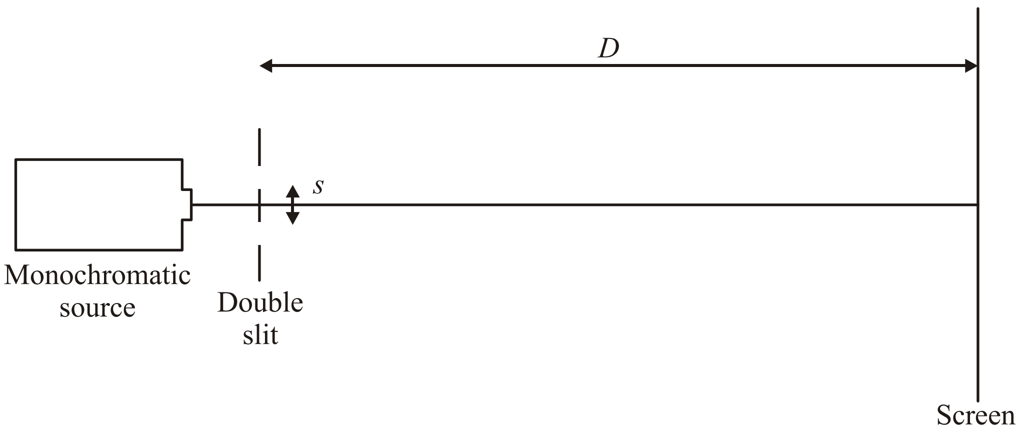
....

....

....

(4)
(Total 12 marks)

165. (a) Monochromatic red light of wavelength 720 nm is used to produce a two slip interference pattern on a screen.



(i) Give typical values for the slit separation *s* and the distance *D* between the double slit and screen.

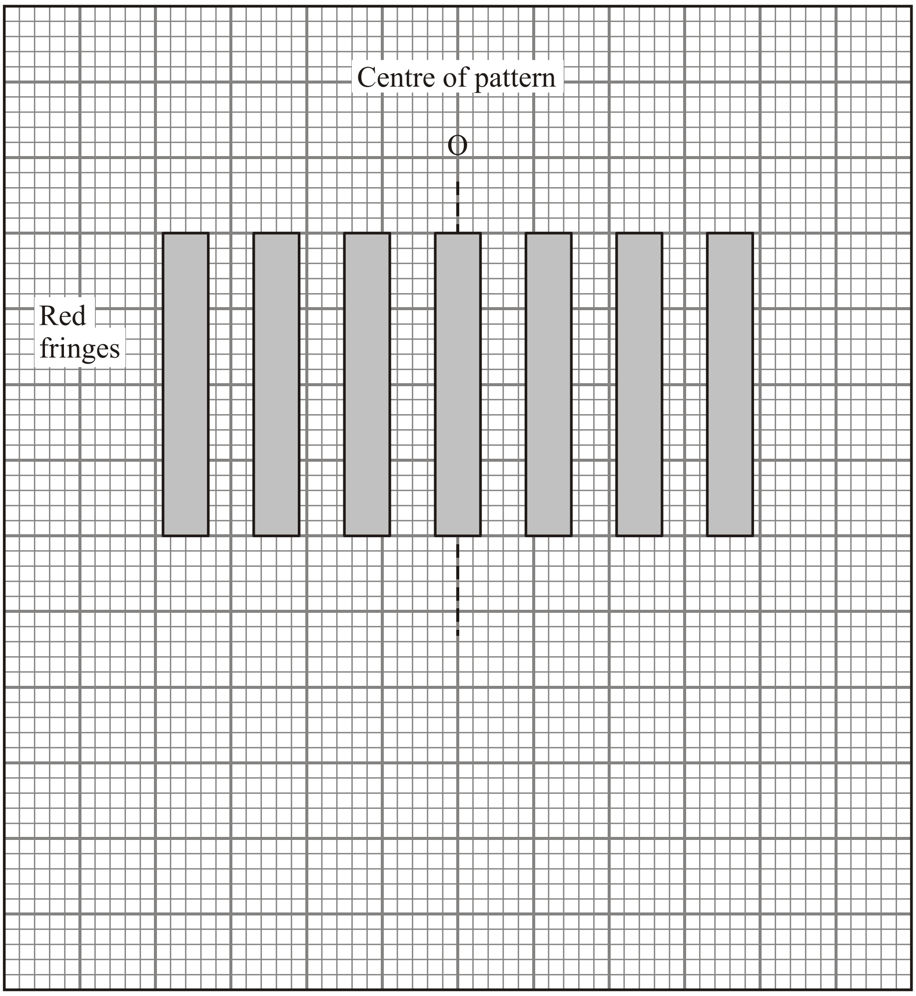
s ....

D ....

(2)

(ii) A drawing of the central section of the interference pattern is shown on the grid below. The centre of the pattern is at O.

SCALE
1 cm
represents
5 mm



Determine a value for the separation of the red fringes. Show your working.

....

....

....

Fringe separation = ...

(3)

(b) The red source is replaced by a monochromatic blue source of wavelength 480 nm to produce a second interference pattern. The practical arrangement remains unchanged.

Use the lower part of the grid to draw the five central blue fringes. Use the lines below for any calculation you make.

....

....

....

....

....

(3)

(c) Describe the appearance of the central fringe formed at O when a white light source is used.

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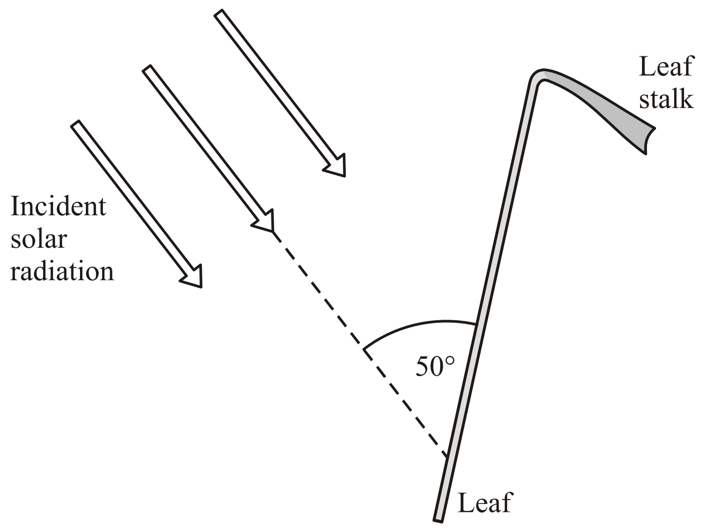
(2)
(Total 10 marks)

166. A leaf of a plant tilts towards the Sun to receive solar radiation of intensity 1.1 kW m $^{-2}$, which is incident at 50° to the surface of the leaf.



(a) The leaf is almost circular with an average radius of 29 mm. Show that the power of the radiation perpendicular to the leaf is approximately 2 W.

....

....

....

....

(3)

(b) Calculate an approximate value for the amount of solar energy received by the leaf during 2.5 hours of sunlight.

....

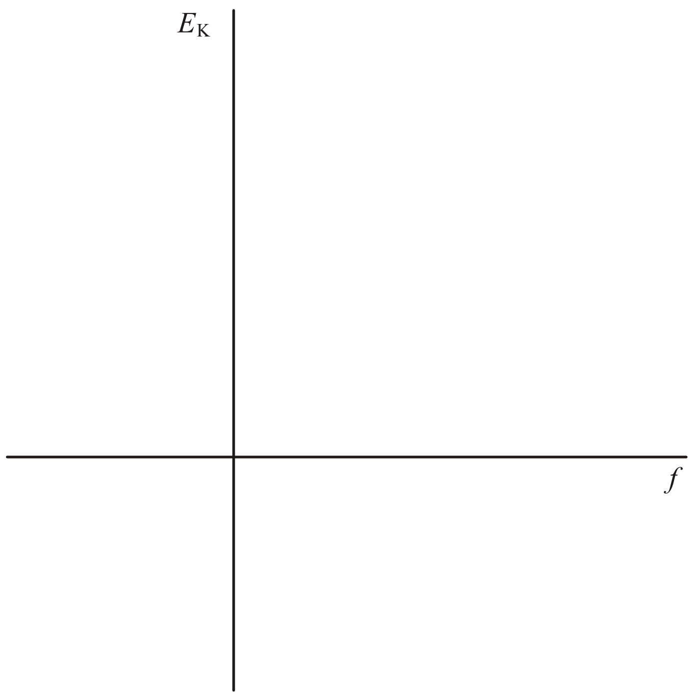
....

Energy = ...

(2)
(Total 5 marks)

167. Photoelectrons are emitted from the surface of a metal when radiation above a certain frequency, f_o, is incident upon it. The maximum kinetic energy of the emitted electrons is E_K.

(a) On the axes below sketch a graph to show how E_K varies with frequency f.



(2)

(b) State how the work function, ϕ, of the metal can be obtained from the graph.

....

....

(1)

(c) Explain why this graph always has the same gradient irrespective of the metal used.

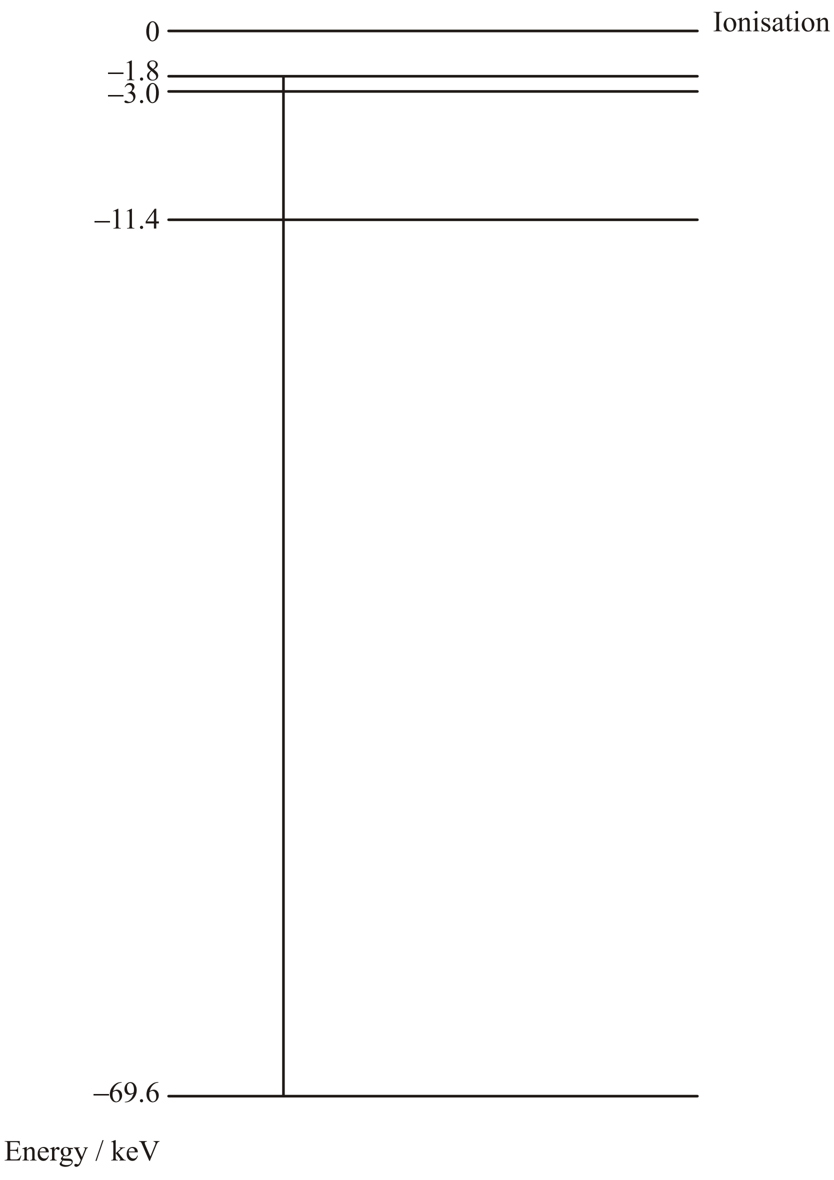
....

....

(1)

(Total 4 marks)

168. The diagram shows some of the energy levels of a tungsten atom.



(a) An excited electron falls from the –1.8 keV level to the –69.6 keV level. Show that the wavelength of the emitted radiation is approximately 0.02 nm.

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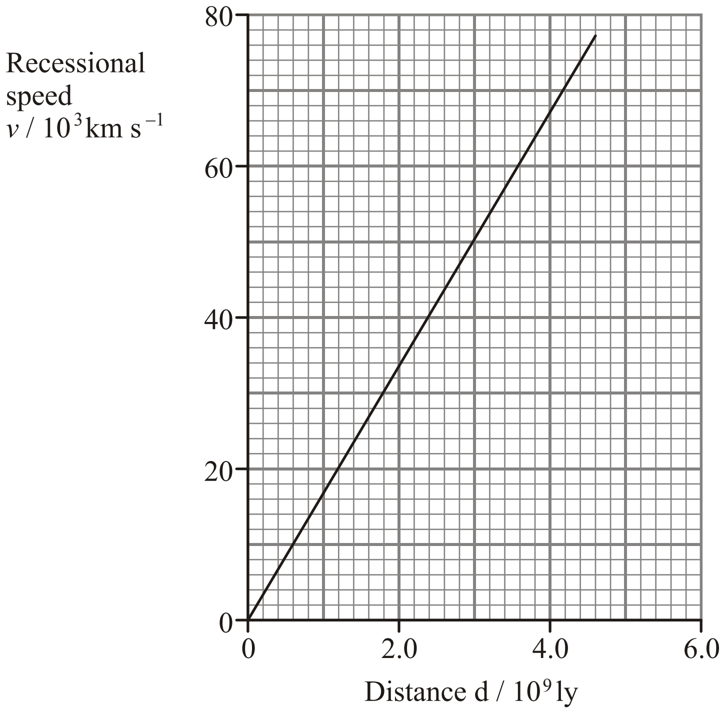
(4)

(b) To which part of the electromagnetic spectrum does this radiation belong?

....

(1)
(Total 5 marks)

169. (a) Edwin Hubble examined the relationship between the recessional speed of galaxies, v, and their distance, d, from Earth. The graph shows the best-fit line for his results.



(i) Use the graph to determine a value for the Hubble constant, H, in s^{-1}. Show your working.

....

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....

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....

....

....

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

(4)

(ii) What is the main source of uncertainty in the value of H?

....

(1)

(b) Explain how the Hubble constant provides us with an estimate for the age of the Universe, t.

....

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....

....

(2)

(c) Ionised calcium has a line spectrum which includes a spectral line of wavelength 393 nm. The observed wavelength of this calcium line in the radiation from a distant galaxy is 469 nm. Calculate the galaxy's recessional speed.

....

....

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....

....

Recessional speed = ...

(3)

(d) Briefly explain how the value of the average mass-energy density of the Universe will determine whether the Universe is open or closed.

....

....

....

....

(2)
(Total 12 marks)