Class	Index Number	Name
22S		

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2023
Preliminary Examination

PHYSICS, Higher 2 **9749/02**

Paper 2 Structured Questions **12th September 2023**
2 hours

Candidates answer on the Question Paper.
No additional materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, index number and Civics Group on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 12
2	/ 12
3	/ 13
4	/ 7
5	/ 16
6	/ 20
Total	/ 80

This document consists of **24** printed pages including this page.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1}
	$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant,	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall,	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho g h$
gravitational potential,	$\phi = -\frac{Gm}{r}$
temperature,	$T/\text{K} = T/^{o}\text{C} + 273.15$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_o \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$
	$v = \pm \omega \sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_o \sin \omega t$
magnetic flux density due to a long straight wire,	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	$B = \frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid,	$B = \mu_0 n I$
radioactive decay,	$x = x_o \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{1/2}}$

Answer **all** questions in the spaces provided.

1 **(a)** Define gravitational potential energy of a mass at a point.

....

.... [1]

(b) A spherical planet has mass M and radius R. The planet may be considered to have all its mass concentrated at its centre.

A rocket is launched from the surface of the planet such that the rocket moves radially away from the planet. The rocket engines are stopped when the rocket is at a height R above the surface of the planet.

The mass of the rocket, after its engines have been stopped, is m.

(i) Show that, for the rocket to travel from a height R to a height $2R$ above the planet's surface, the change ΔU in magnitude of the gravitational potential energy of the rocket is given by the expression

$$\Delta U = \frac{GMm}{6R}.$$

[2]

(ii) During the ascent from a height R to a height $2R$, the speed of the rocket changes from 7600 m s^{-1} to 7320 m s^{-1}. The planet has a radius of 3.40×10^6 m.

Determine a value for the mass M of the planet.

M = ………………………….. kg [3]

(iii) State two assumptions made in the determination in **(b)(ii)**.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………………… [2]

(c) **(i)** A satellite is orbiting in a geostationary orbit around the Earth of mass M.

Explain why the satellite must be above the equator.

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……………………………………………………………………………………………..

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…………………………………………………………………………………………… [2]

(ii) Deduce the distance r of the geostationary satellite from the centre of the Earth in terms of M.

Explain your working clearly.

[2]

2 **(a)** State what is meant by *specific latent heat of vaporization*.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………………………………………………………………………………………………… [1]

(b) When a liquid is boiling, thermal energy must be supplied in order to maintain a constant temperature.

State two processes for which thermal energy is required during boiling.

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

………………………………………………………………………………………………

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

………………………………………………………………………………………………
[2]

(c) A styrofoam container of negligible heat capacity contains 900 g of water at 85 °C. 100 g of ice at 0 °C was then added to water. With reference to the data below,

Specific latent heat of fusion of water / J kg^{-1}	3.34×10^5
Specific heat capacity of water / J kg^{-1} K^{-1}	4200
Specific latent heat of vaporisation of water / J kg^{-1}	2.26×10^6

(i) Calculate the equilibrium temperature of the mixture.

temperature = ………………………….. °C [2]

(ii) Explain why exposure to steam at 100 °C produces a more severe burn than exposure to the same amount of hot water at 100 °C.

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………………………………………………………………………………………… [1]

(d) A fixed mass of an ideal gas undergoes the cycle of changes XYZX as shown in Fig. 2.1. Referring to Fig. 2.1,

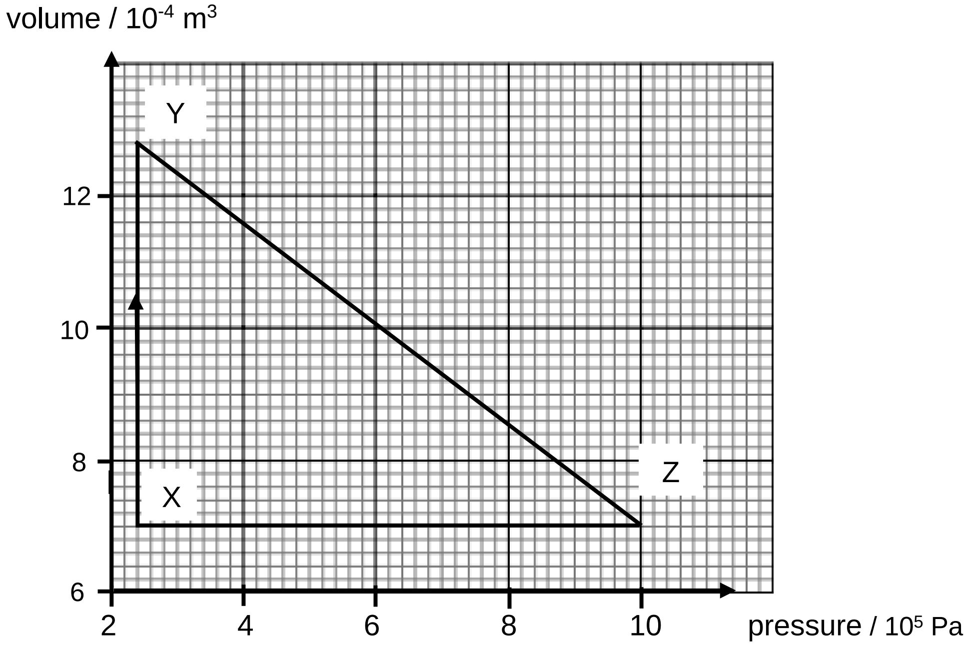

Fig. 2.1

(i) determine the work done *on* the gas in the process XY,

work done on gas = ………………………….. J [2]

(ii) explain why the process ZX must involve heat transfer.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

………………………………………………………………………………………… [2]

(iii) On Fig. 2.1, mark an 'x' at the point where the gas has approximately the highest temperature.

Explain how you arrived at the answer.

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………………………………………………………………………………………. [2]

3 **(a)** The apparatus illustrated in Fig 3.1 is used to demonstrate two-source interference using light.

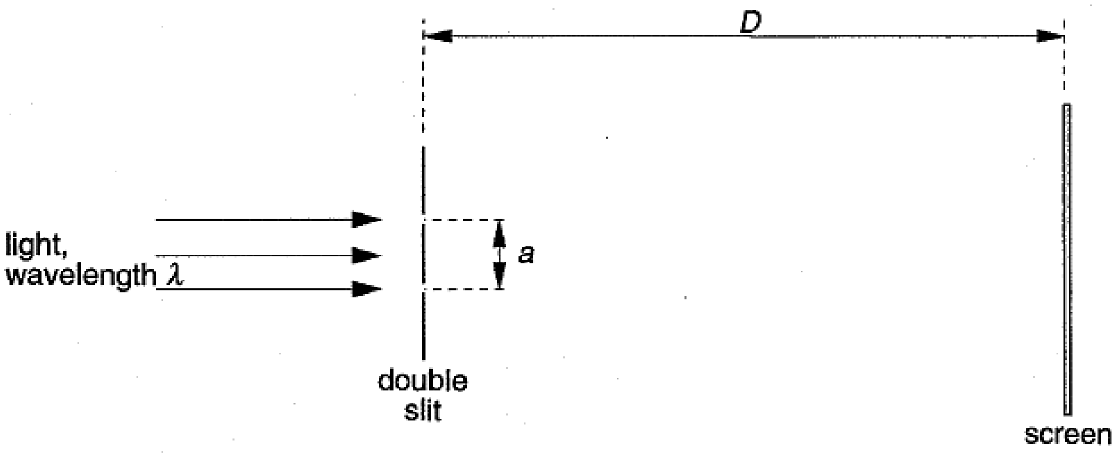


Fig. 3.1 (not drawn to scale)

The separation of the two slits in the double slit arrangement is a and the interference fringes are viewed on a screen at a distance D from the double slit. When light of wavelength λ is incident on the double slit, the separation of the bright fringes on the screen is x.

State and explain the effect, if any, on the separation of the fringes and on the contrast between the bright and dark fringes when the incident light is polarised into a single plane before reaching the double slits.

Separation: ....

Contrast: ....

....

.... [2]

(b) In Fig. 3.2, T_1 and T_2 are two adjacent transmitters 1.0 m apart with a receiver aerial R at mid-point between them. The transmitters are set up to emit vertically polarised coherent microwaves of wavelength 3.0 cm and of equal amplitudes *A*.

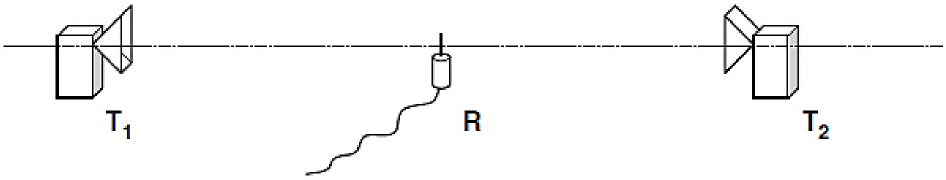


Fig. 3.2

(i) A student observes that the signal at the receiver R falls from maximum to zero when receiver R moved 0.75 cm towards a transmitter.

Explain these observations. Include any quantitative calculations.

....

....

....

....

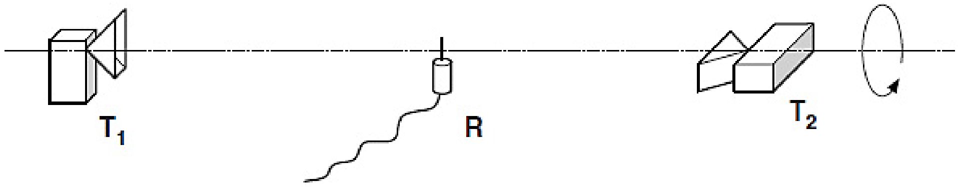
....

....

....

.... [3]

(ii) With R at the mid-point between T_1 and T_2, the student rotates T_2 through 90° about an axis through T_1 and T_2 as shown in Fig. 3.3 such that T_2 emits horizontally polarised wave.



Fig, 3.3

The student observes that the intensity of the signal at R is halved.

The detected signal remains the same when R is moved 0.75 cm towards a transmitter.

By considering the Principle of Superposition, explain these observations. Include any quantitative calculations.

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………………………………………………………………………………………… [3]

(c) Visible white light, which has a range for wavelengths of red light of 700 nm to violet light of 400 nm, is passed through a diffraction grating of 200 lines per mm as shown in the Fig. 3.4. A screen was placed 3.00 m from the diffraction grating and is perpendicular to the incident beam of white light.

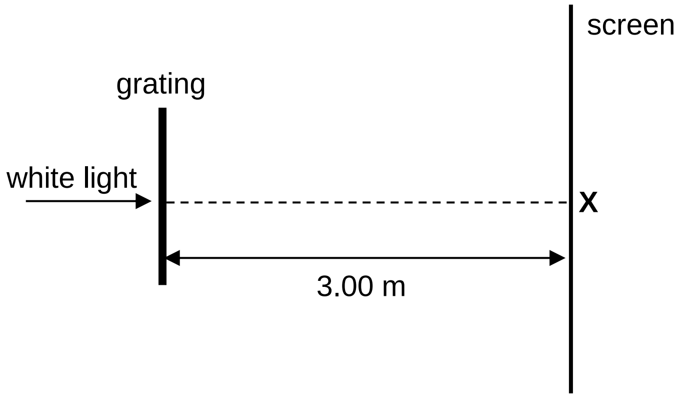

Fig. 3.4

(i) Explain why point **X** appears white.

……………………………………………………………………………………………..

…………………………………………………………………………………………… [1]

(ii) Determine the range of distances from **X** for the 1st order of fringes observed.

………………………….. m to ………………………….. m [2]

(iii) Show with calculation whether the 3rd order fringes overlaps with the 2nd order fringes.

……………………………………………………………………………………………..

…………………………………………………………………………………………… [2]

4 **(a)** A student uses a circuit for an experiment. The circuit contains a milliammeter, a fixed resistor of resistance R_F and a set of known resistors of different resistance, R. These are connected using switch S, as shown in Fig. 4.1.

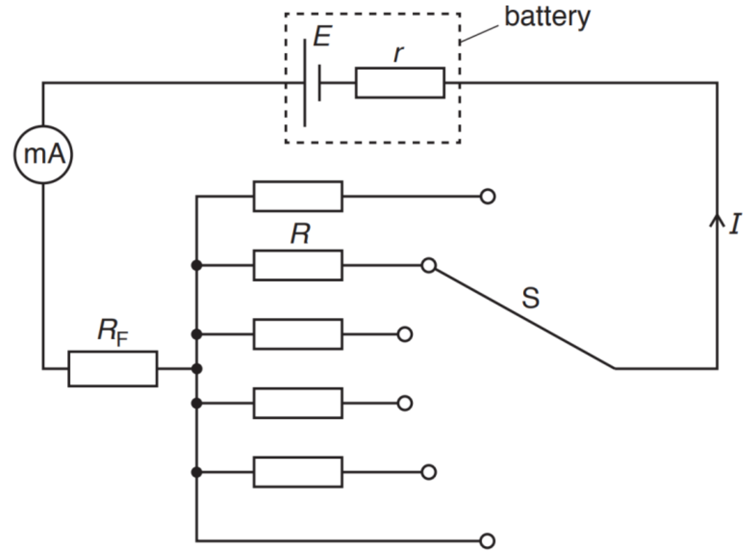

Fig. 4.1

The student records the current I for each value of R. He plots a graph of R against $\frac{1}{I}$. Fig. 4.2 shows the shape of the graph.

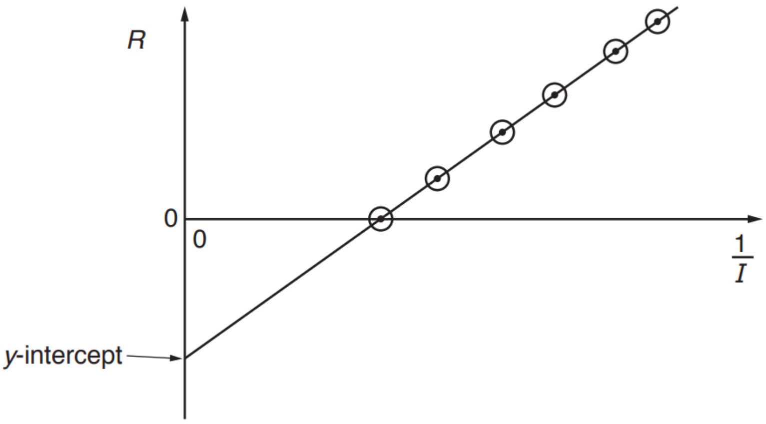

Fig. 4.2

State the physical significance of the gradient and the y-intercept on the graph. You may use the space below to do any necessary working.

gradient ....

y-intercept ....

[2]

(b) An electric cable is made up of 24 thin strands of copper wire, as shown in Fig. 4.3.

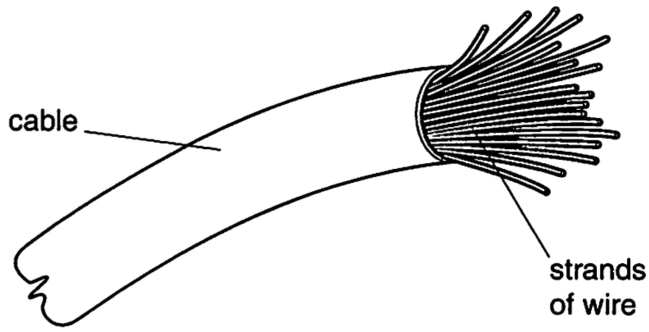

Fig. 4.3

Each strand has diameter 0.26 mm. Copper has resistivity 1.7×10^{-8} Ω m.

Calculate the resistance of the cable of length 5.0 m,

resistance = ………………………….. Ω [2]

(c) State and explain why the resistance of metals increases with temperature.

…………………………………………………………………………………………………

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…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………………………………………………………… [3]

5 **(a)** A student suggests that one possible nuclear reaction is

$$^{56}_{26}\text{Fe} + ^{1}_{0}\text{n} \longrightarrow ^{20}_{9}\text{F} + ^{37}_{17}\text{C}l.$$

Explain why the reaction would not result in an overall release of energy.

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………………………………………………………………………………………………… [2]

(b) The graph in Fig. 6.1 shows the kinetic energy spectrum for β^- particles emitted in the decay of platinum $^{199}_{78}\text{Pt}$ to gold $^{199}_{79}\text{Au}$.

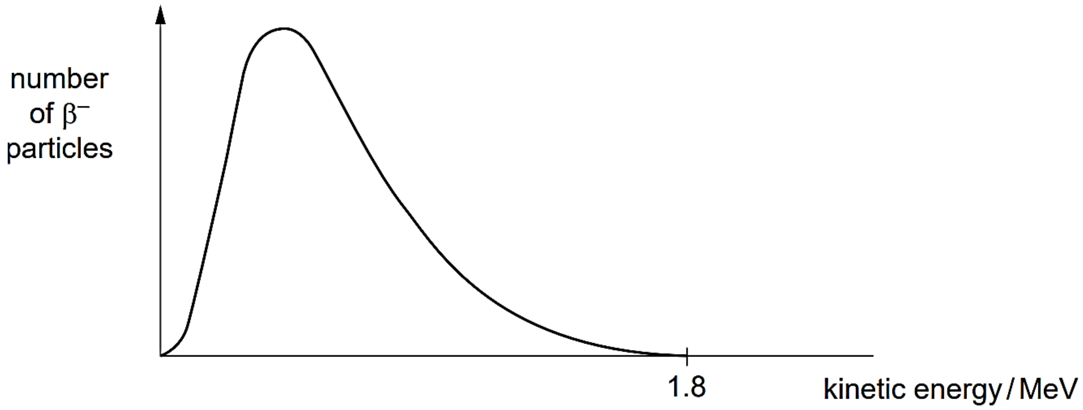

Fig. 6.1

Explain how a consideration of this kinetic energy spectrum provided evidence for the prediction of the existence of the neutrino.

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………………………………………………………………………………………………… [3]

(c) Data for the α-decay of bismuth-212 ($^{212}_{83}Bi$) to form thallium-208 ($^{208}_{81}Tl$) are given in Fig. 6.2.

nucleus	mass of nucleus / u
Bismuth-212	211.9459
Thallium-208	207.9374
Helium-4	4.0015

Fig. 6.2

(i) Calculate the energy released during the decay.

energy released = …………………………….. J [2]

(ii) For a stationary unstable nucleus of nucleon number A that undergoes α-decay, it can be shown that the ratio of the kinetic energy of α-particle to the daughter nucleus after decay is given by

$$\frac{\text{kinetic energy of } \alpha\text{-particle}}{\text{kinetic energy of daughter nucleus}} = 0.25A - 1$$

Using your answer in **(c)(i)** and the above equation, show that the energy of the α-particle is 6.4 MeV.

[3]

(iii) In practice, the α-particle is found to have an energy of 6.1 MeV, rather than 6.4 MeV as calculated in (c)(ii).

Suggest why in this case, it is likely that the thallium nucleus and the α-particle do not move off in opposite direction.

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…………………………………………………………………………………………… [2]

(iv) **1.** Initially, a radioactive source contains *N* nuclei of bismuth-212.

After two hours, it is found that the number of bismuth-212 nuclei has reduced to approximately 0.25*N*. However, although bismuth-212 decays to form thallium-208, the number of thallium nuclei is much less than 0.75*N*.

Suggest an explanation for these observations.

……………………………………………………………………………………………

…………………………………………………………………………………………… [1]

2. The half-life of bismuth-209 is 1.9×10^{19} years.
Estimate the number of nuclei in a 10 kg sample of bismuth-209 that are likely to disintegrate in the next 100 years.

number of nuclei = …………………………….. [3]

6 Read the following article and answer the questions that follow.

Optical Tweezers

Light as a particle, photon, carries energy and momentum.

In 1970, Arthur Ashkin discovered that by using light from a tightly focused laser beam, you can effectively trap and even move microscopic particles. This led to the development of "optical tweezers", which allow scientists to study microscopic and even nanoscopic materials, including particles the size of just a few atoms.

In recent years, optical tweezers have been successfully used to study a variety of biological systems, including trapping single viruses and characterising biological motors within cells. Hence, in 2018, Arthur Ashkin was awarded the Nobel Prize in Physics for his groundbreaking work on optical trapping.

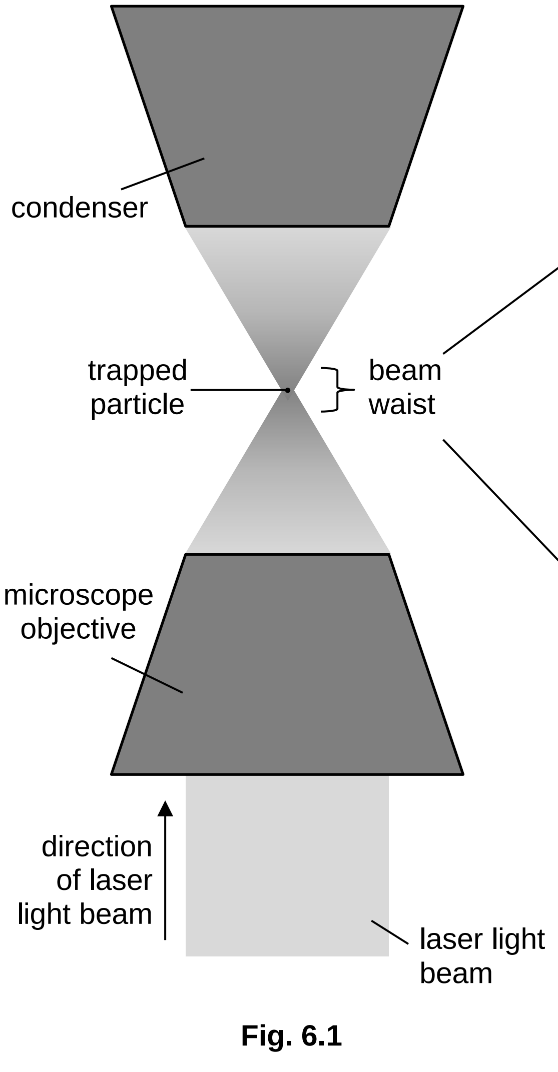

Fig. 6.1

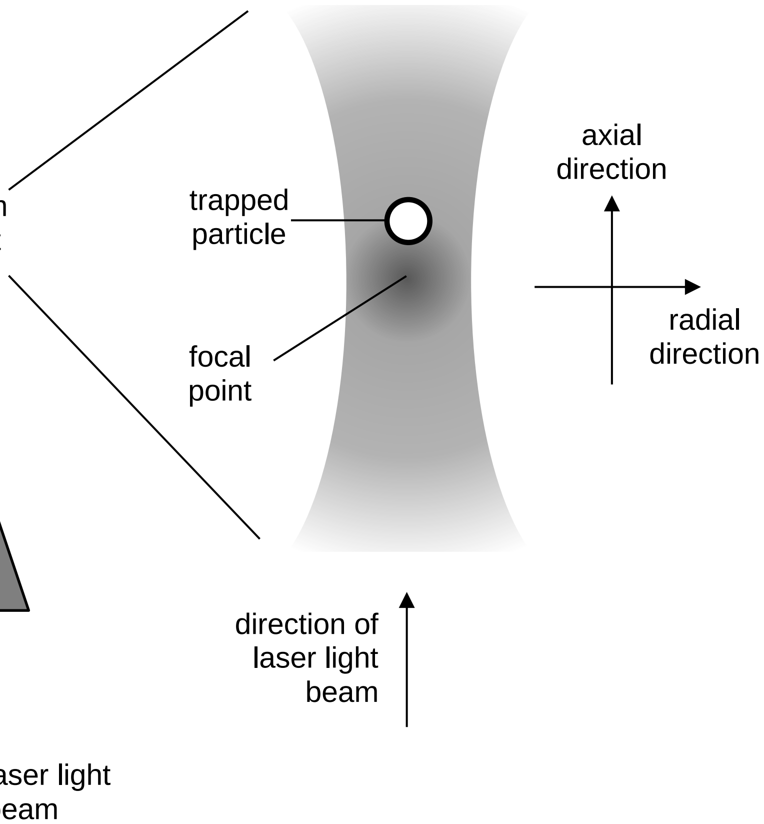

Fig. 6.2

In a general optical tweezer setup, as shown in Fig. 6.1, parallel laser light is passed through a microscope objective, which focuses the laser at its focal point. The beam then diverges and enters a condenser. This forms the "beam waist" (the narrowest part of the focused laser beam), which is where the particle will be trapped, as shown in Fig. 6.2.

When trapped, the particle experiences forces from the laser light in all directions due to reflection and refraction. These forces act as a form of restoring force so that if the particle is displaced slightly, these forces will return it back to its equilibrium position. Hence, the particle remains trapped within the beam.

The forces experienced by the trapped particle are generally categorised into two types: *gradient* forces and *scattering* forces. *Gradient* forces act in all directions on the particle and arise from the intensity profile of the beam waist – the particle experiences an attractive force towards the most intense part of the beam, which is the centre and the focal point of the beam. *Scattering* forces, on the other hand, act in the direction of travel of the laser light and arise from the reflection of light off the particle, which tends to push and displace the particle in the direction of the laser light.

Fig. 6.3 and Fig. 6.4 show the variation with displacement of the restoring forces acting on the particle along the radial direction (perpendicular to the direction of beam propagation) and the axial direction (parallel to the direction of beam propagation) respectively.

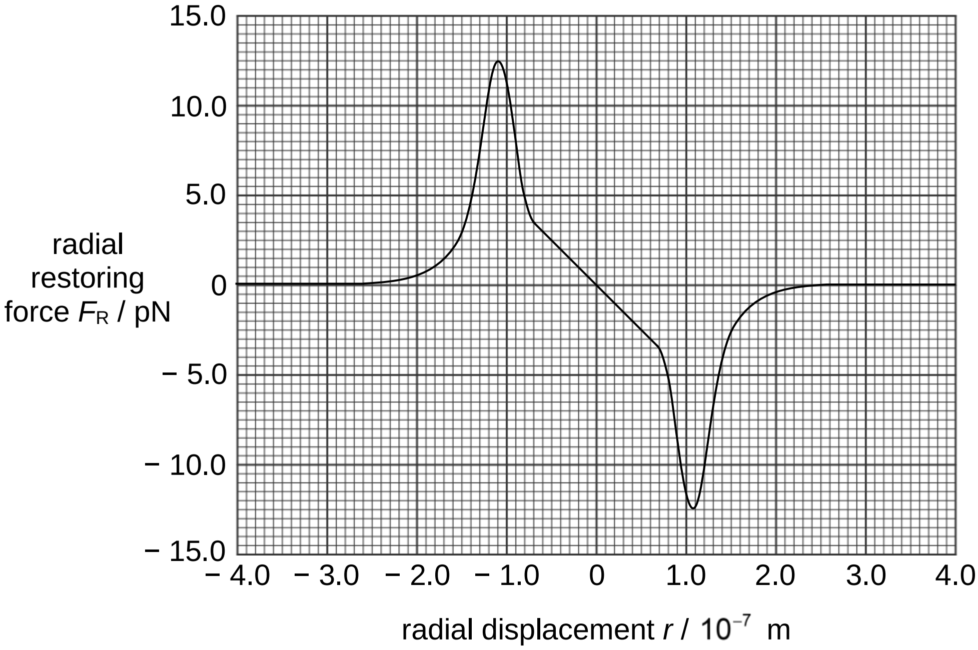

Fig. 6.3

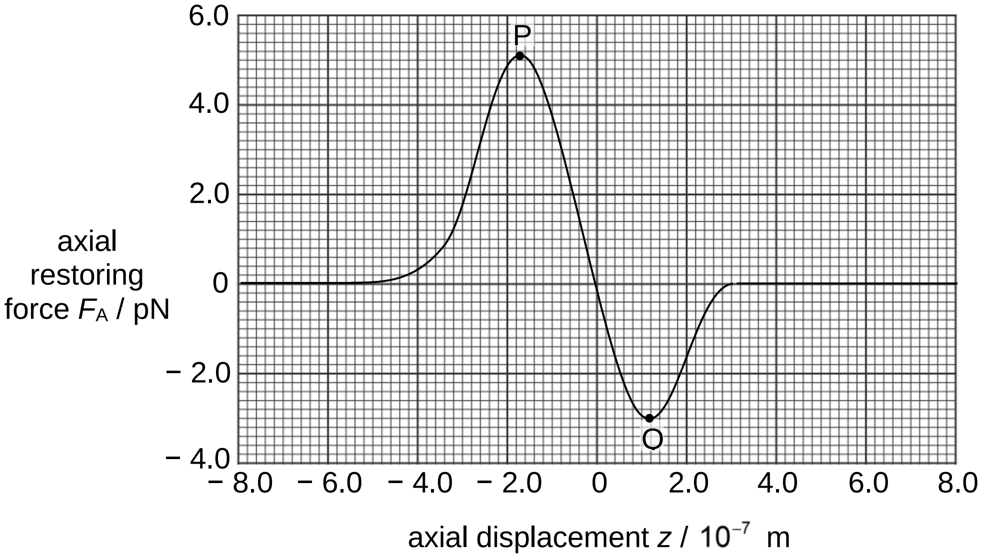

Fig. 6.4

(a) Suggest why *gradient* forces need to be larger in magnitude as compared to *scattering* forces in order for the particle to remain trapped in the beam.

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………………………………………………………………………………………………… [2]

(b) If the radial displacement r of a trapped particle from its equilibrium position is small, the radial restoring force F_R experienced by the particle can be modelled using Hooke's Law for a mass on a spring, which can be expressed as

$$F_R = -kr$$

where k is the radial spring constant.

(i) From Fig. 6.3, estimate the maximum displacement of the particle from its equilibrium position in which the restoring force can be approximated using Hooke's Law.

maximum displacement = …………………………. m [1]

(ii) From Fig. 6.3, determine k.

k = …………………………. N m^{-1} [1]

(iii) The particle is displaced from its equilibrium position along the radial direction such that the radial restoring force F_R can be described by Hooke's Law. It then begins to oscillate about its equilibrium position. The mass of the particle is 1.50×10^{-14} kg.

1. Using the features of the graph in Fig. 6.3, explain why the oscillation of the particle can be described as simple harmonic.

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……………………………………………………………………………………………

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…………………………………………………………………………………………… [2]

2. Determine the frequency of oscillation of the particle.

frequency = …………………………. Hz [2]

(c) By referring to Fig. 6.3, sketch on Fig. 6.5 the variation with axial displacement z of the particle's potential energy U along the radial direction from $r = -0.5 \times 10^{-7}$ m to $r = +0.5 \times 10^{-7}$ m as it oscillates in the radial direction.

Assume U at the equilibrium position ($r = 0$) be zero.

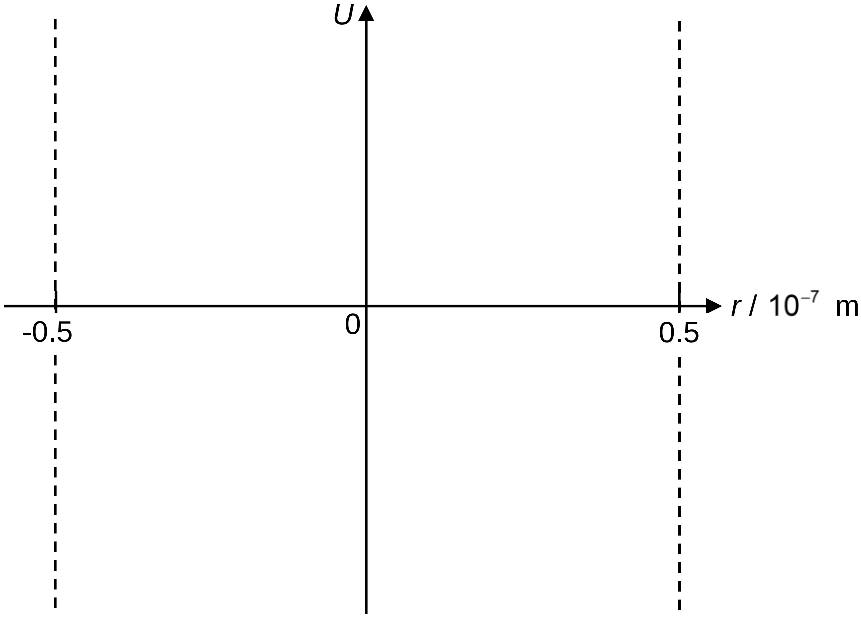

Fig. 6.5

[2]

(d) When the properties of a biological molecule like DNA are being studied, it is usually first attached to a microscopic glass bead. The bead is then immersed in a medium with a refractive index that is smaller than the refractive index of the glass bead. Following which, the bead is trapped and manipulated by optical tweezers in order to study the molecule's properties.

The restoring forces experienced by the trapped glass bead can be explained using the refraction of light through the glass bead. Fig. 6.6 shows a light ray from the laser beam being refracted as it passes through the glass bead.

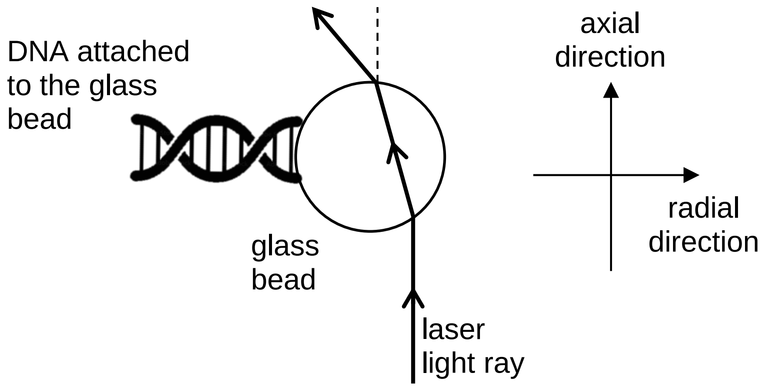

Fig. 6.6

By considering the momentum of photons and Newton's laws of motion, explain how the refraction of the light ray exerts a force radially to the right on the glass bead.

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……..…………………………………………………………………………………………….. [4]

(e) A photon of wavelength 960 nm enters the glass bead and undergoes refraction, as shown in Fig. 6.7. It enters the glass beads at the angle of 32° to the axial direction. It leaves the glass bead with the same wavelength but at 10° to the axial direction.

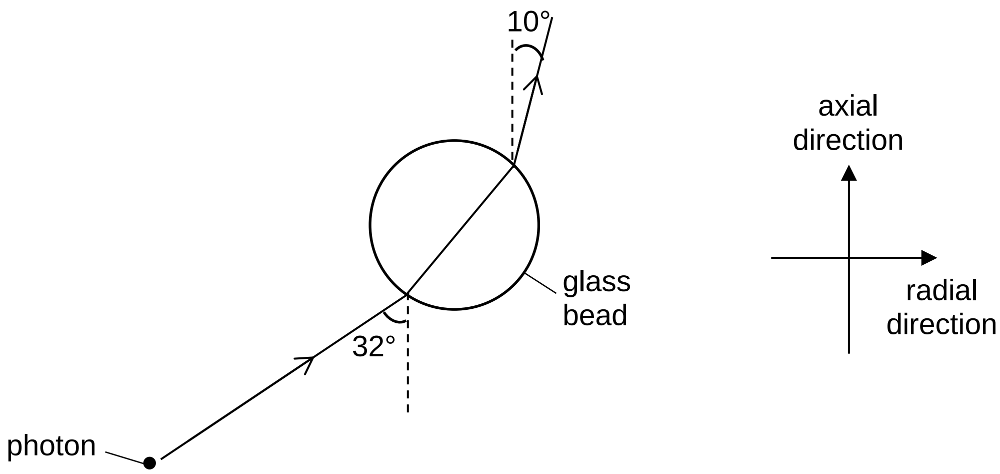

Fig. 6.7

Calculate

(i) the momentum of the incident photon,

momentum = ………………………… kg m s^{-1} [2]

(ii) the magnitude of the impulse of the photon in the axial direction,

impulse = ………………………… kg m s^{-1} [2]

(f) Parallel light rays are converged sharply by the microscope objective lens as it enters the glass bead. The lights are refracted as it comes through and out of the other side of the glass bead. This results in the light going out to travel more along the axial direction, as illustrated in Fig. 6.8.

A force due to this refraction of light will act on the glass bead along the axial direction.

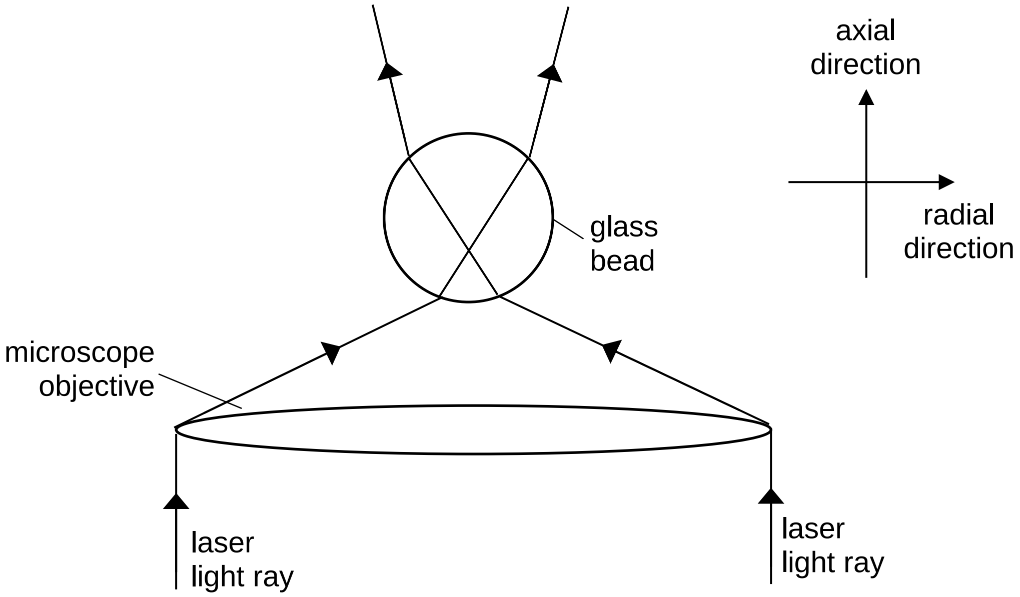

Fig. 6.8

Referring to Fig. 6.4, the maximum axial restoring force indicated with point P has a higher magnitude than that indicated with point Q.

Suggest why this is so.

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

……..………………………………………………………………………………………. [2]

End of paper

Solution for 2023 SAJC Prelim Paper 2

1(a)	Gravitational potential energy of a mass at a point is defined as the work done on the mass in moving it from infinity to that point.
(b)(i)	Change in gravitational potential $\Delta\Phi = -\frac{GM}{3R} - (-\frac{GM}{2R}) = \frac{GM}{6R}$ Hence the change in gravitational potential energy $\Delta U = m\,\Delta\Phi = \frac{GMm}{6R}$
(b)(ii)	Gain in gravitational potential energy = Loss in kinetic energy $\Delta U = ½\, mu^2 - ½\, mv^2$ $\frac{GMm}{6R} = ½\, m\,(7600^2 - 7320^2)$ $\frac{GM}{6R} = (2.09 \times 10^6)$ $(6.67 \times 10^{-11} M)/(6 \times 3.4 \times 10^6) = 2.09 \times 10^6$ $M = 6.39 \times 10^{23}$ kg
(b)(iii)	Ignore friction with atmosphere / Rocket is outside atmosphere / No energy is lost as heat and sound Not influenced by another planet. Mass of rocket is assumed constant / mass of fuel is negligible. Any two.
(c)(i)	The gravitational force acting on the satellite provides the centripetal force for the circular motion. Since gravitational force acts towards the centre of the earth, the circular orbit must be centred on the Earth's centre. If the orbit is not vertically above the equator, the satellite would have varying latitude and so cannot be geostationary.
(c)(ii)	$mr\omega^2 = \frac{GMm}{r^2}$ $r^3 = \frac{GM}{\omega^2} = \frac{GMT^2}{4\pi^2}$ $= \frac{6.67 \times 10^{-11} \times (24 \times 60 \times 60)^2\, M}{4\pi^2}$ $r = 0.233\, M^{1/3}$

2 **(a)** the energy per unit mass required to change a substance from the liquid phase to the gas phase without a change of temperature

(b) **1.** increasing separation of molecules / breaking or overcoming (intermolecular) forces between molecules / overcome potential barrier

2. doing work against atmosphere (during expansion)

(c) **(i)** Assuming no heat lost to surroundings,
Heat supplied by water = heat gained by ice

$$m_{water}\ c\ \Delta\theta = m_{ice}\ l_f + m_{ice}\ c\ \Delta\theta$$
$$900 \times 4200 \times (85 - \theta) = 100 \times 3.34 \times 10^5 + 100 \times 4200 \times \theta$$
$$\theta = 68.5°C$$

(ii) For (the same mass of) steam and water to reach thermal equilibrium with the skin, there is an extra amount of thermal energy released during condensation (from steam to water).

(d) **(i)** Area under graph (against the y-axis) = PΔV

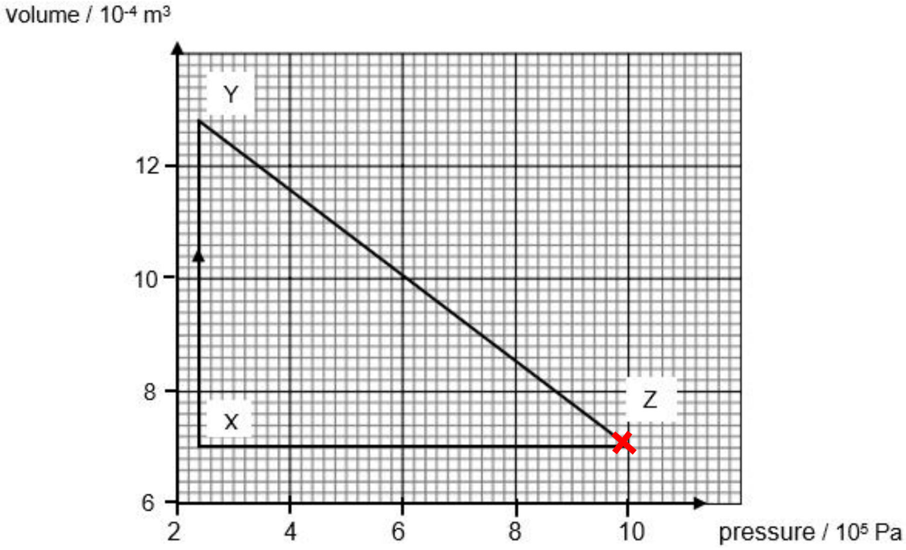
$= (2.4 \times 10^5)(12.8 - 7.0) \times 10^{-4}$

$= 139$ J

Work done on gas = − 139 J

(ii) No work done ZX, by First Law of Thermodynamics / ΔU = Q + W, since if there is decrease in internal energy, there must be heat removed from the system.

(iii)



At (9.8×10^5, 7.2×10^{-4}).
At that point (marked x), the PV product is the largest.

3(a)	Separation: No change, since λ, D and a are constants. Contrast: decreases, since polarization causes intensity to decrease, hence bright fringe is less bright, dark fringe is just as dark.
(b) (i)	The waves of equal f and amplitude in opposite direction interfere/superpose producing a stationary wave. Stationary wave has nodes and antinodes distance between a node and anti-node is λ/4 = 0.75 cm
(ii)	Resultant wave is the vector sum of the individual waves. Amplitude of the resultant wave = A√2. Intensity is proportional to square of amplitude, hence signal intensity is halved.
(c) (i)	All wavelengths meet constructively at that point
(ii)	$\frac{1 \times 10^{-3}}{200} \sin\theta = 1\lambda$ $= 700 \times 10^{-9}$ and 400×10^{-9} $\theta = 8.05°$ and $4.59°$ distance from X = 3.00 tan 4.59° and 3.00 tan 8.05° = 0.241 m to 0.424 m
(iii)	If the shortest wavelength (violet) of 3rd order diffract at smaller angle than the longer wavelength (red) of the 2nd order, they will interfere. $\frac{1 \times 10^{-3}}{200} \sin\theta = 3 \times 400 \times 10^{-9} \rightarrow \theta = 13.9°$ $\frac{1 \times 10^{-3}}{200} \sin\theta = 2 \times 700 \times 10^{-9} \rightarrow \theta = 16.3°$ Hence, they will overlap.

4 **(a)** gradient = E
y-intercept = $-(R_F + r)$

(b) $R = \frac{\rho l}{A} = \frac{1.7 \times 10^{-8} \times 5.0}{\pi\left(\frac{0.26}{2} \times 10^{-3}\right)^2} = 1.6\ \Omega$

The cable is made of 24 wires in parallel.

Resistance of cable = $\left(\frac{1}{1.6} \times 24\right)^{-1} = 0.067\ \Omega$

(c) As temperature increases, amplitude of vibration of lattice ions / metal ions (do not accept: metal atoms / molecules / particles) increase. Drift velocity of the free electrons decreases. No or insignificant increase in the number of charge carriers. Hence, overall effect resistance increases.

5 (a) Binding energy per nucleon is a maximum at around A = 56. Products splitting a Fe-56 nucleus must have a lower total binding energy. (Reaction would require) a net input of energy.

(b) Total energy released (and momentum) per decay is constant. If there is no other particle emitted, ALL the beta particles should have the same energy. There is a range of energies of β^- particles as shown from the figure. Hence, there must exist another particle, neutrino, to possess/share the remaining energy (and momentum).

(c) (i) Energy released = loss in mass × c^2

$= (211.9459 – 207.9374 – 4.0015)(1.66 \times 10^{-27})(3.0 \times 10^{8})^2$

$= 1.0458 \times 10^{-12}$

$= 1.05 \times 10^{-12}$ J

(ii) KE of α-particle = (0.25 × 212 – 1)(KE of Thallium)

KE of Thallium = (1/52)(KE of α-particle)

KE of α-particle + KE of Thallium = 1.0458×10^{-12}

KE of α-particle + (1/52)(KE of α-particle) = 1.0458×10^{-12}

KE of α-particle = 1.026×10^{-12} J

$= (1.026 \times 10^{-12}) / (1.6 \times 10^{-19} \times 10^{6})$

= 6.41 MeV

(iii) A γ-ray photon is emitted. The emitted γ-ray photon has a certain momentum associated with its wavelength / frequency / energy. Hence, by conservation of momentum, the α-particle and thallium nucleus may not be in exactly opposite directions due to the emission of γ photon.

(iv) 1. Thallium-208 has a much shorter half-life than Bismuth-212 / much higher decay constant

2. $N_0 = 10 / (209\ u) = 2.882 \times 10^{25}$ (using u)

OR $N_0 = 2.88038 \times 10^{25}$ (using N_A)

$A = \lambda N = (\ln 2 / 1.9 \times 10^{19})\ 2.882 \times 10^{25} = 1.051 \times 10^{6}\ yr^{-1}$

Since 100 years is much smaller than half-life, activity is constant over 100 years. No. of nuclei disintegrated = A t = $1.051 \times 10^{6} \times 100 = 1.05 \times 10^{8}$

6 **(a)** Scattering forces tend to push the particle in the direction of the beam. The gradient forces must be greater in magnitude so that if the particle is displaced from the focal point along the direction of the beam, there will be a net force to attract towards the focal point.

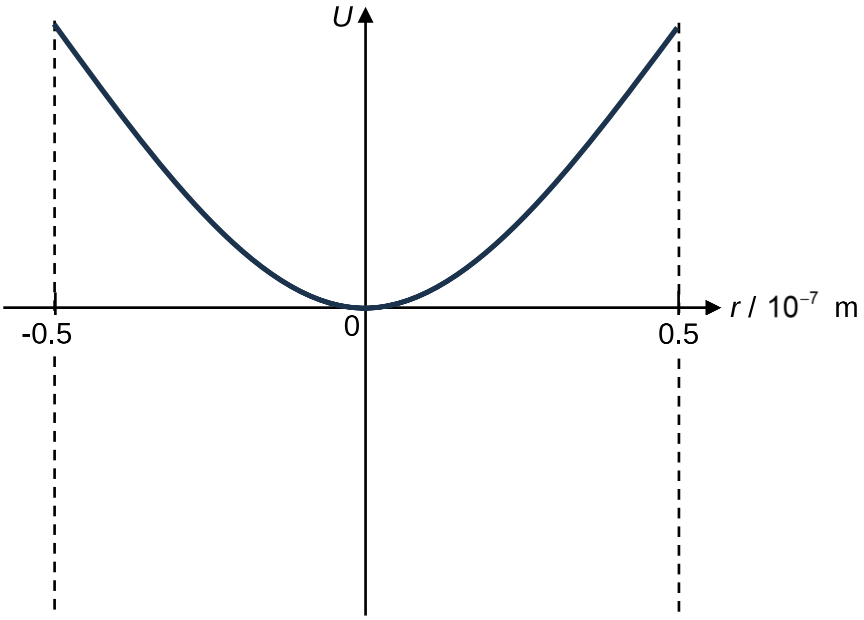
(b) **(i)** 0.70×10^{-7} m or 7.0×10^{-8} m

(ii) $F = kx$
$3.5 \times 10^{-12} = k(0.70 \times 10^{-7})$
$k = 5.0 \times 10^{-5}$ N m^{-1}

(iii) 1. Straight line / Constant gradient passing through the origin indicates force is proportional to displacement from equilibrium position. Negative gradient indicates force is directed towards the equilibrium position

2. $a = -\omega^2 x$
$(3.5 \times 10^{-12}) / (1.50 \times 10^{-14}) = -(2\pi f)^2(0.70 \times 10^{-7})$
$f = 9189 = 9190$ Hz

(c)



Quadratic curve (U or N shaped curve)
Positive and intersect at origin

(d) Incident photon has no momentum along the radial direction initially. Refracted photon through the glass bead gains momentum to the left. By Newton's second law, refracted photon experiences a force towards the left. By Newton's third law, the glass bead experiences a force towards the right

OR

Incident photon has no momentum along the radial direction initially. Refracted photon through the glass bead gains momentum to the left. By conservation of momentum, glass bead gains momentum to the right. By Newton's second law, the glass bead experiences a force towards the right

(e) **(i)** $p = h / \lambda$
$= (6.63 \times 10^{-34}) / (960 \times 10^{-9})$
$= 6.91 \times 10^{-28}$ kg m s^{-1}

(ii) impulse $= p_f - p_i$
$= (6.91 \times 10^{-28} \times \cos 10°) - (6.91 \times 10^{-28} \times \cos 32°)$
$= 9.44 \times 10^{-29}$ kg m s^{-1}

(f) Some lights / photons are reflected off the glass bead resulting in the scattering force in the positive axial direction. This force due to reflection will in a larger net restoring force in the positive axial direction (when glass bead is displaced negatively)