

Anglo-Chinese Junior College
Physics Preliminary Examination
Higher 2



A Methodist Institution
(Founded 1886)

PHYSICS

Paper 1 Multiple Choice

9749/01

19 September 2025

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

Do not use staples, paper clips, glue or correction fluid.

Write your name and index number on the Answer Sheet provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A, B, C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this Question Paper.

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

DATA AND FORMULAE

Data

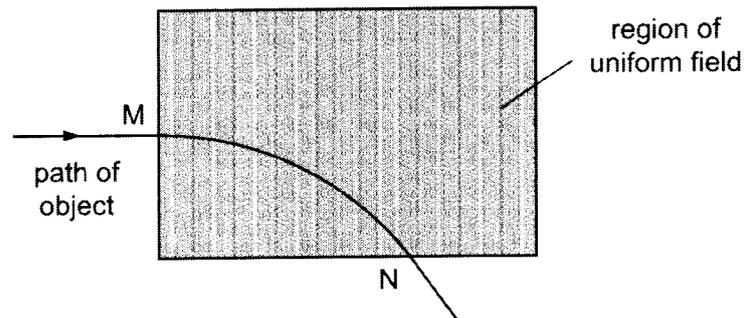
speed of light in free space	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g = 9.81 \text{ m s}^{-2}$

Formulae

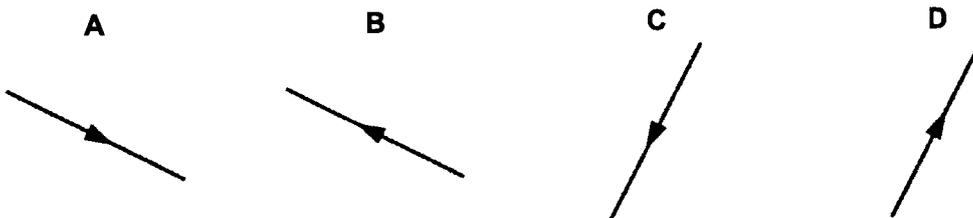
uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas	$W = p \Delta V$
hydrostatic pressure	$p = \rho g h$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T/K = T/^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3} \frac{Nm}{V} \langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \dots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \dots$
electric potential	$V = \frac{Q}{4\pi\epsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
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	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

[Turn over]

- 1 A moving object enters a uniform field of force at M, travels at constant speed and exits the field at N as shown.



Which arrow best represents the direction of the change in velocity of the object from M to N?

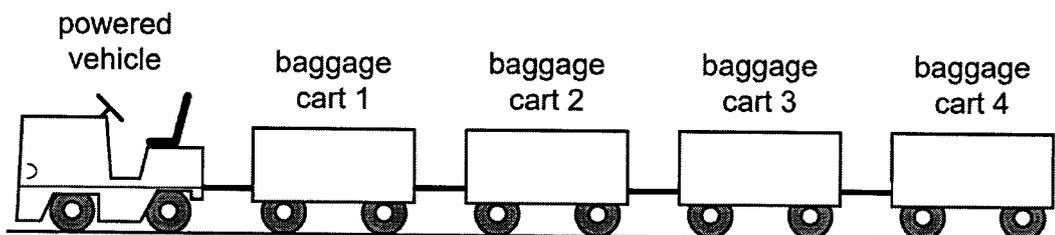


- 2 An object is thrown vertically upwards in air. The times for the upward motion t_u and the downward motion t_d to return to the same height are compared.

Which statement is correct?

- A** t_d is greater because at a given speed the resultant force when the object is moving downwards is smaller than the retarding force when it is moving upwards.
- B** t_d is greater because the object moves faster on its downward motion and therefore the air resistance is greater.
- C** t_u is greater because at a given speed, the resultant force when the object is moving downwards is greater than the retarding force when it is moving upwards.
- D** t_u is greater because the object moves faster on its downward motion due to gravitational force acting in the same direction as its motion.

- 3 A transport system used to move luggage from the airport terminal to the aircraft consists of a powered vehicle connected to four baggage carts by a series of connecting bars.



The mass of each of the baggage carts is 400 kg and the system starts with an acceleration of 2.0 m s^{-2} .

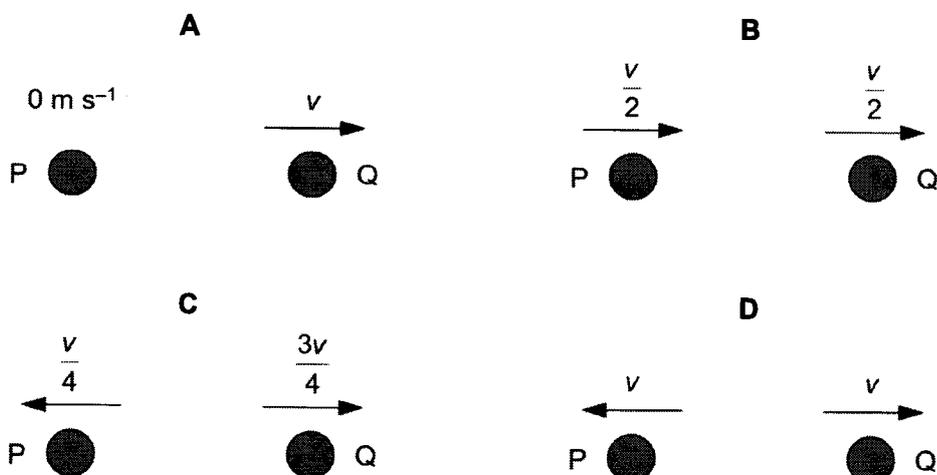
Ignore any frictional forces on the carts.

What is the tension in the connecting bar between baggage carts 2 and 3?

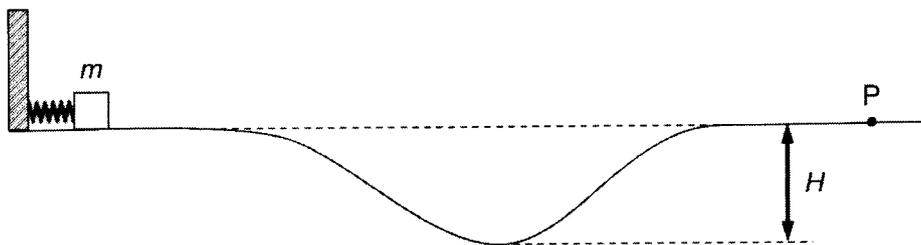
- A 400 N B 800 N C 1200 N D 1600 N
- 4 A small ball P moves with speed v towards another identical ball Q along a line joining the centres of the two balls. Ball Q is at rest initially and they collide elastically.



Which of the following shows the final velocities of the balls?



- 5 A small object of mass m is launched by a spring and travels along a rough track to a point P as shown.



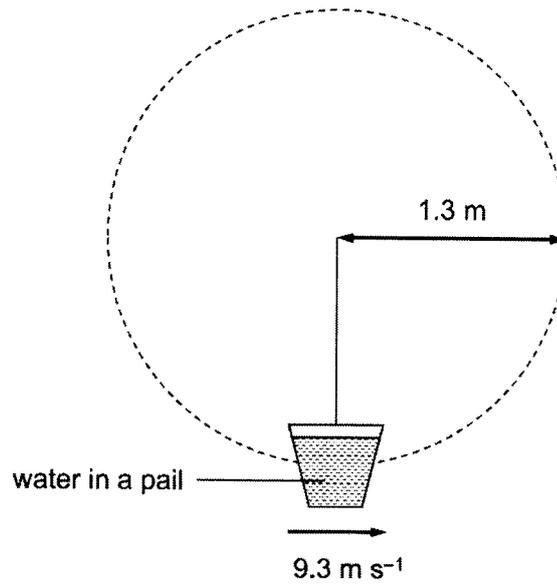
The spring constant of the spring is k and its initial compression is x .

As it travels to P, it goes through a distance d and a dip of depth H . The object experiences a constant frictional force f for the entire motion.

What is the kinetic energy of the object at point P?

- A $\frac{1}{2}kx^2 - fd$
- B $\frac{1}{2}kx^2 - fd - mgH$
- C $\frac{1}{2}kx^2 + fd$
- D $\frac{1}{2}kx^2 + fd + mgH$

- 6 A pail of water is spun vertically in a circular motion with a radius of 1.3 m as shown.

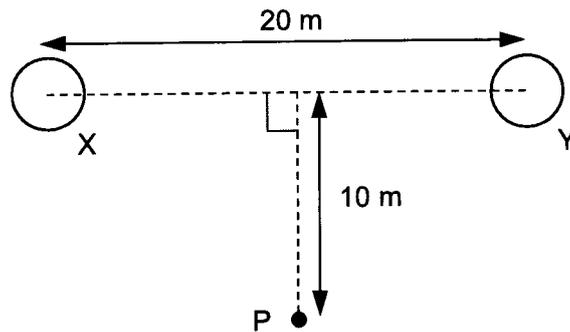


The mass of water is 0.52 kg and the speed of the pail at the bottom of the circle is 9.3 m s⁻¹.

What is the normal contact force acting on the water at the bottom of the circle?

- A 5.1 N B 30 N C 35 N D 40 N

- 7 Two identical 30 kg point masses X and Y are placed 20 m apart as shown.



P is a point 10 m perpendicular to the midpoint between X and Y.

What is the resultant gravitational field strength g and gravitational potential ϕ at P?

	$g / \text{N kg}^{-1}$	$\phi / \text{J kg}^{-1}$
A	1.4×10^{-11}	-2.8×10^{-10}
B	1.4×10^{-11}	0
C	2.0×10^{-11}	-2.8×10^{-10}
D	2.0×10^{-11}	0

- 8 A satellite orbits a planet at a distance r from its centre. Its kinetic energy is 3.2 MJ.

Another identical satellite orbits the planet at a distance $2r$ from its centre.

What is the gravitational potential energy of this second satellite?

- A** -0.80 MJ **B** -1.6 MJ **C** -3.2 MJ **D** -6.4 MJ

- 9 An isolated container is divided into two sections of equal volumes by a partition. The ideal gas in each section has the same pressure P .

What is the final pressure after the partition is removed?

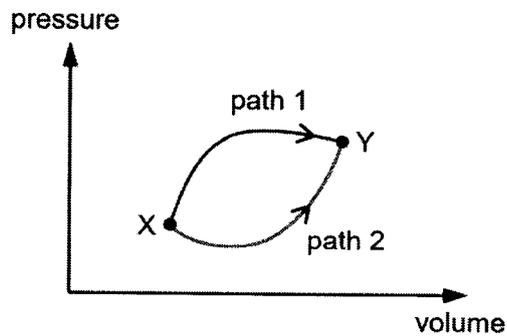
- A $\frac{1}{2}P$ B P C $\frac{3}{2}P$ D $2P$

- 10 A fixed volume container contains a mixture of two monatomic gases X and Y at the same temperature. The mass of the molecules of X is twice that of molecules of Y.

What is the ratio $\frac{\text{root mean square speed of molecules of X}}{\text{root mean square speed of molecules of Y}}$?

- A 0.50 B 0.71 C 1.4 D 2.0

- 11 A fixed mass of gas undergoes a change from state X to Y via two different paths as shown.



In path 1, 4.0 J of work is done by the gas and there is a thermal transfer of 10 J of energy into it.

In path 2, 2.0 J of work is done by the gas.

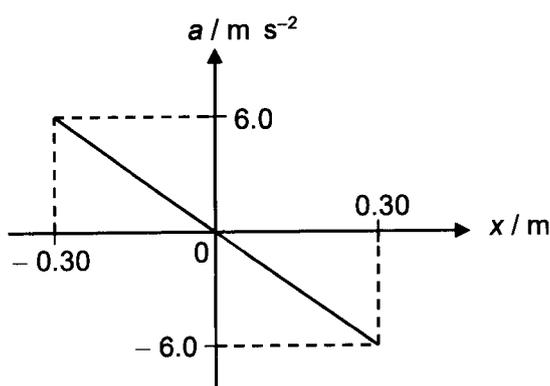
What is the thermal transfer of energy into the gas in path 2?

- A 4.0 J B 8.0 J C 12 J D 16 J

- 12 An object is displaced from its equilibrium position and the oscillating system undergoes heavy damping.

Which of the following is true for the system?

- A The object does not return to its equilibrium position for a very long time.
 B The object oscillates with its amplitude decreasing exponentially with time.
 C The object oscillates with its amplitude varying linearly with time.
 D The object returns to its equilibrium position in the shortest possible time.
- 13 A particle moves such that its acceleration a is related to its displacement x from a fixed point as shown below.



What is its angular frequency?

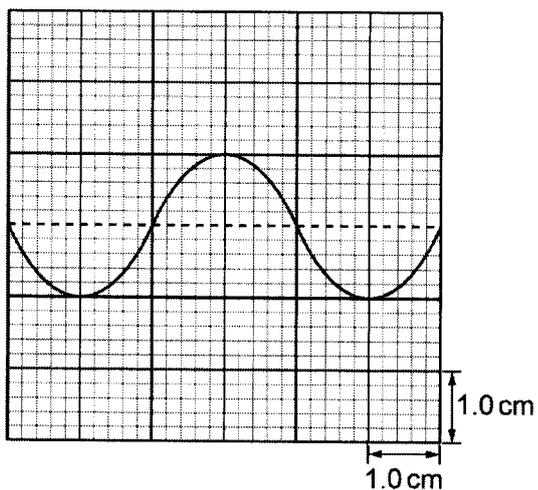
- A 0.050 rad s^{-1}
 B 1.8 rad s^{-1}
 C 4.5 rad s^{-1}
 D 20 rad s^{-1}
- 14 A progressive longitudinal sound wave moves through air. P, Q, R, S and T are the positions of the air particles along part of the wave at one instant.



Which pair of particles has a phase difference of π rad?

- A P and S B P and T C Q and R D R and S

- 15 A microphone and a cathode-ray oscilloscope (CRO) are used to analyse a sound wave. The trace is displayed on the screen of the CRO as shown.



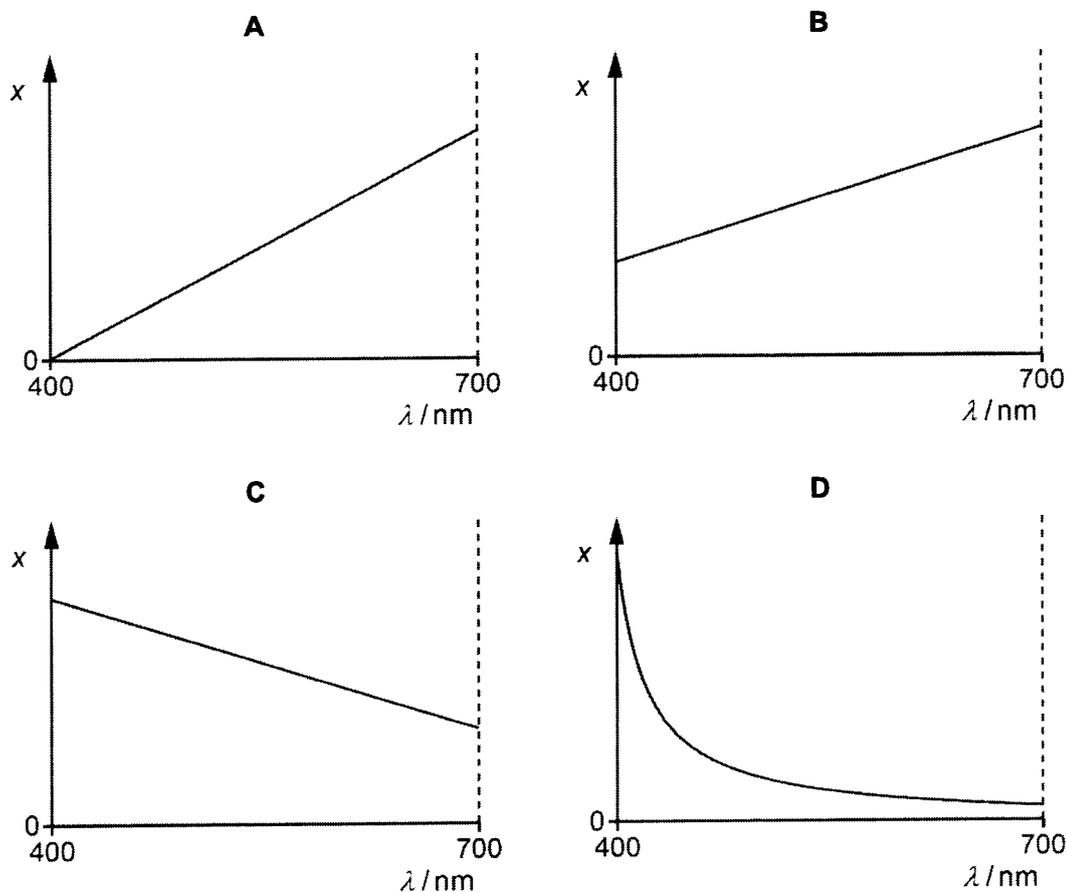
The speed of sound is 330 m s^{-1} and the CRO has a time-base setting of $4.0 \times 10^{-5} \text{ s cm}^{-1}$.

What is the wavelength of the sound wave?

- A** 1.3 cm **B** 2.6 cm **C** 4.0 cm **D** 5.3 cm

- 16 The wavelength λ of light incident normally on a double slit is varied from 400 nm to 700 nm. This causes a variation in the distance x between the centres of two adjacent bright fringes on the screen.

Which graph shows the variation of x with λ ?

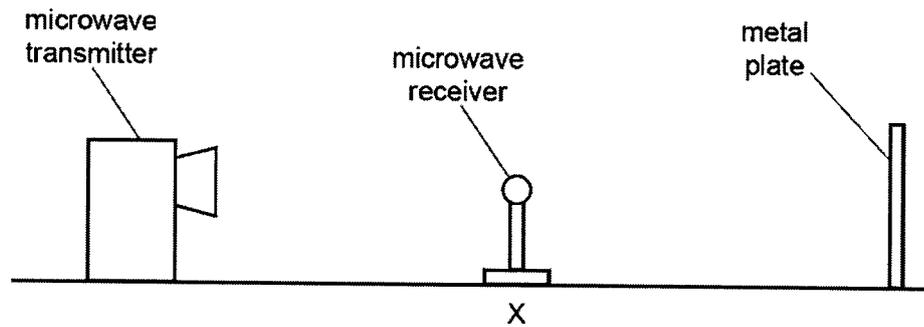


- 17 The diameter of the receiving dish of a telescope is 5.1 m. It receives light of wavelength $0.40 \mu\text{m}$ from two point sources at a distance of 2.8×10^{25} m away.

What is the minimum separation of the two points sources so that the light from them can be resolved?

- A 1.1×10^{18} m
- B 2.2×10^{18} m
- C 1.8×10^{32} m
- D 3.6×10^{32} m

- 18 A transmitter produces microwaves that travel in air towards a metal plate as shown.

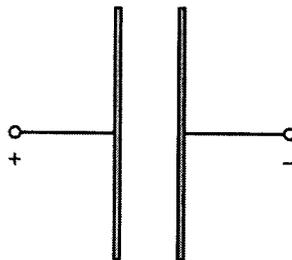


The microwaves have a wavelength of 12.0 cm.

A microwave receiver is initially placed at position X where it detects an intensity maximum. The receiver is then slowly moved away from X directly towards the plate.

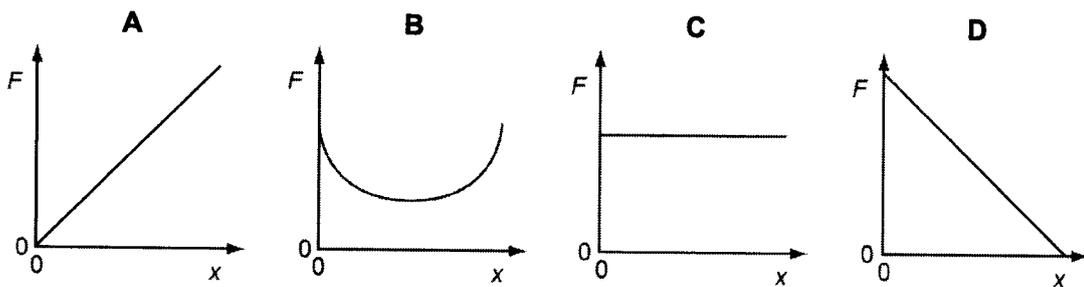
What is the number of intensity minima that are detected by the receiver as it moves from X to a position that is 33.5 cm away from X?

- A 2 B 3 C 5 D 6
- 19 Two oppositely-charged parallel plates are arranged as shown.



An α -particle is released from rest from the surface of the positively-charged plate.

Which graph shows how the force F on the α -particle varies with its distance x from the positive plate?



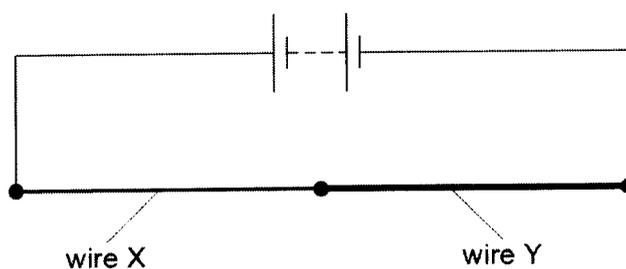
[Turn over]

- 20 A charged object sets up an electric and gravitational field.

What is a similarity between the electric potential and the gravitational potential produced by the object?

- A Both potentials are equal to the work done by an external force.
- B Both potentials are inversely proportional to the square of the distance from the centre of the object.
- C Both potentials are negative.
- D Both potentials change when moving along a field line.
- 21 Two wires, X and Y, are made from the same metal. The diameter of wire Y is twice that of wire X.

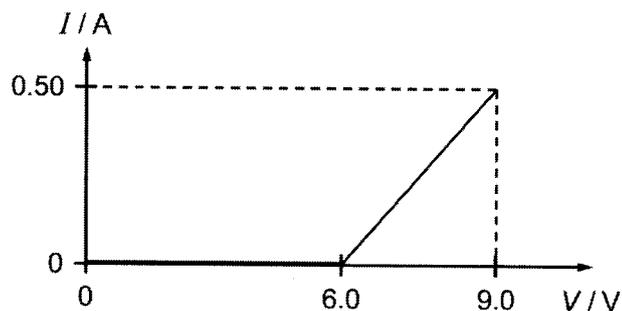
Both wires are connected in series to a battery as shown.



What is the ratio $\frac{\text{average drift speed of free electrons in wire Y}}{\text{average drift speed of free electrons in wire X}}$?

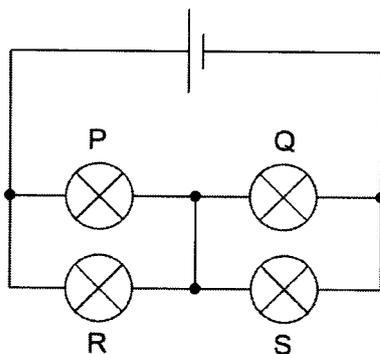
- A 0.25 B 0.50 C 2.0 D 4.0

- 22 The graph shows the variation with potential difference V of the current I in an electrical component.



Which statement about the electrical component is correct?

- A The resistance decreases at voltages from 6.0 V to 9.0 V.
 - B The resistance is 0.056Ω at a voltage of 9.0 V.
 - C The resistance is 6.0Ω at a voltage of 9.0 V.
 - D The resistance is zero at voltages between 0 and 6.0 V.
- 23 A cell is connected to four identical lamps as shown.

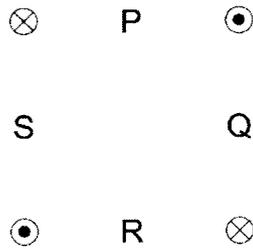


What happens when lamp Q is blown out?

- A Lamp P becomes brighter than before.
- B Lamp S becomes brighter than before.
- C Lamp S does not light up.
- D Lamps P and R remain as bright as before.

[Turn over]

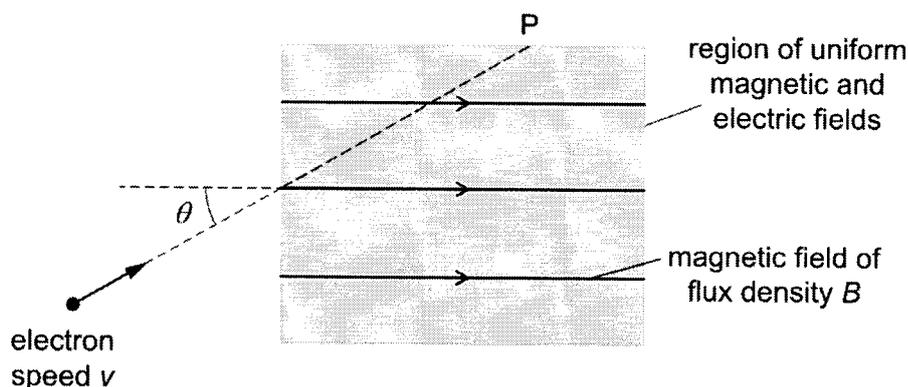
- 24 Four long, straight wires carrying equal current with directions as shown, are placed at the corners of a square. The positions P, Q, R and S are the mid-points of the lines joining the wires.



Which statement correctly describes the directions of the resultant magnetic field at the positions P, Q, R and S?

- A Different at all four positions.
- B P is the same as at Q, R is the same as at S but opposite to the directions at P and at Q.
- C P is the same as at R, Q is the same as at S but opposite to the directions at P and at R.
- D The same at all four positions.

- 25 An electron is travelling in a vacuum at speed v . The electron enters a region of uniform magnetic field of flux density B . A uniform electric field also exists in the region so that the electron remains undeflected and exits the region at point P as shown.

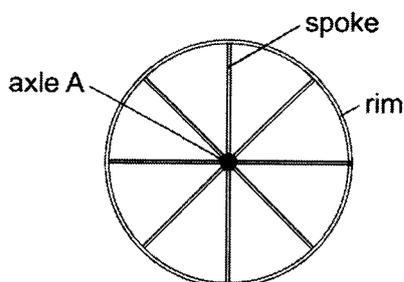


The initial direction of the electron is at an angle of θ to the direction of the magnetic field.

What is the magnitude and direction of the electric field?

	magnitude	direction
A	$B \sin \theta$	into the page
B	$B \sin \theta$	out of the page
C	$Bv \sin \theta$	into the page
D	$Bv \sin \theta$	out of the page

- 26 A metal wheel consists of an axle A, eight spokes and a rim as shown.



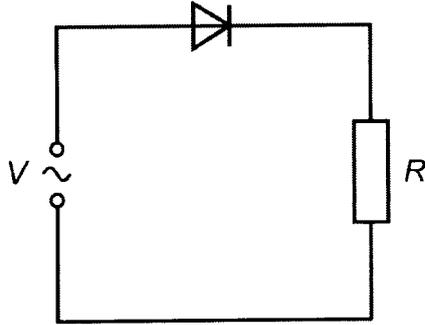
The rim has a radius of 0.65 m and the wheel rotates with an angular speed of 120 rad s^{-1} . There is a uniform magnetic field of flux density 0.23 T perpendicular to the plane of the page.

What is the magnitude of the e.m.f. induced across each spoke?

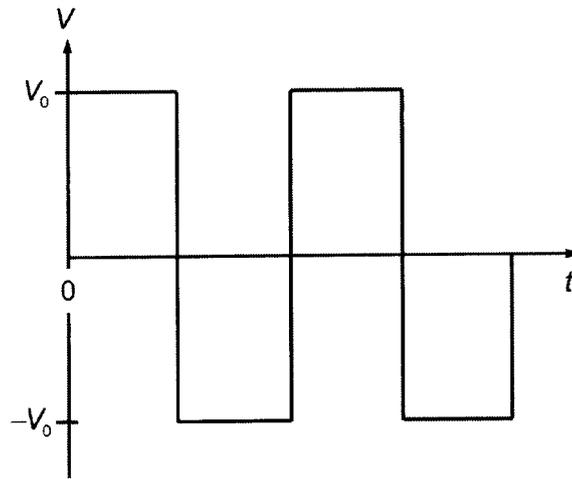
- A** 2.9 V **B** 5.8 V **C** 12 V **D** 18 V

[Turn over]

- 27 An alternating square wave power supply V is connected to a resistor of resistance R and a diode in the circuit as shown.



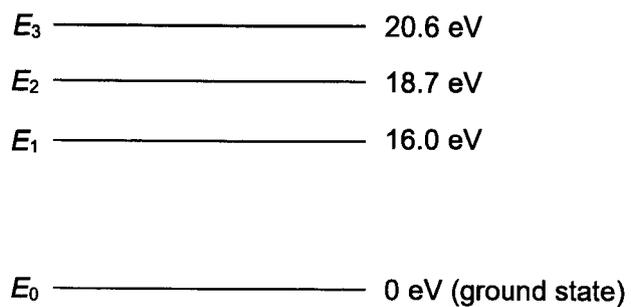
The variation of V with time t is shown in the graph.



What is the mean power dissipated in the resistor?

- A $\frac{V_0^2}{4R}$ B $\frac{V_0^2}{2R}$ C $\frac{V_0^2}{\sqrt{2}R}$ D $\frac{V_0^2}{R}$

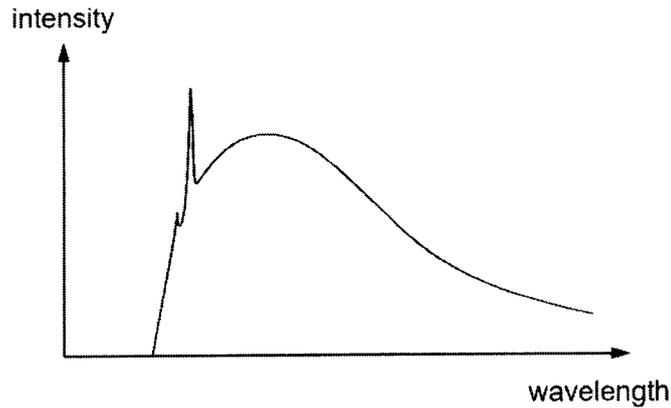
28 Some electron energy levels for a mixture of gas are shown in the diagram.



Which transition will result in the emission of light of wavelength 650 nm?

- A $E_2 \rightarrow E_1$
- B $E_3 \rightarrow E_0$
- C $E_3 \rightarrow E_1$
- D $E_3 \rightarrow E_2$

- 29 The diagram shows an X-ray spectrum produced when electrons strike a heavy metal target.



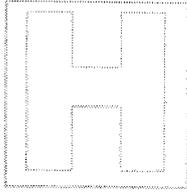
The potential difference through which electrons are accelerated from rest is now increased.

Which row describes the change in the spectrum?

	minimum X-ray wavelength	wavelengths of characteristic spectra
A	decreases	decreases
B	decreases	no change
C	increases	decreases
D	increases	no change

- 30 Which observation shows that a radioactive source emits **only** α -radiation?
- A** The count rate reduces significantly 1 cm away from the source in air.
 - B** The count rate reduces significantly when the source is surrounded by a lead block.
 - C** The radiation beam is deflected by an electric field perpendicular to it.
 - D** The radiation beam remains undeflected by a magnetic field parallel to it.

End of Paper



Anglo-Chinese Junior College
Physics Preliminary Examination
Higher 2



A Methodist Institution
(Founded 1886)

CANDIDATE
NAME

CLASS

CENTRE
NUMBER

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INDEX
NUMBER

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PHYSICS

Paper 2 Structured Questions

9749/02

28 August 2025

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

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

Answer all the 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 Examiners' use only	
1	/ 7
2	/ 7
3	/ 5
4	/ 11
5	/ 10
6	/ 9
7	/ 11
8	/ 20
Total	/ 80

DATA AND FORMULAE

Data

speed of light in free space,	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$ $(1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$
elementary charge,	$e = 1.60 \times 10^{-19} \text{ C}$
the Planck constant,	$h = 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27} \text{ kg}$
molar gas constant,	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall,	$g = 9.81 \text{ m s}^{-2}$

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,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
temperature	$T/K = T/^{\circ}\text{C} + 273.15$
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.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $= \pm \omega \sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \dots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \dots$
electric potential,	$V = \frac{Q}{4\pi\epsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
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	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{1/2}}$

[Turn over

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

- 1 A rigid bar of mass 450 g is held horizontally by two supports A and B, as shown in Fig. 1.1.

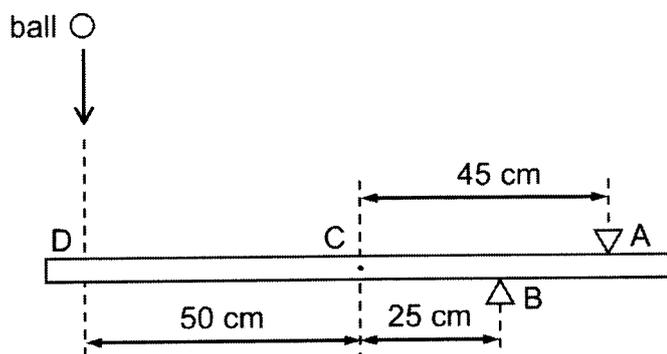


Fig. 1.1

Support A is 45 cm from the centre of gravity C of the bar and support B is 25 cm from C. A ball of mass 140 g falls vertically onto the bar such that it hits the bar at point D, which is 50 cm from C, as shown in Fig. 1.1.

The variation with time t of the velocity v of the ball before, during and after hitting the bar is shown in Fig. 1.2.

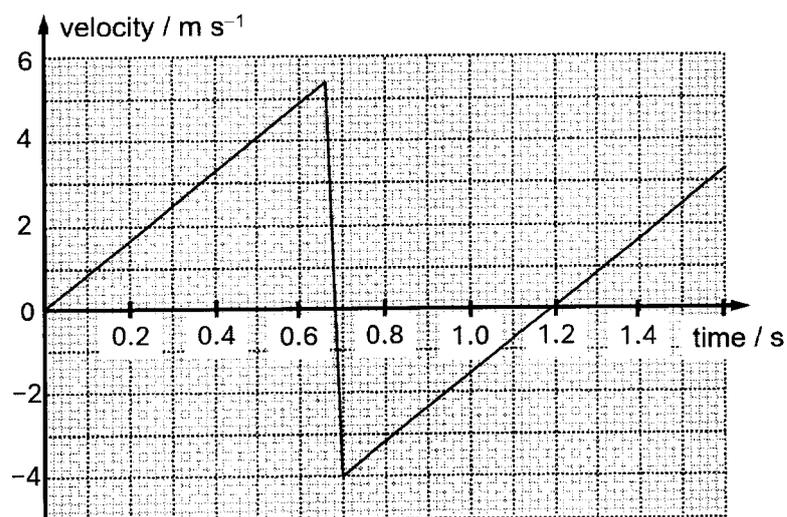


Fig. 1.2

- (a) For the time that the ball is in contact with the bar, use Fig. 1.2 to determine
- (i) the change in momentum of the ball,

change in momentum = N s [2]

- (ii) the magnitude of the force exerted by the ball on the bar.

force = N [3]

- (b) Hence, for the time that the ball is in contact with the bar, calculate the magnitude of the force exerted on the bar by support A.

force = N [2]

[Total: 7]

- 2 A plane is flying with a velocity v of 220 m s^{-1} at an angle of 30° with respect to the horizontal, as shown in Fig. 2.1.

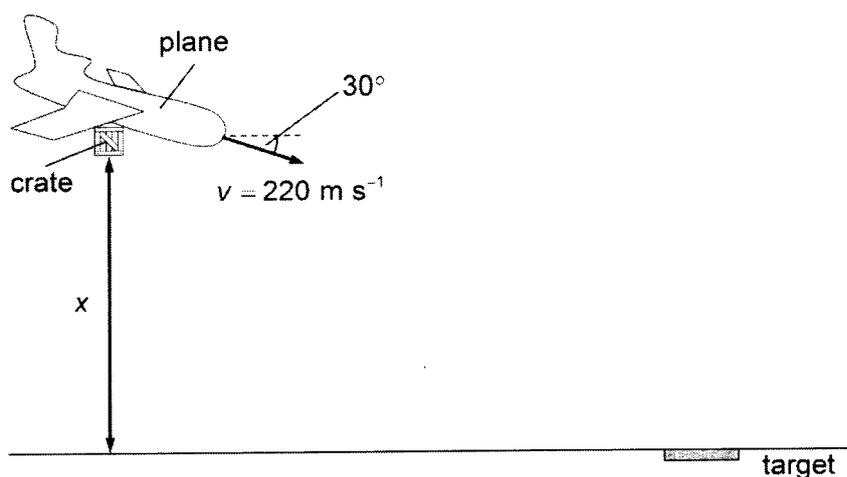


Fig. 2.1

At an altitude of x , a crate is released from the plane. The crate hits the target on the ground after 16.8 s . Assume air resistance is negligible.

- (a) (i) Calculate the value of x .

$$x = \dots\dots\dots \text{ m [2]}$$

- (ii) Determine the speed attained by the crate just before it hits the target.

$$\text{speed} = \dots\dots\dots \text{ m s}^{-1} [3]$$

- (iii) On Fig. 2.2, sketch the variation with time t of the horizontal velocity v_x of the crate. Label this graph S.

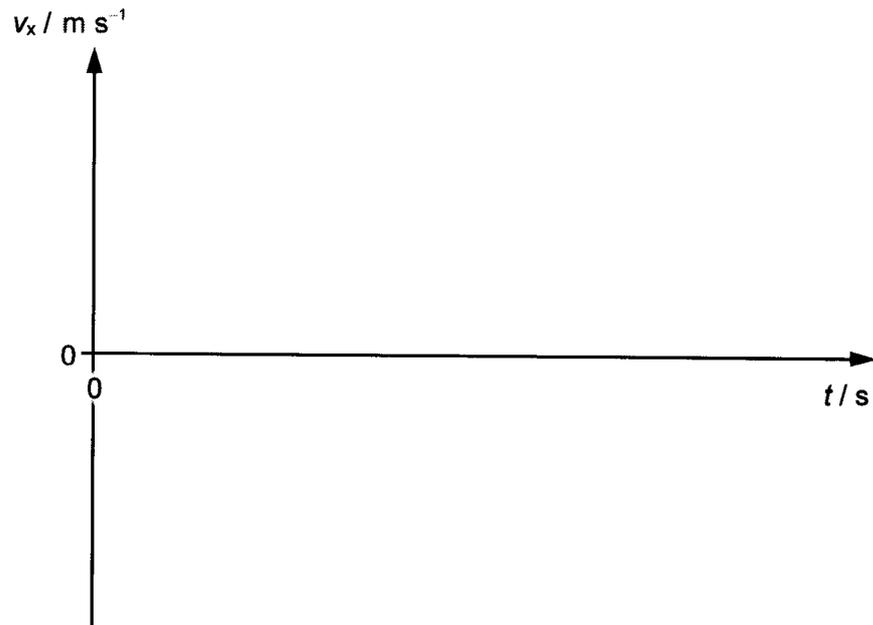


Fig. 2.2

[1]

- (b) If air resistance is not negligible, on Fig. 2.2, sketch the variation with t of v_x . Label this graph R.

[1]

[Total: 7]

[Turn over

- 3 A student, aspiring to be an astrophysicist is contemplating about the possibility of building a spacecraft that can house astronauts for a prolonged period.

Fig. 3.1 shows the spacecraft rotating in space. The spacecraft has a ring structure and uses its own rotation to create an artificial gravity that is similar to Earth for the inhabitants.

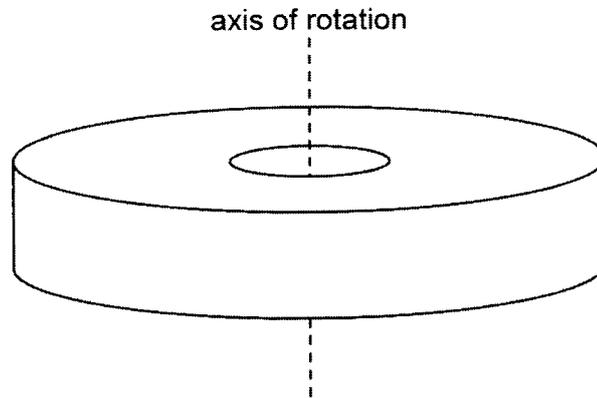


Fig. 3.1

- (a) Fig. 3.2 shows the cross section of the spacecraft and how the astronaut is positioned.

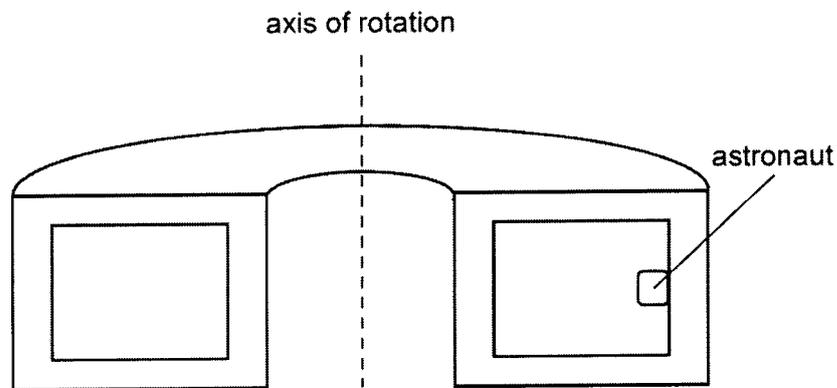


Fig. 3.2

On Fig. 3.2, draw arrow(s) to represent the force(s) acting on the astronaut. [1]

(b) The astronaut in the spacecraft has a constant speed of 100 m s^{-1} .

(i) Explain why the astronaut experiences a resultant force.

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

(ii) Determine the radius of the spacecraft so that the resultant force experienced by the astronaut is equal to his weight on Earth.

radius = m [2]

[Total: 5]

[Turn over

4 (a) State what is meant by a polarised wave.

.....

.....

..... [1]

(b) Two sheets of polaroid P and Q are placed close to each other. Their directions of polarisation are parallel to each other, as shown in Fig. 4.1.

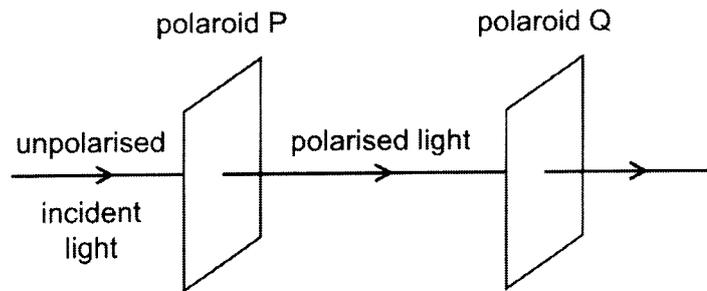


Fig. 4.1

A monochromatic beam of unpolarised light is incident on polaroid P. The beam after passing through polaroid Q has an amplitude of A_0 .

Polaroid Q is now rotated about the axis of the light beam by 30° .

Determine the amplitude of the light, in terms of A_0 , after passing through polaroid Q.

amplitude = [2]

(c) State what is meant by the diffraction of light waves.

.....

.....

..... [1]

- (d) After passing through polaroid Q, the light is incident normally on a single slit and a diffraction grating.

Fig. 4.2 shows two of the emerging beams from the grating. The angle between the two first-order emerging beams is 16° .

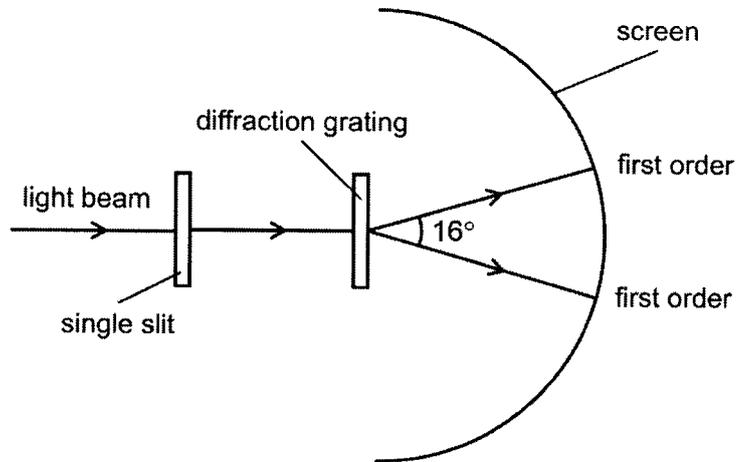


Fig. 4.2 (not to scale)

The grating has a line spacing of 3.4×10^{-6} m.

- (i) Calculate the wavelength of the light.

wavelength = m [2]

- (ii) Hence, state the colour of the visible light beam.

..... [1]

[Turn over

- (iii) Determine the total number of emerging beams from the grating that can be observed on the screen.

number of emerging beams = [2]

- (iv) State and explain the change(s), if any, to the diffraction pattern on the screen when polaroids P and Q are removed.

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

[Total: 11]

- 5 (a) Define *resistance* of a circuit component.

.....
 [1]

- (b) Fig. 5.1 shows a potential divider circuit consisting of two resistors of resistances A and B .

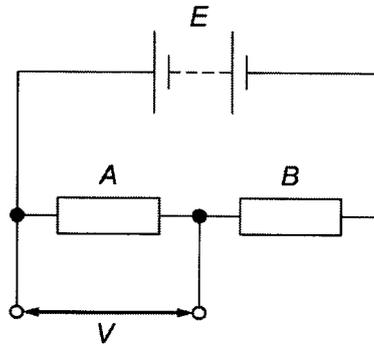


Fig. 5.1

The battery has an e.m.f. E and negligible internal resistance.

By considering the current in circuit, show that the potential difference V across the resistor of resistance A is given by the expression

$$V = \frac{A}{A+B} E$$

[1]

[Turn over

- (c) The resistances *A* and *B* are $1500\ \Omega$ and $4000\ \Omega$ respectively. A voltmeter is connected in parallel with the $1500\ \Omega$ resistor and a thermistor is connected in parallel with the $4000\ \Omega$ resistor, as shown in Fig. 5.2.

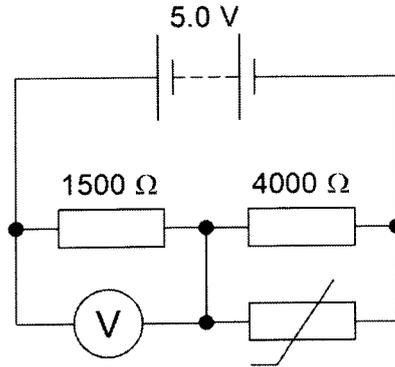


Fig. 5.2

The battery has an e.m.f. of 5.0 V and the voltmeter is ideal.

- (i) State and explain the change in the reading of the voltmeter as the temperature of the thermistor is raised.

.....

.....

.....

.....

..... [3]

- (ii) The resistance of the thermistor at $20\ ^\circ\text{C}$ is $2700\ \Omega$.

Calculate the reading on the voltmeter when the temperature of the thermistor is $20\ ^\circ\text{C}$.

voltmeter reading = V [3]

(iii) For the same change in temperature, state and explain how the change in the voltmeter reading will be different if the battery has significant internal resistance.

.....

.....

.....

..... [2]

[Total: 10]

6 (a) Define *magnetic flux density*.

.....

.....

.....

..... [2]

(b) A horseshoe magnet is placed on a top-pan balance. A rigid copper wire is held horizontally between the poles of the magnet as shown in Fig. 6.1.

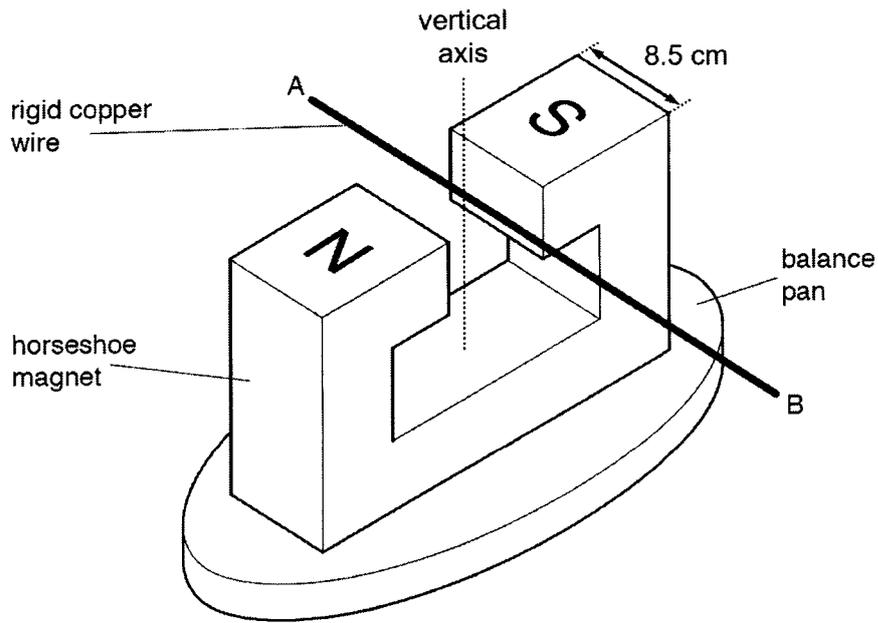


Fig. 6.1

The wire is clamped at ends A and B.

When a direct current of 4.6 A is switched on in the wire, the reading on the balance increases.

(i) State and explain the direction of the force acting on the wire.

.....

.....

..... [2]

(ii) Hence, state the direction of the current in the wire.

..... [1]

- (iii) The width of each pole is 8.5 cm and the magnetic flux density B in the region between the poles of the magnets is 3.7 mT. Assume that the magnetic flux density exists only between the poles.

Calculate the force on the wire.

force = N [2]

- (iv) The wire is now rotated about the vertical axis through 45° as shown by the top view in Fig. 6.2.

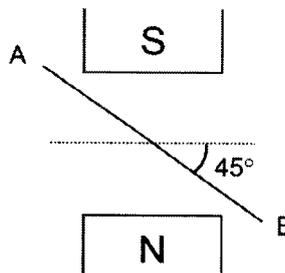


Fig. 6.2

Explain why the reading on the balance remains the same when the wire is rotated about the vertical axis.

.....

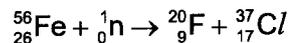
.....

..... [2]

[Total: 9]

[Turn over

- 7 (a) Explain, with reference to the variation of binding energy per nucleon with nucleon number, why the following nuclear fission reaction of iron-56 ($^{56}_{26}\text{Fe}$) to fluorine-20 ($^{20}_9\text{F}$) and chlorine-37 ($^{37}_{17}\text{Cl}$) would **not** result in an overall release of energy.



.....

.....

.....

..... [2]

- (b) A uranium-235 nucleus absorbs a neutron and becomes unstable. It then undergoes a fission reaction. One possible reaction is

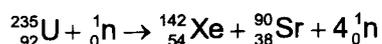


Table 7.1 shows the mass defects of the nuclei for this fission reaction.

Table 7.1

nuclei	mass defect / u
uranium-235 ($^{235}_{92}\text{U}$)	1.910
xenon-142 ($^{142}_{54}\text{Xe}$)	1.273
strontium-90 ($^{90}_{38}\text{Sr}$)	0.8405

Calculate the energy released from the fission of one nucleus of uranium-235.

energy = J [2]

- (c) Strontium-90 is unstable and decays into the isotope yttrium-90.

A sample initially contains only nuclei of strontium-90. The half-life of strontium-90 is 28.8 years. The ratio

$$\frac{\text{number of decayed nuclei of strontium-90}}{\text{number of undecayed nuclei of strontium-90}}$$

is equal to R .

Determine the value of R after 144 years.

$$R = \dots\dots\dots [3]$$

- (d) A power source contains 0.13 kg of strontium-90. Each nucleus of strontium-90 that decays emits 0.546 MeV of energy.

- (i) Calculate the initial number N_0 of nuclei of strontium-90 in the power source.

$$N_0 = \dots\dots\dots [1]$$

- (ii) Determine the initial activity of the source.

$$\text{activity} = \dots\dots\dots \text{Bq} [1]$$

[Turn over

- (iii) Hence, determine the initial power output from the source due to the decay of strontium-90.

power output = W [2]

[Total: 11]

- 8 Read the passage and answer the questions that follow.

A common non-invasive medical imaging technique valued for its affordability, portability and minimal safety concerns is ultrasound. It is widely used in gynaecology and many cardiovascular applications.

Ultrasound waves are produced by a transducer as shown in Fig. 8.1. An oscillating voltage is applied to a piezoelectric element formed by a composite of lead zirconate titanate (PZT). The PZT element's thickness oscillates at the same frequency as the applied voltage. Placing the element in contact with a patient's skin transfers the mechanical motion into a pressure wave which is transmitted into the body.

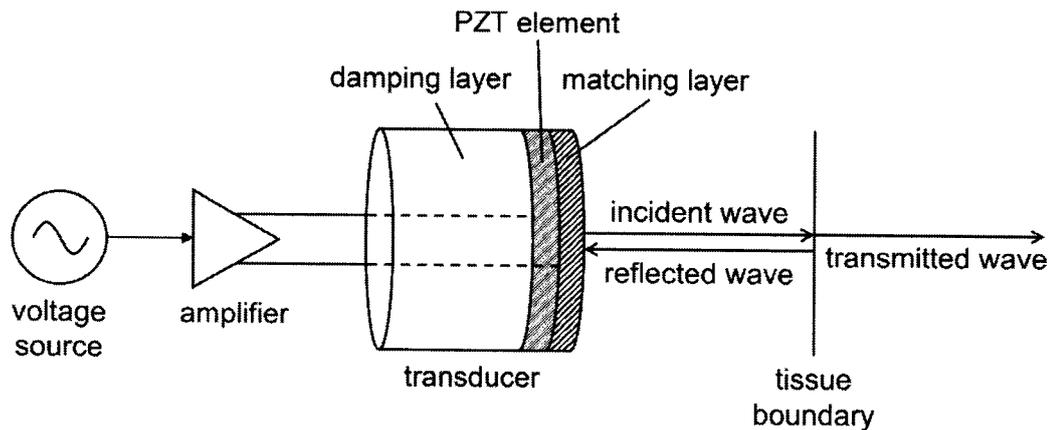


Fig. 8.1

At boundaries between tissues, a certain fraction of the wave energy is reflected back towards the transducer where it is detected to form the ultrasound image. The remainder is transmitted through the boundary deeper into the body.

The propagation of ultrasound energy through the body depends on the characteristic acoustic impedance Z of tissue. Z is determined by the physical properties of the tissue such as its density and compressibility. Table 8.1 shows the acoustic properties for air and some biological tissues.

Table 8.1

	acoustic impedance Z ($10^5 \text{ g cm}^{-2} \text{ s}^{-1}$)	speed of sound v (m s^{-1})	density ρ (kg m^{-3})	compressibility κ ($10^{11} \text{ cm g}^{-1} \text{ s}^2$)
air	0.00043	330	1.3	71 000
bone	7.63	4000	1908	0.328
fat	1.34	1450	925	5.14
brain	1.58	1540	1025	4.11
muscle	1.71	1590	1075	3.68
liver	1.65	1570	1050	3.86
kidney	1.62	1560	1040	3.95

[Turn over

The following equations relate the transmitted I_t and reflected I_r intensities to the incident intensity I_i at a boundary.

$$\frac{I_t}{I_i} = \frac{4Z_1Z_2}{(Z_1 + Z_2)^2}$$

$$\frac{I_r}{I_i} = \frac{(Z_1 - Z_2)^2}{(Z_1 + Z_2)^2}$$

where Z_1 and Z_2 are the acoustic impedances for the medium before and the medium after the boundary respectively.

As the acoustic impedance of the PZT element Z_{PZT} is large compared to that of skin Z_{skin} , a large amount of energy will be reflected from the patient's skin, preventing effective transmission of ultrasound waves from the transducer into the body. To improve this efficiency, a matching layer is attached to the PZT element. Its acoustic impedance is given by

$$Z_{\text{matching layer}} = \sqrt{Z_{\text{PZT}}Z_{\text{skin}}}$$

The thickness of this matching layer should be one-quarter of the ultrasound wavelength to maximise energy transmission through the layer in both directions.

Finally, to enhance the quality of the ultrasound image, contrast agents like microbubbles are injected into the patient. They are filled with compressible gas and respond to the ultrasound beam by compressing in high pressure regions and expanding in low pressure regions. They absorb energy during the compression and re-radiate them during expansion to produce a strong echo signal returning to the transducer.

- (a) Acoustic impedance Z is related to the density ρ and compressibility κ of tissues by the equation

$$Z = \rho^a \kappa^b$$

where a and b are constants.

By considering the units of Z , ρ and κ , determine the values of a and b .

$$a = \dots\dots\dots$$

$$b = \dots\dots\dots$$

[2]

- (b) (i) Calculate $\frac{I_r}{I_i}$ when the ultrasound beam travels from muscle to bone.

$$\frac{I_r}{I_i} = \dots\dots\dots [2]$$

- (ii) Hence, explain why in the imaging of the heart, the ultrasound must pass in between the ribs.

.....
 [1]

- (iii) State the two biological tissues shown in Table 8.1 whose boundary is the hardest to detect by ultrasound.

..... [1]

[Turn over

- (c) As an ultrasound beam of initial intensity I_0 propagates through tissue, its intensity decreases exponentially. The transmitted intensity I depends on the frequency f of the wave, propagation distance x and the intensity attenuation coefficient μ of the tissue. The relationship is given by the equation:

$$I = I_0 e^{-\mu f x}$$

where μ for soft tissue is $0.23 \text{ cm}^{-1} \text{ MHz}^{-1}$.

- (i) Determine the distance at which the intensity of a 5.0 MHz ultrasound beam will be reduced by half when travelling through soft tissue.

distance = cm [2]

- (ii) Hence, state and explain whether high or low frequency ultrasound waves are used when imaging organs deeper in the body.

.....

 [2]

- (d) The PZT element in the transducer has an acoustic impedance of $30 \times 10^5 \text{ g cm}^{-2} \text{ s}^{-1}$ while the corresponding value for skin is $1.7 \times 10^5 \text{ g cm}^{-2} \text{ s}^{-1}$.

- (i) Show that only 20% of the energy from the transducer is transmitted into the patient if the PZT element is in direct contact with the patient's skin.

[2]

- (ii) Hence, determine the efficiency in transmitting energy from the PZT element to a patient's skin when a matching layer is used.

efficiency = % [4]

- (iii) For a particular composite material used to make the matching layer, a 5.0 MHz ultrasound beam travels at a speed of 2500 m s^{-1} in it.

Calculate the thickness of the matching layer.

thickness = m [1]

[Turn over

- (e) Fig. 8.2 shows the change in the shape of a microbubble as an ultrasound pressure wave passes through the tissue in which the microbubble is located.

Sketch the sinusoidal variation with time of pressure at this location.

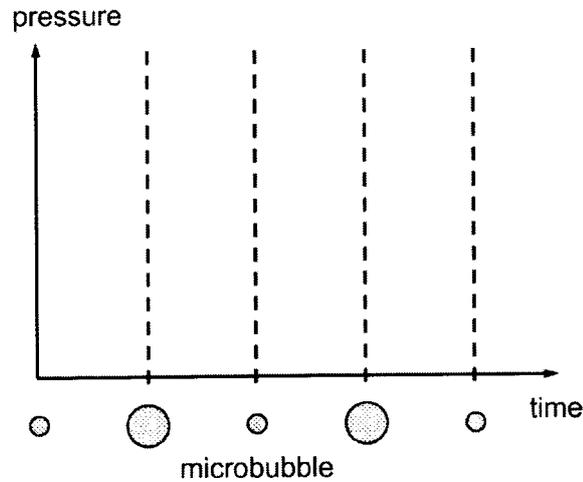


Fig. 8.2

[1]

- (f) Ultrasound is the only imaging technique that is routinely used in pregnancy to assess the health of the foetus. It is preferred over X-rays as it does not involve ionising radiation.

Explain the indirect effect of ionising radiation on living tissues and cells.

.....

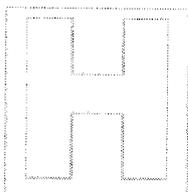
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.....

..... [2]

[Total: 20]

End of Paper



Anglo-Chinese Junior College

Physics Preliminary Examination

Higher 2



A Methodist Institution
(Founded 1886)

CANDIDATE
NAME

CLASS

CENTRE
NUMBER

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INDEX
NUMBER

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PHYSICS

Paper 3 Longer Structured Questions

9749/03

3 September 2025

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.

You may use an HB pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, glue or correction fluid.

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

Section A

Answer **all** questions.

Section B

Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

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 Examiners' use only	
Section A	
1	/ 6
2	/ 10
3	/ 13
4	/ 11
5	/ 10
6	/ 10
Total	/ 60
Section B	
7 / 8	/ 20
Grand Total	/ 80

This paper consists of 25 printed pages

DATA AND FORMULAE

Data

speed of light in free space,

$$c = 3.00 \times 10^8 \text{ m s}^{-1}$$

permeability of free space,

$$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$$

permittivity of free space,

$$\begin{aligned} \epsilon_0 &= 8.85 \times 10^{-12} \text{ F m}^{-1} \\ &= (1/(36\pi)) \times 10^{-9} \text{ F m}^{-1} \end{aligned}$$

elementary charge,

$$e = 1.60 \times 10^{-19} \text{ C}$$

the Planck constant,

$$h = 6.63 \times 10^{-34} \text{ J s}$$

unified atomic mass constant,

$$u = 1.66 \times 10^{-27} \text{ kg}$$

rest mass of electron,

$$m_e = 9.11 \times 10^{-31} \text{ kg}$$

rest mass of proton,

$$m_p = 1.67 \times 10^{-27} \text{ kg}$$

molar gas constant,

$$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$$

the Avogadro constant,

$$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$$

the Boltzmann constant,

$$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$$

gravitational constant,

$$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$$

acceleration of free fall,

$$g = 9.81 \text{ m s}^{-2}$$

Formulae

uniformly accelerated motion,

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

work done on/by a gas,

$$v^2 = u^2 + 2as$$

$$W = p \Delta V$$

hydrostatic pressure,

$$p = \rho g h$$

gravitational potential,

$$\phi = -\frac{Gm}{r}$$

temperature

$$T/K = T/^\circ\text{C} + 273.15$$

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.,

$$x = x_0 \sin \omega t$$

velocity of particle in s.h.m.,

$$v = v_0 \cos \omega t$$

$$= \pm \omega \sqrt{x_0^2 - x^2}$$

electric current

$$I = Anvq$$

resistors in series,

$$R = R_1 + R_2 + \dots$$

resistors in parallel,

$$1/R = 1/R_1 + 1/R_2 + \dots$$

electric potential,

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

alternating current/voltage,

$$x = x_0 \sin \omega t$$

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

$$B = \frac{\mu_0 NI}{2r}$$

magnetic flux density due to a long solenoid

$$B = \mu_0 nI$$

radioactive decay,

$$x = x_0 \exp(-\lambda t)$$

decay constant,

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

Section A

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

- 1 (a) Express the unit of resistivity in SI base units.

SI base units = [2]

- (b) Estimate the current flowing into a smartphone while it is being charged by a standard phone charger.

current = A [1]

(c) Fig. 1.1 shows a circuit set up to measure the resistance R of a resistor.

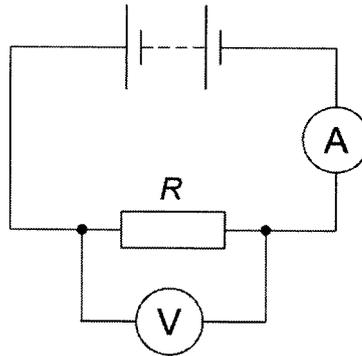


Fig. 1.1

The following readings are obtained:

voltmeter: $V = (5.02 \pm 0.01) \text{ V}$

ammeter: $I = (0.038 \pm 0.001) \text{ A}$

Determine the value of R together with its actual uncertainty.

$R = \dots\dots\dots \pm \dots\dots\dots \Omega$ [3]

[Total: 6]

2 (a) State Coulomb's law.

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

(b) State the relationship between electric field strength and electric potential.

.....
..... [1]

(c) Fig. 2.1 shows two charged isolated conducting spheres.

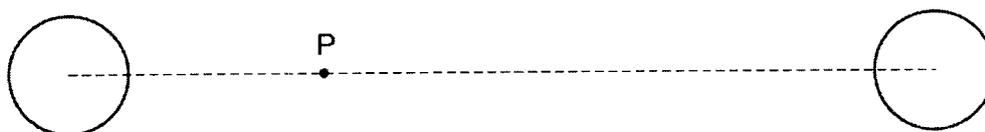


Fig. 2.1

P is a point on the line joining the centres of the spheres.

Explain why it is not possible for the total electric potential and the resultant electric field to simultaneously be zero at point P.

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

- (d) A conducting sphere is held midway between two vertical, parallel metal plates in a vacuum, as shown in Fig. 2.2.

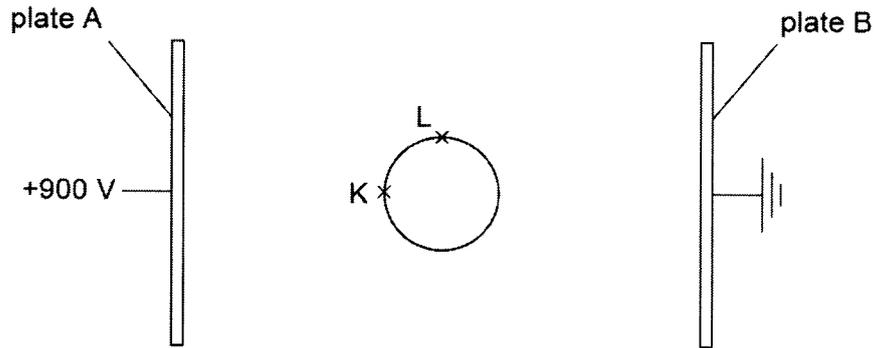


Fig. 2.2

Plate A is at a potential of +900 V and plate B is earthed.

Points K and L are two points on the surface of the sphere.

- (i) On Fig. 2.2, draw field lines to represent the electric field between the sphere and the two metal plates. [2]

- (ii) Explain why the electric potentials at points K and L are equal.

.....

.....

.....

..... [2]

- (iii) Determine the electric potential at point K.

electric potential = V [1]

[Total:10]

- 3 (a) State what is meant by the *internal energy* of a system.

.....
 [1]

- (b) A square box of volume V contains N molecules of an ideal gas. Each molecule has mass m .

Using the kinetic theory of ideal gases, it can be shown that, if all the molecules are moving with speed v at right angles to one face of the box, the pressure p exerted on the face of the box follows the expression

$$pV = Nm v^2 \quad \text{(equation 1)}$$

This expression leads to the formula

$$p = \frac{1}{3} \rho \langle c^2 \rangle \quad \text{(equation 2)}$$

for the pressure p of an ideal gas, where ρ is the density of the gas and $\langle c^2 \rangle$ is the mean-square speed of the molecules.

Explain how each of the following terms in equation 2 is derived from equation 1:

$\frac{1}{3}$:

.....

$\langle c^2 \rangle$:

.....

[2]

- (c) Hence, use equation 2 to show that the internal energy U of an ideal gas is given by

$$U \propto T$$

where T is the thermodynamic temperature of the gas.

[3]

- (d) An ideal gas of volume 0.26 m^3 is at a pressure of $2.0 \times 10^5 \text{ Pa}$ and temperature of $20 \text{ }^\circ\text{C}$.

- (i) Calculate the number of molecules of the gas.

no. of molecules = [2]

- (ii) Hence, calculate the internal energy of the gas.

internal energy = J [1]

[Turn over

- (e) The volume V of the gas in (d) is now varied, keeping its pressure constant.

On Fig. 3.1, sketch the variation with V of the internal energy U of the gas.



Fig. 3.1

[1]

- (f) The heat capacity of a fixed mass of gas depends on the conditions under which heat is supplied. If the gas is heated at constant pressure, the heat capacity is C_p ; while that heated at a constant volume is C_v .

Suggest, with a reason, if C_p or C_v is higher.

.....

.....

.....

.....

..... [3]

[Total: 13]

- 4 A light spring hangs vertically from a fixed point. An object of mass m is attached to the free end of an unstretched spring as shown in Fig. 4.1.

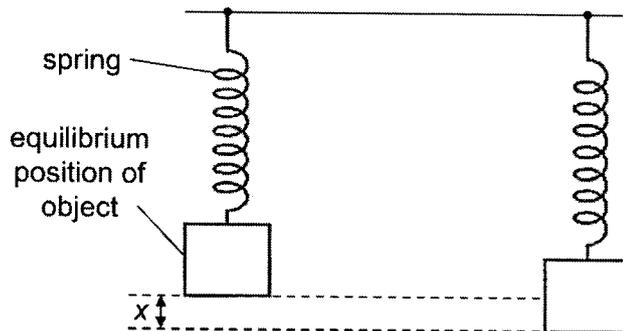


Fig. 4.1

The extension of the spring at equilibrium is x_0 and its spring constant is k .

- (a) State an expression relating the forces acting on the object when it is in the equilibrium position.

..... [1]

- (b) The object is displaced vertically downwards and then released.

Using the expression in (a), show that the object's acceleration a is related to its displacement x from the equilibrium position by the equation:

$$a = -\frac{k}{m}x$$

Explain your working.

[2]

- (c) Fig. 4.2 shows the variation of the kinetic energy of the object with time.

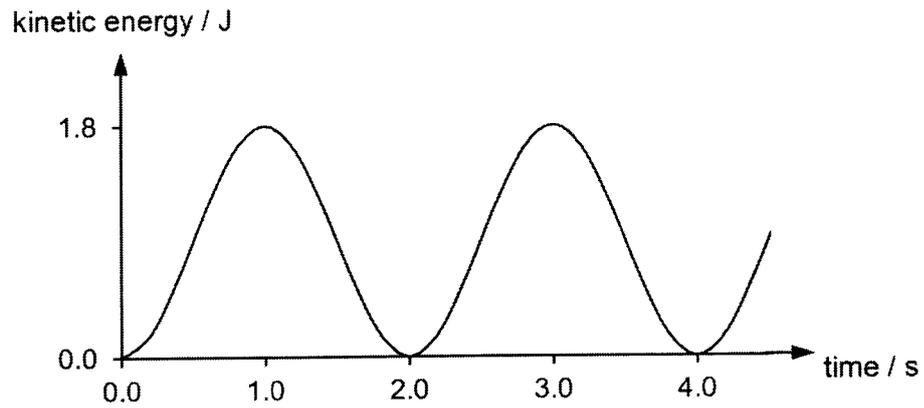


Fig. 4.2

- (i) Determine the frequency of the oscillation.

frequency = Hz [2]

- (ii) Determine the mass of the object given that the spring constant is 28 N m^{-1} .

mass = kg [2]

- (iii) Calculate the maximum velocity of the object.

velocity = m s^{-1} [1]

(iv) Calculate the amplitude of the oscillation.

amplitude = m [1]

(d) On Fig. 4.3, sketch the variation with time t of the displacement x of the object.

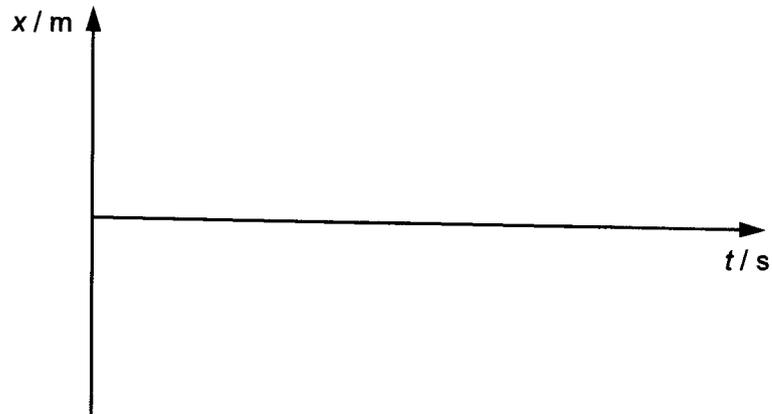


Fig. 4.3

[2]

[Total: 11]

- 5 (a) State Faraday's law of electromagnetic induction.

.....

 [1]

- (b) A small coil C is placed inside a solenoid as shown in Fig. 5.1.

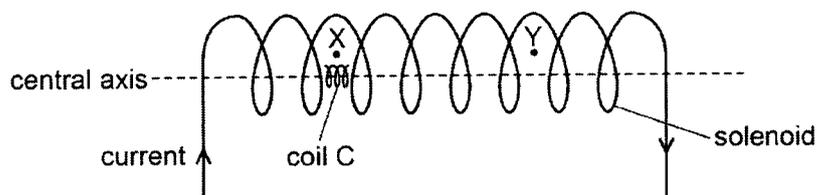


Fig. 5.1 (not to scale)

The centre of coil C is on the central axis of the solenoid.

There is a constant current in the solenoid and coil C is moved through the solenoid from position X to position Y.

Explain why the magnetic flux linkage in coil C is constant.

.....

 [1]

- (c) Coil C is now held stationary at X and an alternating current (a.c.) power supply is now connected to the solenoid. The alternating current I varies with time t according to

$$I = 4.8 \sin(10\pi t)$$

where I is in A and t is in s.

- (i) Show that the period of the alternating current is 200 ms.

[1]

- (ii) Coil C has 71 turns and cross-sectional area 0.64 cm^2 . The solenoid has 4000 turns per unit metre.

Show that the maximum magnetic flux linkage in coil C is $1.1 \times 10^{-4} \text{ Wb}$.

[3]

- (iii) Hence, determine the maximum electromotive force (e.m.f.) induced in coil C.

e.m.f. = V [2]

- (iv) On Fig. 5.2, sketch the variation of the induced e.m.f. E in coil C with time between $t = 0$ and $t = 400 \text{ ms}$.

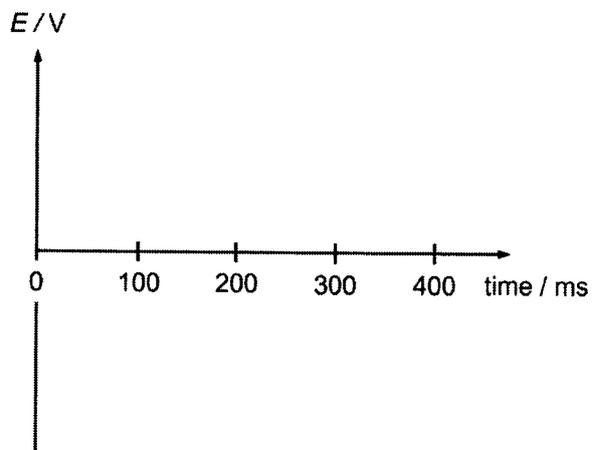


Fig. 5.2

[2]

[Total: 10]

[Turn over

6 (a) State and explain two observations of the photoelectric effect that provide evidence for the particulate nature of electromagnetic radiation.

1.
.....
.....
.....
2.
.....
.....
.....

[4]

(b) Electromagnetic radiation of a varying frequency f and constant intensity I is used to illuminate a metal surface. The variation with f of the maximum kinetic energy E_{MAX} of the emitted electrons is shown in Fig. 6.1.

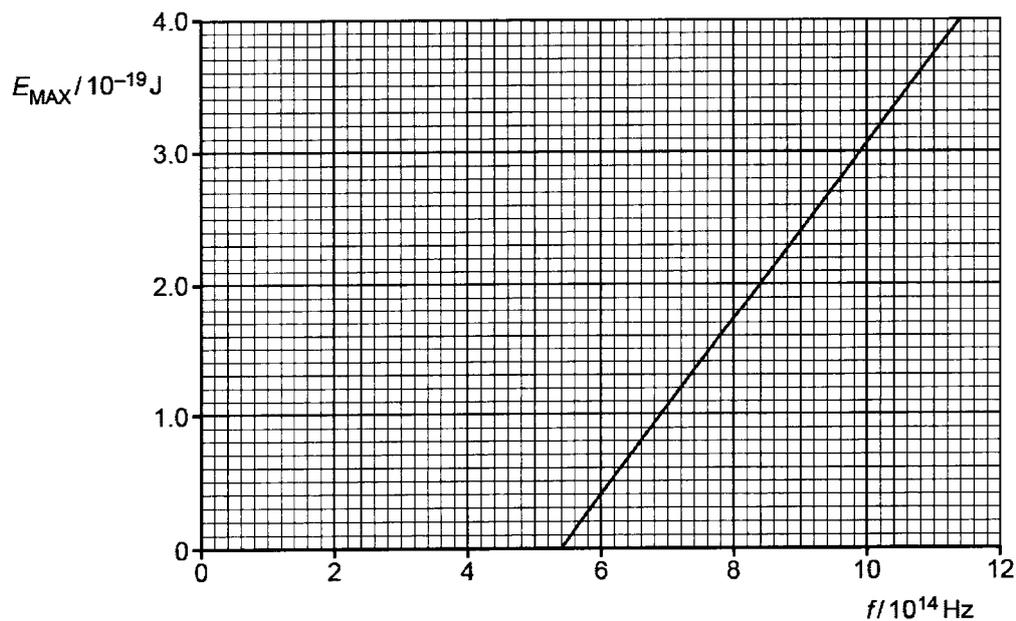


Fig. 6.1

Using Fig. 6.1, determine

- (i) the Planck constant, and

Planck constant = J s [2]

- (ii) the work function of the metal surface in eV.

work function = eV [2]

- (c) A different metal with a lower work function is used, with the same intensity I of radiation.

On Fig. 6.1, sketch the variation with f of the maximum kinetic energy E_{MAX} of the emitted electrons. [2]

[Total: 10]

Section B

Answer **one** question from this section in the spaces provided.

- 7 A submarine uses cables to recover a submerged wooden chest as shown in Fig. 7.1.

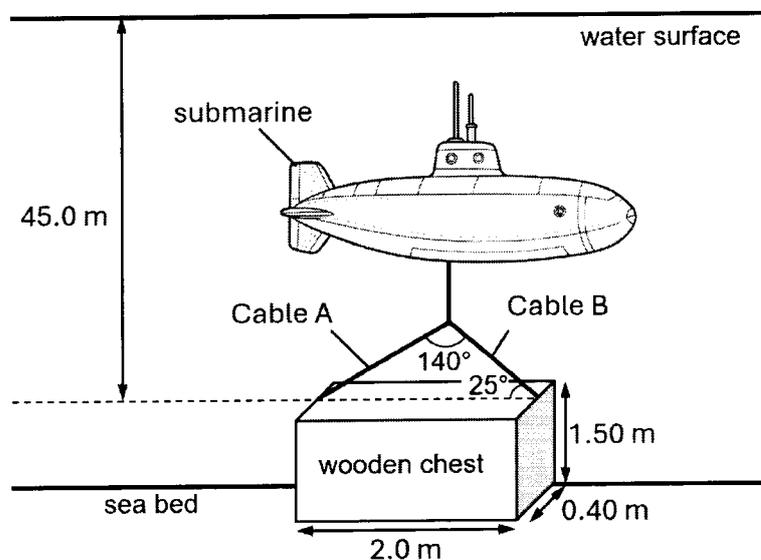


Fig. 7.1 (not to scale)

The submarine has a mass of 3600 kg. The density of seawater is 1030 kg m^{-3} and the average density of the chest is 1800 kg m^{-3} .

- (a) Show that the hydrostatic pressure p of a fluid at a depth h and density ρ is given by the expression

$$p = \rho gh.$$

[2]

(b) The box is held in equilibrium slightly above the sea bed.

(i) Explain why the seawater exerts an upthrust on the chest.

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

(ii) Calculate the upthrust of the wooden chest when it is raised above the sea bed.

upthrust = N [2]

(iii) Calculate the weight of the wooden chest.

weight = N [1]

(iv) Determine the tension in cable A and cable B.

tension in cable A = N

tension in cable B = N

[4]

[Turn over

- (c) The submarine is propelled forward at a constant velocity of 4.5 m s^{-1} by a 0.50 MW motor connected to a propeller. The drag force F_d acting on the submarine and the chest is given by

$$F_d = kv^2,$$

where $k = 3.5 \times 10^3 \text{ N s}^2 \text{ m}^{-2}$.

- (i) Calculate the thrust provided by the propeller.

thrust = N [2]

- (ii) Calculate the efficiency of the motor when the submarine is cruising at a speed of 4.5 m s^{-1} .

efficiency = % [2]

- (d) The total mass of the submarine is suddenly decreased by 200 kg by pumping water out of the submarine horizontally in a negligible time. The volume of the submarine remains unchanged.

- (i) Calculate the initial upward acceleration of the submarine.

acceleration = m s^{-2} [3]

(ii) Explain why the acceleration of the submarine eventually decreases to zero as the submarine ascends.

.....

.....

..... [2]

[Total: 20]

- 8 (a) State what is meant by a *geostationary orbit*.

.....
 [1]

- (b) The planet Saturn has the most extensive and complex ring system of any planet in the Solar System. The rings have varying width and thickness. They are made up of mainly ice particles, with a trace of rocky material which are in orbit around Saturn. One of the rings, the D-ring, has an outer radius of 7.45×10^7 m and a particle on the outer circumference of the ring has a speed of 2.26×10^4 m s⁻¹.

- (i) Calculate the angular velocity of the particle about Saturn.

angular velocity = rad s⁻¹ [1]

- (ii) A stationary orbit about Saturn is defined in the same way as a geostationary orbit about Earth, except that it applies to Saturn instead.

The rotational period of Saturn is 10 hours and 14 minutes. Use your answer in (i) to deduce whether the particle is in a stationary orbit about Saturn.

.....
 [2]

- (iii) Show that the radius r of the orbit of a particle moving with angular velocity ω around Saturn is given by the expression

$$r^3 \omega^2 = GM,$$

where M is the mass of Saturn. Assume that Saturn is a point mass.

[2]

- (iv) Hence, show that the mass of Saturn is 5.7×10^{26} kg.

[2]

- (c) (i) Define *gravitational potential* at a point.

.....

 [2]

- (ii) On Fig 8.1, draw equipotential lines to illustrate the gravitational field around Saturn.

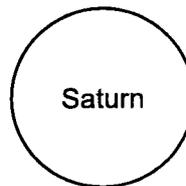


Fig. 8.1

[2]

- (iii) Determine the minimum additional velocity required for the particle in (b) to escape from Saturn's gravitational field.

minimum additional velocity = m s⁻¹ [3]

(d) Saturn's largest moon, Titan, is the second largest moon in the solar system. Titan has a radius of 2580 km and is 1.22×10^6 km from Saturn. The mass of Titan is 1.4×10^{23} kg. Ignore the effect of other nearby masses.

(i) Determine the distance from the centre of Titan where the resultant gravitational field strength between Titan and Saturn is zero.

distance = m [3]

(ii) On Fig. 8.2, sketch the variation with distance from the centre of Titan of the gravitational field strength along the line joining the centres of Titan and Saturn. The graph should range from Titan's surface to Saturn's surface.

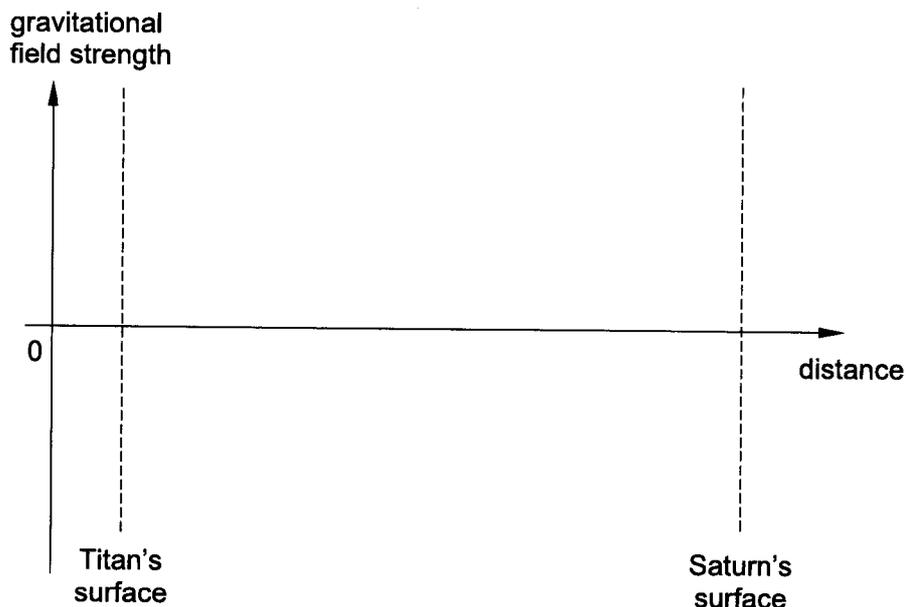


Fig. 8.2

[2]

[Total: 20]

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