3

RIVER VALLEY HIGH SCHOOL
JC2 PRELIMINARY EXAM

H2 PHYSICS 9749
PAPER 1
24 SEPTEMBER 2021

1 HOUR

CANDIDATE NAME									
CENTRE NUMBER	S					**INDEX NUMBER**				
CLASS	2	0	J						

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, class and index number above.

There are **thirty** questions in this section. Answer **all** questions. For each question, there are four possible answers, **A**, **B**, **C** and **D**. Choose the **one** you consider correct and shade your choice in **soft pencil** on the separate **Optical Answer Sheet**.

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

Any rough working should be done on the Question Paper.

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

Hand in the Optical Answer Sheet.

This document consists of **17** printed pages.

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-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	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T / \text{K} = T / ^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
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	$R = R_1 + R_2 + \ldots$
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	$x = x_0 \sin \omega t$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

For each question, there are four possible answers, **A**, **B**, **C** and **D**. Choose the **one** you consider correct and shade your choice in **soft pencil** on the separate **Answer Sheet**.

1 Which of the following gives the correct base units for the permittivity of free space, ε_o?

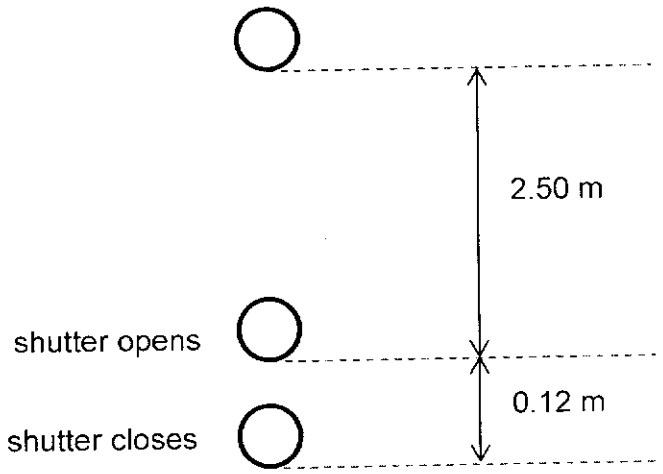
A $C^2 N^{-1} m^{-2}$

B $kg^{-1} m^{-3} s^4 A^2$

C $kg\ m^{-3} A^2$

D $kg^{-1} m^3 s^2 A^{-2}$

2 A photographer wishes to check the time for which the shutter on a camera stays open when a photograph is being taken. It is found that before the shutter opens, the ball falls 2.50 m from rest. During the time that the shutter remains open, the ball falls a further 0.12 m as illustrated.



What is the time that the shutter remains open?

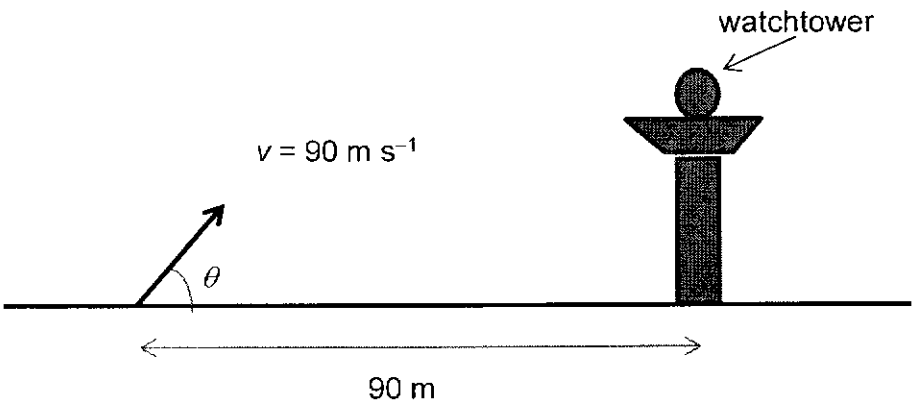
A 0.017 s

B 0.16 s

C 0.71 s

D 0.73 s

3 A projectile is fired at a speed of 90 m s^{-1} at sea level at an angle of $\theta = 31.6°$ with respect to the horizontal as shown below. The projectile hits the top of a watchtower located 90 m away.



How high is the top of the watchtower above sea level? Neglect air resistance.

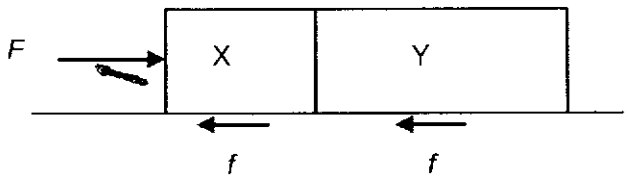
A 49 m

B 72 m

C 83 m

D 113 m

4 Two blocks, X and Y, of masses m and $2m$ respectively, are accelerated along a rough surface by a force F applied to block X. The magnitude of the frictional force experienced by each of the block is f.



What is the magnitude of the force exerted by block Y on block X?

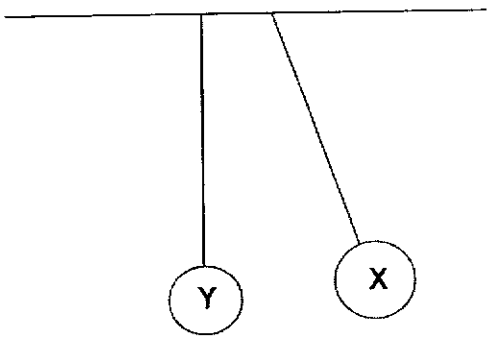
A $\frac{1}{3}(F-2f)$

B $\frac{1}{3}(F-f)$

C $\frac{1}{3}(2F-f)$

D $\frac{2}{3}(F-f)$

5 Two steel balls X and Y are suspended on strings. Ball X is pulled to one side as shown.



After ball X is released, the balls collide.

Which quantities must be conserved in the collision?

A kinetic energy, total energy and momentum

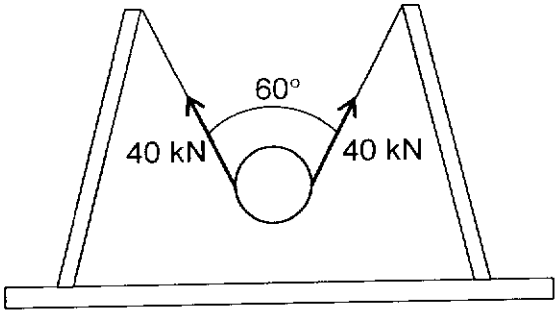
B kinetic energy and momentum only

C kinetic energy and total energy only

D total energy and momentum only

6 In reverse bungee jumping, passengers in a spherical cage are pulled upwards by a pair of elastic cords attached to the side of the cage as shown.

The weight of the passengers and the cage is W.



What is the maximum value of W if the passengers and the cage are flung upwards with an acceleration of g?

A 20 kN **B** 35 kN **C** 46 kN **D** 69 kN

7 A 2.0 kg block slides down a plane that is inclined at 25° with the horizontal, at a uniform speed of 2.0 m s^{-1}. What is the rate of frictional force doing work on the block?

A 17 W **B** 22 W **C** 36 W **D** 46 W

8 A pendulum bob of mass 1.27 kg is supported by a string so that the radius of its path is 0.600 m. It is moving with velocity 0.575 m s^{-1} horizontally at the centre of its motion when the string is vertical.

What is the tension in the string at this instant?

A 11.8 N

B 12.5 N

C 13.2 N

D 13.7 N

9 The table shows three geostationary satellites, **P**, **Q** and **R**, and their masses.

satellite	mass of satellite / kg
P	1200
Q	1500
R	3500

Which satellite has the largest centripetal force?

A P

B Q

C R

D They have the same magnitude of centripetal force

10 A polystyrene cup contains a mass of 88 g of water at 30 °C. A cube of ice of mass 12 g and temperature 0 °C is placed in the water. The water, of specific heat capacity 4.2×10^3 J kg K^{-1}, is stirred till all the ice melts.

Assuming negligible heat loss to the cup and surroundings, what is the final temperature of the water?

specific latent heat of fusion of ice = 3.3×10^5 J kg K^{-1}.

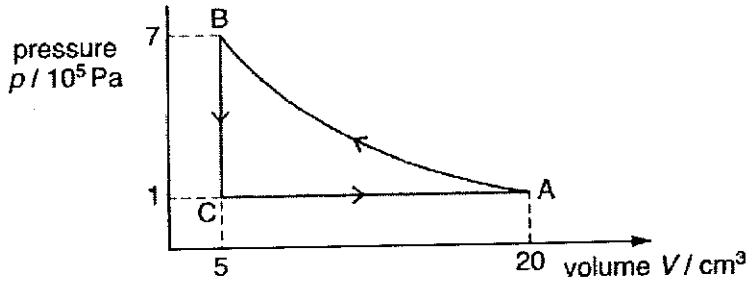
A 17 °C

B 19 °C

C 21 °C

D 23 °C

11 An ideal gas undergoes a cycle of changes A → B → C → A, as shown.



Which of the following statements is correct?

A Process A → B is isothermal.

B Process B → C is isochoric.

C Work of 15 J is done by the gas in process C → A.

D The internal energy of the gas is zero.

12 Fig. 12.1 shows the variation with displacement x of velocity v of a simple harmonic oscillator. Fig. 12.2 shows the variation with time t of the acceleration a of the oscillator.

Which of the points on the a-t graph corresponds to the state of motion represented by point **P**?

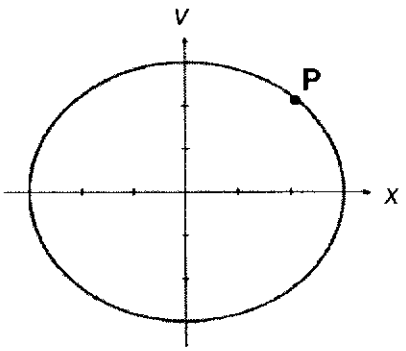


Fig. 12.1

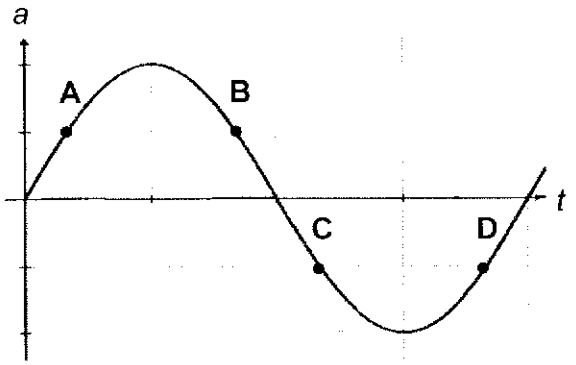


Fig. 12.2

13 An object that undergoes simple harmonic motion has an amplitude A and total energy E.

What is the displacement of the object from the equilibrium position when its kinetic energy is $\frac{3}{4}E$?

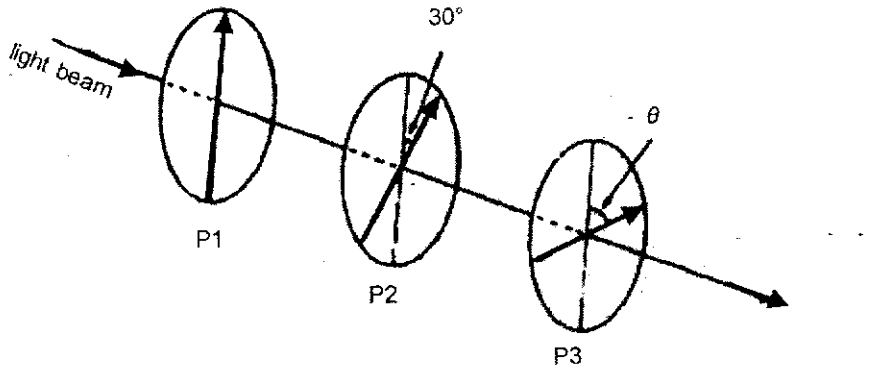
A 0.25 A

B 0.50 A

C 0.75 A

D 0.87 A

14 A beam of unpolarised light passes through three polaroids P_1, P_2 and P_3. The polarising axis of each polaroid is shown by an arrow. Polaroids P_1 and P_2 are fixed, with their polarising axes at 30° to each other and P_3 can be set with its polarising axis at a variable angle θ to that of P_1.



For what values of θ do the emergent light have the lowest intensity?

A 30°, 120°

B 60°, 240°

C 90°, 270°

D 120°, 300°

15 A point source of sound emits energy equally in all directions at a constant rate and a detector placed 2.0 m from the source measures an intensity of 3.0 W m^{-2}. The amplitude of the wave at the source is then doubled.

What intensity would the detector measure if it is now placed at a distance 4.0 m from the source?

A 3.0 W m^{-2}

B 1.5 W m^{-2}

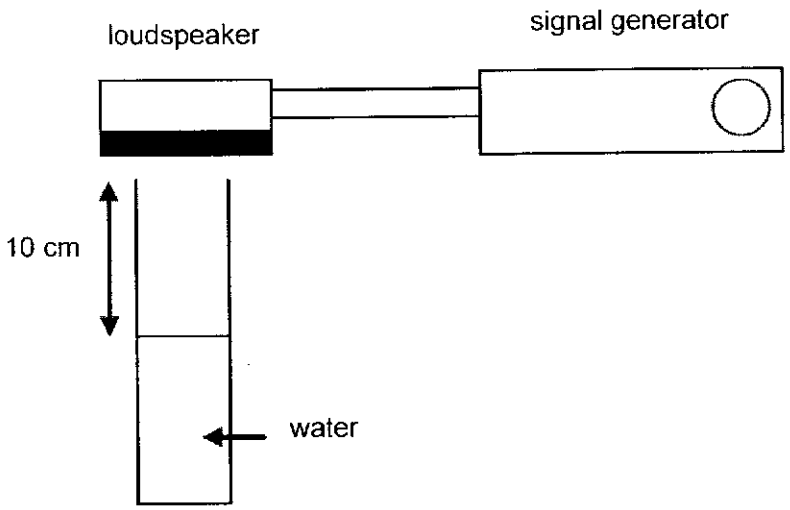
C 0.75 W m^{-2}

D 0.38 W m^{-2}

16 The figure below shows an experiment to produce a stationary wave in an air column. A loudspeaker connected to a signal generator is placed above the column.

The frequency of the signal generator is increased gradually from 3000 Hz and two consecutive resonances occur when the frequency of the signal generator is set to 3875 Hz and 5425 Hz respectively.

The length of the air column is kept constant at 10 cm throughout the experiment.



Assuming the effects of end correction are negligible, what is the speed of sound in air?

A 300 m s^{-1} **B** 310 m s^{-1}

C 330 m s^{-1} **D** 340 m s^{-1}

17 Which of the following statements about two consecutive antinodes in a stationary wave is false?

A Their oscillations are in phase with each other.

B Both particles at the antinodes will pass through their equilibrium positions with same speed.

C The acceleration of the particles are always equal in magnitude and opposite in direction.

D Both have maximum energies since the amplitudes of oscillations are maximum.

18 Two protons are 1.0×10^{-14} m apart.

Approximately how many times is the electrostatic force between them greater than the gravitational force between them?

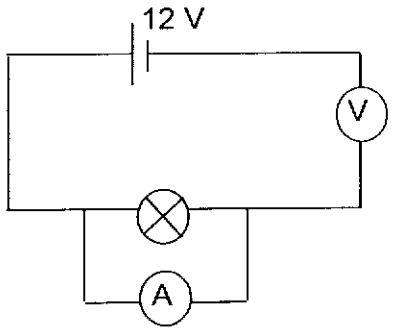
A 10^{23}

B 10^{30}

C 10^{36}

D 10^{42}

19 An ammeter and a voltmeter are connected to a bulb of resistance 4.0 Ω as shown below.



Which of the following situations is most likely to happen?

A Ammeter will fuse.

B Ammeter reads 3.0 A and voltmeter reads 12 V.

C Ammeter reads zero current and voltmeter reads 12 V.

D Both ammeter and voltmeter give zero readings.

20 A new rechargeable battery has the marking *"500 mA h"* printed on it.

Which of the following is correct with regards to the battery?

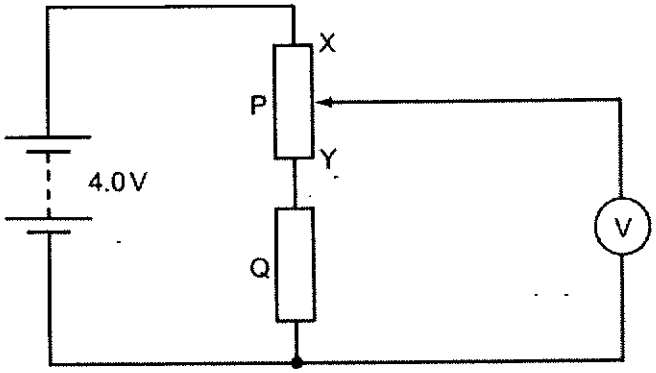
A The e.m.f. of the battery is 500 V.

B The current from the battery is always 0.5 A.

C The energy stored in the battery is 1800 J.

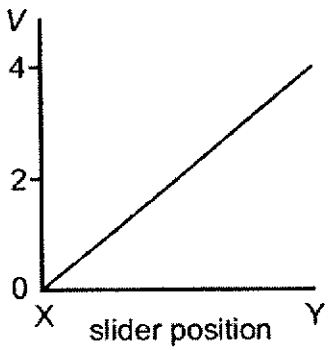
D The charge stored in the battery is 1800 C.

21 In the circuit below, P is a potentiometer of total resistance 10 Ω and Q is a fixed resistor of resistance 10 Ω. The battery has an e.m.f. of 4.0 V and negligible internal resistance. The voltmeter has a very high resistance. The slider on the potentiometer is moved from X to Y and a graph of voltmeter reading V is plotted against slider position.

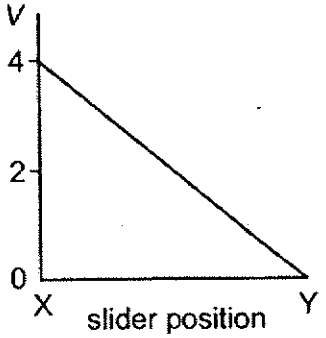


Which of the following shows the correct graph obtained?

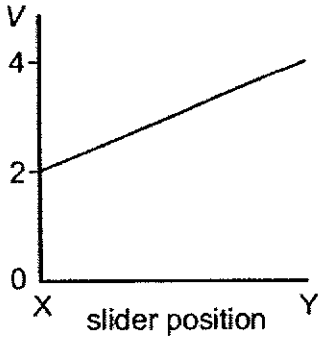
A



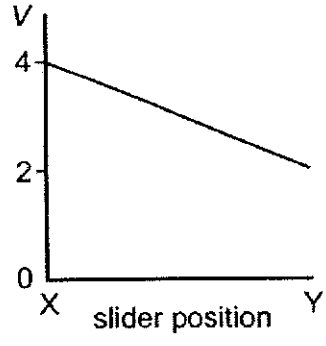
B



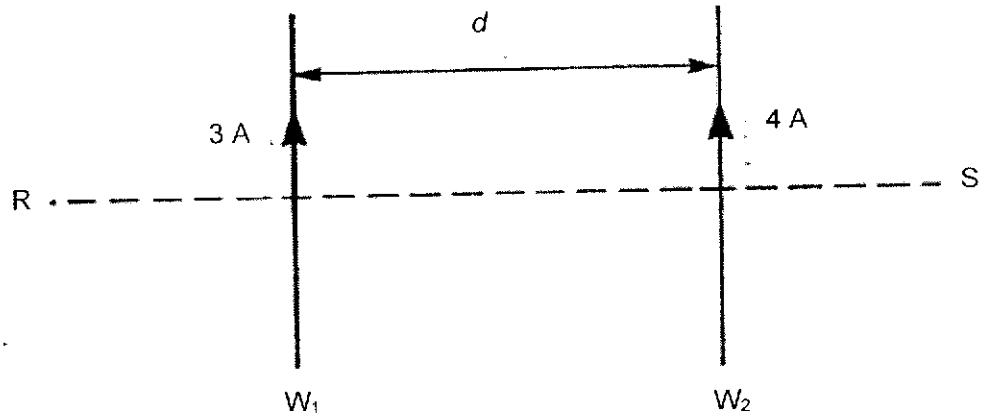
C



D



22 Two vertical wires W_1 and W_2 are distance d apart carrying currents of 3 A and 4 A respectively.



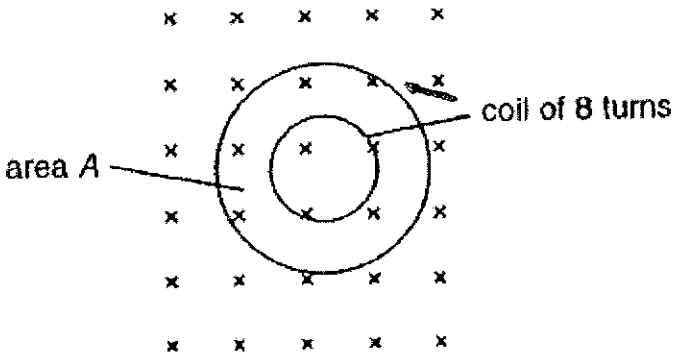
The combined magnetic fields due to these currents gives a position of zero magnetic flux density on the horizontal line RS passing through the wires.

What is the distance of this position from the wire W_1?

A $\frac{1}{4}d$ **B** $\frac{3}{7}d$

C $\frac{4}{7}d$ **D** $\frac{3}{4}d$

23 A uniform magnetic field of flux density B passes normally through a plane area A. In this plane lies a coil of eight turns of wire, each of area $\frac{1}{4}A$.

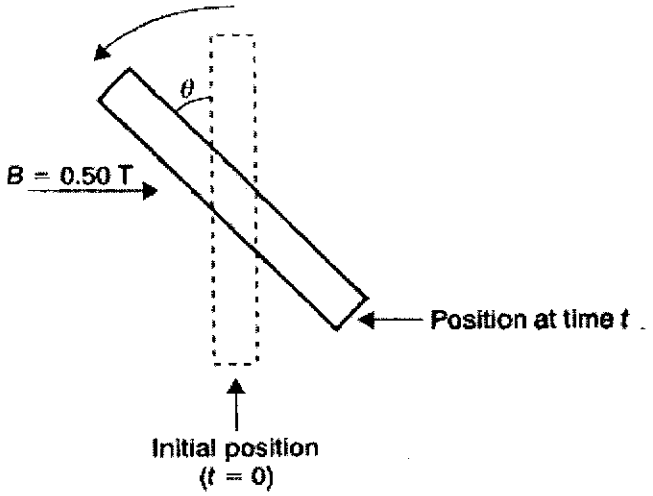


What is the magnetic flux linkage for the coil in terms of B and A?

A $\frac{1}{4}BA$ **B** $2BA$

C $4BA$ **D** $8BA$

24 A flat circular coil of wire 30 turns, each of area 0.025 m^2, is initially placed with its plane at right angles to a uniform magnetic field of flux density 0.50 T.



What is the magnitude of the induced e.m.f. in the coil when t = 1.0 s, if the coil is rotating at 60° s^{-1}?

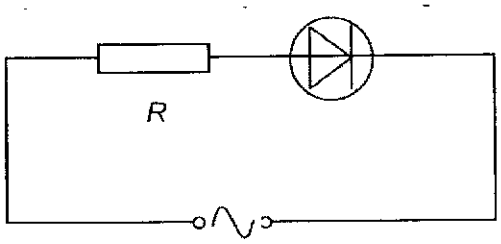
A 0.20 V

B 0.34 V

C 0.38 V

D 0.39 V

25 A sinusoidal current of peak value I_o is passed through the circuit shown.



What is the mean rate of heat dissipated in terms of R?

A 1.41 I_0^2R

B I_0^2R

C 0.5 I_0^2R

D 0.25 I_0^2R

26 The ratio of turns of the primary coil to the secondary coil of a practical transformer is 10:1. The primary coil p.d. and current are 20 V and 3 A respectively. The efficiency of the transformer is 0.8.

Assuming that the energy loss is purely due to the resistance of the windings, which of the following statements is false?

A The secondary voltage is 2 V.

B The secondary current is 24 A.

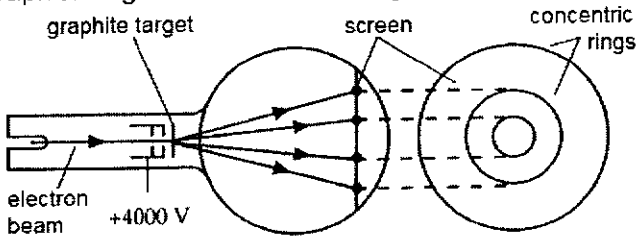
C The output power is 60 W.

D The power loss is 12 W.

27 Which option shows the change in velocity, frequency and wavelength of an electromagnetic wave as it travels from an optically less dense to an optically denser medium?

	velocity	frequency	wavelength
A	decreases	unchanged	decreases
B	increases	unchanged	increases
C	decreases	decreases	unchanged
D	increases	increases	unchanged

28 In an experimental setup, a beam of accelerated electrons strikes an extremely thin layer of polycrystalline graphite target and concentric rings are seen on the tube face as shown.



If the setup is modified such that instead of electron beam, a beam of protons strike the graphite target with the same speed, the radii of the concentric rings will

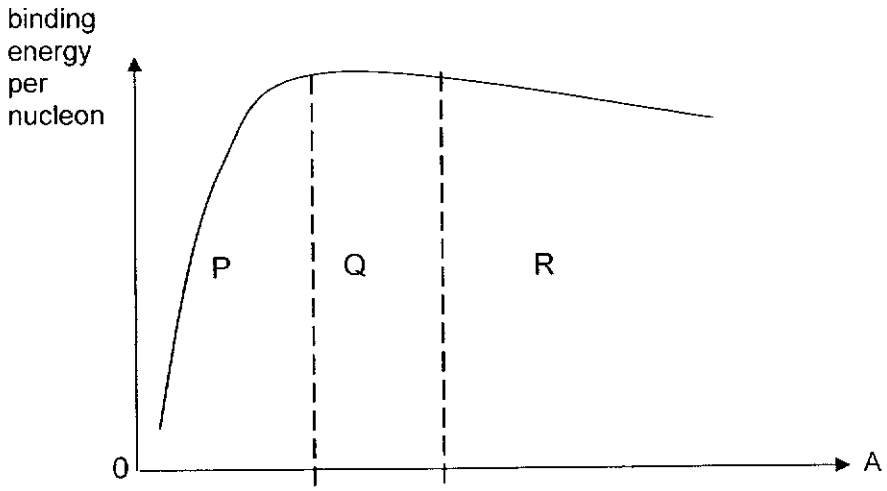
A decrease.

B increase.

C stay the same.

D not be seen. (No rings appear.)

29 The graph shows how the binding energy per nucleon of a nucleus varies with nucleon number A.



Which one of the following statements is **not** true?

A Nuclei in region Q are more stable than nuclei in region R.

B Nuclear fusion reactions bring nuclei in region P closer to region Q.

C Energy is released in nuclear fission reactions from nuclei in region P.

D The binding energy per nucleon increases most significantly at lower nucleon numbers.

30 The following represents a sequence of radioactive decays involving two α-particles and two β-particles.

$$^{232}_{90}\text{Th} \xrightarrow{\alpha} \text{W} \xrightarrow{\beta} \text{X} \xrightarrow{\beta} \text{Y} \xrightarrow{\alpha} \text{Z}$$

What is the nuclide Z?

A $^{224}_{88}\text{Ra}$ **B** $^{228}_{88}\text{Ra}$ **C** $^{228}_{89}\text{Ac}$ **D** $^{228}_{90}\text{Th}$

END OF PAPER

1B	6B	11B	16B	21D	26C
2A	7A	12C	17A	22B	27A
3A	8C	13B	18C	23B	28A
4C	9C	14D	19C	24B	29C
5D	10A	15A	20D	25D	30A

1 Which of the following gives the correct base units for the permittivity of free space, ε_o?

A $C^2 N^{-1} m^{-2}$

B $kg^{-1} m^{-3} s^4 A^2$

C $kg\ m^{-3} A^2$

D $kg^{-1} m^3 s^2 A^{-2}$

1 **B**

$\varepsilon_o = \frac{Qq}{4\pi F r^2}$ from Electric Force Formula.

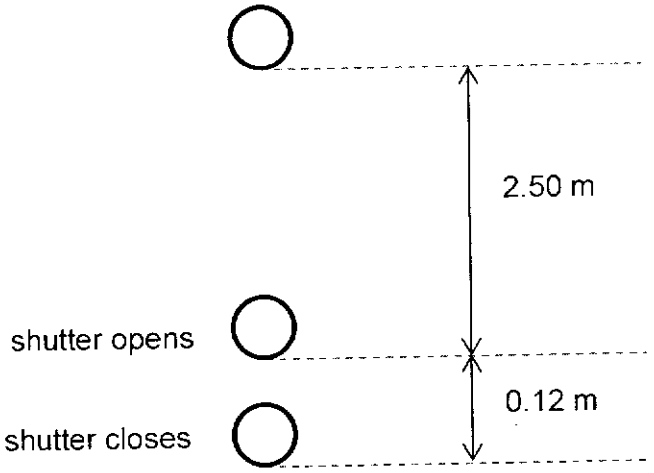
Q, q have units A. s

F has units $kgms^{-2}$

r has unit as m

Therefore, ε_o has units $kg^{-1} m^{-3} s^4 A^2$.

2 A photographer wishes to check the time for which the shutter on a camera stays open when a photograph is being taken. It is found that before the shutter opens, the ball falls 2.50 m from rest. During the time that the shutter remains open, the ball falls a further 0.12 m as illustrated.



What is the time that the shutter remains open?

A 0.017 s

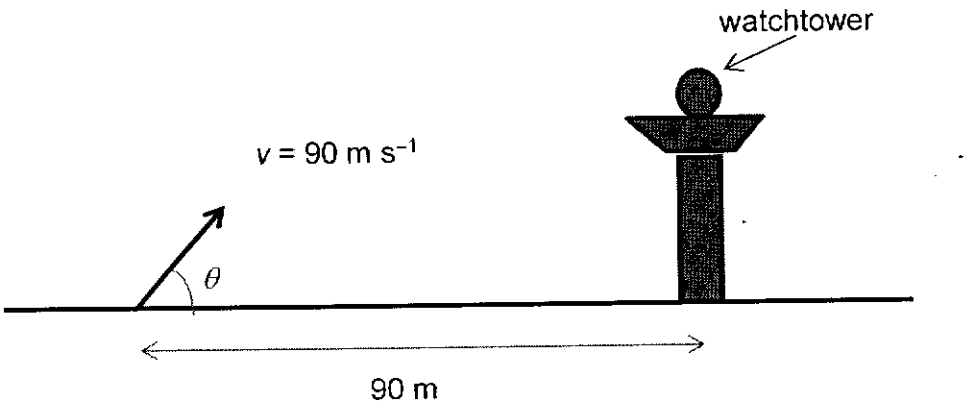
B 0.16 s

C 0.71 s

D 0.73 s

A Let time taken to fall 2.50 m be t.
$s = ut + \frac{1}{2} at^2$
$2.5 = 0 + \frac{1}{2} (9.81) t^2$
$t = 0.714$ s
Let time taken to fall 2.62 m be t_1.
$s = ut + \frac{1}{2} at^2$
$2.5 + 0.12 = 0 + \frac{1}{2} (9.81) t_1^2$
$t_1 = 0.731$ s
The time when the shutter remains open = $t_1 - t = 0.017$ s

3 A projectile is fired at a speed of 90 m s^{-1} at sea level at an angle of $\theta = 31.6°$ with respect to the horizontal as shown below. The projectile hits the top of a watchtower located 90 m away.



How high is the top of the watchtower above sea level? Neglect air resistance.

A 49 m

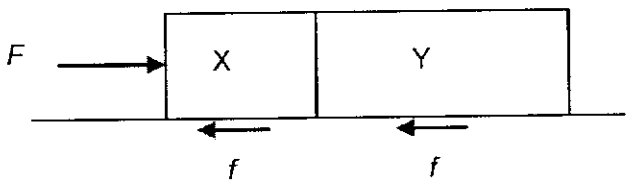
B 72 m

C 83 m

D 113 m

A Horizontal displacement of cannon ball $S_X = 90 \cos 31.6° \times t = 90$
$\Rightarrow t = 1.174$ s
Vertical displacement of cannon ball $S_Y = 90 \sin 31.6\ (1.174) - ½\ (9.81)\ (1.174)^2$
= 48.6 m
= 49 m = height of the top of the watchtower above sea level

4 Two blocks, X and Y, of masses m and $2m$ respectively, are accelerated along a rough surface by a force F applied to block X. The magnitude of the frictional force experienced by each of the block is f.



What is the magnitude of the force exerted by block Y on block X?

A $\frac{1}{3}(F-2f)$

B $\frac{1}{3}(F-f)$

C $\frac{1}{3}(2F-f)$

D $\frac{2}{3}(F-f)$

Ans: C

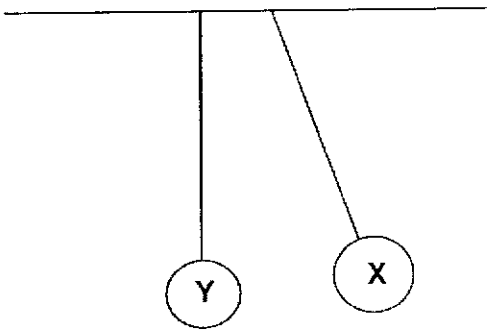
$F_{net} = F - 2f = (m + 2m)a_{net} \rightarrow a_{net} = (F - 2f)/3m$

Analysing FBD of X:

$F - f - F_{Y\text{-}ON\text{-}X} = ma_{net} \rightarrow F_{Y\text{-}ON\text{-}X} = F - f - m[(F - 2f)/3m]$

$= F - f - F/3 + 2/3\, f = 2/3\, F - 1/3\, f = 1/3\, (2F - f)$

5 Two steel balls X and Y are suspended on strings. Ball X is pulled to one side as shown.



After ball X is released, the balls collide.

Which quantities must be conserved in the collision?

A kinetic energy, total energy and momentum

B kinetic energy and momentum only

C kinetic energy and total energy only

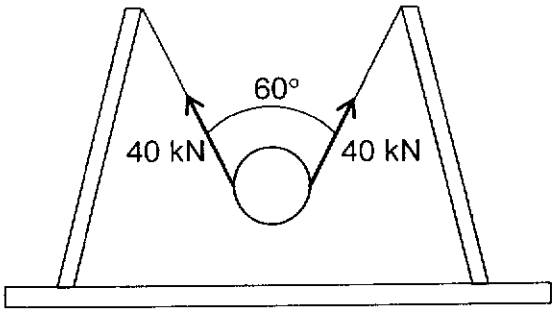
D total energy and momentum only

Ans: D

Collisions could be categorised as elastic or inelastic. Only in elastic collisions are kinetic energy conserved. Hence, only total energy (i.e. including sound, light, heat, etc.) and momentum, must be conserved.

6 In reverse bungee jumping, passengers in a spherical cage are pulled upwards by a pair of elastic cords attached to the side of the cage as shown.

The weight of the passengers and the cage is W.



What is the maximum value of W if the passengers and the cage are flung upwards with an acceleration of *g*?

A 20 kN **B** 35 kN **C** 46 kN **D** 69 kN

B Resultant upward force = 2(40kN cos 30°) – W = W
80kN cos 30° = 2 W
W = 40kN cos 30° = 35 kN

7 A 2.0 kg block slides down a plane that is inclined at 25° with the horizontal, at a uniform speed of 2.0 m s^{-1}. What is the rate of frictional force doing work on the block?

A 17 W **B** 22 W **C** 36 W **D** 46 W

A

$$F_{friction} = (2)(9.81)(\sin 25°) = 8.292\,\text{N (negative)}$$

$$\text{Power} = \frac{WD}{t} = F\frac{d}{t} = (F_{friction})(\text{Velocity}) = 16.6\,\text{W (negative)}$$

8 A pendulum bob of mass 1.27 kg is supported by a string so that the radius of its path is 0.600 m. It is moving with velocity 0.575 m s^{-1} horizontally at the centre of its motion when the string is vertical.

What is the tension in the string at this instant?

A 11.8 N

B 12.5 N

C 13.2 N

D 13.7 N

C

$T - mg = mv^2/r$

$T = m\,(g + v^2/r)$

$T = 1.27\,(9.81 + 0.575/0.600) = 13.2$ N

9 The table shows three geostationary satellites, **P**, **Q** and **R**, and their masses.

satellite	mass of satellite / kg
P	1200
Q	1500
R	3500

Which satellite has the largest centripetal force?

A P

B Q

C R

D They have the same magnitude of centripetal force

C geostationary satellites → same period T of 24 h → same r and ω

centripetal force = $mr\omega^2$

so mass is the factor. Biggest mass → largest centripetal force

10 A polystyrene cup contains a mass of 88 g of water at 30 °C. A cube of ice of mass 12 g and temperature 0 °C is placed in the water. The water, of specific heat capacity 4.2×10^3 J kg K^{-1}, is stirred till all the ice melts.

Assuming neligible heat loss to the cup and surroundings, what is the final temperature of the water?

specific latent heat of fusion of ice = 3.3×10^5 J kg K^{-1}.

A 17 °C

B 19 °C

C 21 °C

D 23 °C

A heat gained by ice in melting + heat gained by melted ice water = heat lost by water

$12\,[3.3 \times 10^5 + 4.2 \times 10^3 \times (T - 0)] = 88 \times 4.2 \times 10^3 \times (30 - T)$

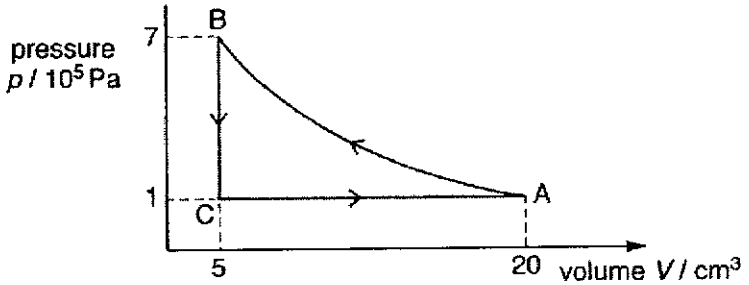
$3.96 \times 10^3 + 50.4\,T = 11.088 \times 10^3 - 369.6\,T$

$420\,T = 7128$

$T = 17$ °C

distractor: T = 19 °C (melted ice omitted)

11 An ideal gas undergoes a cycle of changes A → B → C → A, as shown.



Which of the following statements is correct?

A Process A → B is isothermal.

B Process B → C is isochoric.

C Work of 15 J is done by the gas in process C → A.

D The internal energy of the gas is zero.

B constant volume process is also known as isochoric process,
Option A is wrong as pV is not constant which would be the case if T is constant (isothermal).
Option C is a trick question to see if students noticed the prefix in the V axis. V is in cm^3 while P is of the order of magnitude of 5.
Option D is a trick on semantics. While the CHANGE in internal energy of the gas may be zero in this cycle, the internal energy is not zero.

12 Fig. 12.1 shows the variation with displacement x of velocity v of a simple harmonic oscillator. Fig. 12.2 shows the variation with time t of the acceleration a of the oscillator.

Which of the points on the a-t graph corresponds to the state of motion represented by point **P**?

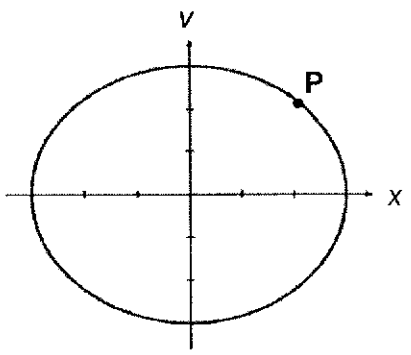


Fig. 12.1

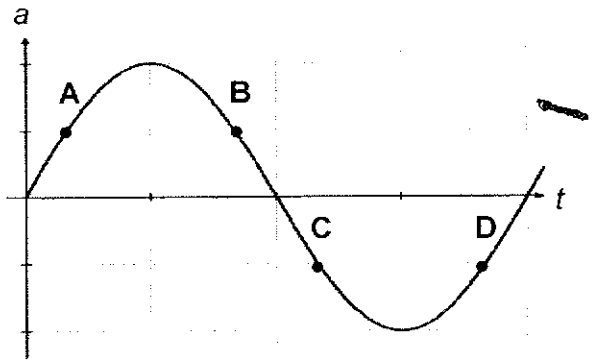


Fig. 12.2

C At point P, the displacement and velocity is positive.
Using $a = -\omega^2 x$. The a should be Negative (A and B no longer plausible)
For v, sketch x-t graph and find the point of positive velocity (gradient of x-t graph).

13 An object that undergoes simple harmonic motion has an amplitude A and total energy E.

What is the displacement of the object from the equilibrium position when its kinetic energy is $\frac{3}{4}E$?

A 0.25 A

B 0.50 A

C 0.75 A

D 0.87 A

B When x= 0, $E_k = E$

$E = \frac{1}{2} m \omega^2 A^2$

$E_k = \frac{1}{2} m \omega^2 (A^2 - x^2)$

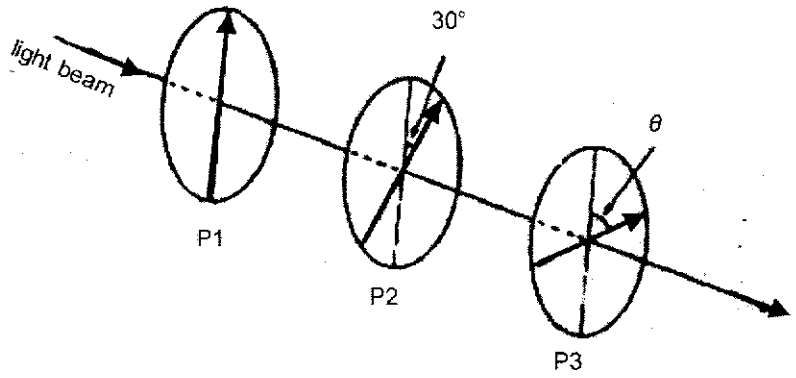
$\frac{3}{4} E = \frac{1}{2} m \omega^2 (A^2 - x^2)$

$\frac{3}{4}(\frac{1}{2} m \omega^2 A^2) = \frac{1}{2} m \omega^2 (A^2 - x^2)$

$\frac{3}{4} A^2 = (A^2 - x^2)$

$x = 0.50 A$

14 A beam of unpolarised light passes through three polaroids P_1, P_2 and P_3. The polarising axis of each polaroid is shown by an arrow. Polaroids P_1 and P_2 are fixed, with their polarising axes at 30° to each other and P_3 can be set with its polarising axis at a variable angle θ to that of P_1.



For what values of θ do the emergent light have the lowest intensity?

A 30°, 120°

B 60°, 240°

C 90°, 270°

D 120°, 300°

Ans: **D**

To achieve minima for emergent light, P3 has to be perpendicular to P2 axis, i.e. 90° + 30° = 120°, and 180° + 120° = 300°

15 A point source of sound emits energy equally in all directions at a constant rate and a detector placed 2.0 m from the source measures an intensity of 3.0 W m^{-2}. The amplitude at the source is then doubled.

What intensity would the detector measure if it is now placed at a distance 4.0 m from the source?

A 3.0 W m^{-2}

B 1.5 W m^{-2}

C 0.75 W m^{-2}

D 0.38 W m^{-2}

Ans: A

$I \propto 1/r^2$

$I_1 \propto A^2$

$3.0 = k/(2.0)^2 \rightarrow k = 12$

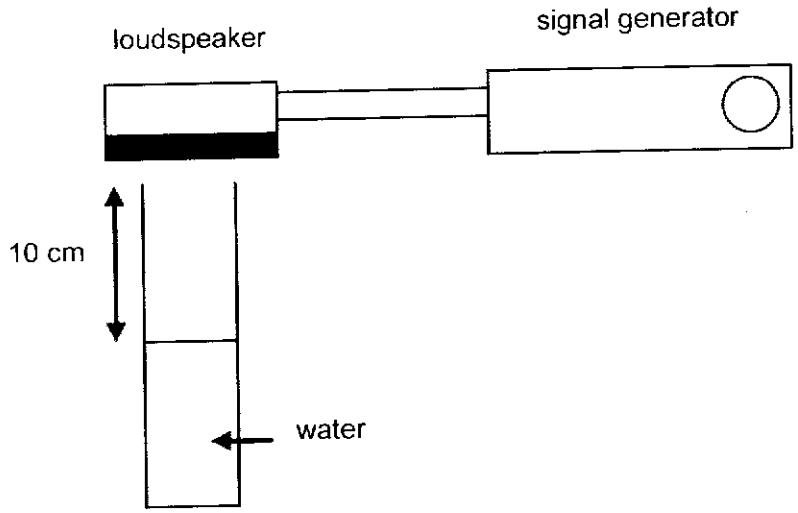
$I_2 \propto (2A)^2 = 4I_1$

$I_2 = 4I_1 = 4[12/(4.0)^2] = 3.0\ W\ m^{-2}$

Option B: used $I \propto 1/r$

Option C: used $I \propto A$ and $I \propto 1/r$

16 The figure below shows an experiment to produce a stationary wave in an air column. A loudspeaker connected to a signal generator, is placed above the column. The frequency of the signal generator is increased gradually from 3000 Hz and two consecutive resonances occur when the frequency of the signal generator is set to 3875 Hz and 5425 Hz respectively. The length of the air column is kept constant at 10 cm throughout the experiment.



Assuming the effects of end correction are negligible, what is the speed of sound in air?

A 300 m s^{-1}

B 310 m s^{-1}

C 330 m s^{-1}

D 340 m s^{-1}

Ans: B

$v = f\lambda \rightarrow (3875)(\lambda 1) = (5425)(\lambda 2)$

$\lambda 1 = 4L/(2n - 1)$

$\lambda 2 = 4L/(2(n+1) - 1) = 4L/(2n + 1)$

$(3875)(4L/(2n - 1)) = (5425)(4L/(2n + 1)) \rightarrow (3875)/(2n - 1) = (5425)/(2n + 1)$

$(2n + 1)/(2n - 1) = (5425)/(3875) \rightarrow (2n + 1)/(2n - 1) = 1.4 \rightarrow 2n + 1 = 2.8n - 1.4$

$\rightarrow n = 3$

therefore $v = (3875)(4(0.10)/(2(3) - 1)) = 310\ m\ s^{-1}$

17 Which of the following statements about two consecutive antinodes in a stationary wave is false?

A Their oscillations are in phase with each other.

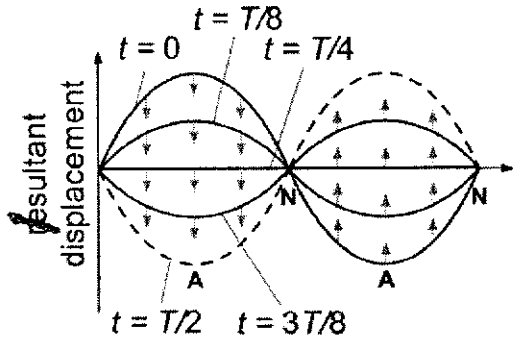
B Both particles at the antinodes will pass through their equilibrium positions with same speed.

C The acceleration of the particles are always equal in magnitude and opposite in direction.

D Both have maximum energies since the amplitudes of oscillations are maximum.

A Points between two adjacent nodes are in phase. Points in adjacent segments are anti-phase.

All the points between *adjacent* nodes are **in phase** though they **do not have the same amplitude**. Points in adjacent segments are **anti-phase**.



18 Two protons are 1.0×10^{-14} m apart.

Approximately how many times is the electrostatic force between them greater than the gravitational force between them?

A 10^{23}

B 10^{30}

C 10^{36}

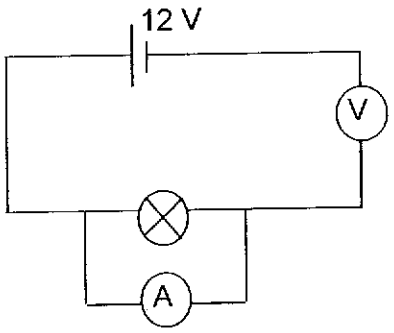
D 10^{42}

C

$$\text{gravitational force} = \frac{(6.67\times10^{-11})(1.67\times10^{-27})^2}{(1.0\times10^{-14})^2} = 1.86 \times 10^{-36}\ \text{N}$$

$$\text{electrostatic force} = \frac{(1.60\times10^{-19})^2}{4\pi(8.85\times10^{-12})(1.0\times10^{-14})^2} = 2.30\ \text{N}$$

19 An ammeter and a voltmeter are connected to a bulb of resistance 4.0 Ω as shown below.



Which of the following situations is most likely to happen?

A Ammeter will fuse.

B Ammeter reads 3.0 A and voltmeter reads 12 V.

C Ammeter reads zero current and voltmeter reads 12 V.

D Both ammeter and voltmeter give zero readings.

C Voltmeter in series, which has very high resistance compared to bulb. The current in the circuit is almost zero, so ammeter reads zero current.
The entire emf is across the voltmeter therefore it reads the emf of cell.

20 A new rechargeable battery has the marking *"500 mA h"* printed on it.

Which of the following is correct with regards to the battery?

A The e.m.f. of the battery is 500 V.

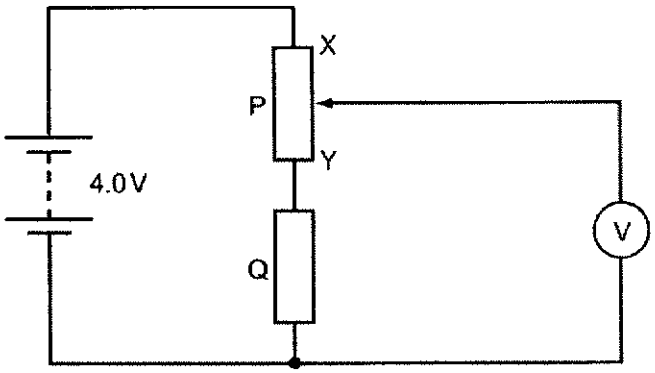
B The current from the battery is always 0.5 A.

C The energy stored in the battery is 1800 J.

D The charge stored in the battery is 1800 C.

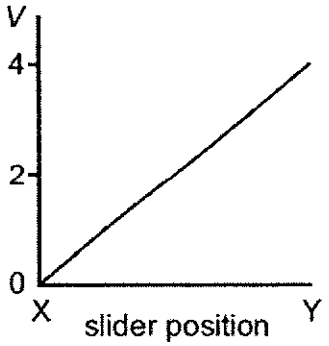
D $Q = It = (500/1000)(3600) = 1800$ C

21 In the circuit below, P is a potentiometer of total resistance 10 Ω and Q is a fixed resistor of resistance 10 Ω. The battery has an e.m.f. of 4.0 V and negligible internal resistance. The voltmeter has a very high resistance. The slider on the potentiometer is moved from X to Y and a graph of voltmeter reading V is plotted against slider position.

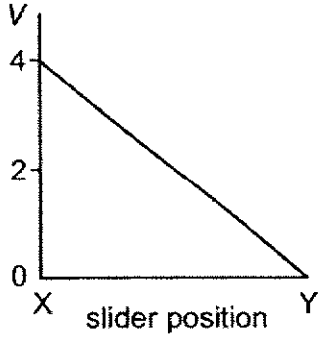


Which of the following shows the correct graph obtained?

A

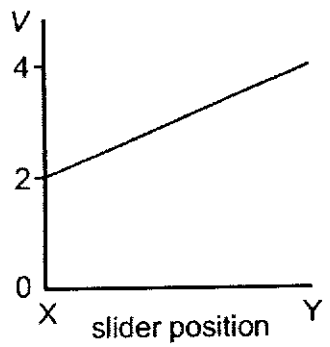


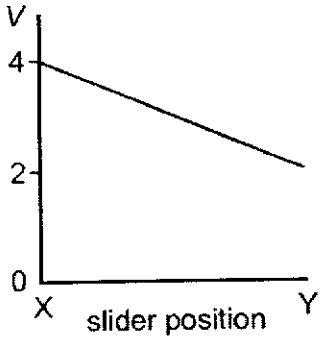
B



C

D

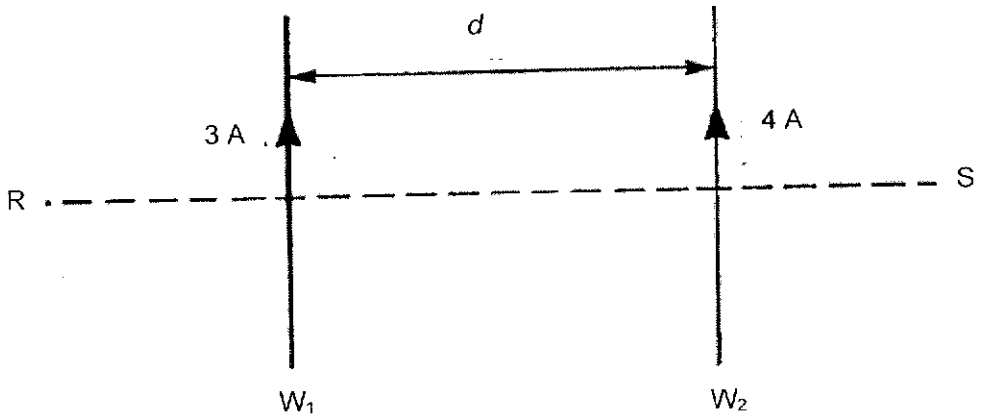




At X, voltmeter reads emf of supply = 4 V

D At Y, voltmeter reads pd across resistor Q = 2 V

22 Two vertical wires W_1 and W_2 are distance d apart carrying currents of 3 A and 4 A respectively.



The combined magnetic fields due to these currents gives a position of zero magnetic flux density on the horizontal line RS passing through the wires.

What is the distance of this position from the wire W_1?

A $\frac{1}{4}d$

B $\frac{3}{7}d$

C $\frac{4}{7}d$

D $\frac{3}{4}d$

Ans: B

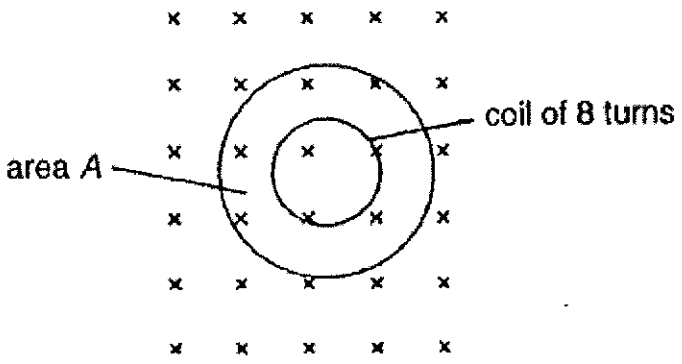
For zero magnetic flux density, B1 = B2

$B1 = \mu_0 I_1/2\pi x$

$B2 = \mu_0 I_2/2\pi(d - x)$

$\mu 0I1/2\pi x = \mu 0I2/2\pi(d - x) \rightarrow (3)/x = (4)/(d - x) \rightarrow 3d - 3x = 4x \rightarrow x = 3/7\ d$

23 A uniform magnetic field of flux density B passes normally through a plane area A. In this plane lies a coil of eight turns of wire, each of area ¼ A.



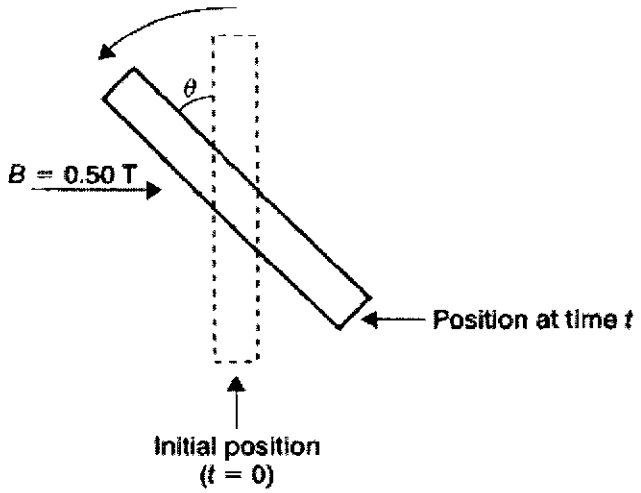
What is the magnetic flux linkage for the coil in terms of B and A?

	A	¼ BA	**B**	$2BA$
	C	$4BA$	**D**	$8BA$

Ans: B

$\varphi = NBA = 8B\left(\frac{1}{4}A\right) = 2BA$

24 A flat, circular coil of wire 30 turns, each of area 0.025 m^2, is initially placed with its plane at right angles to a uniform magnetic field of flux density 0.50 T.



What is the magnitude of the induced e.m.f. in the coil when t = 1.0 s, if the coil is rotating at 60° s^{-1}?

	A	0.20 V	**B**	0.34 V
	C	0.38 V	**D**	0.39 V

Ans: B

$\varphi = NBA = NBA\cos\omega t$

$\omega = \frac{60}{180} \times \pi = 1.05\ rad\ s^{-1}$

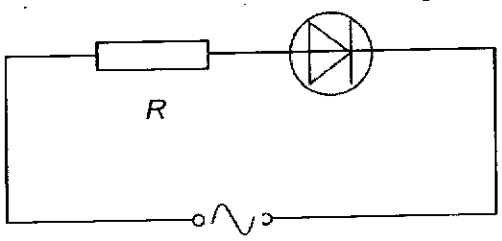
$|\varepsilon| = N\frac{\Delta\varphi}{\Delta t} = NBA\omega\sin\omega t = 30(0.50)(0.025)(1.05)\sin 60(1) = 0.34\ V$

Option A: $NBA\omega\cos\omega t = 30(0.50)(0.025)(1.05)\cos 60(1) = 0.20\ V$

Option C: $\varphi = NBA = 0.38$ V

Option D: $NBA\omega = 30(0.50)(0.025)(1.05) = 0.39\ V$

25 A sinusoidal current of peak value I_o is passed through the circuit shown.



What is the mean rate of heat dissipated in terms of R?

	A	1.41 I_0^2R	**B**	I_0^2R
	C	0.5 I_0^2R	**D**	0.25 I_0^2R

Ans: D

$P = I_{rms}^2R$

With a diode in the circuit, half-wave rectified.

Normally sinusoidal current, $I_{rms} = I_0/\sqrt{2} \rightarrow I_{rms}^2 = I_0^2/2$

But for half-wave rectified, $P = \frac{1}{2}(I_0^2/2)R = 0.25\ I_0^2R$

26 The ratio of turns of the primary coil to the secondary coil of a practical transformer is 10:1. The primary coil p.d. and current are 20 V and 3 A respectively. The efficiency of the transformer is 0.8.

Assuming that the energy loss is purely due to the resistance of the windings, which of the following statements is false?

A The secondary voltage is 2 V.

B The secondary current is 24 A.

C The output power is 60 W.

D The power loss is 12 W.

Ans: C

Option A: Np/Ns = Vp/Vs → 10 = 20/Vs → Vs = 2 V

Option B: Np/Ns = Is/Ip → 10 = Is/3 → Is (ideal) = 30 A. → Is (efficiency = 0.8) = 24 A

Option C: Ps (output) = VsIs = (2)(24) = 48 W

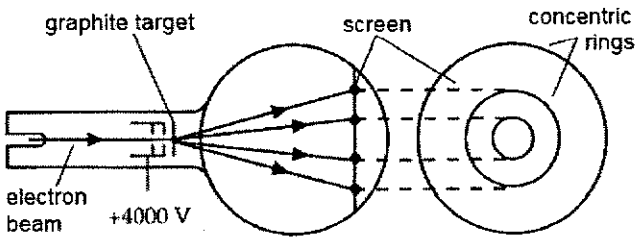
Option D: Ps (loss) = VsIs (loss) = (2)(6) = 12 W

27 Which option shows the change in velocity, frequency and wavelength of an electromagnetic wave as it travels from an optically less dense to an optically denser medium?

	velocity	frequency	wavelength
A	decreases	unchanged	decreases
B	increases	unchanged	increases
C	decreases	decreases	unchanged
D	increases	increases	unchanged

A

28 In an experimental setup, a beam of accelerated electrons strikes an extremely thin layer of polycrystalline graphite target and concentric rings are seen on the tube face as shown.



If the setup is modified such that instead of electron beam, a beam of protons strike the graphite target with the same speed, the radii of the concentric rings will

A decrease.

B increase.

C stay the same.

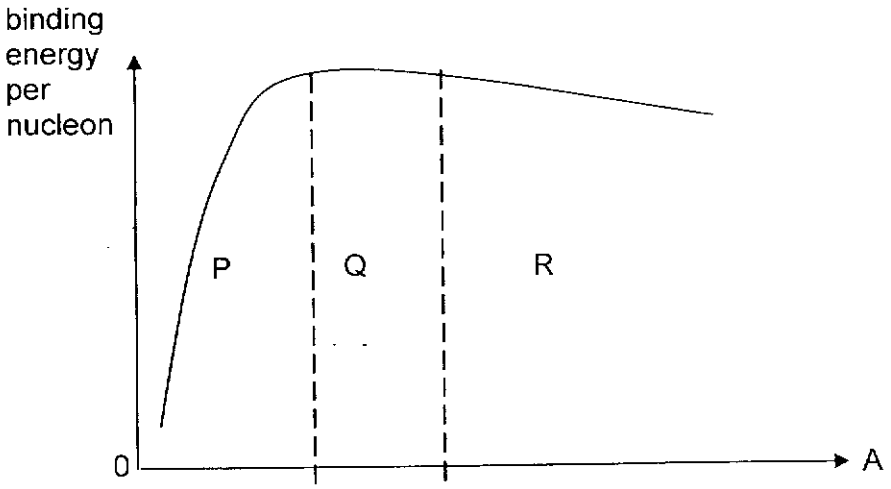
D not be seen. (No rings appear.)

A proton with the same v but bigger m than electron will have a much larger momentum p

de Broglie relation: $\lambda = \frac{h}{p}$ hence wavelength of proton is smaller

hence radii decrease.

29 The graph shows how the binding energy per nucleon of a nucleus varies with nucleon number A.



Which one of the following statements is **not** true?

A Nuclei in region Q are more stable than nuclei in region R.

B Nuclear fusion reactions bring nuclei in region P closer to region Q.

C Energy is released in nuclear fission reactions from nuclei in region P.

D The binding energy per nucleon increases most significantly at lower nucleon numbers.

C Nuclei in region P will undergo nuclear fusion reactions to become more stable heavier nuclei.

30 The following represents a sequence of radioactive decays involving two α-particles and two β-particles.

$$^{232}_{90}\text{Th} \xrightarrow{\alpha} \text{W} \xrightarrow{\beta} \text{X} \xrightarrow{\beta} \text{Y} \xrightarrow{\alpha} \text{Z}$$

What is the nuclide Z?

A $^{224}_{88}\text{Ra}$ **B** $^{228}_{88}\text{Ra}$ **C** $^{228}_{89}\text{Ac}$ **D** $^{228}_{90}\text{Th}$

A $^{232}_{90}\text{Th} \rightarrow {}^{228}_{88}\text{W} + {}^{4}_{2}\alpha$

$^{228}_{88}\text{W} \rightarrow {}^{228}_{89}\text{X} + {}^{0}_{-1}\beta$

$^{228}_{89}\text{X} \rightarrow {}^{228}_{90}\text{Y} + {}^{0}_{-1}\beta$

$^{228}_{90}\text{Y} \rightarrow {}^{224}_{88}\text{Z} + {}^{4}_{2}\alpha$

END OF PAPER

RIVER VALLEY HIGH SCHOOL
JC2 PRELIMINARY EXAMINATION

H2 PHYSICS 9749
PAPER 2
13 SEP 2021

2 HOURS

CANDIDATE NAME								
CENTRE NUMBER	S					**INDEX NUMBER**		
CLASS	2	0	J					

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.
Write your name, centre number, index number and class 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 or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

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

*Answer **all** questions.*

The number of marks is given in brackets [ ] at the end of each question or part question.

FOR EXAMINERS' USE	
1	/ 7
2	/ 10
3	/ 15
4	/ 10
5	/ 5
6	/ 8
7	/ 5
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Deduction	
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This document consists of **19** printed pages.

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_O	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_O	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-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	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/\text{°C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
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	$R = R_1 + R_2 + \ldots$
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	$x = x_0 \sin \omega t$
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	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 A student takes measurements to determine the acceleration of a ball as it rolls down a slope. He uses the apparatus illustrated in Fig. 1.1.

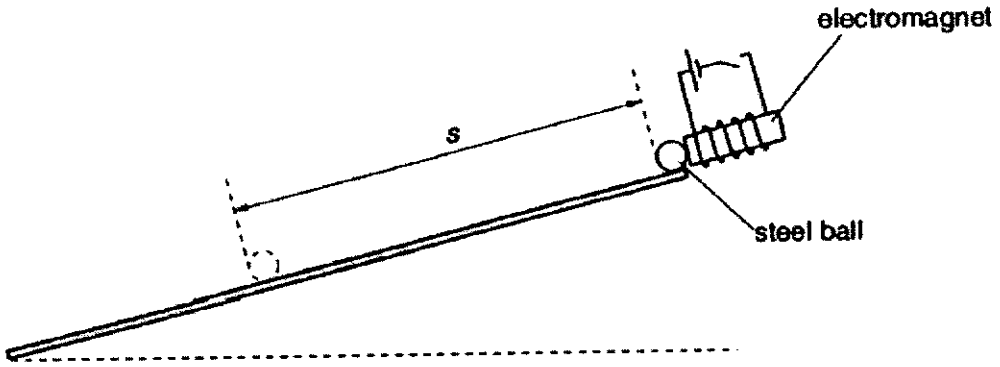


Fig. 1.1

The student measures the time t for the ball to roll a distance s down the slope after the ball has been released from the electromagnet.

The variation with t^2 of the distance s is shown in Fig. 1.2.

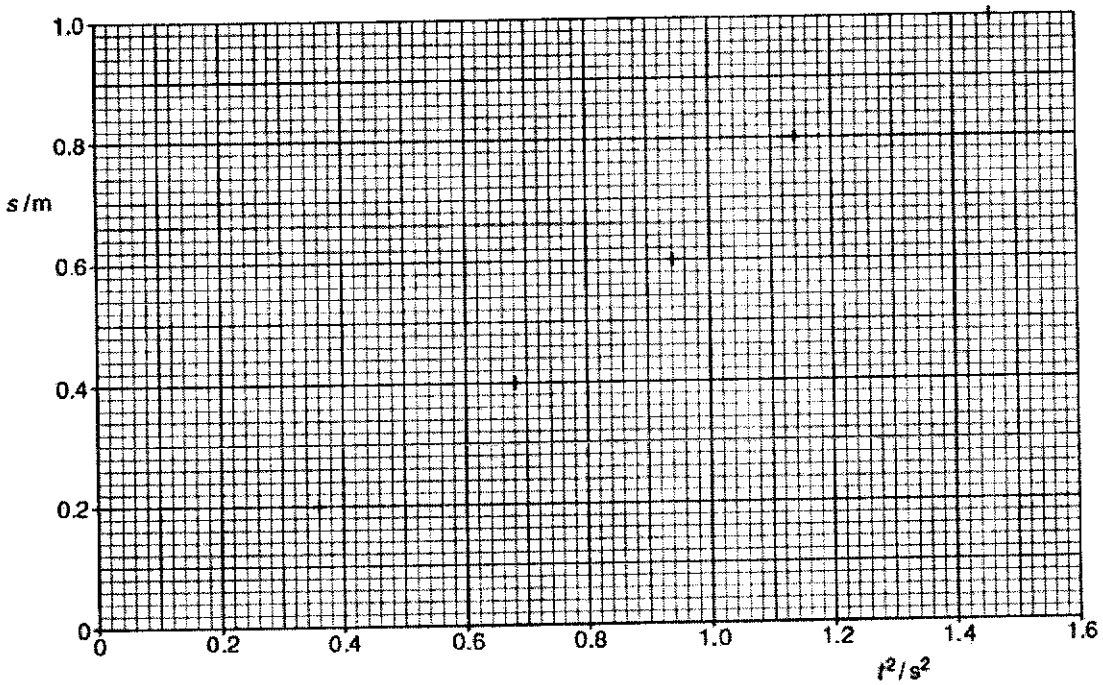


Fig. 1.2

(i) Use Fig. 1.2 to determine a value for the acceleration of the ball down the slope.

acceleration = ...m s^{-2} [5]

(ii) State the feature of the data shown in Fig. 1.2 that indicates the presence of

1. random error,

.....

.....

..... [1]

2. systematic error.

.....

.....

..... [1]

2 Fig. 2.1 shows a block of mass M_1 = 4.0 kg released from a vertical height of 6.0 m on a curved frictionless track. It slides down the track and makes a head-on elastic collision with a block of mass M_2 = 9.0 kg that is initially at rest.

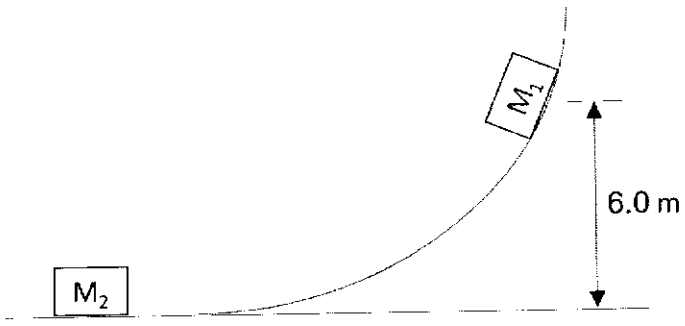


Fig. 2.1

(a) State the principle of conservation of linear momentum.

.....

..... [1]

(b) Calculate the velocity of M_1 just after it collides with M_2.

velocity of M_1 just after collision = ... $m\ s^{-1}$ [4]

(c) Calculate the maximum height to which M_1 rises after the collision.

maximum height M_1 rises after collision = ... m [2]

(d) Sketch a graph, on the given axes in Fig. 2.2, to show how the velocity of M_1 varies from the time of its release to the time it reaches maximum height on its return. [3]

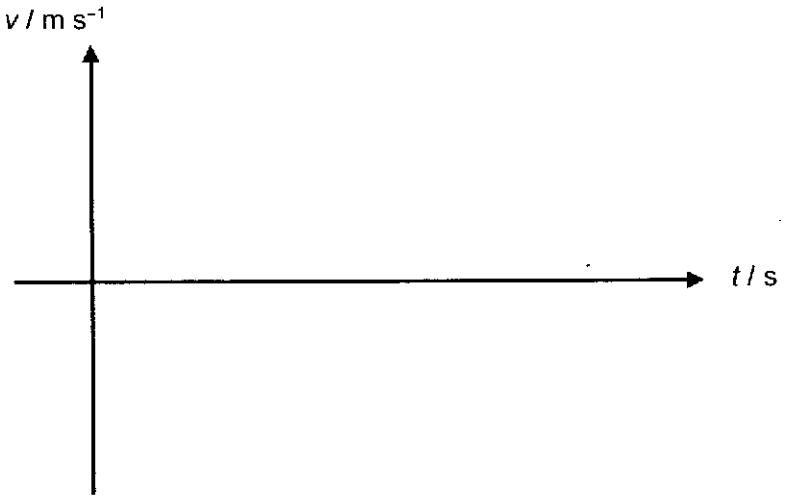


Fig. 2.2

3 (a) (i) Explain what is meant by the term *escape speed*.

.....

.....

.....

..... [2]

(ii) Mars has a radius of approximately 3.4×10^6 m and a mass of 6.4×10^{23} kg. Show that the escape speed from Mars is approximately 5 km s^{-1}.

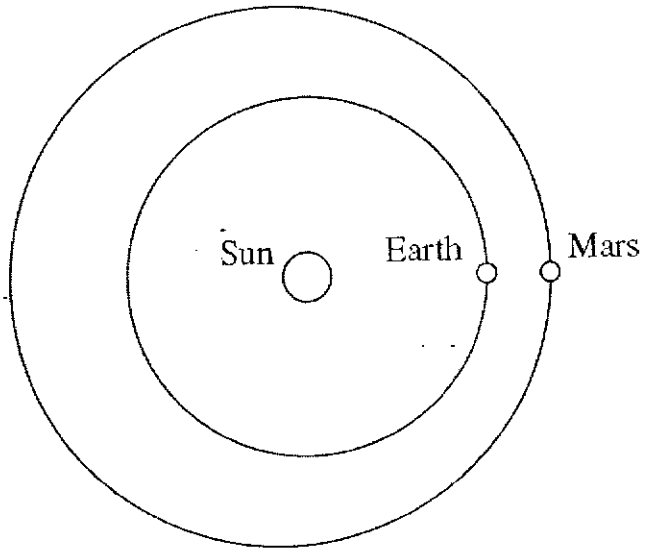
[3]

(iii) Suggest why a rocket would be able to escape from Mars with an initial speed much less than the escape speed given in part **(a)(ii)**.

.....

..... [1]

(b) Fig. 3.1 shows the Sun, Earth and Mars in alignment. Earth and Mars rotate around the Sun in the same directional sense.



Not to scale

Fig. 3.1

A rocket of mass 2.05×10^6 kg leaves the surface of Mars closest to Earth and heads for Earth.

Fig. 3.2 below gives data relevant to the rocket at the start of its journey.

astronomical object (AO)	mass of AO / kg	distance of rocket from the centre of AO / m	rocket's gravitational potential due to AO / J kg^{-1}	sign of gravitational potential
Mars	6.4×10^{23}	3.4×10^6	1.26×10^7	
Earth	6.0×10^{24}	5.6×10^{10}		negative
Sun	2.0×10^{30}	2.3×10^{11}	5.80×10^6	

Fig. 3.2

(i) Complete Fig. 3.2 by calculating the magnitude of gravitational potential of the rocket due to the presence of Earth and the signs of the gravitational potential energies due to Mars itself and the Sun.

[2]

(ii) Calculate the total gravitational potential energy of the rocket on the surface of Mars.

total gravitational potential energy = ... J [2]

(c) (i) Derive an expression to show that for satellites in a circular orbit

$$T^2 \propto r^3$$

where T is the period of orbit and r is the radius of the orbit.

[2]

(ii) The orbits of the Earth and Mars can be approximated to be circular orbits around the Sun.

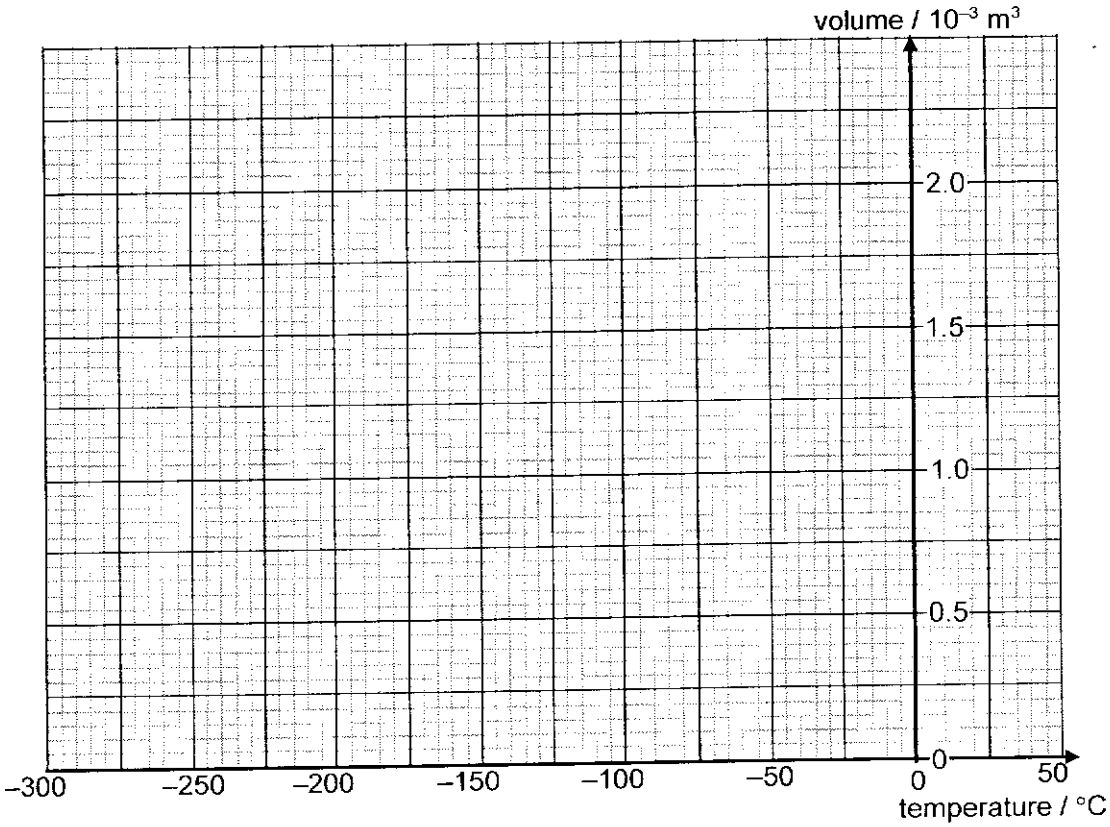
Hence, estimate the orbital period of Mars.

orbital period of Mars = ... days [3]

4 A fixed mass of ideal gas at a low temperature is trapped in a container at constant pressure. The gas is then heated and the volume of the container changes so that the pressure stays constant at 1.00×10^5 Pa.

When the gas reaches a temperature of 0.00 °C, the volume is 2.20×10^{-3} m^3.

(a) Draw a graph on the axes below to show how the volume of the gas varies with temperature in °C. [2]



(b) Calculate the number of moles of gas in the container.

number of moles = ... mol [2]

(c) Calculate the average kinetic energy of a molecule when this gas is at a temperature of 50.0 °C.

kinetic energy = ... J [2]

(d) Hence or otherwise, calculate the total internal energy of the gas at a temperature of 50.0 °C.

internal energy = ... J [2]

(e) By considering the collisions of gas molecules with the walls of the container, explain why the volume of the container must change if the pressure is to remain constant as the temperature increases.

.....

.....

.....

..... [2]

5 A graph of the voltage input to an ideal transformer is shown in Fig. 5.1. The 45:1 step-down transformer has a mean input power of 25 W.

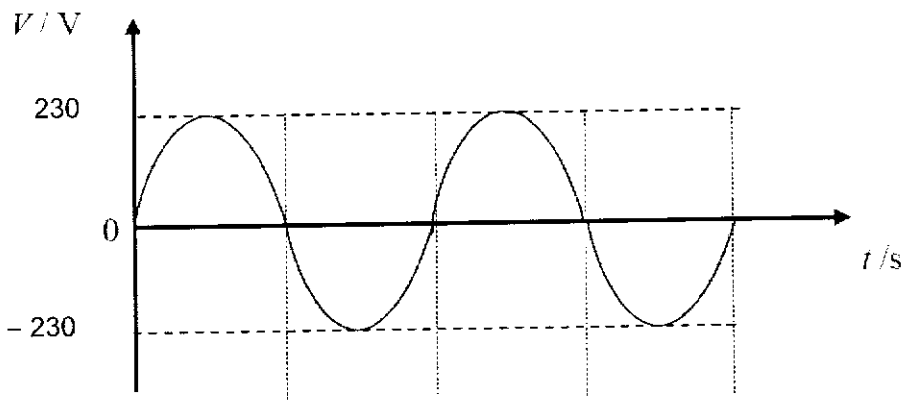


Fig. 5.1

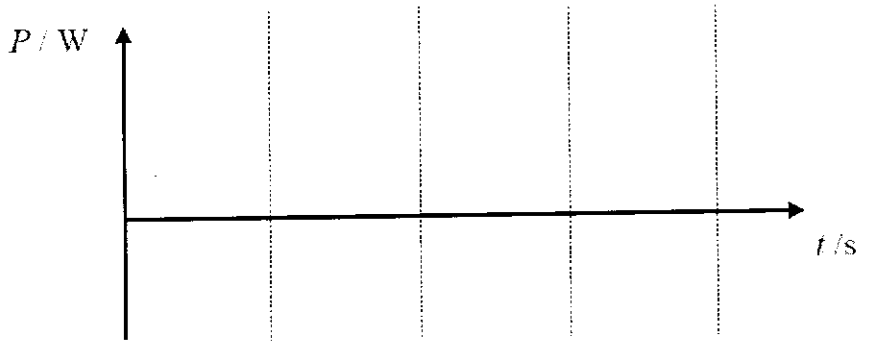


Fig. 5.2

(a) On the *P-t* graph in Fig. 5.2, sketch the variation of power input to the transformer with time for two complete cycles. Indicate the value for the maximum input power. [2]

(b) Calculate the r.m.s. value of the output voltage.

r.m.s. value of output voltage = ... V [3]

6 (a) Using energy considerations, distinguish between *electromotive force* and *potential difference*.

.....

.....

.....

.....

.....

..... [2]

(b) An electric hotplate is designed to operate on a power supply of 240 V and has two coils of wire of resistivity of 9.8×10^{-7} Ω m. Each coil of wire has a length of 16 m and cross-sectional area 0.20 mm^2.

(i) For one of the coils, calculate

1. its resistance,

resistance = ... Ω [2]

2. the power dissipation when a 240 V supply is connected across it.

power = ... W [2]

(ii) Fig. 6.1 shows how the two coils can be connected for the hotplate to operate at different powers.

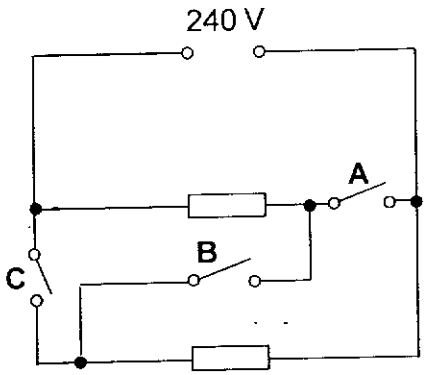


Fig. 6.1

On Fig. 6.2, fill up the table with "ON" or "OFF" to obtain the lowest and highest levels of operating power.

	switch A	switch B	switch C
Lowest			
Highest			

[2]

Fig. 6.2

7 Fig. 7.1 shows a microwave transmitter aimed at a metal plate.

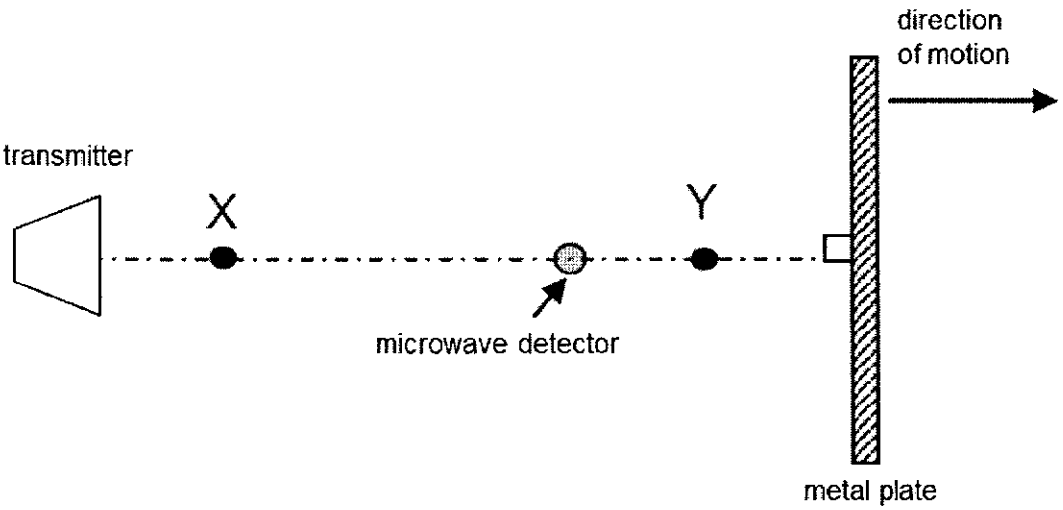


Fig. 7.1

(a) A small detector, moved along the line XY, travels 16 cm in moving from the first to the 12th consecutive nodal position.

Show that the microwaves emitted have a frequency of 10 GHz. [3]

(b) The detector is now at position Y and the metal plate is moved to the right, along the direction XY at a constant speed.

State and explain what is observed at the detector.

.....

.....

.....

.....

.....

..... [2]

8 **(a)** When monochromatic light is shone on a clean metal surface, electrons are emitted from the surface due to the photoelectric effect.

(i) State what is meant by the threshold frequency of the metal.

.....

.....

..... [1]

(ii) Explain why the photoelectric effect is not observed below the threshold frequency.

.....

.....

.....

.....

.....

..... [2]

(b) Monochromatic light of wavelength 5.40×10^{-7} m is incident on a metal surface which has a work function of 1.40×10^{-19} J.

(i) Calculate the threshold frequency for the metal.

threshold frequency = ... Hz [2]

(ii) Calculate the energy of a single photon of this light.

energy of photon = ... J [2]

(iii) Calculate the maximum speed of the emitted electrons.

maximum speed = ... m s^{-1} [3]

(iv) Calculate the de Broglie wavelength of the fastest electrons.

de Broglie wavelength = ... nm [2]

(c) Fig. 8.1 below represents the energy levels of the four lowest states of the hydrogen atom.

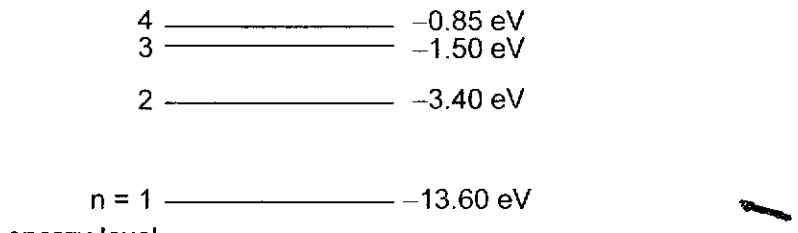


Fig. 8.1

(i) State what happens in the atom when line spectra are produced.

.....

.....

..... [1]

(ii) State the transition and determine the wavelength of one possible **visible** spectral line detected in the **emission** spectrum of atomic hydrogen, due to transitions between these states.

transition = level ..... to .....

wavelength = ... μm [3]

(d) Fig. 8.2 below represents a typical X-ray spectrum.

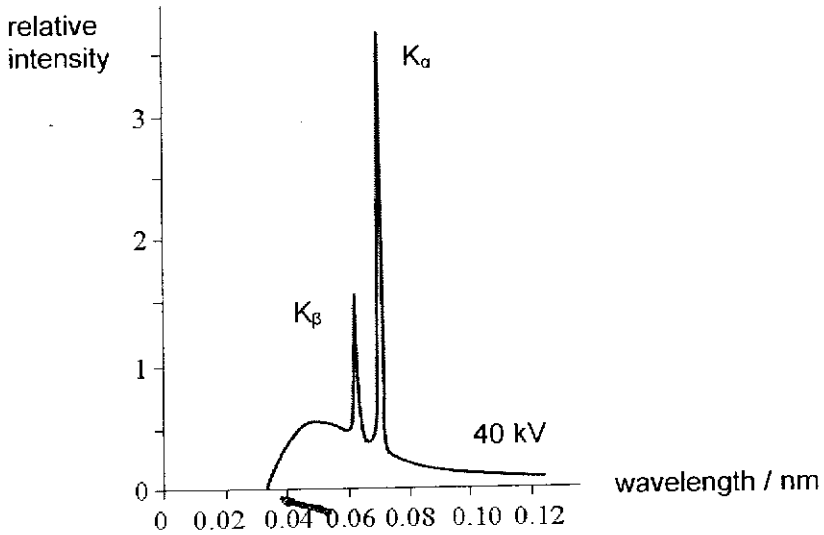


Fig. 8.2

(i) Distinguish between the mechanisms that produce **characteristic** X-ray spectra in Fig. 8.2 and the line spectra in part **(c)(i)**.

.....

.....

.....

.....

.....

..... [2]

(ii) Estimate the maximum velocity of the incoming electrons.

maximum velocity ≈ ..... m s^{-1} [2]

END OF PAPER