2016 JC2 Preliminary Examination

Name		Class	16S

PHYSICS **9646/01**
Higher 2

Multiple Choice **15 September 2016**

1 hour 15 min

Additional Materials: Multiple Choice Answer Sheet
Soft clean eraser
Soft pencil (type B or HB is recommended)

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your **name** and **class** in the spaces provided at the top of this page.

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and index number on the Answer Sheet in the spaces provided.

There are **forty** 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 booklet.

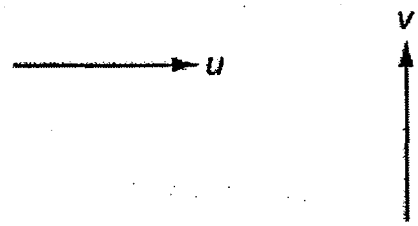
Data

speed of light in free space,	c	$= 3.00 \times 10^{8}\ \text{m s}^{-1}$
permeability of free space,	μ_o	$= 4\pi \times 10^{-7}\ \text{H m}^{-1}$
permittivity of free space,	ε_o	$= 8.85 \times 10^{-12}\ \text{F m}^{-1}$
		$(1/(36\pi)) \times 10^{-9}\ \text{F m}^{-1}$
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

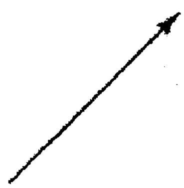
uniformly accelerated motion,	s	$= ut + \frac{1}{2}at^2$
	v^2	$= u^2 + 2as$
work done on/by a gas,	W	$= p\,\Delta V$
hydrostatic pressure,	p	$= \rho g h$
gravitational potential,	ϕ	$= -\dfrac{Gm}{r}$
displacement of particle in s.h.m.,	x	$= x_o \sin \omega t$
velocity of particle in s.h.m.,	v	$= v_o \cos \omega t$
		$= \pm \omega\sqrt{(x_o^2 - x^2)}$
mean kinetic energy of a molecule of an ideal gas	E	$= \frac{3}{2}kT$
resistors in series,	R	$= R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	$= 1/R_1 + 1/R_2 + \ldots$
electric potential,	V	$= \dfrac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	x	$= x_o \sin \omega t$
transmission coefficient,	T	$\propto \exp(-2kd)$
		where $k = \sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay	x	$= x_o \exp(-\lambda t)$
decay constant	λ	$= \dfrac{0.693}{t_{\frac{1}{2}}}$

1 The initial velocity of an object is shown by the vector u. The final velocity of the object is shown by the vector v.

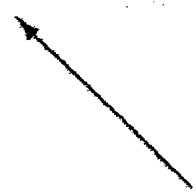


Which arrow shows the change in velocity of the object?

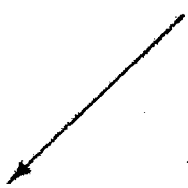
A



B



C



D

2 To find the resistivity of a semiconductor, a student makes the following measurements of a cylindrical rod of the material.

length = 25 ± 1 mm

diameter = 5.0 ± 0.1 mm

resistance = 68 ± 1 Ω

He calculates the resistivity to be 5.34×10^{-2} Ω m.

How should the uncertainty be included in his statement of the resistivity?

A $(5.34 \pm 0.07) \times 10^{-2}$ Ω m

B $(5.34 \pm 0.09) \times 10^{-2}$ Ω m

C $(5.3 \pm 0.4) \times 10^{-2}$ Ω m

D $(5.3 \pm 0.5) \times 10^{-2}$ Ω m

3 An object is released from the open door of an aircraft in level flight.
It is observed that it takes three seconds for the object to reach terminal velocity.
Which statement about the motion of the object is correct?

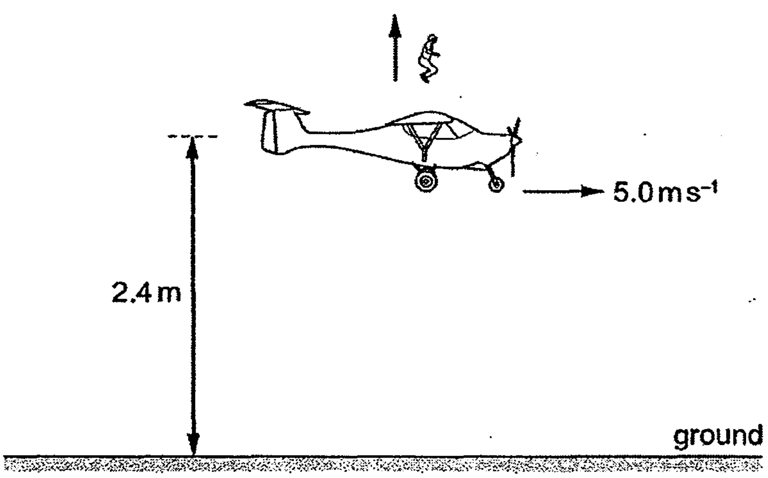
A The horizontal component of its velocity is constant.

B The horizontal component of its acceleration is zero.

C The vertical component of its velocity decreases for three seconds.

D The vertical component of its acceleration is zero after three seconds.

4 A toy aeroplane is flying above the ground at a constant horizontal velocity of 5.0 m s^{-1} when the toy pilot is ejected. The aeroplane propels the toy pilot upward from a height of 2.4 m above the ground so that the vertical component of his speed is initially 3.0 m s^{-1}.



With what speed does the toy pilot hit the ground? Ignore the effects of air resistance.

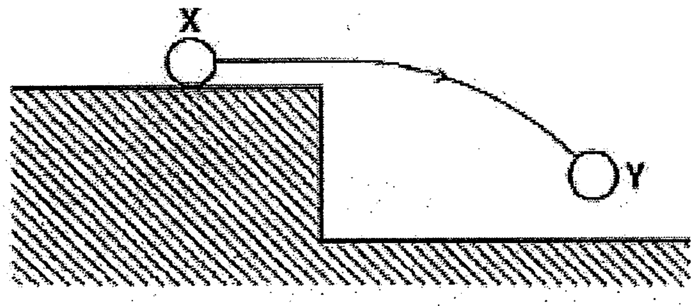
A 3.7 m s^{-1}

B 5.8 m s^{-1}

C 7.5 m s^{-1}

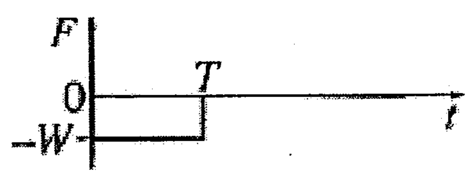
D 9.0 m s^{-1}

5 A ball of weight W slides along a smooth horizontal surface until it falls off the edge at time T.

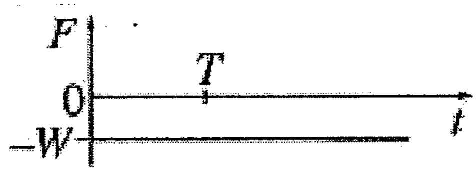


Which graph represents how the resultant vertical force F, acting on the ball, varies with time t as the ball moves from position X to position Y?

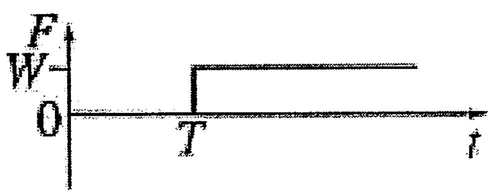
A



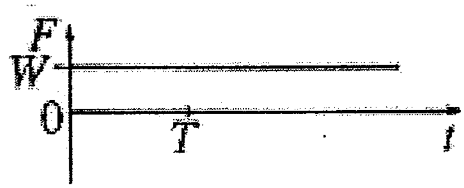
B



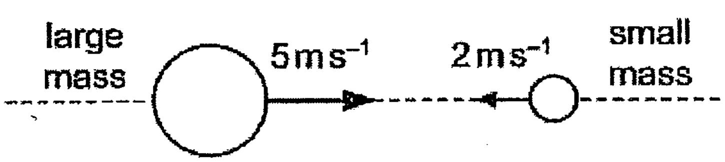
C



D



6 A large mass moving at a velocity of 5 m s^{-1} collides head-on with a small mass moving at a velocity of 2 m s^{-1} in the opposite direction.



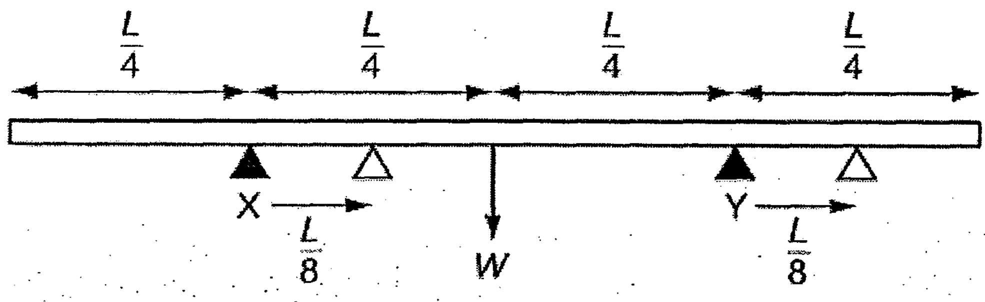
The collision is elastic.

After the collision, both masses move to the right. The large mass has a velocity v_1 and the small mass has a velocity v_2.

Which pair of values v_1 and v_2 is possible?

	v_1	v_2
A	2 m s^{-1}	5 m s^{-1}
B	3 m s^{-1}	10 m s^{-1}
C	4 m s^{-1}	4 m s^{-1}
D	5 m s^{-1}	12 m s^{-1}

7 A uniform plank, of weight W and length L is supported at points X and Y, each at distances $\frac{L}{4}$ from the ends of the plank.



What will be the increase of the force on the plank exerted by support X if both X and Y are moved a distance $\frac{L}{8}$ to the right from their original positions?

A $\frac{W}{16}$

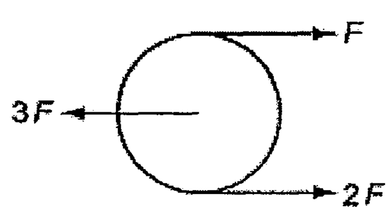
B $\frac{W}{8}$

C $\frac{W}{4}$

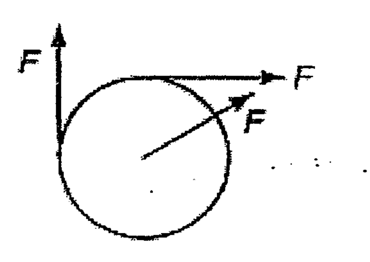
D $W\left(\frac{5}{16}\right)$

8 An isolated disc is subjected to three forces, each given in terms of units of magnitude F. In which situation will the disc experience both a resultant force and a resultant torque?

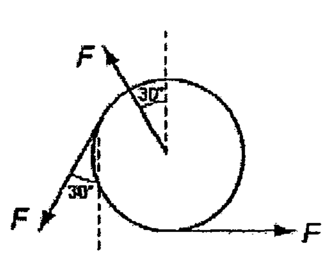
A



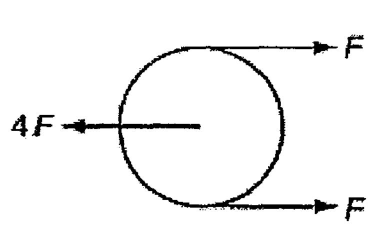
B



C



D



9 The function of many machines is to change energy from one form to another as efficiently as possible.

Which machine is 100% efficient?

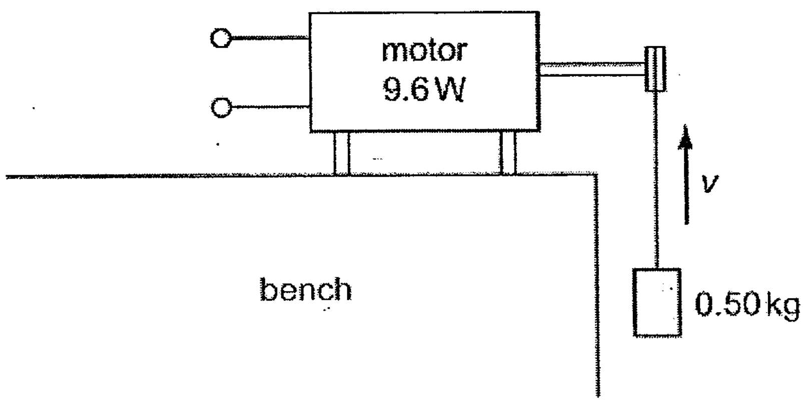
A a car engine as it converts chemical energy to kinetic energy

B an electrical heater in a kettle as it converts electrical energy to heat

C a lamp as it converts electrical energy to light

D a rocket as it converts chemical energy to gravitational potential energy

10 A small electric motor is 20% efficient. Its input power is 9.6 W when it is lifting a mass of 0.50 kg at a steady speed *v*.



What is the value of *v*?

A 0.39 m s^{-1}

B 2.0 m s^{-1}

C 2.8 m s^{-1}

D 3.0 m s^{-1}

11 The root-mean-square speed of the molecules of an ideal gas is *v*. Determine the new root-mean-square speed if the gas is heated at constant volume so that its pressure is increased from *p* to 3*p*.

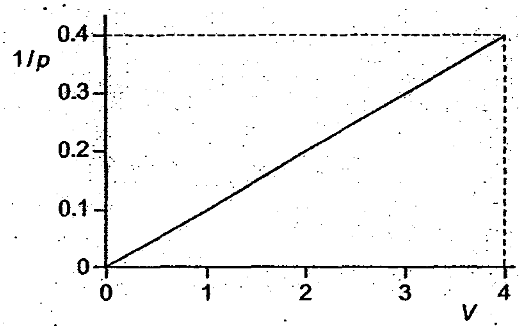
A $\frac{1}{9}v$

B $v\sqrt{3}$

C $3v$

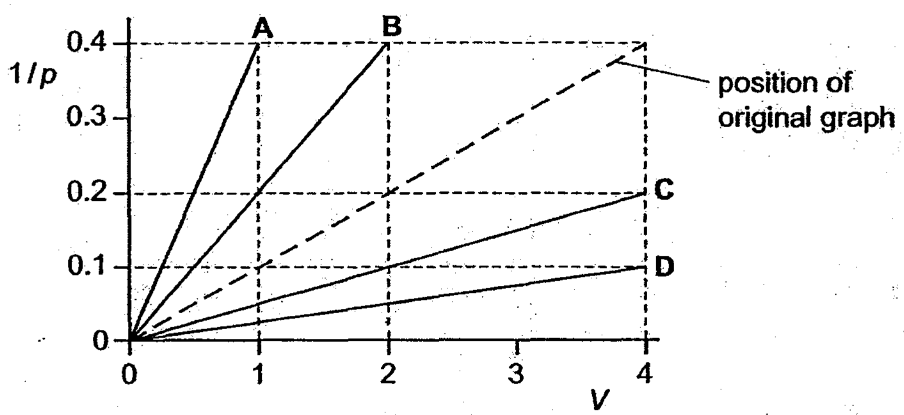
D $9v$

12 A fixed amount of an ideal gas has pressure p and volume V. The graph shows the variation of $1/p$ with V at a constant temperature.



The amount of gas and the thermodynamics temperature are both doubled.

Which line will be produced?



13 In an experiment to determine the specific heat capacity of a liquid by an electrical method, a student obtained the following results.

Mass of liquid heated	1.5 kg
Initial liquid temperature	300 K
Final liquid temperature	357 K
Electrical power of heating	1.0 kW
Time of heating	180 s

What is the specific heat capacity of the liquid?

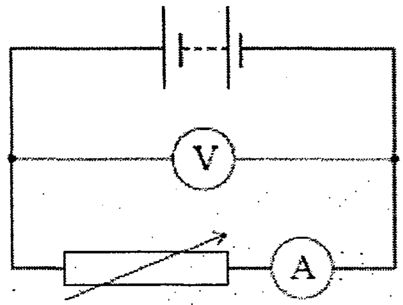
A 2.1 J kg^{-1} K^{-1}

B 18 J kg^{-1} K^{-1}

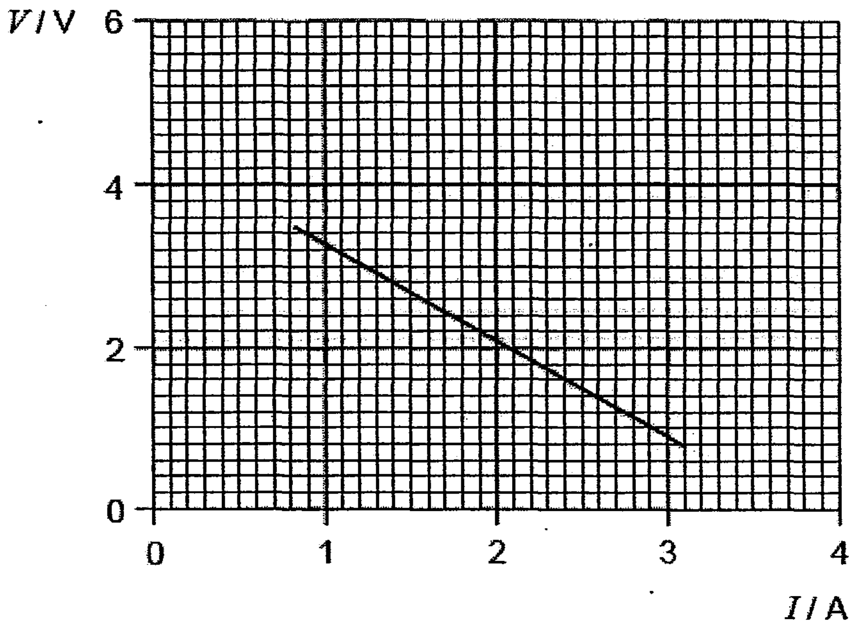
C 1800 J kg^{-1} K^{-1}

D 2100 J kg^{-1} K^{-1}

14 To investigate the variation of current I in a variable resistor with the potential difference V across it, the circuit shown below was used.



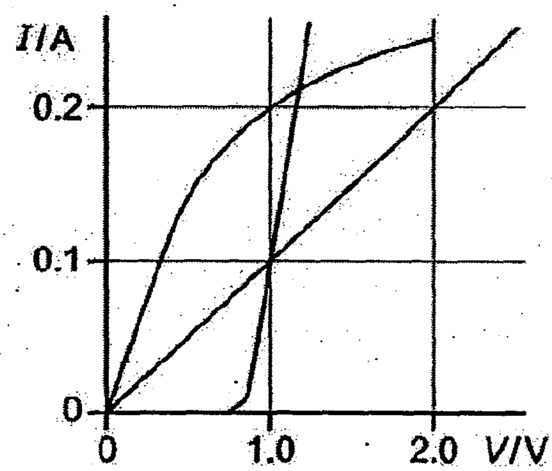
The variation of current I with V is shown below.



From the data it can be shown that the internal resistance of the battery is

A 0.2 Ω **B** 0.5 Ω **C** 1.2 Ω **D** 1.8 Ω

15 The graph shows the I-V characteristics of three electrical components, a diode, a filament lamp and a resistor, plotted on the same axes.



Which statement is correct?

A The resistance of the resistor equals that of the filament lamp when V = 0.8 V.

B The resistance of the diode is constant above 0.8 V.

C The resistance of the filament lamp is twice that of the resistor at 1.0 V.

D The resistance of the diode equals that of the filament lamp at about 1.2 V.

16 Bulb A has a power rating of 1000 W, 120 V. Bulb B has a power rating of 1000 W, 240 V. The bulbs are connected in series and powered by a source of e.m.f. E = 30 V. The resistance of bulbs A & B is assumed to be constant.

Which of the following must be **true**?

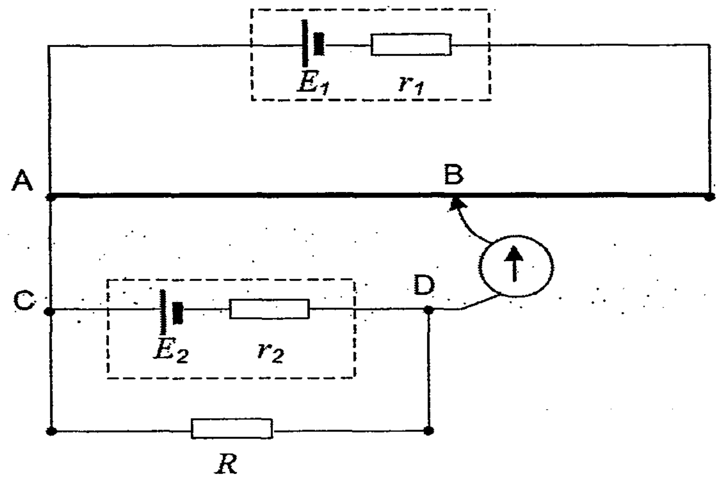
A Bulb B will be brighter than bulb A.

B Current through bulb B is higher than the current through bulb A.

C Bulb A and bulb B have the same resistance value.

D Bulb A has higher resistance than bulb B.

17 The circuit below shows a potentiometer connected to a cell E_2 of internal resistance r_2 and resistor R. Point B is the balance point when the galvanometer shows null deflection.



Which of the following statements about the potentiometer circuit is **true**?

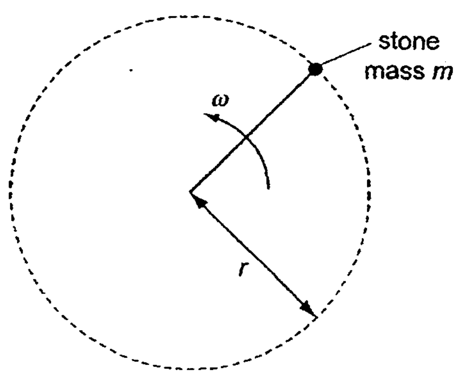
A At balance point, the current through AB has the same magnitude as the current through CD.

B At balance point, there is no current running through CD.

C At balance point, the potential difference between AB equals E_2 if r_2 is zero.

D The length AB will be shorter if r_2 is zero.

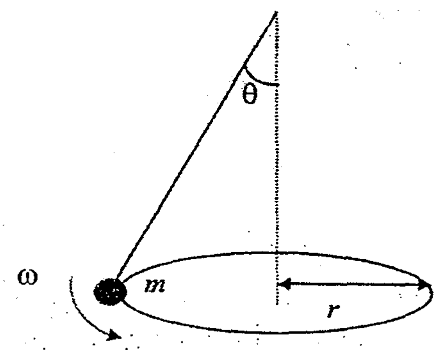
18 A stone with mass m is attached to light rod. The stone is rotated in a vertical circle of radius r with a constant angular speed ω as shown.



What is the difference between the maximum and minimum magnitude of the tension in the light rod during one revolution of the stone? The acceleration of free fall is g.

A zero **B** $2mg$ **C** $mr\omega^2$ **D** $2mr\omega^2$

19 A small bob of mass m which hangs from a light string is set to move in a horizontal circle of radius r with angular velocity ω. The string makes an angle θ with the vertical.



What is the tension in the string?

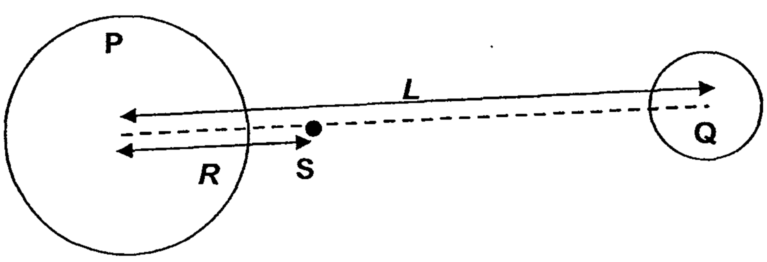
A $\dfrac{mg}{\sin\theta}$

B $\dfrac{mg}{\tan\theta}$

C $\dfrac{mr\omega^2}{\tan\theta}$

D $\dfrac{mr\omega^2}{\sin\theta}$

20 There are two isolated planets P and Q of masses M_P and M_Q respectively. Their centres are of distance L apart and they rotate with a uniform angular velocity ω about a common axis S which intersects the line joining their centres perpendicularly as shown.



If the distance of planet P from the axis S is R, which of the following does ***not*** give the correct expression for the centripetal force on planet Q?

A $M_P R\omega^2$

B $M_Q(L - R)\omega^2$

C $\dfrac{GM_PM_Q}{L^2}$

D $\dfrac{GM_PM_Q}{R^2}$

21 Planet **X** has a density ρ, radius R and acceleration of free fall a.

What is the acceleration of free fall of Planet **Y** with density 2ρ and radius $2R$?

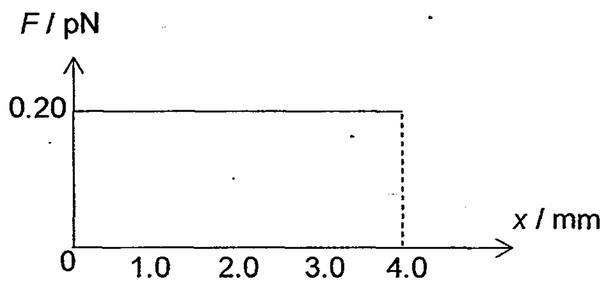
A $8a$

B $4a$

C a

D $0.5a$

22 The force F experienced by an electron when placed in an electric field varies with displacement x as shown in the graph below.



Calculate the change in electric potential energy of the electron when it was moved from x = 1.0 mm to x = 3.0 mm in the direction of the force.

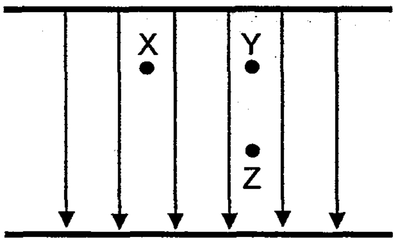
A -8.0×10^{-16} J

B -4.0×10^{-16} J

C 4.0×10^{-16} J

D 8.0×10^{-16} J

23 The diagram shows the electric field lines due to two charged parallel plates.



Which of the following statements must always be true?

A The upper plate is at a positive potential and the lower plate is at a negative potential.

B A proton at Z experiences a greater force than if it were placed at Y.

C A proton at Z would experience the same force if it were placed at X.

D A proton at Z experiences less force than if it were placed at Y.

24 Which of the following is ***not*** an example of a system in approximate simple harmonic motion?

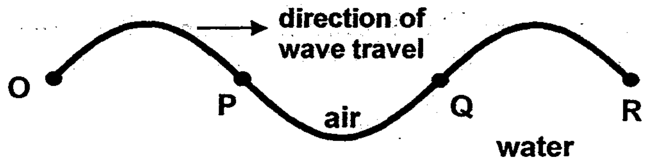
A A ball bouncing on the floor.

B A child swinging on a swing.

C A guitar string that has been struck.

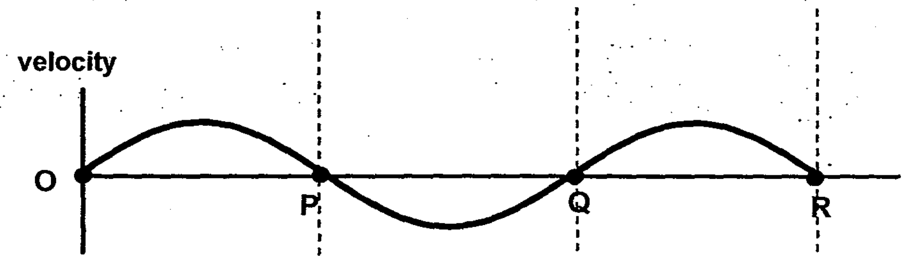
D A car's radio antenna as it waves back and forth.

25 At a particular instant the profile of a surface wave on water is shown below.

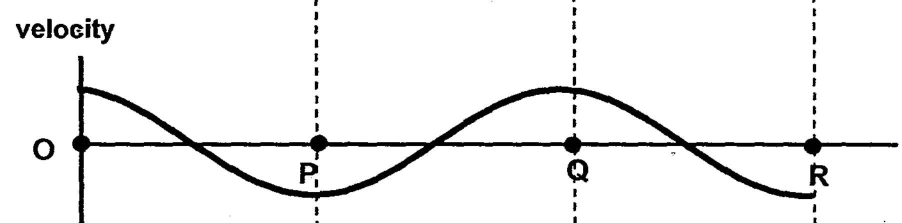


Which of the following graphs best represents the vertical velocity of the water molecules at this instant, taking upward velocity as positive?

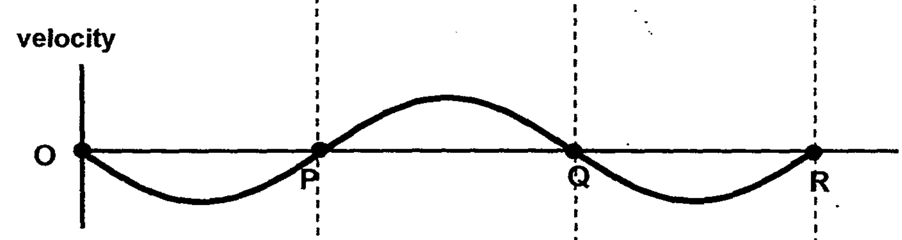
A



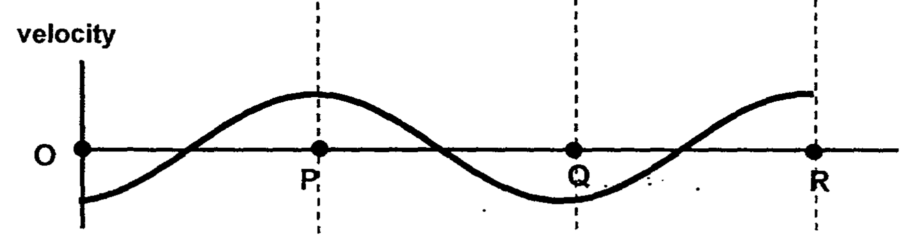
B



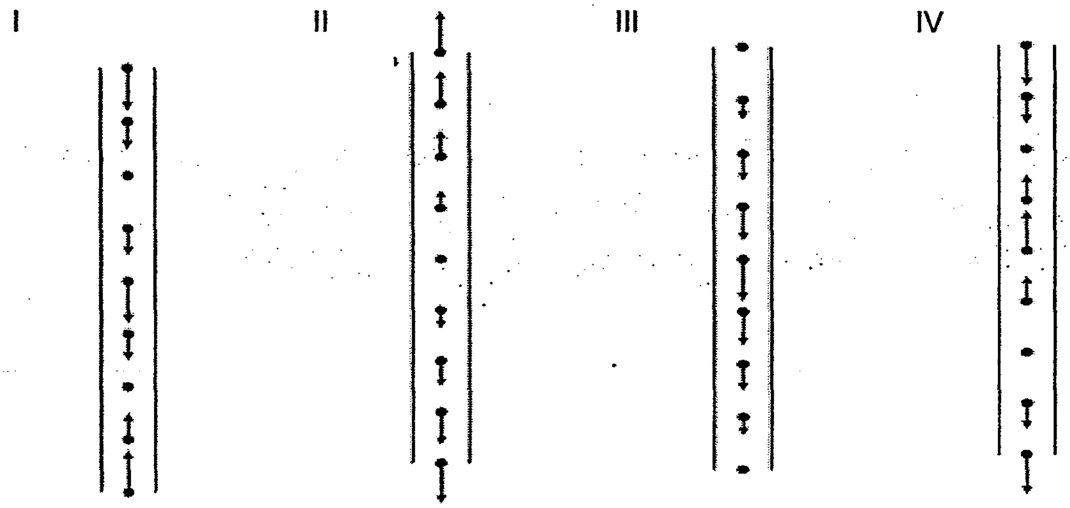
C



D



26 The arrows on the diagrams represent the movement of the air molecules in a pipe in which a stationary longitudinal wave has been set up. The length of each arrow represents the amplitude of the motion, and the arrow head shows the direction of motion at a particular instant.



Which of the following diagrams shows a possible stationary wave that could be set up in the pipe?

A II and IV

B I and IV

C I, II and IV

D III only

27 A diffraction grating with 400 lines per mm is illuminated with yellow light of 600 nm. What is the angle the second maxima makes with the principal axis?

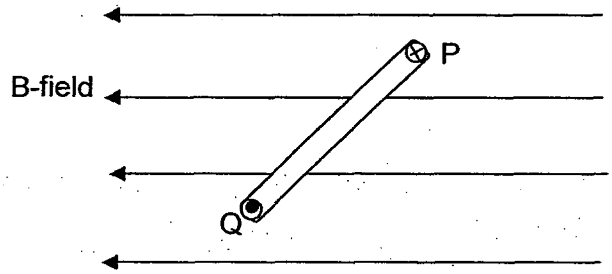
A 2.75°

B 13.9°

C 28.7°

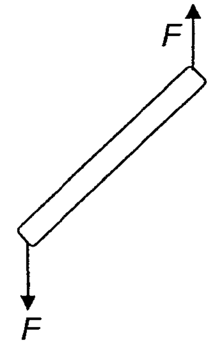
D 73.7°

28 The figure below shows the top view of a current carrying coil in a uniform magnetic field at a particular time instant. The current at P is flowing perpendicularly into the plane of the paper and the current at Q is flowing perpendicularly out of the plane of the paper.

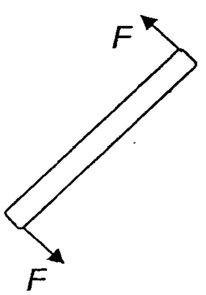


Which of the following correctly shows the direction of the forces, *F* acting on the coil at that time instant?

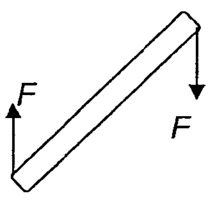
A



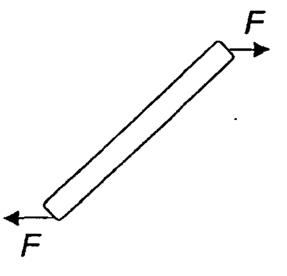
B



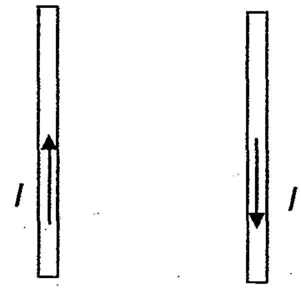
C



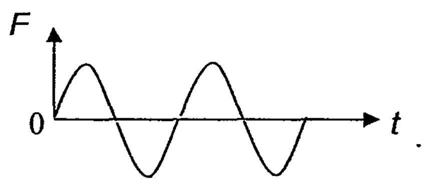
D

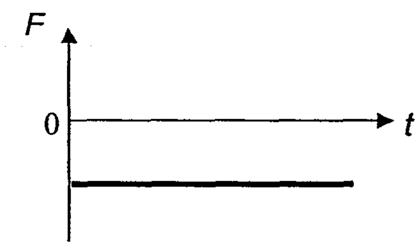


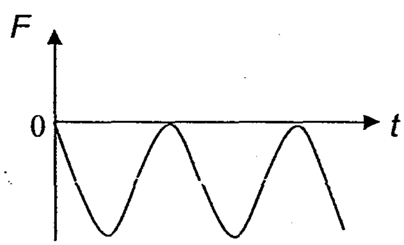
29 Two parallel conductors carry sinusoidal alternating currents that differ in phase by π radian. The figure below shows the flow of current at one particular time instant.

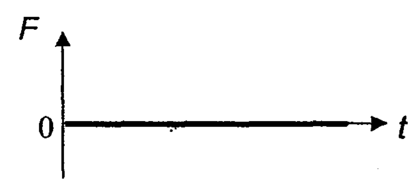


Which of the following graphs shows a possible variation of the force experienced by one of the conductors with respect to time?

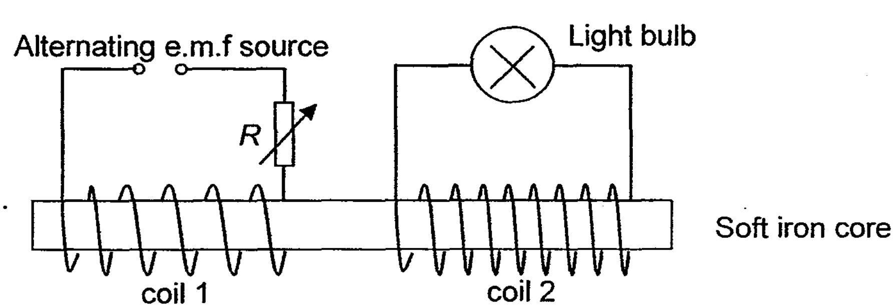
A


B


C


D


30 The figure below shows a system designed to control the brightness of a light bulb. Coil 1 and coil 2 are not electrically connected.



Which combination of actions will result in the dimmest possible light?

A R is reduced and the soft iron core is removed from coil 2.

B R is increased and the soft iron core is inserted into coil 2.

C R is increased and the soft iron core is removed from coil 2.

D R is reduced and the soft iron core is inserted into coil 2.

31 A flat circular coil has 120 turns and an area of 0.070 m^2. It is placed perpendicularly to a magnetic field. The flux density of the magnetic field is changed steadily from 80 mT to –80 mT over a period of 4.0 s.

What is the e.m.f. induced in the coil during this time?

A 1.40 mV

B 4.48 mV

C 168 mV

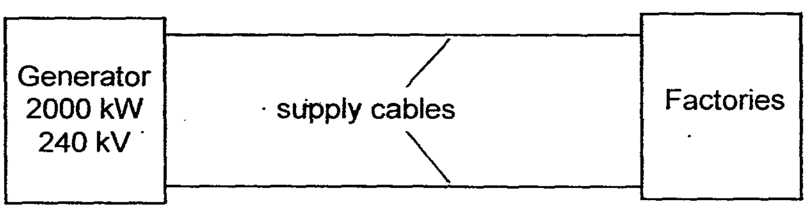
D 336 mV

32 An ideal transformer has 100 turns in its primary coil and 500 turns in its secondary coil. The power supplied is 2000 W and the alternating voltage in the primary coil and secondary coil are V_p and 2000 V respectively.

Which of the following gives the correct values of voltage V_p and current I_p in the primary coil?

	V_p / V	I_p / A
A	400	1.0
B	400	5.0
C	10 000	1.0
D	10 000	5.0

33 The diagram shows a generator with supply cables linking to the factories. The generator produces an electrical power of 2000 kW, 240 kV. The supply cables have a total resistance of 1.5 kΩ.



What is the power loss in the supply cables?

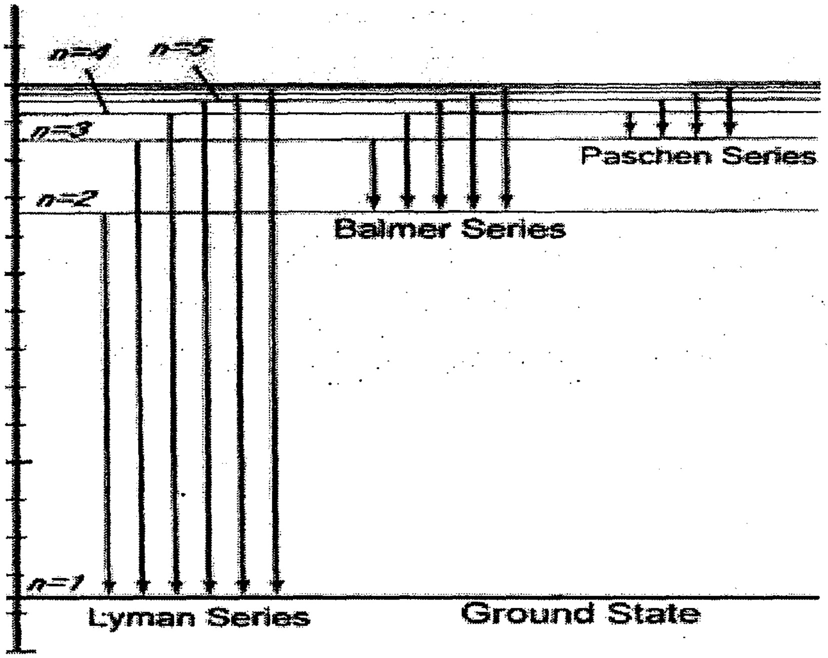
A 38.4 kW

B 104 kW

C 208 kW

D 2000 kW

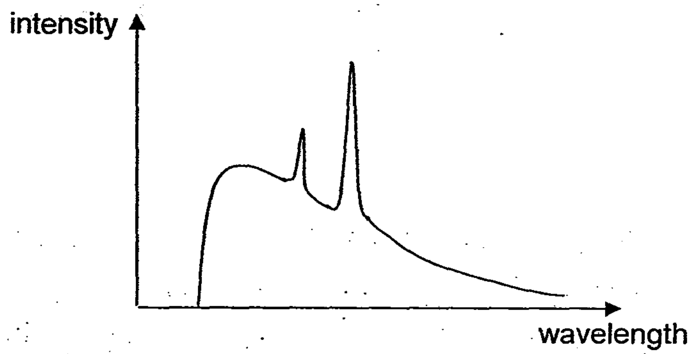
34 The diagram below shows the energy level diagram of hydrogen.



Which of the following gives the correct region of the electromagnetic spectrum of the observed spectral lines?

	Lyman Series	Balmer Series	Paschen Series
A	infra red	infra red	visible light
B	infra red	visible light	ultra violet
C	ultra violet	visible light	infra red
D	ultra violet	infra red	visible light

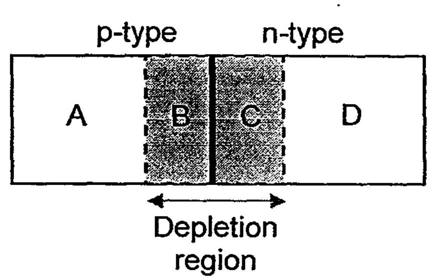
35 The following graph shows the spectrum of X-rays emitted from an X-ray tube.



If the potential difference between the target and cathode is increased, while keeping the current in the X-ray tube constant, which of the following combinations represents a possible change in wavelength and intensity of the **spikes**?

	wavelength	intensity
A	remain the same	increase
B	decrease	remain the same
C	remain the same	remain the same
D	decrease	increase

36 A p-n junction in equilibrium is shown in the diagram below.



Which of the following statements is false?

A The depletion region increases when a negative potential is applied at region A and a positive potential is applied at region D.

B Region B is negatively charged.

C The electric field in region A is towards the left.

D Under forward-bias, mobile electrons move from region D to region A.

37 Why is laser light monochromatic?

A The atoms in the laser medium are in a state of population inversion.

B The excited atoms in the laser medium are in a metastable state.

C Photons which trigger off stimulated emission produce more photons of the same energy.

D The photons produced by stimulated emission are reflected back by the use of reflecting mirrors in the laser system.

38 Which of the statements is correct for a p-type semiconductor?

A There are excess holes in the valence band.

B There are excess holes in the conduction band.

C There are excess electrons in the valence band.

D There are excess electrons in the conduction band.

39 In the Rutherford scattering experiment, most α-particles passed through the foil undeflected. Which one of the following is a correct conclusion from this result?

A The atom is overall neutral.

B The nucleus has a positive charge.

C Most of the mass of an atom is within the nucleus.

D The diameter of the nucleus is much less than the diameter of the atom.

40 The mass of a beryllium nucleus ($^{7}_{4}Be$) is $7.01473u$. The mass of a proton is $1.00728u$ while the mass of a neutron is $1.00867u$.

What is the binding energy per nucleon of this nucleus?

A 1.6 MeV

B 5.4 MeV

C 9.4 MeV

D 12.5 MeV

End of Paper

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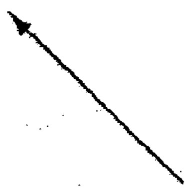
2016 JC2 Preliminary Examination
9646 H2 Physics Paper 1 Solutions

Qn	Ans	Suggested solution
1	**B**	$\Delta v = v + (-u)$ 
2	**D**	Using $R = \frac{\rho L}{A} = \frac{4\rho L}{\pi d^2}$ Error equation is given by $\frac{\Delta\rho}{\rho} = \left(\frac{\Delta R}{R}\right) + 2\left(\frac{\Delta d}{d}\right) + \left(\frac{\Delta L}{L}\right)$ Thus, $\frac{\Delta\rho}{\rho} = \left(\frac{1}{68}\right) + 2\left(\frac{0.1}{5.0}\right) + \left(\frac{1}{25}\right) = 0.0947$ ➔ $\Delta\rho = 0.5 \text{ x } 10^{-2}\ \Omega\text{ m (1 s.f.)}$ $\rho = (5.3 \pm 0.5) \text{ x } 10^{-2}\ \Omega\text{ m}$
3	**D**	Since terminal velocity is involved, there is significant air resistance acting on the object. The horizontal component of its velocity decreases in the 1st 3 seconds. The horizontal component of its acceleration is non-zero. The vertical component of its velocity increases in the 1st 3 seconds. Statement **D** is correct, since terminal velocity is constant.
4	**D**	$u_y = 3\text{ m s}^{-1}$ (upwards) Use $v_y^2 = u_y^2 + 2a_y s_y$ $= 3^2 + 2(-9.81)(-2.4)$ $v_y = -7.49\text{ m s}^{-1}$ (7.49 downwards) $v_x = u_y = 5\text{ m s}^{-1}$ $v = \sqrt{(7.49)^2 + 5^2} = 9\text{ m s}^{-1}$
5	**C**	When the ball is in contact with the surface, resultant vertical force = 0 When it leaves the surface, resultant vertical force = W
6	**B**	For elastic collision, the relative speed of approach = relative speed of separation Taking rightwards as positive, Relative speed of approach $u_1 - u_2 = 5 - (-2) = 7\text{ m s}^{-1}$ = relative speed of separation $(v_2 - v_1)$

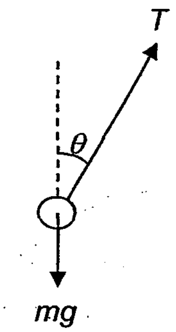
PHYSICS DEPARTMENT
2016 JC2 Preliminary Examination
9646 H2 Physics Paper 1 Solutions

Qn	Ans	Suggested solution
7	C	Before the pivots are translated, taking moments about pivot Y, $\left(\frac{L}{4}\right)W = \left(\frac{L}{2}\right)F_x \rightarrow F_x = \frac{W}{2}$ After the pivots are translated, taking moments about pivot Y, $\left(\frac{L}{4}+\frac{L}{8}\right)W = \left(\frac{L}{2}\right)F_x' \rightarrow F_x' = \frac{3W}{4}$ Thus, increase in the contact force acting on the plank by support X $= F_x' - F_x = \frac{W}{4}$
8	B	Only options B and D have resultant force. Taking moments about the centre of the circle, Only options A, B and C have resultant torque.
9	B	All the input energy is converted into useful energy in the form of heat in the heater
10	A	Efficiency of motor = rate of work done in lifting load / input power $0.2P = \frac{mgh}{t} = mgv$ $0.2(9.6) = 0.50(9.81)v$ $v = 0.39 \text{ m s}^{-1}$
11	B	The average random kinetic energy of a gas molecule, $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ $\Rightarrow \sqrt{\langle c^2\rangle} = \sqrt{\frac{3kT}{m}}$ Since $pV \propto T$, the final temperature will be 3 times the initial temperature. $\Rightarrow \frac{c_{rms}'}{c_{rms}} = \frac{\sqrt{3T}}{\sqrt{T}}$ $\Rightarrow c_{rms}' = \sqrt{3}v$
12	D	$pV = nRT \rightarrow \frac{1}{p} = \frac{V}{nRT}$ Hence, graph of $1/p$ vs V: gradient = $\frac{1}{nRT}$ In original graph, gradient = 0.4 / 4 = 0.1. Hence, when n and T are doubled, gradient of new graph = $\frac{1}{4}$ x gradient of original graph = 0.025.

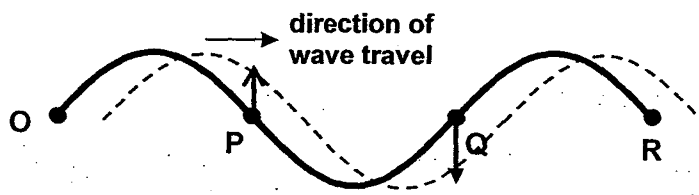
PHYSICS DEPARTMENT
2016 JC2 Preliminary Examination
9646 H2 Physics Paper 1 Solutions

Qn	Ans	Suggested solution
13	D	Thermal energy supplied $Q = Pt = mc\Delta\theta$ $\Rightarrow 1000 \times 180 = 1.5 \times c \times (357 - 300)$ $\Rightarrow c = 2100$ J kg^{-1} K^{-1}
14	C	$V = E - Ir$ gradient $= -r = \dfrac{3.4-1.6}{0.9-2.4} = -1.2$ $r = 1.2\ \Omega$
15	D	Resistance is defined as the ratio V/I, and not the inverse-gradient of the I-V graph. The resistance at various points on an I-V graph may either be found by calculating the values of V/I at the particular point or finding the inverse-gradient of the straight line drawn from origin to that point. At about 1.2 V, the I-V graphs for the diode and filament lamp intersect. Hence, they will have the same value of V/I or resistance. **[B]** is incorrect, as the ratio V/I changes even though it is a straight line graph after 0.8 V. This is because the straight line does not begin from the origin. **[C]** is incorrect as the resistance of the filament is half that of the resistor's at 1.0 V
16	A	$P_A = \dfrac{120^2}{R} \Rightarrow R_A = 14.4\ \Omega$ $P_B = \dfrac{240^2}{R} \Rightarrow R_B = 57.6\ \Omega$ Since in series circuit, current must be the same across the 2 bulbs. Bulb B will be brighter since it has higher power dissipation $P = I^2R$ (i.e. higher resistance.)
17	C	**A** At balance point, the p.d. between AB has the same magnitude as the p.d. between CD, not current. **B** The circuit containing E_2, R and r_2 is closed and hence current flows through CD. **D** If r_2 is zero, p.d. between CD is higher (= E_2). To balance, p.d. between AB must also increase. Hence balance length AB will be longer.
18	B	At the top, the resultant force = $mg + T_1 = mr\omega^2 \rightarrow T_1 = mr\omega^2 - mg$ (1) At the bottom, the resultant force = $T_2 - mg = mr\omega^2 \rightarrow T_2 = mr\omega^2 + mg$ (2) (2) – (1): $T_2 - T_1 = 2mg$

PHYSICS DEPARTMENT
2016 JC2 Preliminary Examination
9646 H2 Physics Paper 1 Solutions

Qn	Ans	Suggested solution
19	**D**	Resolve vertically, $T\cos\theta = mg$ (1) Resolve horizontally, $T\sin\theta = mr\omega^2$ (2) From (1): $T = \dfrac{mg}{\cos\theta}$ From (2): $T = \dfrac{mr\omega^2}{\sin\theta}$ 
20	**D**	$\dfrac{GM_PM_Q}{L^2} = M_PR\omega^2 = M_Q(L-R)\omega^2$ A: Centripetal force on P. B: Centripetal force on Q. C: These centripetal forces are provided by gravitational force between P and Q.
21	**B**	X: $a = \dfrac{GM}{R^2} = \dfrac{G\rho\left(\frac{4}{3}\pi R^3\right)}{R^2} = \dfrac{4G\rho R}{3}$ Y: $a_Y = \dfrac{4G(2\rho)(2R)}{3} = \mathbf{4a}$
22	**B**	Work done on electron = Fs = area under F-x graph = gain in KE = loss in EPE $= (0.20 \times 10^{-12})(3-1) \times 10^{-3}$ $= 4.0 \times 10^{-16}$ J Change in electric potential energy is **negative**.
23	**C**	A: not necessary, as long as the upper plate is at a higher potential than the lower plate. B, C, D: the field is uniform, so the force acting on a proton anywhere in the field is the same.
24	**A**	Acceleration of the bouncing ball is not directly proportional to displacement, moreover, there is no equilibrium point. For all other options, acceleration is directed towards the equilibrium point, and value changes with displacement. (For SHM, $a = -\omega^2x$)

PHYSICS DEPARTMENT
2016 JC2 Preliminary Examination
9646 H2 Physics Paper 1 Solutions

Qn	Ans	Suggested solution
25	D	At equilibrium points, velocity is maximum. At amplitude, velocity is zero.  P is on its way upwards, hence velocity is positive. Q is on its way downwards, hence velocity is negative.
26	A	At the open ends, the particle is at the anti-node i.e. greatest amplitude When the particle is at the node, it is permanently at rest and its adjacent particles move towards it simultaneously.
27	C	$d\sin\theta = n\lambda$ 400 lines per mm implies that distance between lines = $\frac{1}{400}$ mm d = 0.0025 mm = 2.5 x 10^{-6} m $2.5\times10^{-6}\sin\theta = 2(6\times10^{-7})$ $\sin\theta = \frac{2(6\times10^{-7})}{2.5\times10^{-6}}$=0.48 $\theta = 28.7^{o}$
28	A	Use Fleming's Left Hand Rule, direction of force is perpendicular to current and B-field.
29	C	Currents travelling in conductors in opposite direction causes repulsion. Since current is sinusoidal, the force should also be sinusoidal. Since it consistently repels, the force should always be positive or negative (depending on the sign convention used). **Option A** suggests that sometimes it repels, sometimes attracts, due to a change in signs for *F*.
30	C	**The iron core should be removed from coil 2** as the soft iron core reinforces the *B*-field created by coil 1 linking through coil 2. By removing the soft iron core from coil 2, the *B*-field experienced by coil 2 is reduced, thus the induced e.m.f will also drop in magnitude. **R_1 should be increased** to reduce the current flowing through coil 1, thus reducing the strength of the *B*-field generated by coil 1.
31	D	$\Delta\Phi = N\,\Delta B\,A$ = (120)[(–80 – 80) × 10^{-3}](0.070) = –1.344 Wb $\varepsilon = -\frac{\Delta\Phi}{t} = -\frac{-1.344}{4.0}$ = 0.336 V

PHYSICS DEPARTMENT
2016 JC2 Preliminary Examination
9646 H2 Physics Paper 1 Solutions

Qn	Ans	Suggested solution
32	B	$\frac{V_p}{V_s}=\frac{N_p}{N_s}$ → $V_P=\frac{N_pV_s}{N_s}=\frac{(100)(2000)}{500}=$ **400 V** $V_pI_p=P$ → $I_p=\frac{P}{V_p}=\frac{2000}{400}=$ **5.0 A**
33	B	Supply current $I=\frac{P}{V}=\frac{2000}{240}=8.33$ A Power loss = $I^2R=(8.33)^2(1.5\times10^3)=$ **1.04×10^5 W**
34	C	Lyman Series has the highest energy, highest frequency and shortest wavelength, ultra-violet. Paschen series has the lowest energy, lowest frequency and longest wavelength, infra-red. Balmer Series is in between the two above, visible light.
35	A	Wavelength corresponding to the spikes depends on the target atoms. Hence no change in the wavelength. Since the overall power ($P = VI$) of the electrons beam increases, the overall power of X-ray photons released will increase. Hence intensity increases.
36	C	A: true. Under reverse-bias, depletion region increases. B: true, when mobile electrons diffuse from n-type to p-type. C: false. There is no field in region A, it is neutral. D: true. Under forward-bias, mobile electrons move from n- to p-type.
37	C	Monochromatic mean 'one colour' which implies one frequency.
38	A	Holes in valence band serve as mobile charge carriers.
39	D	A: then all and not most α-particles would be undeflected. B: then there should be deflection by electric repulsion. C: then the α-particles would rebound upon collision.
40	B	${}^{7}_{4}Be$ has 4 protons and 3 neutrons. Its mass defect, $m = 4(1.00728) + 3(1.00867) - 7.01473 = 0.0404u$ Its binding energy, $E = mc^2 = (0.0404)(1.66\times10^{-27})(3.00\times10^8)^2 = 6.036\times10^{-12}$ J $E=\frac{6.036\times10^{-12}}{1.6\times10^{-13}}=37.7$ MeV Its binding energy per nucleon $=\frac{37.7}{7}=$ **5.4 MeV**

2016 JC2 Preliminary Examination

Name		Class	16S

PHYSICS **9646/02**

Higher 2

Structured Questions **26 August 2016**

1 hour 45 min

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

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your **name** and **class** in the spaces provided at the top of this page.

Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use highlighters, glue or correction fluid.

There are **seven** questions in this paper.
Answer **all** questions.

At the end of the examination, fasten all your work securely together.

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

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
Total	

Data

speed of light in free space, $c = 3.00 \times 10^{8}\ \text{m s}^{-1}$

permeability of free space, $\mu_o = 4\pi \times 10^{-7}\ \text{H m}^{-1}$

permittivity of free space, $\varepsilon_o = 8.85 \times 10^{-12}\ \text{F m}^{-1} = (1/(36\pi)) \times 10^{-9}\ \text{F m}^{-1}$

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

displacement of particle in s.h.m., $x = x_o \sin \omega t$

velocity of particle in s.h.m., $v = v_o \cos \omega t$

$v = \pm \omega \sqrt{(x_o^2 - x^2)}$

mean kinetic energy of a molecule of an ideal gas $E = \frac{3}{2}kT$

resistors in series, $R = R_1 + R_2 + \ldots$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = \frac{Q}{4\pi\varepsilon_o r}$

alternating current / voltage, $x = x_o \sin \omega t$

transmission coefficient, $T \propto \exp(-2kd)$

where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$

radioactive decay $x = x_o \exp(-\lambda t)$

decay constant $\lambda = \frac{0.693}{t_{1/2}}$

1. **(a)** Discuss whether the resultant force on a body may or may not be in the same direction as its acceleration.

____

____

____ [1]

(b) A car is travelling along a road that has a uniform downhill gradient as shown in Fig. 1.1.

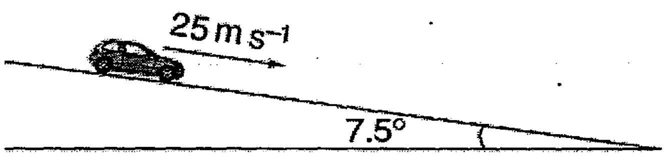


Fig. 1.1

The car has a total mass of 850 kg. The angle of the road to the horizontal is 7.5°. The car is travelling at a constant speed of 25 m s^{-1}.

(i) The driver then applies the brakes to reduce its speed to 12.5 m s^{-1}. The constant stopping force, *F* resisting the motion of the car is 1620 N.

1. Show that the deceleration of the car with the brakes applied is 0.63 m s^{-2}.

[2]

2. Calculate the distance that the car travels during the deceleration to a speed of 12.5 m s^{-1}.

distance = ______________ m [2]

(ii) Having descended the slope, the car travels along a horizontal straight section of the road at a speed of 12.5 m s^{-1}. In order to stop the car completely, the brakes are applied again so that the stopping force *F*, increases steadily to a maximum and then decreases to zero as shown in Fig. 1.2.

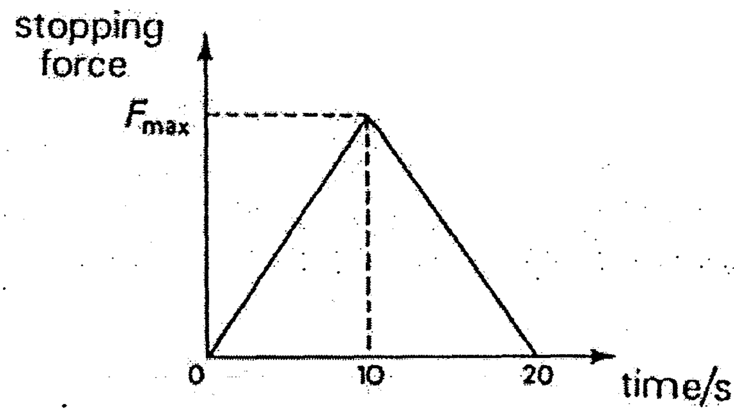


Fig. 1.2

Calculate

1. the change in momentum of the car between t = 0 s and t = 20 s,

change of momentum = ____________________ N s [1]

2. the value of F_{max}.

F_{max} = ____________________ N [2]

3. On Fig. 1.3, sketch a graph to show the variation with time, t of the velocity, v of the car.

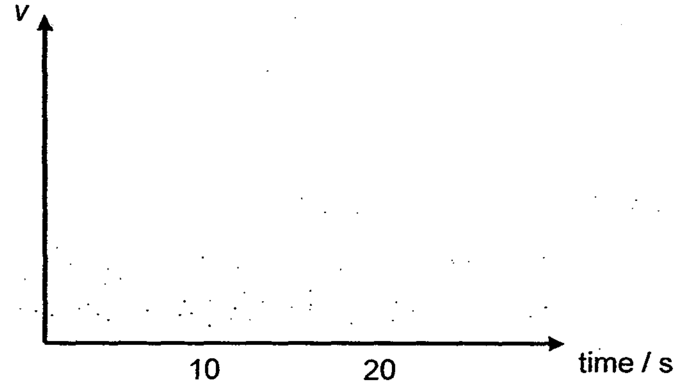


Fig. 1.3

[2]

(iii) Explain why the braking process in **(b)(ii)** would seem to a driver to be a more gentle stop than the braking process in **(b)(i)** with a constant force F for the same duration that the force is exerted.

____

____

____

____ [2]

2. Fig. 2.1 shows a kitchen cupboard securely mounted to a vertical wall. The cupboard rests on a support at **A**.

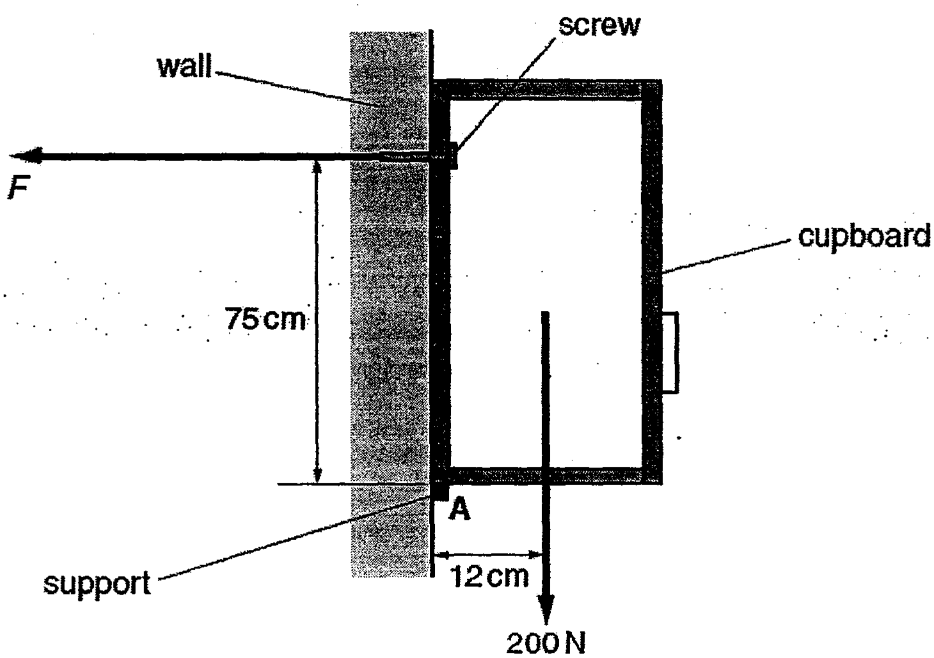


Fig. 2.1

The total weight of the cupboard and its contents is 200 N. The line of action of its weight is at a distance of 12 cm from **A**. The screw securing the cupboard to the wall is at a vertical distance of 75 cm from **A**.

(a) The direction of the force *F* provided by the screw on the cupboard is horizontal. Show that *F* is 32 N.

[1]

(b) **(i)** On Fig. 2.1, sketch the force provided by the support on the cupboard. Label this force *R*. [1]

(ii) Hence or otherwise, determine the magnitude of R.

$R =$ ______________ N [2]

(c) State and explain how your answer to **(b)(ii)** would change, if at all, if the cupboard is empty.

____

____

____

____ [2]

3. **(a)** State the *First Law of Thermodynamics.*

____

____

____ [2]

(b) 0.20 moles of an ideal gas is trapped in a closed cylinder sealed by a piston at an initial temperature of 300 K and initial pressure p. The gas undergoes a cycle of changes **A** → **B** → **C** → **A** as shown in Fig. 3.1 below.

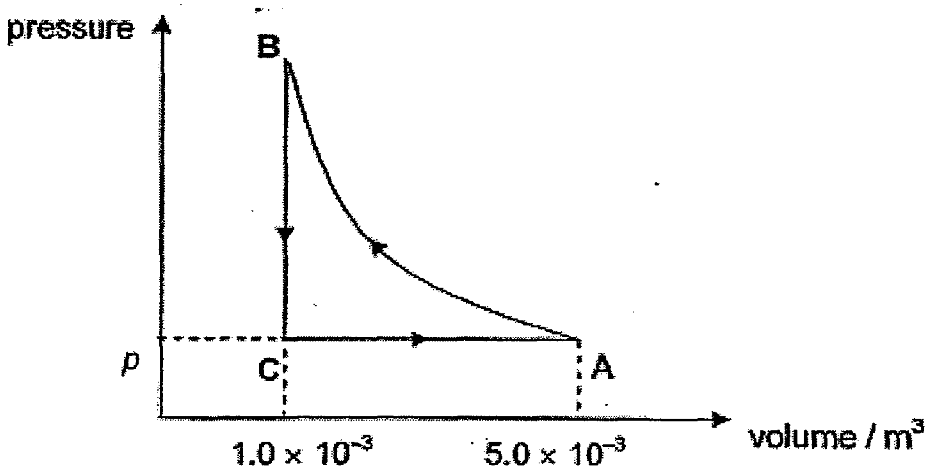


Fig. 3.1

From **A** to **B**, the gas is compressed isothermally at a temperature of 300 K during which 800 J of work is done on the gas.

From **B** to **C**, the gas is cooled at a constant volume of 1.0×10^{-3} m^3 till its pressure returns to p.

From **C** to **A**, the gas expands at constant pressure p.

(i) Calculate the pressure p.

pressure p = ______________ Pa [2]

(ii) State and explain whether the temperatures at **A** and **C** are the same.

____

____

____

____ [2]

(iii) Calculate the work done on the gas during the change from **C** to **A**.

work done on the gas = ______________ J [2]

(iv) Calculate the net heat supplied to the gas in one complete cycle.

net heat supplied to the gas = ______________ J [2]

4. **(a)** In order to investigate the photoelectric effect, a student set up the apparatus illustrated in Fig. 4.1. When the potential difference V is varied it is found that the photoelectric current varies as shown by curve A in Fig. 4.2.

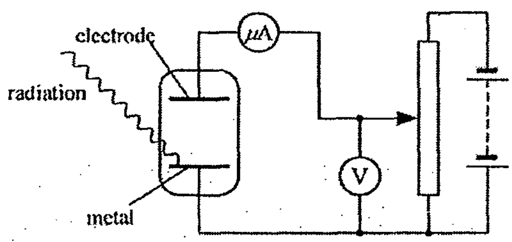


Fig. 4.1

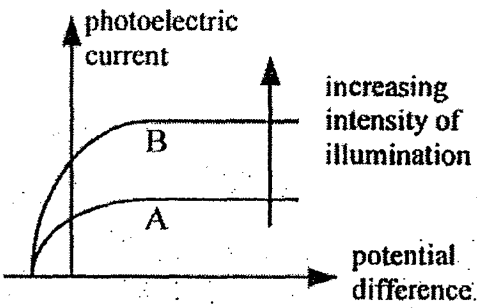


Fig. 4.2

(i) Explain why, for curve A, the photoelectric current reaches a maximum value no matter how large V is made.

____

____

____

____

____ [2]

(ii) The intensity of illumination is then increased and the experiment repeated to obtain curve B.

Explain why the maximum photoelectric current is increased.

____

____

____

____

____ [2]

(b) In a photoelectric emission experiment, light of wavelength 410 nm was shone on a metal surface of work function energy of 2.0 eV so that an area of 24 mm^2 was illuminated. A photocurrent of 4.8×10^{-10} A was observed.

Determine

(i) the rate of emission of photoelectrons,

rate of emission = ______________ s^{-1} [1]

(ii) the intensity of the light source, assuming that 1 in 2500 photons succeeds in ejecting an electron from the surface.

intensity = ______________ $W\ m^{-2}$ [3]

5. Strontium-90 decays with the emission of a β-particle to form Yttrium-90. The decay is represented by the equation

$$^{90}_{38}Sr \rightarrow\ ^{90}_{39}Y +\ ^{0}_{-1}e + 0.55\ \text{MeV}$$

The half-life of Strontium-90 is 27.7 years.

(a) Define *half-life*.

____

____

______________________________________ [1]

(b) What is meant by *binding energy* of a nucleus?

____

____

______________________________________ [1]

(c) Suggest, with a reason, which nucleus $^{90}_{38}Sr$ or $^{90}_{39}Y$ has a greater binding energy.

____

____

______________________________________ [2]

(d) At the time of purchase of a Strontium-90 source, the activity is 3.7×10^6 Bq. Calculate, for this sample of Strontium,

(i) the initial number of atoms,

initial number of atoms = ________________ [2]

(ii) the initial mass,

initial mass = ______________ kg [2]

(iii) $\frac{A}{A_o}$, where A is the activity of the sample 5.0 years after purchase and A_o is the initial activity.

$\frac{A}{A_o}$ = ______________ [2]

6. For thousands of years, Man has studied the night sky and some ancient buildings provide evidence of careful and patient astronomical observations by people of many different cultures. As instrumentation has improved, so has the precision with which astronomical observations could be made. Between 1576 and 1597, Brahe made comprehensive observations of planetary positions and, on his death, these records became available to Kepler.

Kepler was able to interpret the observations and deduced three laws, one of which had a great impact on latter discoveries. He deduced that, for a circular orbit of a planet around the Sun of mass M, if T is the period of orbit and r is the radius of the orbit, then

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

As a result of Kepler's work, Newton formulated the law of gravitation.

(a) By relating the gravitational force on a planet to the centripetal acceleration it causes, show that, for a circular orbit,

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

[2]

(b) The planet Jupiter has a number of moons. Data for some of these are given in Fig. 6.1.

Moon	Period T / days	mean distance from centre of Jupiter r / 10^9 m	$\log_{10}$ (T / days)	$\log_{10}$ (r / m)
Sinope	758	23.7	2.88	10.37
Leda	239	11.1	2.38	10.05
Callisto	16.7	1.88		
Lo	1.77	0.422		
Metis	0.295	0.128	–0.53	8.11

Fig. 6.1

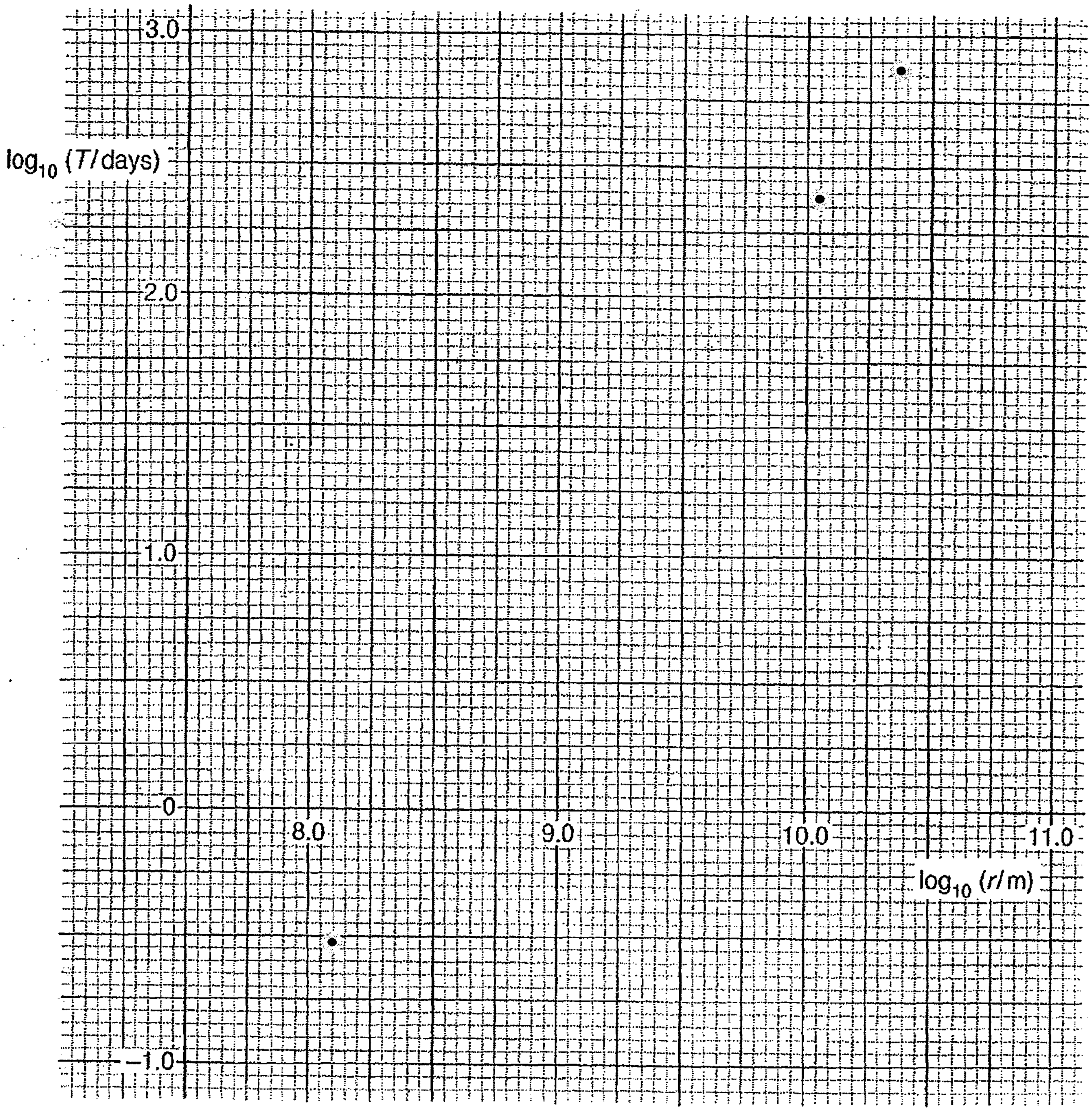


Fig. 6.2

(i) Complete Fig. 6.1 by calculating values for $\log_{10}$ (*T*/days) and $\log_{10}$ (*r*/m).

[1]

(ii) On the axes of Fig. 6.2, plot a graph of $\log_{10}$ (*T*/days) against $\log_{10}$ (*r*/m).

[2]

(c) **(i)** Determine the gradient of the graph in Fig. 6.2.

gradient = ______________ [2]

(ii) Hence discuss whether the data in Fig. 6.1 support the relation given in **(a)**.

____

____ [2]

(d) Observations show that the moon Ganymede orbits Jupiter with a period of 7.16 days. Use the graph of Fig. 6.2 to estimate the orbital radius of Ganymede.

orbital radius = ______________ m [2]

(e) It was reported in a newspaper that the moon Thebe has been discovered which orbited Jupiter every 16.2 hours at a height of 222 thousand kilometres above its surface. Comment on the accuracy of this statement.

[2]

(f) Suggest whether the graph of Fig. 6.2 could be used to check data on the orbital radii and periods of the moons of another planet (e.g. Saturn).

[1]

It is recommended that you spend about 30 minutes on this question.

7 Fig. 7.1 illustrates a bow used in archery competitions.

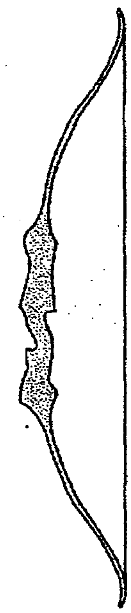


Fig. 7.1

A designer of bows is attempting to maximise the efficiency of his bow. This means that as much of the potential energy stored in the bow as possible is converted to the kinetic energy of an arrow.

Some preliminary experiments are carried out with the bow when the centre of the string is moved through a distance *x* by a force *F* as shown in Fig. 7.2.

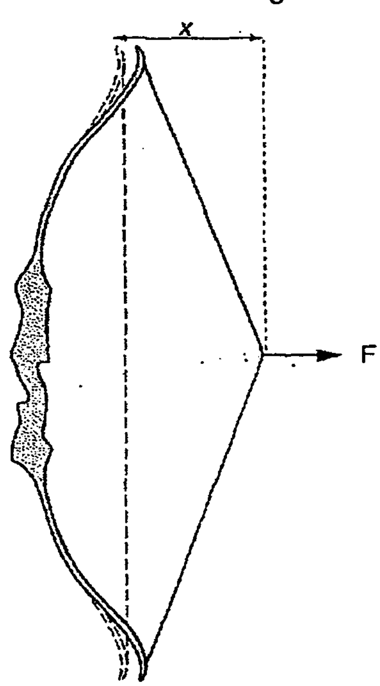


Fig. 7.2

These experiments indicate that x is not proportional to F.

The efficiency of the bow may be defined as

$$\text{efficiency} = \frac{\text{kinetic energy of an arrow}}{\text{potential energy of the bow}}$$

Design a laboratory experiment to investigate how the efficiency varies with the distance x moved by the centre of the string.

You should draw diagram(s) to show the arrangement of your apparatus. In your account, you should pay attention to

(a) the identification and control of variables,

(b) the equipment you would use,

(c) the procedure to be followed,

(d) determine the potential energy stored in the bow just before the arrow is released,

(e) determine the kinetic energy of the arrow after the string is released,

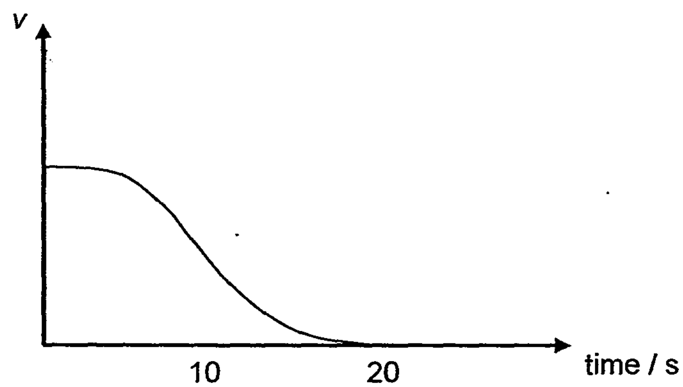
(f) any precautions that you would be taken to improve the accuracy and safety of the experiment.

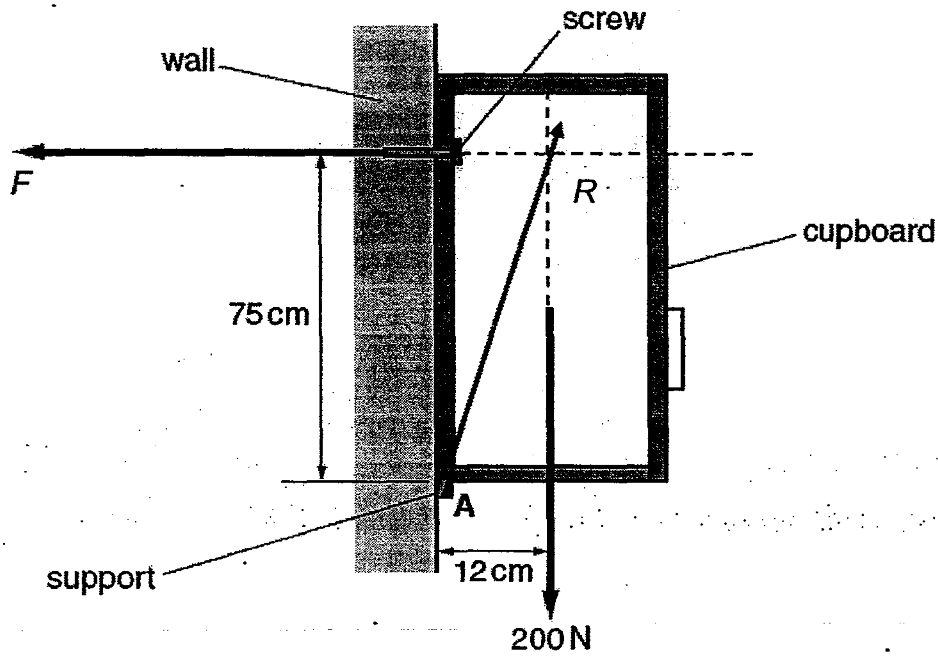
Diagram

[12]

End of Paper

PHYSICS DEPARTMENT
2016 JC2 Preliminary Examination
9646 H2 Physics Paper 2 Suggested Solutions

Qn	Suggested solution	Remarks
1(a)	Based on Newton's 2nd law of motion, the resultant force **must be in the same direction** as its acceleration because the **change of momentum occurs in the direction of the resultant force.**	[1]
(b)(i)1.	$F_R = 1620 - (850)(9.81)(\sin 7.5^o) = 531.6$ N By Newton's 2nd law of motion, $a = \frac{F}{m} = \frac{531.6}{850} = 0.63\ m\ s^{-2}$	[1] – ans [1] – sub
2.	$v^2 = u^2 + 2as$ $s = \frac{12.5^2 - 25^2}{2(-0.63)}$ $= 372\ m$	[1] – sub [1] – ans
(ii)1.	$\Delta p = mv - mu$ $= 850(0 - 12.5) = -1.06 \times 10^4\ Ns$	[1] – ans
2.	$\Delta p = \int F\ dt$ $1.06 \times 10^4 = \frac{1}{2} F_{max}(20)$ $F_{max} = 1060\ N$	[1] – sub [1] – ans
3.		[1] – shape For 0-10s, 10s-20s [-1] – start/end line not horizontal
(iii)	The braking process in **(b)(ii) gradually decreases from a maximum to zero** whereas the braking process **in (b)(i) is constant and decreases to zero abruptly** at the end of the journey.	[1] [1]
2(a)	Taking moments about A, $F = \frac{200(12)}{75} = 32$ N	[1] – sub

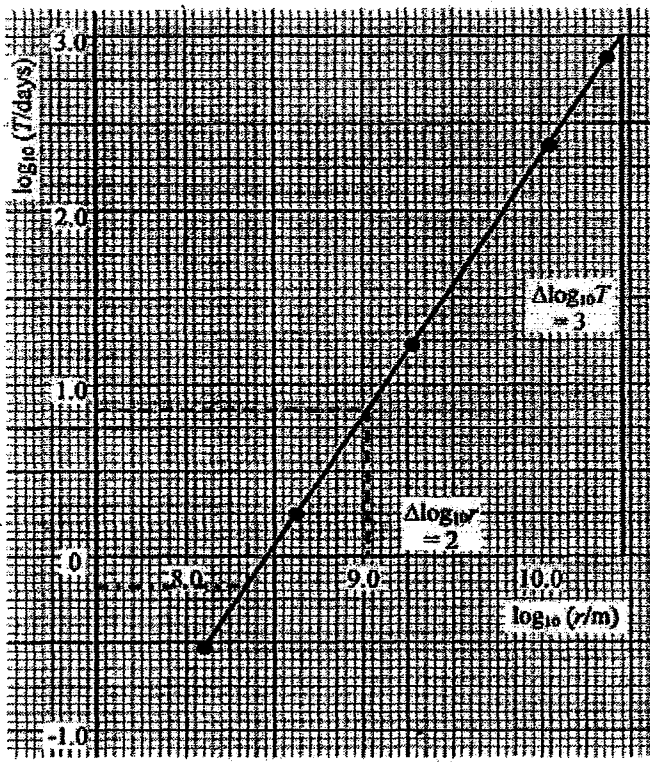
(b)(i)		**[1]**
(ii)	$R_x = F = 32$ N $R_y = W = 200$ N $R = \sqrt{32^2 + 200^2}$ $= 203$ N	**[1] – sub** **[1] – ans**
(c)	The **force R will decrease** in order to balance the **decrease in the clockwise moment due to the weight of the cupboard.**	**[1]** **[1]**
3(a)	The First Law of Thermodynamics states that the **increase** in internal energy of a system is equal to the sum of heat supplied **to** the system and work done **on** the system.	**[2] or zero**
(b)(i)	Using $pV = nRT$ $p = \frac{nRT_A}{V_A} = \frac{0.20 \times 8.31 \times 300}{5.0 \times 10^{-3}} = 9.97 \times 10^4$ Pa	**[1] sub** **[1] ans**
(ii)	The temperature at **A** and **C** is **not the same.** The product of pV at **A** and **C** are not same. $p \times 1.0 \times 10^{-3} \neq p \times 5.0 \times 10^{-3}$	**[1] state** **[1] expl**
(iii)	Work done by gas = $p\,\Delta V$ $= \mathbf{9.97 \times 10^4 \times (5.0 \times 10^{-3} - 1.0 \times 10^{-3})}$ $= 399$ J ∴ Work done on the gas = – **399 J**	**[1] sub** **[1] ans**
(iv)	$\Delta U = Q + W$ $\mathbf{0 = Q + (800 - 399)}$ $\Rightarrow \mathbf{Q} = -401$ J Heat supplied to the gas = – **401 J**	**[1] sub** **[1] ans**
4(a)(i)	Electrons emitted from the metal will be collected at electrode for positive values of V. **Since the number of electrons emitted per unit time is constant** (intensity remains constant), **the rate of flow of electrons is constant** thus current does not continue to increase. **The increase in *V* only increases the acceleration of the electrons** but not its rate of emission from the metal.	**[1]** **[1]**
(ii)	The **maximum photoelectric current is dependent on the rate of emission of photoelectrons, which is dependent on the rate of incidence of photons. This would depend on the intensity of the radiation.**	**[1]** **[1]**

(b)(i)	The current, $I = ne$ where n = number of photoelectrons emitted per second → $n = \frac{I}{e} = \frac{4.8\times10^{-10}}{1.6\times10^{-19}}$ = **3.0×10^9 s^{-1}**	[1] - ans
(ii)	The intensity, $i = \frac{Nhf}{A}$ where N = number of photons incident per second = 2500n and A = area illuminated → $i = \frac{Nhc}{A\lambda} = \frac{2500(3.0\times10^{9})(6.63\times10^{-34})(3.0\times10^{8})}{(24\times10^{-6})(410\times10^{-9})}$ = **0.152 W m^{-2}**	[1] - N relate to n [1] - sub [1] - ans
5(a)	**Half-life** of a radioactive nuclide is defined as the **average** time taken for half of the original number of radioactive **nuclei** in a sample to decay.	[1]
(b)	**Binding energy of a nucleus** is the **minimum** energy required to break the nucleus into its individual nucleons.	[1]
(c)	$^{90}_{39}Y$ has a greater binding energy. There is a **release of energy**, so the product has greater binding energy (more stable).	[1] [1]
(d)(i)	$\lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{27.7(365)(24)(3600)}$ = **7.93×10^{-10}** s^{-1} $A = \lambda N$ → $N = \frac{A}{\lambda} = \frac{3.7\times10^{6}}{7.93\times10^{-10}}$ = **4.66×10^{15}**	[1] - λ value [1] - ans
(ii)	90 g of strontium contains 6.02×10^{23} atoms. mass of this sample of strontium = $\frac{4.66\times10^{15}}{6.02\times10^{23}}(90 \times 10^{-3})$ = **6.97×10^{-10} kg**	[1] - sub [1] - ans
(iii)	Number of half-live, $n = \frac{5}{27.7} = 0.18$ $\frac{A}{A_o} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^{0.18}$ = **0.88**	[1] - sub [1] - ans
6(a)	**Gravitational force** acting on the planet provides the **centripetal force** necessary for the planet to move in a circular orbit. $\frac{GMm}{r^2} = mr\omega^2$ $\frac{GM}{r^3} = \left(\frac{2\pi}{T}\right)^2$ $\frac{GM}{r^3} = \frac{4\pi^2}{T^2}$ $T^2 = \frac{4\pi^2 r^3}{GM}$	[1] - concept [1] - working

(b)(i)

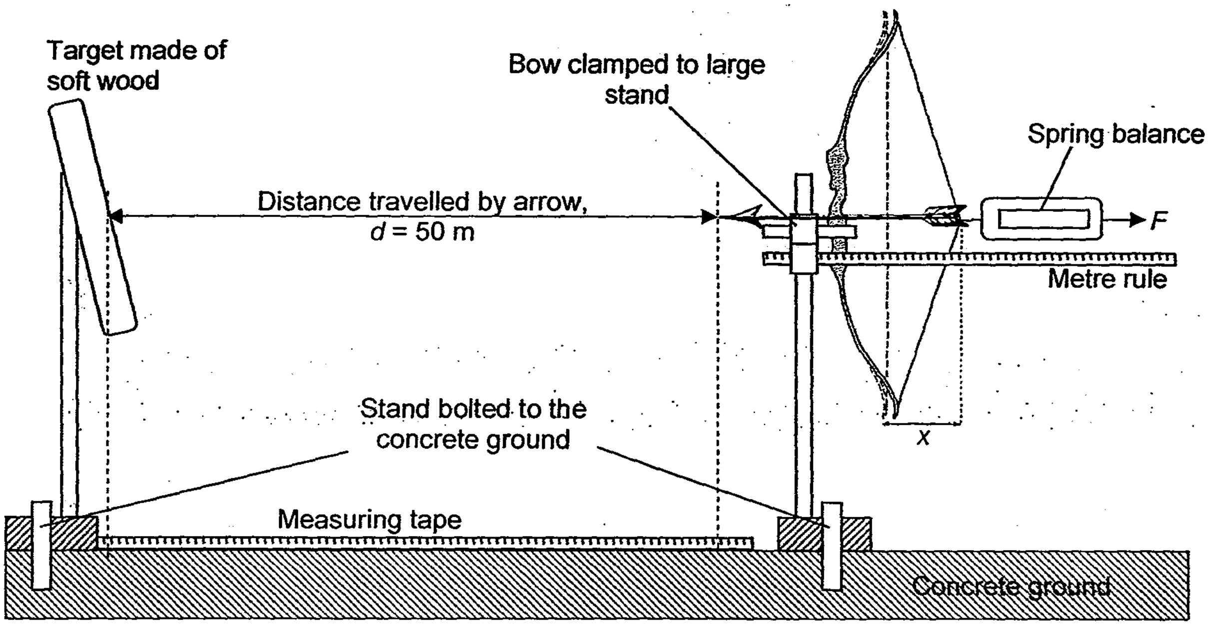
Moon	Period T/days	mean distance from centre of Jupiter r / 10^9 m	$\log_{10}$ (T/days)	$\log_{10}$ (r/m)
Sinope	758	23.7	2.88	10.37
Leda	239	11.1	2.38	10.05
Callisto	16.7	1.88	**1.22**	**9.27**
Lo	1.77	0.422	**0.25**	**8.63**
Metis	0.295	0.128	-0.53	8.11

All correct values [1]

(ii)		**[1] All points plotted correctly.** **[1] best fit line**
(c)(i)	Gradient of the graph = $\frac{3.0-0.0}{10.45-8.45}=1.5$	**[1] sub** **[1] ans**
(ii)	The **data support the relation** in (a). From $T^2=\frac{4\pi^2 r^3}{GM}$ Let $k=\frac{4\pi^2}{GM}$ which is a constant $T^2 = kr^3$ $2\lg T = \lg k + 3\lg r$ $2\lg T = 3\lg r + \lg k$ $\lg T = 1.5 \lg r + \frac{1}{2}\lg k$ ----- (1) Since a straight line graph is obtained and the gradient of the graph is equal to 1.5 which is consistent with the equation (1), thus the data support the relation in (a).	**[1] ans** **[1] expl**
(d)	Given period T = 7.16 days, $\Rightarrow \lg(7.16)$ = **0.85.** From the graph, $\lg r$ = 9.025 Thus the orbital radius of Ganymede = $10^{9.025}$ = **1.06 x 10^9 m**	**[1] value** **[1] ans**
(e)	Given period T = 16.2 hours = 0.675 days $\Rightarrow \lg(0.675)$ = -0.17 From the graph, $\lg r$ = 8.35 Thus the orbital radius of Thebe = $10^{8.35}$ = 2.24 x 10^8 m Thus the distance from the centre of the Jupiter to Thebe is 224 thousand kilometres instead of the same distance above the surface of the Jupiter. The statement is **inaccurate**.	**[1] working** **[1] statement**
(f)	The graph of Fig. 6.2 **cannot** be used to check data on the orbital radii and periods of the moons of another planet such as Saturn because it's **mass is different** from the mass of Jupiter.	**[1]**

Suggested solution to Planning

Diagram :



Variables:

Independent variable: **distance, *x***

Dependent variable: ***efficiency, η***

Controlled variables: 1. Point of application of the pulling force

2. Mass of arrow

Procedures:

1. Set up the apparatus as shown in the diagram.

(Type of <u>apparatus</u> used to measure/ vary the variables)

2. The **distance *x*** is measured using a **<u>metre rule</u>** which is clamp horizontally next to the bow for easy measurement.
3. The **force *F*** required to stretch the string a distance *x* is measured using a **<u>spring balance / newtonmeter</u>** by hooking it to the middle of the string and pulling on it.
4. The **distance *d*** travelled by the arrow to the target is set at 50 m, measured using a **<u>measuring tape</u>**. This distance is measured from the tip of the arrow to the middle of the target.
5. The mass of the arrow, *m*, is measured using a mass balance.
6. The **time taken *t*** for the arrow to travel distance *d* is measured using a **<u>stopwatch</u>**.

7. To calculate the potential energy of the bow E_p:
   a. Starting from a small value of x, stretch the string of the bow, and record x.
   b. Measure force F using the spring balance and record F.
   c. Repeat (a) and (b) for increasing values of x.
   d. Plot a graph of F against x, and draw the best fit curve.
   e. The potential energy E_P of the bow when the string is stretched a distance x is given by, E_P = area under the F-x graph.

(How to vary and measure the independent variable)

8. Mount the arrow in the bow and pull the string back a distance x.
9. Measure and record the value of x.

(Measuring/ Calculating the dependent variable)

10. Aim the arrow at the centre of the target and release the arrow. Measure and record the time of flight t.
11. Repeat steps (8) to (10) to obtain an average value of t.
12. Calculate the speed of the arrow, $v = \frac{\text{distance}}{\text{time}} = \frac{d}{t_{average}}$.
13. Calculate the kinetic energy of the arrow, $E_K = \frac{1}{2}mv^2$. Record this value.
14. Calculate the potential energy E_P of the bow. Record this value.
15. Calculate the efficiency of the bow, $\eta = \frac{E_K}{E_P}$.
16. Repeat steps (8) to (15) using other values of x.

Analysis

1. Assume that η and x are related by the equation : $\eta = kx^n$
2. $\lg \eta = n \lg x + \lg k$
3. Plot a graph of $\lg \eta$ against $\lg x$.
4. The relationship is valid if a straight line graph is obtained, where n = gradient of the graph and $\lg k$ = intercept.

Safety Precautions

1. Ensure that the shooting area is cleared of people before shooting the arrow.
2. Wear protective eye-wear and arm guards in case the string breaks.
3. Arrow should be aimed only at target.
4. Target should be made from soft materials such as cork or Styrofoam to reduce chances of arrows being deflected in other directions.

Steps taken to produce reliable results

1. Distance from the arrow to the target, d should be large, i.e. greater than 25 m, to ensure the time of flight t is adequately long to be measured on a stopwatch with acceptable percentage uncertainty.
2. Perform the experiment in an enclosed area with no wind or neglect measurements if wind is detected during experiment.

Suggested mark scheme to Planning Question

Diagram		**[1]**
Good choice of apparatus and a clearly labeled diagram.		
- Bow properly clamped at the centre to a fixed object/mass - Labelled distance travelled by arrow to target - Position of centre of bow and target should be about the same height	**D1**	
Procedure		**[6]**
Mention of apparatus used for different measurement / Determination of kinectic energy and stored potential energy		
- Force ***F*** is measured using newton meter / spring balance and pulled horizontally.	**P1**	
- Distance ***x*** is measured with a metre rule	**P2**	
- Measure ***d*** using measuring tape and time ***t*** using stopwatch	**P3**	
- Measure mass of error ***m*** using electronic balance	**P4**	
- Determine kinetic energy of arrow, $E_K = \frac{1}{2}mv^2$ and $v = \frac{\text{distance}}{\text{time}} = \frac{d}{t_{average}}$.	**P5**	
- Determine stored potential energy E_P = area under ***F-x*** graph **[Do not accept answers based on Hooke's law]**	**P6**	
Control of variables		**[1]**
1. Point of application of the pulling force	**C1**	
2. Mass of arrow		
Note: **minus [1]** if dependent or independent variable is stated wrongly		
Analysis		**[1]**
- details of derived quantities to be calculated. Plot lg η vs lg x, y-intercept = lg k, gradient = n must be included to be awarded [1] mark	**A1**	
Safety Precaution		**[1]**
1. Ensure that the shooting area is cleared of people before shooting the arrow.		
2. Wear protective eye-wear and arm guards in case the string breaks.	**S1**	
3. Arrow should be aimed only at target.		
4. Target should be made from soft materials such as cork or Styrofoam to reduce chances of arrows being deflected in other directions.		

Any additional details		[2]
1. Distance from the arrow to the target, *d* should be large, i.e. greater than 25 m, to ensure the time of flight *t* is adequately long to be measured on a stopwatch with acceptable percentage uncertainty.	**AD1**	
2. Perform the experiment in an enclosed area with no wind or neglect measurements if wind is detected during experiment.	**AD2**	

2016 JC2 Preliminary Examination

Name		Class	16S

PHYSICS **9646/03**

Higher 2

Longer Structured Questions **13 September 2016**

2 hours

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

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your **name** and **class** in the spaces provided at the top of this page.

Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use paper clips, highlighters, glue or correction fluid.

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

Section A
Answer **all** questions.

Section B
Answer any **two** questions.

You are advised to spend about one hour on each section.

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

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
Total	

Data

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

Formulae

uniformly accelerated motion,	s	$= ut + \frac{1}{2}at^2$
	v^2	$= u^2 + 2as$
work done on/by a gas,	W	$= p\,\Delta V$
hydrostatic pressure,	p	$= \rho gh$
gravitational potential,	ϕ	$= -\dfrac{Gm}{r}$
displacement of particle in s.h.m.,	x	$= x_o \sin \omega t$
velocity of particle in s.h.m.,	v	$= v_o \cos \omega t$
	v	$= \pm \omega \sqrt{(x_o^2 - x^2)}$
mean kinetic energy of a molecule of an ideal gas	E	$= \frac{3}{2}kT$
resistors in series,	R	$= R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	$= 1/R_1 + 1/R_2 + \ldots$
electric potential,	V	$= \dfrac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	$= x_o \sin \omega t$
transmission coefficient,	T	$\propto \exp(-2kd)$ where $k = \sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay	x	$= x_o \exp(-\lambda t)$
decay constant	λ	$= \dfrac{0.693}{t_{1/2}}$

Section A

Answer **all** the questions in this Section.

1. Fig. 1.1 below shows a frictionless toy runway. Upon release from point A, Car 1 of mass 0.100 kg travels down a slope, and moves round a loop of radius r = 0.25 m, passing through points B and C.

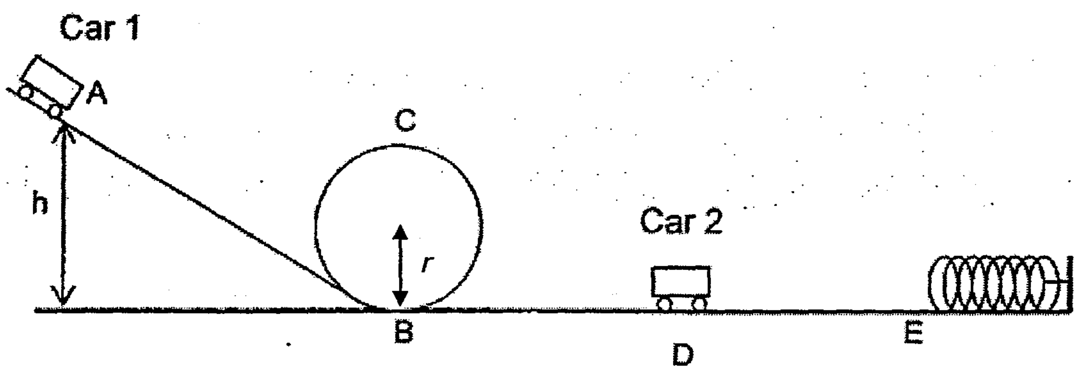


Fig. 1.1 (not drawn to scale)

(a) Show that the minimum speed of Car 1 at point C in order to stay in contact with the runway is 1.6 m s^{-1}.

[2]

(b) Hence or otherwise, calculate the minimum height h at point A in order for Car 1 to remain in contact with the runway at point C.

h = ________________ m [2]

(c) Car 1 moves down the loop and travels at constant speed at 3.5 m s^{-1} from point B towards a stationary Car 2 of mass 0.080 kg at point D. It collides head-on with Car 2 at point D.

Upon collision, the two cars stick together and continue to travel towards point E at speed v until it is stopped by a spring buffer of force constant 120 N m^{-1}.

Determine

(i) the speed v,

v = ______________ m s^{-1} [2]

(ii) the maximum compression of the spring buffer when the cars collide into it.

maximum compression = ______________ m [2]

(d) State and explain how the answer in **(c)(ii)** will change if the runway from points D to E is not smooth.

____

____

____ [1]

2. (a) Define *electric potential.*

____

____

____ [1]

(b) Two point charges P and Q, each of mass m = 24.5 g are separated by a horizontal distance of 30 mm as shown in Fig. 2.1. P has a charge of +40 μC and Q has a charge of –40 μC.

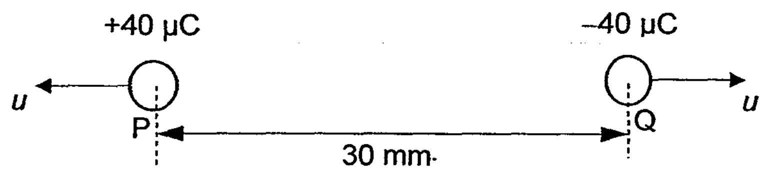


Fig. 2.1

(i) The horizontal distance from P towards Q is r. On Fig. 2.2, sketch the variation with r of the electric potential V due to both point charges P and Q.

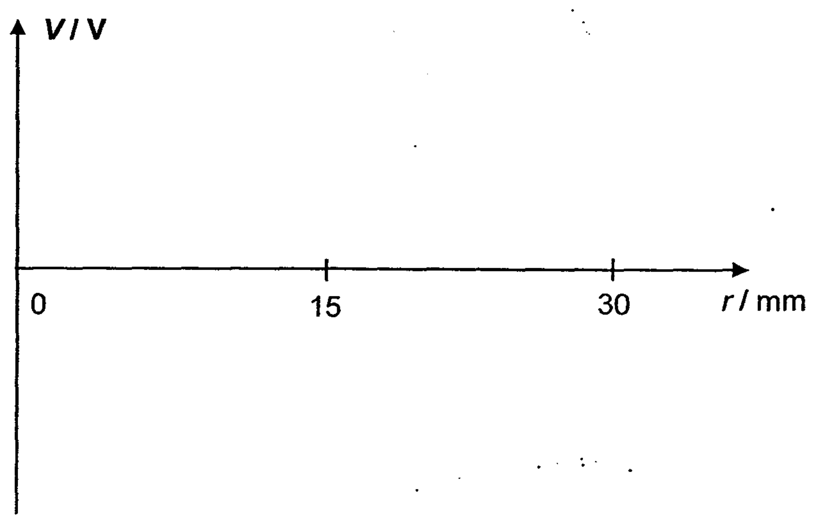


Fig. 2.2

[2]

(ii) Charges P and Q are projected away from each other with an initial speed *u* so that they eventually just reach infinity.

Determine

1. the initial electric potential energy of Q,

Electric potential energy = ____________________ J [2]

2. the initial speed *u*.

u = ____________________ m s^{-1} [2]

3. Railgun is researched as a weapon that would rely on electromagnetic forces to launch a projectile to very high kinetic energy.

The railgun is basically a large electric circuit, made up of three parts: a power source, a pair of parallel conducting rails and a movable conducting projectile as shown in Fig. 3.1.

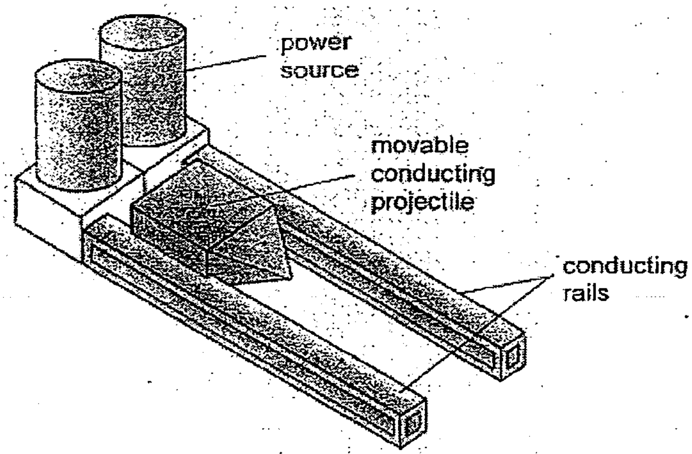


Fig. 3.1

When a potential difference of 1.0 kV is applied, a current I of 56 kA passes through the rail.

I will flow from the power supply to the positive rail, across the projectile of negligible resistance and back to the power supply through the negative rail as shown in Fig. 3.2.

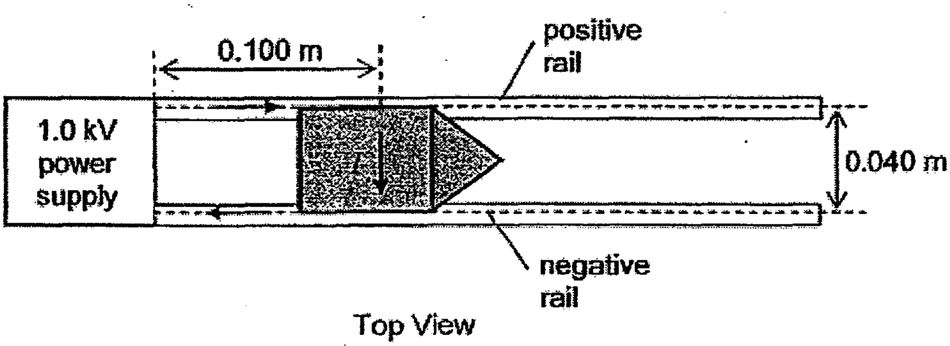


Fig. 3.2

(a) With reference to Fig. 3.2,

(i) show that the resistance of the rails is 0.018 Ω.

[1]

(ii) state the direction of the resultant magnetic field (due to the current) through the projectile.

____ [1]

(b) The resultant magnetic field at the centre of the projectile is 1.12 T and is assumed to be uniform throughout the projectile. As a result, a magnetic force F is exerted on the projectile.

(i) Determine F.

F = ______________ N [2]

(ii) State and explain whether F would be higher or lower in practice as the projectile travels along the rail.

____

____

____

____ [2]

(iii) State the direction of F if the direction of the current is reversed.

____ [1]

(iv) Explain one way in which F can be increased.

____

____

____

____ [1]

4. **(a)** State the laws of electromagnetic induction.

____

____

____

____

____ [2]

(b) Define the weber.

____

____

____ [1]

(c) A magnet is suspended vertically from a fixed point by means of a spring, as shown in Fig. 4.1.

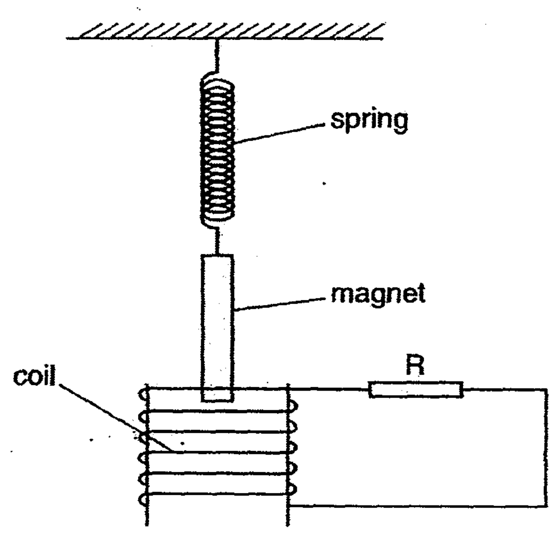


Fig. 4.1

One end of the magnet hangs inside a coil of wire. The coil is connected in series with a resistor R.

The magnet is displaced vertically downward a small distance D and then released. Fig. 4.2 shows the variation with time t of the vertical displacement d of the magnet from its equilibrium position.

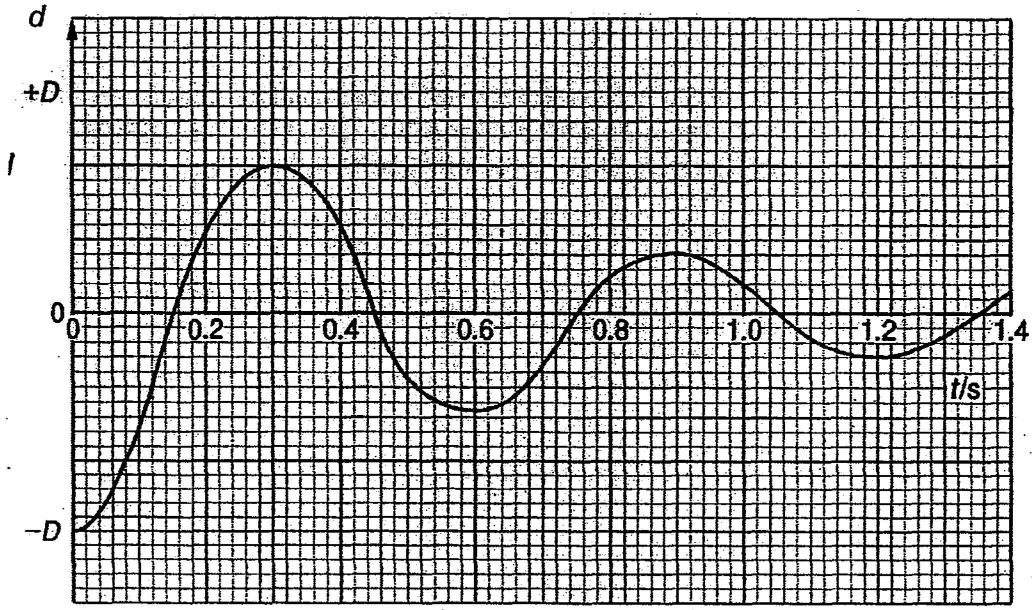


Fig. 4.2

(i) State whether the damping of the magnet is light, heavy or critical.

______________________________ [1]

(ii) Use the laws of electromagnetic induction to explain why the oscillations are damped.

____

____

____

____

____

____

______________________________ [3]

(iii) The resistance of the resistor R is increased. The magnet is again displaced a vertical distance D and released. On Fig. 4.2, sketch the variation with time t of the displacement d of the magnet. [1]

(d) The resistor *R* in Fig. 4.1 is removed, and the opening ends are connected to the circuit in Fig. 4.3, which consists of a 2.0 kΩ resistor, a diode and an oscilloscope. The initial r.m.s. current through the 2.0 kΩ resistor is 5.0 mA. Assume the oscilloscope has infinite resistance.

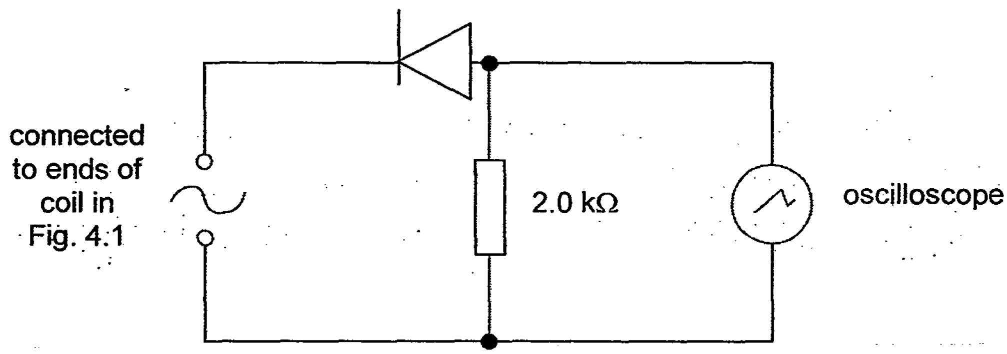


Fig. 4.3

(i) What is meant by *r.m.s. current*?

____

____

____ [1]

(ii) Calculate the initial peak value of the voltage across the 2.0 kΩ resistor.

Initial peak voltage = ______________ V [3]

5 **(a)** Explain what is meant by population inversion and why it is an essential condition in laser production.

[2]

(b) "In an n-type semiconductor, there are excess electrons forming the sea of electrons, thus making the n-type semiconductor negatively charged."

State and explain why the above statement is inappropriate.

[2]

Section B

Answer **two** questions from this Section.

6 **(a)** Define resistance of a resistor.

____

____

____ [1]

(b) A wire with a resistance of 6.0 Ω is stretched so that its new length is three times its original length.

Assuming that the resistivity and density of the material are not changed during the stretching process, calculate the resistance of the longer wire.

resistance = ______________ Ω [3]

(c) The circuit shown in Fig. 6.1 is constructed of resistors, each of which has a maximum safe power rating of 0.40 W.

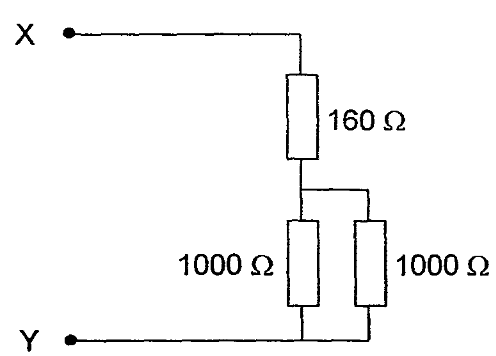


Fig. 6.1

(i) Determine the maximum potential difference that can be applied between X and Y without damage to any of the resistors.

maximum potential difference = ... V [3]

(ii) If this potential difference was exceeded, explain which resistor(s) would be most likely to fail first.

....

....

.... [2]

(d) A student investigated how the resistance R of a small semiconductor device X varies with Celsius temperature θ. Fig. 6.2 shows the variation with temperature θ of resistance R.

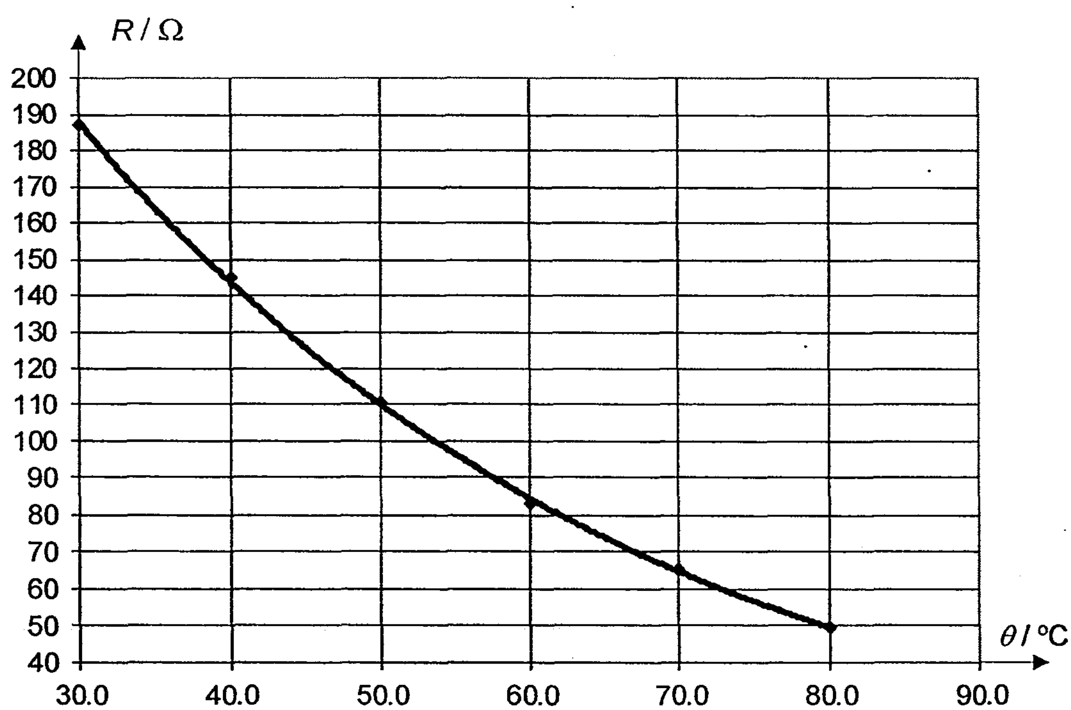


Fig. 6.2

(i) Device X is assumed to conform to a relationship of the form

$$R = Ae^{\frac{B}{T}}$$

where A and B are constants, T represents the thermodynamic temperature.

Calculate a value for A and for B by using values of R corresponding to temperatures of 50.0 °C and 80.0 °C.

A = ______________ Ω [2]

B = ______________ K [2]

(ii) Discuss a method of determining the values of A and B more reliably.

____

____

____ [1]

(e) In Fig. 6.3, sketch a graph of the current I through device X against the potential difference V across it.

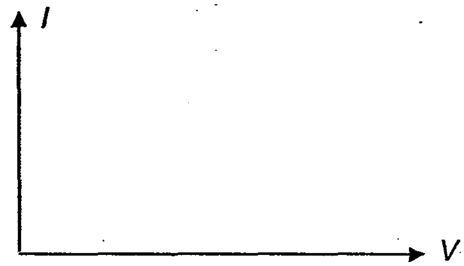


Fig. 6.3

[1]

(f) Device X is now connected to a fixed resistor of resistance 40.0 Ω and a 6.0 V battery of negligible internal resistance as shown in Fig. 6.4.

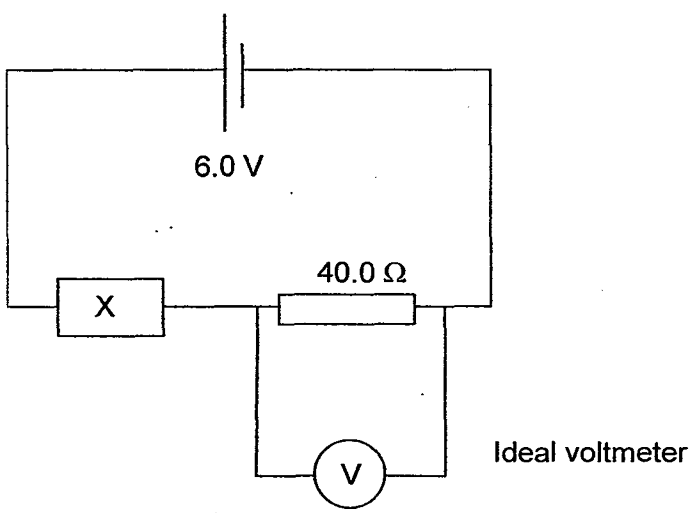


Fig. 6.4

(i) Calculate an estimated value of the voltmeter reading when device X is immersed in water at temperature 30.0 °C.

voltmeter reading V = ______________ V [2]

(ii) The device X is then allowed to heat up. State and explain whether the voltmeter reading would increase or decrease.

____

____

____ [2]

(iii) Suggest how the circuit in Fig. 6.4 can be modified so that a buzzer will sound when the temperature rises too high.

____

____ [1]

7 **(a)** Define *gravitational potential.*

[1]

(b) A certain planet has a radius of 1150 km. Fig. 7.1 below shows the variation with the distance r from the centre of this planet, of the gravitational potential ϕ near it.

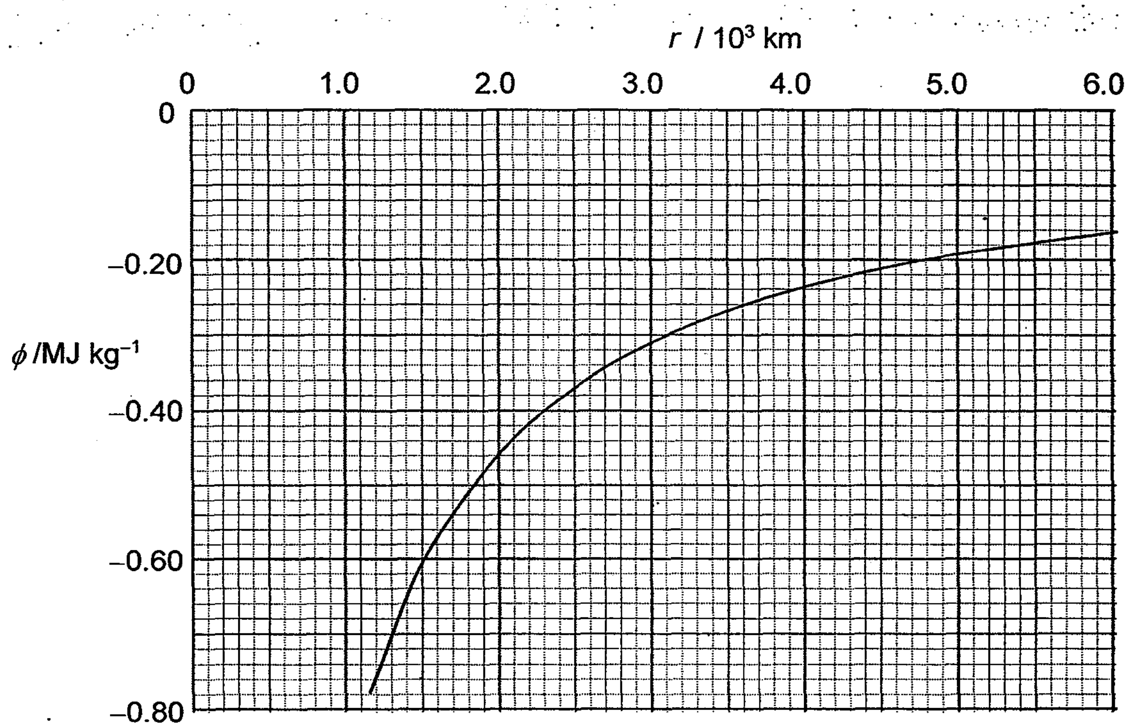


Fig. 7.1

(i) Explain why gravitational potential has a negative value.

[2]

(ii) The gradient of this graph represents the magnitude of a particular vector quantity. State the physical quantity.

[1]

(iii) Use Fig. 7.1 to determine the escape velocity for an object at the surface of the planet, which is the minimum speed required to launch it to infinity.

escape velocity = ... $m\ s^{-1}$ [2]

(c) A geostationary satellite orbits the Earth.

Explain why the satellite's orbit must lie in the plane of the equator.

....

....

....

....

.... [2]

(d) The satellite in **(c)**, of mass 1500 kg, orbits the Earth in a circle of radius r with period T. It is known that the two quantities are related by the equation

$$T = Ar^n$$

The Earth has a mass of 6.0×10^{24} kg and a radius of 6.4×10^6 m.

(i) Determine the values of n and A.

Include appropriate units, if any, with your values.

n = ...

A = ... [4]

(ii) Calculate the distance of the orbit from the *surface* of the Earth.

distance = ... m [2]

(iii) Calculate the total energy of the satellite in orbit.

total energy = ______________ J [2]

(iv) Hence, or otherwise, determine the minimum energy required to put this satellite into orbit.

energy = ______________ J [3]

(v) Suggest why, in practice, most satellites are launched near the equator.

____

____ [1]

8 **(a)** The human ear is the organ for hearing and balance. It consists of three parts – the outer ear, the middle ear and the inner ear, as shown in Fig. 8.1.

Sound waves travel through the outer ear, impacts on the eardrum and causes it to vibrate.

This question deals with some of the physics of the human ear and some properties of sound waves which is a longitudinal progressive wave.

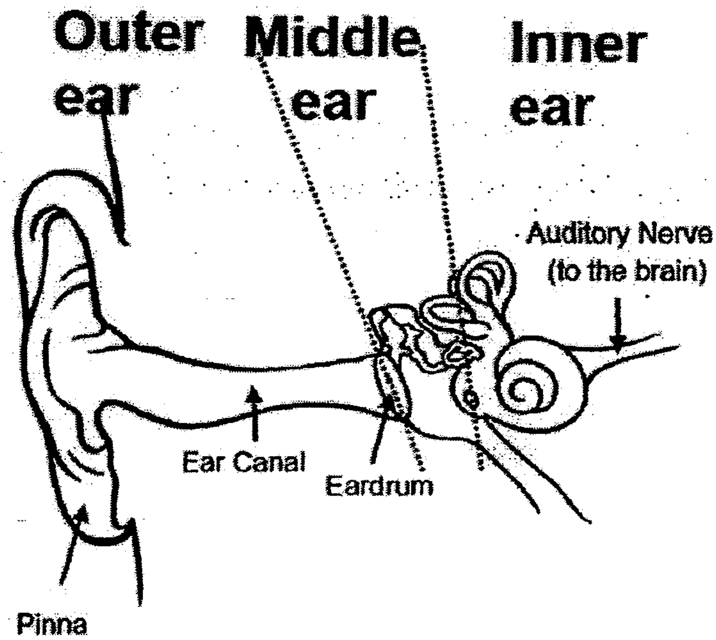


Fig. 8.1

A given sound wave striking the eardrum sets it oscillating in simple harmonic motion. The eardrum oscillates at a frequency of 2500 Hz with amplitude of 1.0×10^{-7} m.

(i) Explain the term *longitudinal progressive* wave.

____

____

____ [1]

(ii) Calculate the period of the oscillation.

period = ______________ s [1]

(iii) On the axes of Fig. 8.2, draw a graph to show how the displacement of the eardrum varies with time for one oscillation. Assume that the displacement is zero at t = 0 ms. [2]

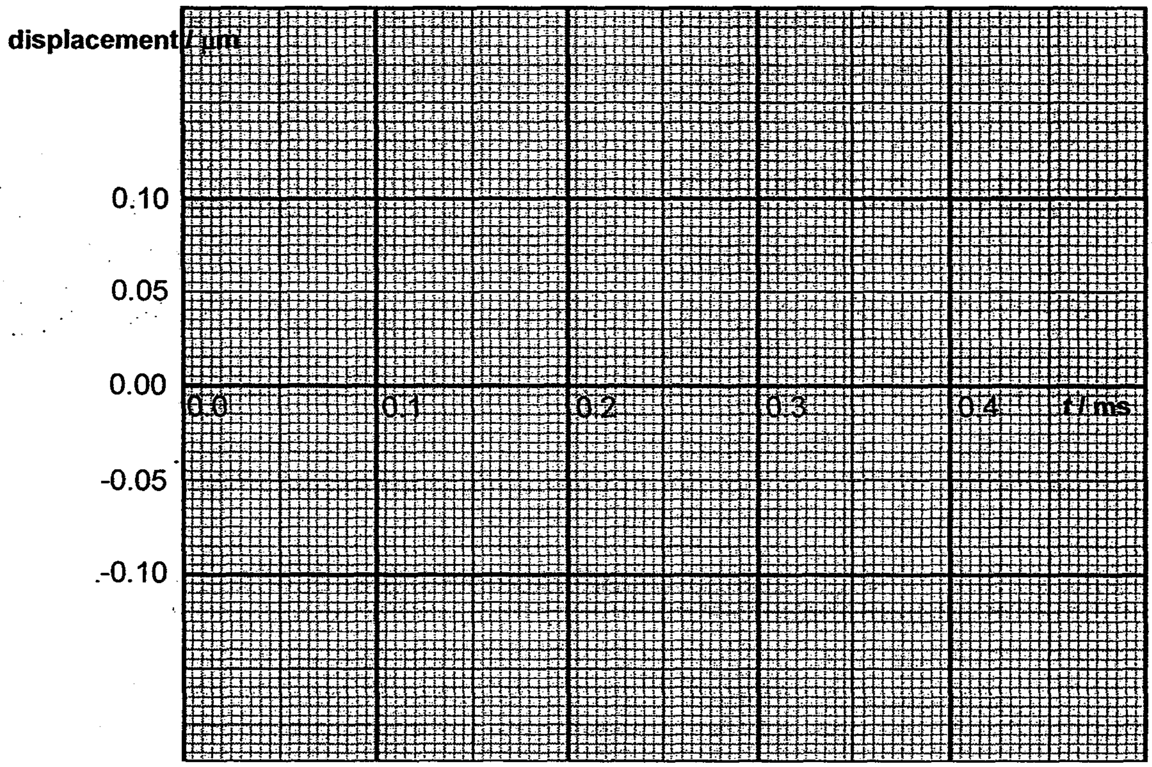


Fig. 8.2

(iv) Calculate the maximum velocity and maximum kinetic energy of the eardrum. You may assume that the mass of the eardrum is 1 g.

maximum velocity = ______________ m s^{-1} [2]

maximum kinetic energy = ______________ J [1]

(v) Mark, on the graph of Fig. 8.2, a point at which maximum acceleration occurs. Mark this point **A.** [1]

(vi) Mark, on the graph of Fig. 8.2, a point at which maximum velocity occurs. Mark this point **K.** [1]

(vii) The human ear is most sensitive to frequencies around 3000 Hz. This is because air in the ear *resonates* at this frequency.

Explain what is meant by *resonance* and describe how resonance allows the ear to respond to quieter sounds at around 3000 Hz than at other frequencies.

....

....

....

....

.... [2]

(b) Fig. 8.3 shows the variation with time t of the displacements x_A and x_B at a point P of two sound waves A and B.

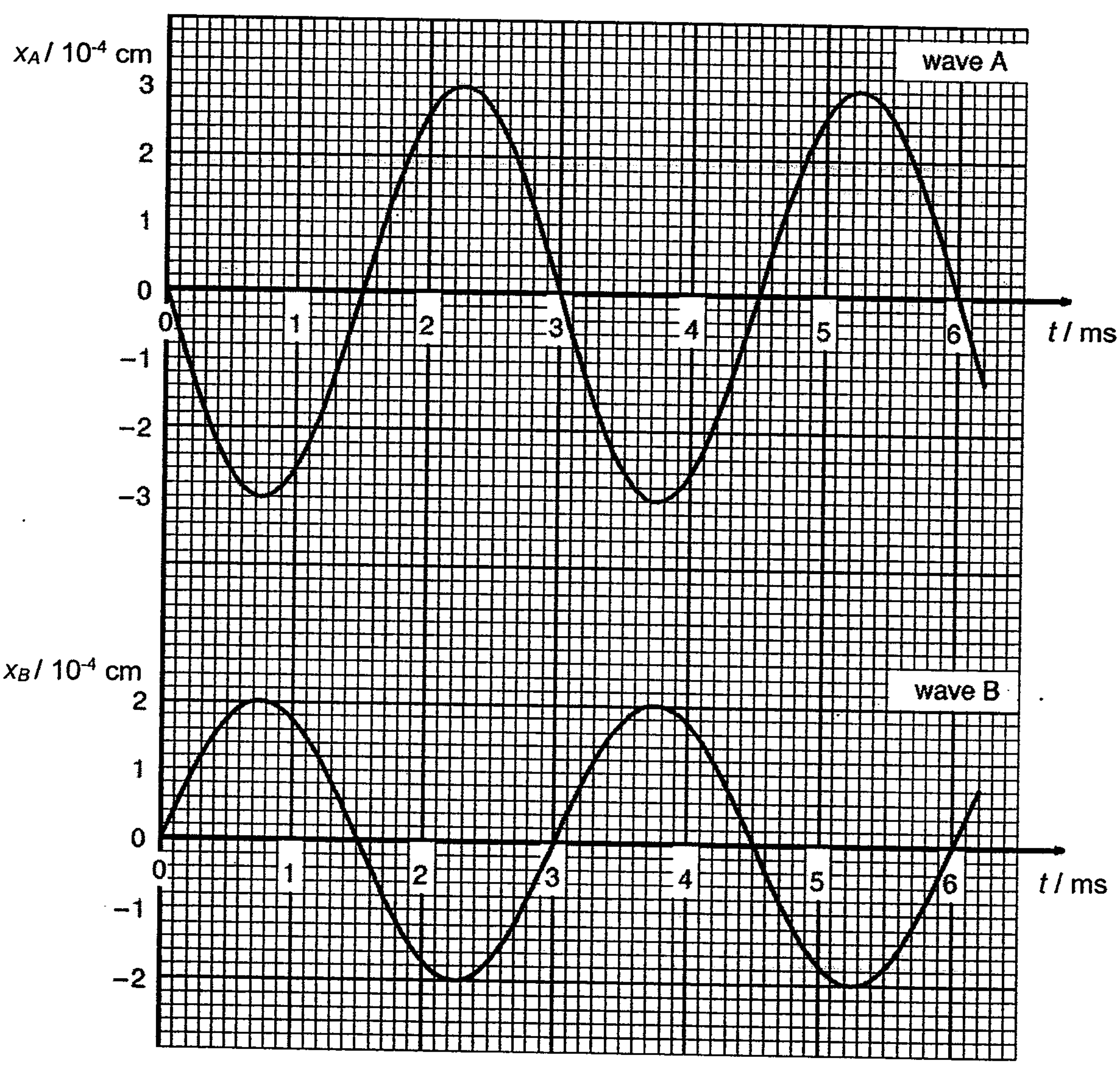


Fig. 8.3

(i) By reference to Fig. 8.3, state one similarity and one difference between these two waves.

Similarity: ____

____ [1]

Difference: ____

____ [1]

(ii) State, with a reason, whether the two waves are coherent.

____

____

____ [1]

(iii) The intensity of wave B alone at point P is I. Calculate the resultant intensity, in terms of I, of the two waves at point P.

resultant intensity = ______________ I [2]

(c) Fig. 8.4 shows two loudspeakers L_1 & L_2 that produced the two sound waves A and B as mentioned in **(b)** respectively.

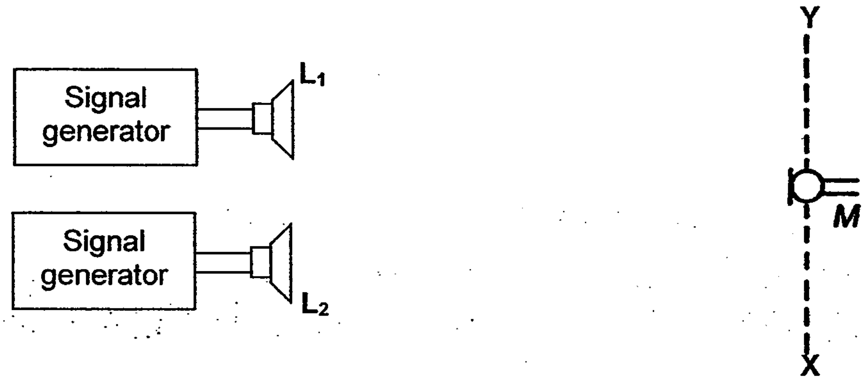


Fig. 8.4

(i) Describe and explain how the sound intensity detected by the microphone, M, changes as M moves slowly from **X** to **Y**.

____

____

____

____ [2]

(ii) Describe and explain any changes in the sound pattern along **XY** detected by the microphone M which would be brought by doubling the frequency of the sound from both signal generators.

____

____

____

____ [2]

End of Paper

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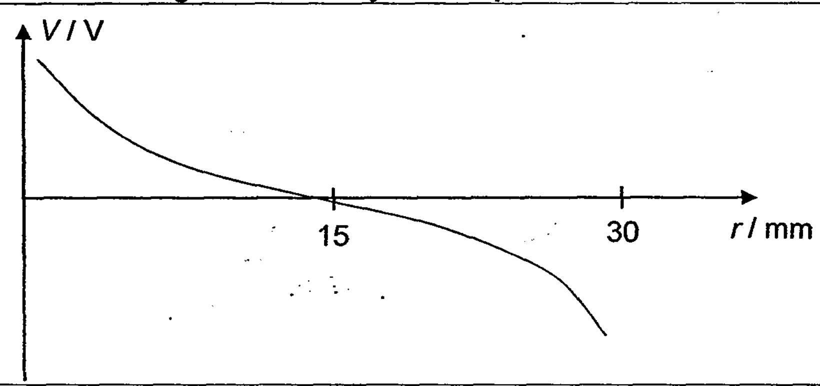
2016 JC2 Preliminary Examinations
9646 H2 Physics Paper 3
Suggested Solutions with Markers' Comments

Qn	Suggested solution	Remarks
1(a)	At point C, $N+mg=\frac{mv^2}{r}\rightarrow N=\frac{mv^2}{r}-mg$ **For the car to remain in contact with the runway, $N > 0$** $\frac{mv^2}{r}-mg\geq 0$ $v\geq\sqrt{gr}=\sqrt{(9.81)(0.25)}=1.6\text{ m s}^{-1}$	**[1] – principle** **[1] – sub**
(b)	By conservation of energy, $(0.100)(9.81)h-(0.100)(9.81)(0.50)=\frac{1}{2}(0.100)(1.6)^2-0$ $0.100(9.81)h-0.4905=0.128$ $h=0.63\text{ m}$	**[1] – sub** **[1] – ans**
(c)(i)	By conservation of momentum, $(0.100)(3.5)+0=(0.180)v_D$ $v_D=1.9\text{ m s}^{-1}$	**[1] – sub** **[1] – ans**
(ii)	By conservation of energy, $\frac{1}{2}(0.180)(1.944)^2-0=\frac{1}{2}(120)x^2$ $x=0.0753\text{ m}\approx 0.075\text{ m}$	**[1] – sub** **[1] – ans**
(d)	The compression will be **smaller** because **some of the kinetic energy of the cars is used to do work against friction.**	**[1]**
2(a)	Electric potential at a point is the **work done per unit positive charge to bring a small charge from infinity to that point.**	**[1]**
(b)(i)		**[1] – shape** **[1] – r - intercept**
(ii)1.	Electric potential energy $=\frac{Q_PQ_Q}{4\pi\varepsilon_o r}=-(9\times 10^9)\left(\frac{(40\times10^{-6})^2}{30\times10^{-3}}\right)$ **= – 480 J**	**[1] - sub** **[1] - ans**
2.	By conservation of energy, KE loss = EPE gain $\frac{1}{2}mu^2(2)-0=0-(-480)\rightarrow u^2=\frac{480}{m}\rightarrow u=\sqrt{\frac{480}{m}}=\sqrt{\frac{480}{24.5\times10^{-3}}}$ **= 140 m s^{-1}**	**[1] - sub** **[1] - ans**
3(a)(i)	$R=\frac{V}{}=\frac{1.0\times10^3}{}=0.018\ \Omega$	**[1]**

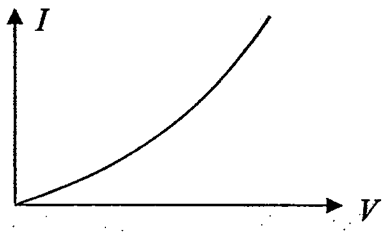
PHYSICS DEPARTMENT
2016 JC2 Preliminary Examinations
9646 H2 Physics Paper 3
Suggested Solutions with Markers' Comments

Qn	Suggested solution	Remarks
(ii)	**Into the page**	**[1]**
3(b)(i)	$F = BIL\sin 90^{\circ} = 1.12(56\times10^{3})(0.04)$ $= 2508.8$ $= 2500$ N	**[1] – Sub** **[1] – Ans**
(ii)	As the projectile travels along the rail, **resistance increases and current *I* decreases.** Therefore **force decreases.**	**[1]** **[1]**
(iii)	**To the right.**	**[1]**
(iv)	Use stronger current/voltage of the power supply OR Decrease resistance of track (includes increasing the cross-sectional area of the track).	**[1]**
4(a)	**Faraday's law** states that the **magnitude of induced e.m.f. in a coil is proportional to the rate of change of magnetic flux linkage** through that coil. **Lenz's law** states that the **direction of the induced e.m.f. opposes the change producing it.**	**[1]** **[1]**
(b)	**The weber** is the **magnetic flux through an area of one square metre if the flux density normal to the plane of the area is one tesla.**	**[1]**
(c)(i)	The oscillations are **lightly damped.**	**[1]**
(c)(i)	As the magnet moves, magnetic **flux linkage** through the coil is **changed.** From Faraday's law, an **e.m.f. is induced** in the coil. Since the **circuit is closed, a current flows.** From Lenz's law, the induced current **produces** a magnetic **force** on the magnet **opposing its motion.**	**[1]** **[1]** **[1]**
(ii)	The amplitude decreases more gradually, i.e. for each cycle, the amplitude is smaller than the existing ones.	**[1]**
(d)(i)	**Root-mean-square** current from an AC source is the **current which will produce the same heating effect in a resistive load as the steady current from a DC source.**	**[1]**
(ii)	For half-wave rectified AC, peak current $I_o = 2I_{rms} = 2(5.0\text{ mA}) =$ **10.0 mA** Peak voltage $V_o = I_o R = (10.0\text{ mA})(2.0\text{ k}\Omega)$ = **20.0 V**	**[1]** - I_o value **[1]** - sub **[1]** - ans
5(a)	**Population inversion** is a condition when there are **more atoms in a higher energy state than in the lower energy state.** This ensures that the **probability** that an incident photon will **stimulate emission exceeds the probability** that the photon will **be absorbed.**	**[1]** **[1]**
(b)	The semiconductor is **neutral**. When it is doped with Group V atoms, they are **neutral since the number of protons and electrons are the same.** The n-type semiconductors are doped with atoms of extra valency. As a result, electrons are the majority charge carriers.	**[1]** **[1]**
6(a)	**Resistance** of a resistor is defined as the **ratio** of the potential difference across it to the current flowing through it.	**[1]**

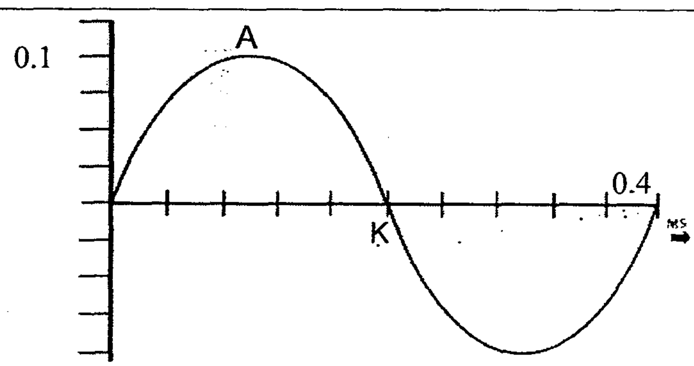
PHYSICS DEPARTMENT
2016 JC2 Preliminary Examinations
9646 H2 Physics Paper 3
Suggested Solutions with Markers' Comments

Qn	Suggested solution	Remarks
(b)	Volume $V = A \times l$ $\Rightarrow A = \frac{V}{l}$ Resistance, $R = \frac{\rho l}{A} = \frac{\rho l}{V/l} = \frac{\rho l^2}{V} = 6.0\ \Omega$ When the length is $3l$, new resistance $= \frac{\rho(3l)^2}{A} = \frac{\rho(9l^2)}{A} = 9\frac{\rho l^2}{A} = 9 \times 6.0 = 54\ \Omega$	**[1] exp** **[1] sub** **[1] ans**
(c)(i)	Maximum safe current passing through the 1000 Ω resistor, $I_{1000\Omega} = \sqrt{\frac{P}{R}} = \sqrt{\frac{0.40}{1000}}$ = 0.020 A Maximum safe current passing through the 160 Ω resistor, $I_{160\Omega} = \sqrt{\frac{P}{R}} = \sqrt{\frac{0.40}{160}}$ = 0.050 A Hence maximum safe current flowing through the circuit without damaging any of the resistor is $I_{max} = 0.020 + 0.020 = 0.040$ A Maximum safe potential difference applied between X and Y $V = 0.040 \times 160 + 0.020 \times 1000$ = 26.4 V	**[1] value** **[1] sub** **[1] ans**
(c)(ii)	One of the 1000 Ω resistors would be most likely to fail. When the maximum safe potential difference is exceeded, the current flowing in the circuit will be more than the safe current. Thus **the current flowing in the 1000 Ω resistor will be more than 0.020 A** which will result in exceeding the maximum safe power.	**[1]** **[1]**
(d)(i)	Given $R = Ae^{\frac{B}{T}} \Rightarrow \ln R = \ln A + \frac{B}{T}$ Temperatures $\theta = 50\ ^0$C corresponds $T = 50 + 273 = 323$K and 80 ^{0}C correspond to $T = 80 + 273 = 353$ K From graph, $R = 110\ \Omega$ at 50 ^{0}C and $R = 50\ \Omega$ at 80 ^{0}C respectively. $\Rightarrow \ln 110 = \ln A + \frac{B}{323}$ ——— (1) $\ln 50 = \ln A + \frac{B}{353}$ ——— (2) (1) – (2) gives $\ln 110 - \ln 50 = \frac{B}{323} - \frac{B}{353}$ Solving ***B* ≈ 3.0 x 10³ K** ***A* ≈ 1.03 x 10⁻² Ω**	**[1] read off values and convert to kelvin** **[1] working** **[1] ans** **[1] ans**
(d)(ii)	A graph of **ln *R* against** $\frac{1}{T}$ using the equation $\ln R = \ln A + \frac{B}{T}$ is plotted. Gradient of the **graph is equal to *B*** and the ***y*-intercept equals to ln *A*.**	**[1]**

PHYSICS DEPARTMENT
2016 JC2 Preliminary Examinations
9646 H2 Physics Paper 3
Suggested Solutions with Markers' Comments

Qn	Suggested solution	Remarks
(e)		[1]
(f)(i)	At 30.0 °C, the resistance of X is approximately 188 Ω. By the potential divider principle, potential difference across the 40.0 Ω resistor is $V = \frac{R}{R+R_X}E$ $V = \frac{40.0}{40.0+188}(6.0)$ = **1.05 V**	[1] sub [1] ans
(ii)	The voltmeter reading will increase. Using the potential divider principle, $V = \frac{R}{R+R_X}E$ As temperature rises, the resistance R_X decreases. Hence the ratio of $V = \frac{R}{R+R_X}E$ increases.	[1] state [1] expl
(iii)	The voltmeter could be replaced by a buzzer. When the temperature rises beyond a certain level, the p.d. across the buzzer rises beyond a trigger value causing the buzzer to be activated.	[1]
7(a)	The **gravitational potential** at a point is defined as the work done per unit mass (by an external agent) in bringing a small mass from infinity to that point.	[1]
(b)(i)	**Potential at infinity is taken to be zero.** Due to the **attractive nature** of the gravitational force, work done per unit mass (by an external agent) to bring an object from infinity to any point is always negative. Hence the potential at any point must always be negative.	[1] [1]
(b)(ii)	gravitational field strength	[1]
(iii)	$(E_p + E_k)_{initial} = (E_p + E_k)_\infty = 0$ $m\phi + \frac{1}{2}mv^2 = 0 \rightarrow -2\phi = v^2 \rightarrow v = \sqrt{-2\phi}$ At the surface, $\phi = -0.78 \times 10^6$ J kg^{-1} $\therefore \quad v = \sqrt{-2\phi} = \sqrt{-2(-0.78 \times 10^6)} =$ **1250 m s^{-1}**	 [1] - sub [1] - ans
(c)	For the satellite to appear stationary when observed from the Earth, the **axis of the orbit of the satellite must be the axis of rotation of the Earth.** The gravitational force by the Earth on the satellite provides the centripetal force and is directed towards the centre of Earth. Since the centripetal force is directed towards the centre of its orbit, thus for any satellite, **the centre of the orbit must be the centre of the Earth.** Hence a geostationary satellite must be above the equator.	[1] [1]

PHYSICS DEPARTMENT
2016 JC2 Preliminary Examinations
9646 H2 Physics Paper 3
Suggested Solutions with Markers' Comments

Qn	Suggested solution	Remarks
(d)(i)	Gravitational force provides the centripetal force, $\dfrac{GMm}{r^2} = mr\omega^2 \rightarrow \dfrac{GM}{r^3} = \omega^2 = \left(\dfrac{2\pi}{T}\right)^2 = \dfrac{4\pi^2}{T^2}$ $\rightarrow T^2 = \dfrac{4\pi^2 r^3}{GM} = \left(\dfrac{4\pi^2}{GM}\right) r^3 \rightarrow T = \left(\dfrac{2\pi}{\sqrt{GM}}\right) r^{3/2}$ $\therefore \quad n = \dfrac{3}{2} = \mathbf{1.5}\,;\ A = \dfrac{2\pi}{\sqrt{GM}} = \dfrac{2\pi}{\sqrt{(6.67\times10^{-11})(6.0\times10^{24})}} = \mathbf{3.14 \times 10^{-7}\ s\ m^{-3/2}}$	**[1] - sub** **[1] - ans *n*** **[1] - ans *A*** **[1] - unit**
(ii)	From $T = Ar^{3/2} \rightarrow r = \left(\dfrac{T}{A}\right)^{2/3} = \left(\dfrac{(24)(3600)}{3.14\times10^{-7}}\right)^{2/3} = 4.23 \times 10^7$ m Distance from surface = $4.23 \times 10^7 - 6.4 \times 10^6$ = $\mathbf{3.59 \times 10^7}$ **m**	**[1] - sub** **[1] - ans**
(iii)	Total energy of satellite = $-\dfrac{GMm}{2r} = -\dfrac{(6.67\times10^{-11})(6.0\times10^{24})(1500)}{2(4.23\times10^7)}$ = $\mathbf{-7.09 \times 10^9}$ **J**	**[1] - sub** **[1] - ans**
(iv)	Potential energy at surface of Earth = $-\dfrac{GMm}{R} = -\dfrac{(6.67\times10^{-11})(6.0\times10^{24})(1500)}{6.4\times10^6}$ = -9.38×10^{10} J Minimum Energy required = $(-7.09 \times 10^9) - (-9.38 \times 10^{10})$ = $\mathbf{8.67 \times 10^{10}}$ **J**	**[1] - sub** **[1] - $E_{surface}$** **[1] - ans**
(v)	Due to the rotation of the Earth, so at the equator, the **linear speed** is the **highest**. A satellite launched near the equator has the highest initial kinetic energy before the launch. Hence it requires the least amount of energy to launch it to its orbit.	**[1]**
8(a)(i)	A longitudinal wave is one whereby **the oscillations of particles are parallel to the direction of propagation** and a **progressive wave is one in which energy travels from source to surroundings.**	**[1]**
(ii)	Period = 1 / *f* = 1 / 2500 = $\mathbf{4 \times 10^{-4}}$ **s**	**[1] – ans**
(iii) **(v)** **(vi)**		
	(ii) sine curve **[1]**, passing 0.2 ms and 0.4 ms **[1]** (iv) correct a **[1]** (v) correct k **[1]**	
(iv)	$v = \omega x_o = (2\pi\, 2500)(1\times10^{-7})$ = $\mathbf{1.57 \times 10^{-3}\ m\ s^{-2}}$ KE = ½ $m\, v_{max}^2$ = ½ $[1 \times 10^{-3}]\,[(2\pi\, 2500)\, 1\times10^{-7}]^2$ = $\mathbf{1.23 \times 10^{-9}}$ **J**	**[1] – sub** **[1] – ans** **[1] – ans**

Qn	Suggested solution	Remarks
(vii)	Resonance is the tendency of a system to **oscillate** at maximum **amplitude** when the **driving frequency matches the natural frequency** of the system. **At other frequencies, there is no resonance**. The **amplitude** of the vibrating ear drum is **less**. Hence they seem softer. **Note**: Amplitude of sound is **NOT** amplified.	[1] [1]
(b)(i)	Similarity: frequency, period Difference: amplitude, phase	[1] [1]
(ii)	Coherent, because phase difference is constant.	[1]
(iii)	$I_B = k(2\times10^{-4})^2 = I$ ---(1) Resultant amplitude = $(3-2)\times10^{-4}$ m = 1×10^{-4} m $I_{resultant} = k(1\times10^{-4})^2$ ---(2) (2)/(1): $I_{resultant} = 0.25\,I$	[1] resultant amplitude [1] Ans
(c)(i)	As M moves from X to Y, it will **pass through alternating maxima and minima** (loud and soft). Loud sound corresponds to constructive interference and soft sound corresponds to destructive interference.	[1] [1]
(ii)	Doubling the frequency **halves the wavelength**, **the distance between two adjacent maxima (loud) will be approximately halved**.	[1] [1]