VICTORIA JUNIOR COLLEGE

2018 JC2 PRELIMINARY EXAMINATIONS

PHYSICS **9749/01**
Higher 2
20 Sep 2018

Paper 1 Multiple Choice **THURSDAY**

2 pm- 3 pm

Additional Materials: Multiple Choice Answer Sheet **1 Hour**

READ THESE INSTRUCTIONS FIRST

Write in soft pencil (2B or softer).
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, CT group and shade your index number on the Answer Sheet provided.

HOW TO SHADE YOUR INDEX NUMBER:
Eg. If your class is 17S43, index number is 06, then shade 1740306.

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

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1} $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant,	$R = 8.31$ J mol^{-1} K^{-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,	$s = ut + (½)\, at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{GM}{r}$
temperature	$T / K = T / °C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_o \sin \omega t$
velocity of particle in s.h.m.,	$v = v_o \cos \omega t$ $= \pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = Q/4\pi\varepsilon_o r$
alternating current/voltage,	$x = x_o \sin \omega t$
Magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
Magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
Magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_o \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 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 5.341×10^{-2} Ω m.
How should the uncertainty be included in his statement of the resistivity?

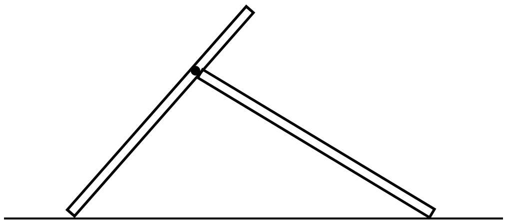
A $(5.34 \pm 0.07) \times 10^{-2}$ Ω m
B $(5.34 \pm 0.09) \times 10^{-2}$ Ω m
C $(5.3 \pm 0.4) \times 10^{-2}$ Ω m
D $(5.3 \pm 0.5) \times 10^{-2}$ Ω m

2 Ball 1 is launched up an inclined plane from point A with an initial speed that is the minimum speed for it to just reach point B at the top of the plane. At the same moment that Ball 1 is launched up the plane, Ball 2 is released from rest from point B. The two balls collide at a point C somewhere on the inclined plane.

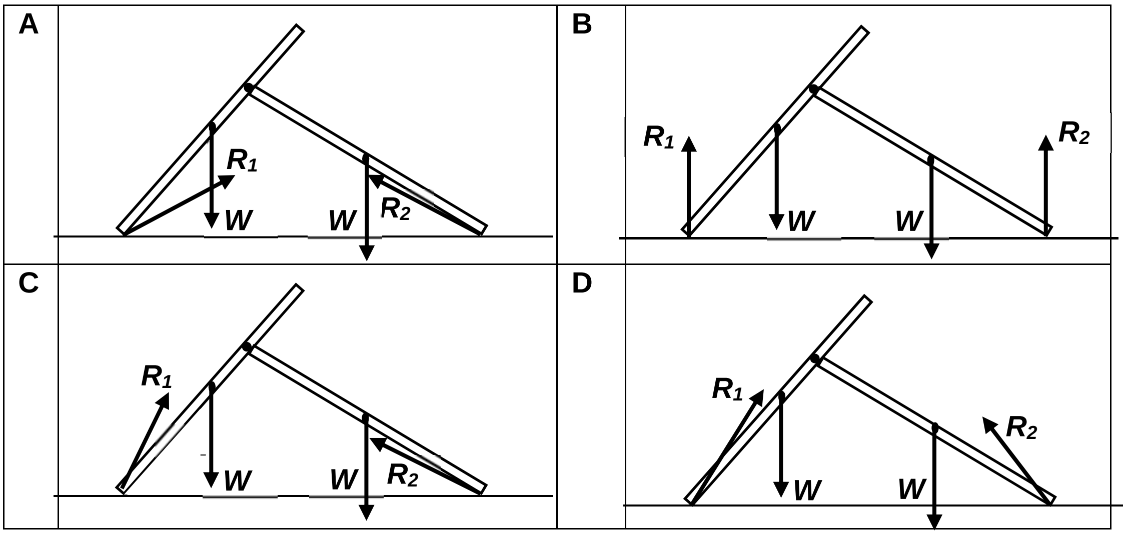
What is the ratio of the distance AC to the distance BC?

A 1 **B** 2 **C** 3 **D** 4

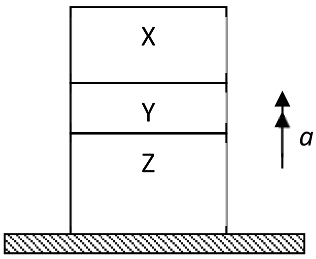
3 Two identical uniform rods, each of weight W, are hinged together to form a structure which is resting on a rough floor as shown.



If the reaction forces acting on the structure by the floor are R_1 and R_2, which of the following shows the forces acting on the structure?



4 Three crates X, Y and Z of masses *3m, m* and *5m* respectively, are stacked on top of one another on the floor of a lift which is moving upwards with an acceleration *a*.



What is the magnitude of the force exerted by crate Y on crate Z during this acceleration?

A $4mg + 4ma$ **B** $4mg + 5ma$

C $4mg - 4ma$ **D** $4mg - 5ma$

5 A 100 kg crate is pulled from rest across a floor with a constant force of 320 N. For the first 20.0 m, the floor is frictionless and for the next 10.0 m, a constant frictional force of 30.0 N acts on the crate. What is the final speed of the crate?

A 8.00 m s^{-1} **B** 8.37 m s^{-1}

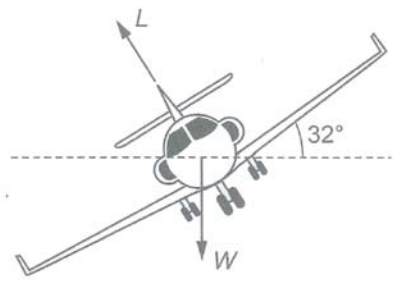
C 13.6 m s^{-1} **D** 13.9 m s^{-1}

6 A truck of mass 3500 kg has an engine which can deliver a constant power. The truck experiences a constant frictional force of 3250 N. The truck travels at a velocity of 16 m s^{-1} when it is accelerating at 0.35 m s^{-2}. What is the maximum speed that the lorry can achieve on level ground?

A 6.0 m s^{-1} **B** 12 m s^{-1}

C 20 m s^{-1} **D** 22 m s^{-1}

7 A small aircraft flies at speed v in a horizontal circle of radius r. To do so, the plane of its wings must be at an angle of 32° to the horizontal as shown. The directions of the two forces in the vertical plane acting on the aircraft, weight W and lift L, are also shown.



At which angle to the horizontal must the aircraft fly in a horizontal circle of radius $\frac{r}{2}$ at a speed of $2v$?

A 17° **B** 51° **C** 68° **D** 79°

8 Which statement about geostationary orbits is false?

A A geostationary orbit must be directly above the equator.

B All satellites in geostationary orbits must have the same mass.

C The period of a geostationary orbit must be 24 hours.

D There is only one possible radius for a geostationary orbit.

9 A satellite of mass 690 kg orbits the Earth along a circular path of radius 7.2×10^6 m. Its orbital speed is 7.5 km s^{-1}. A rocket engine on the satellite is fired. The satellite falls into a lower orbit of radius 6.5×10^6 m where its orbital speed becomes 7.9 km s^{-1}.

Which statement about the change to the total energy of the satellite caused by the rocket burn is correct? [Mass of the Earth = 6.0×10^{24} kg]

A The satellite gains approximately 2×10^9 J.

B The satellite gains approximately 3×10^9 J.

C The satellite loses approximately 2×10^9 J.

D The satellite loses approximately 4×10^9 J.

10 The specific heat capacity of a liquid is to be found using a continuous flow calorimeter. First an input power of 10 W is used. When the input power is 18 W it is found that the liquid flow rate must be *tripled* to give the same temperature rise. What is the rate of heat lost to the surroundings?

A 3.3 W **B** 6.0 W

C 6.7 W **D** 7.5 W

11 The density of helium at 150 kPa is 0.178 kg m^{-3}. What is the root-mean-square speed of its particles?

A 130 m s^{-1} **B** 232 m s^{-1}

C 1300 m s^{-1} **D** 1600 m s^{-1}

12 A particle is oscillating with simple harmonic motion described by the equation:

$$y = 5\sin(20\pi t)$$

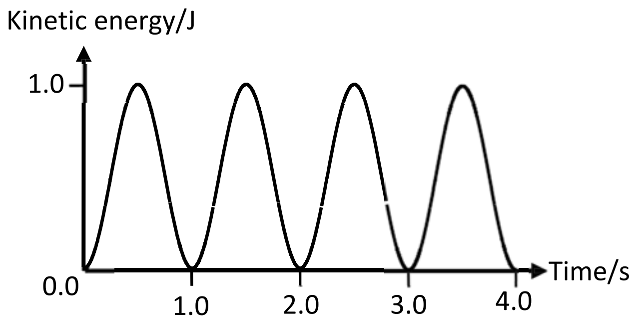
where *y* is in meters and *t* is in seconds.

How long does it take the particle to travel from its position of maximum displacement to a position half way between the maximum displacement and the equilibrium position?

A Less than 12.5 ms **B** 12.5 ms

C Between 12.5 ms and 25 ms **D** 25 ms

13 The time-variation of the kinetic energy of a particle undergoing simple harmonic motion with amplitude of 3.0 cm is shown in the figure below.



What is the maximum velocity of the particle?

A 0.59 m s^{-1} **B** 0.30 m s^{-1} **C** 0.094 m s^{-1} **D** 0.19 m s^{-1}

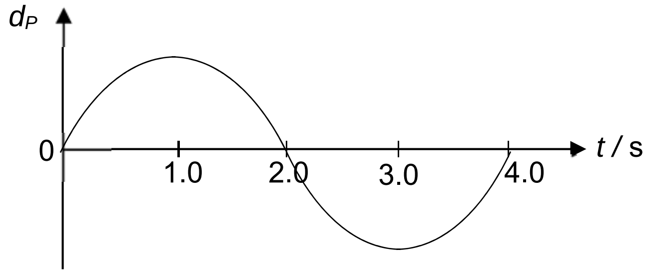
14 An antenna broadcasts a signal uniformly in all directions using a power of 240 W. A receiver dish of diameter 3.0 m and 750 m away receives the signal.

What is the power received by the dish?

A 9.6×10^{-7} W **B** 3.8×10^{-6} W
C 2.4×10^{-4} W **D** 2.9×10^{-3} W

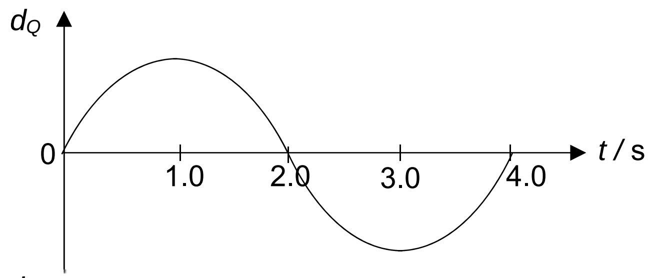
15 P and Q are two points 12 m apart.

A wave travels from P to Q at a speed of 3.0 m s^{-1}. The graph below shows how the displacement of P, d_P, varies with time t:

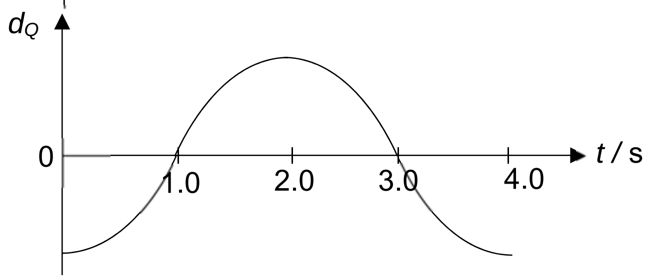


Which of the following graphs correctly shows how the displacement of Q, d_Q, varies with time t?

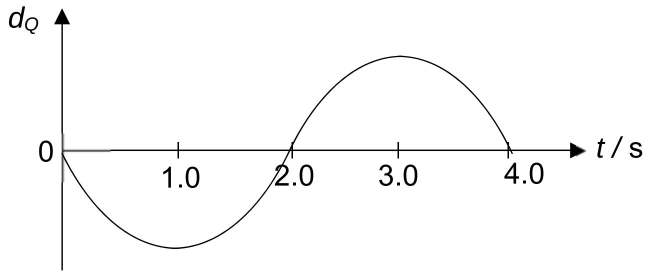
A



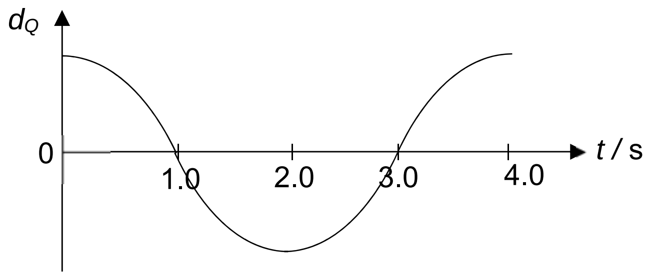
B



C



D



16 A string of length 1.0 m is fixed at both ends, and made to vibrate. Which of the following wavelengths cannot be formed on the string?

A 0.50 m **B** 0.67 m **C** 1.3 m **D** 2.0 m

17 A satellite orbits the Earth at a height of 120 km. It has a camera of aperture 2.5 cm. By considering a wavelength of visible light of 5.5×10^{-7} m, what is the nearest distance between two objects on the surface of Earth that can be distinguished as separate objects?

A 1.3 m **B** 2.6 m **C** 3.9 m **D** 5.2 m

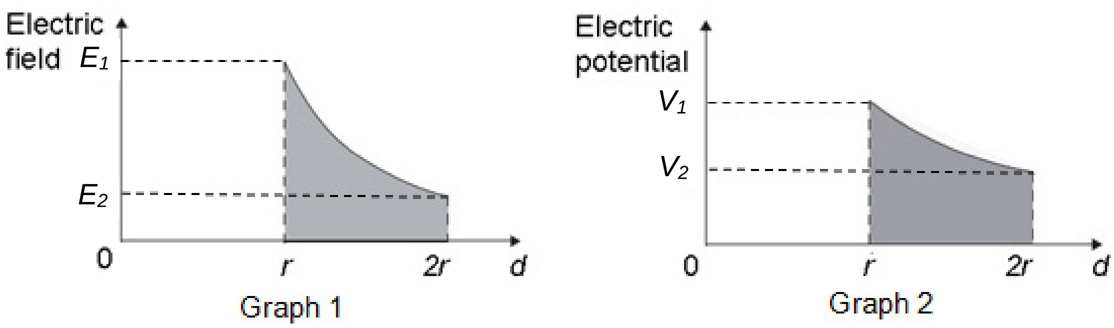
18 Two equal and opposite charges $+q$ and $-q$ are situated 1.00 m apart.

At a point P, 0.40 m from the charge $+q$, the magnitude of the electric field strength due to the charge $+q$ alone is 12 N C^{-1}.

What is the magnitude of the electric field strength at P due to both charges?

A 17 N C^{-1} **B** 20 N C^{-1} **C** 23 N C^{-1} **D** 30 N C^{-1}

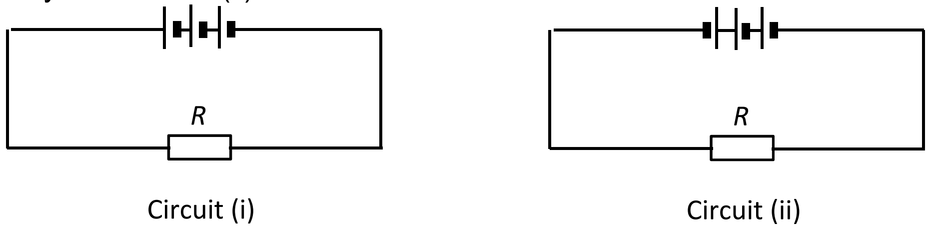
19 The two graphs below represent the variation with distance, d, for $d = r$ to $d = 2r$ of the electric field and the electric potential around an isolated point charge. The electric field strengths and potentials at the two positions are E_1, E_2, V_1 and V_2 respectively as shown in the diagram.



The work done by an external force in moving a test charge $+q$ from $d = 2r$ to $d = r$ is equal to

A q x shaded area under Graph 1.
B q x shaded area under Graph 2
C $q \times \frac{1}{2}(E_1 + E_2)$.
D $q \times (V_2 - V_1)$.

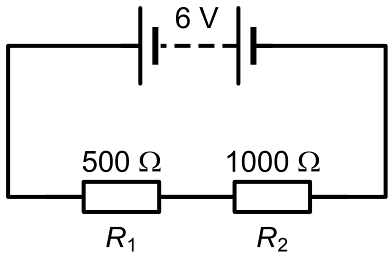
20 Three identical cells each having an e.m.f of 1.5 V and a constant internal resistance of 2.0 Ω are connected in series with a 4.0 Ω resistor *R*, firstly as in circuit (i), and secondly as in circuit (ii).



What is the ratio $\frac{power\ in\ R\ in\ circuit\ (i)}{power\ in\ R\ in\ circuit\ (ii)}$?

A 9.0 **B** 7.2 **C** 5.4 **D** 3.0

21 The diagram shows a 6 V battery, with negligible internal resistance, connected in series to two resistors R_1 and R_2.
R_1 has a resistance of 500 Ω and R_2 has a resistance of 1000 Ω.



A third resistor with a resistance of 500 Ω is placed in parallel across R_2.
Which statement about the new circuit is correct?

A The current in R_2 is larger than before.

B The current through the battery is smaller than before.

C The potential difference across R_1 is larger than before.

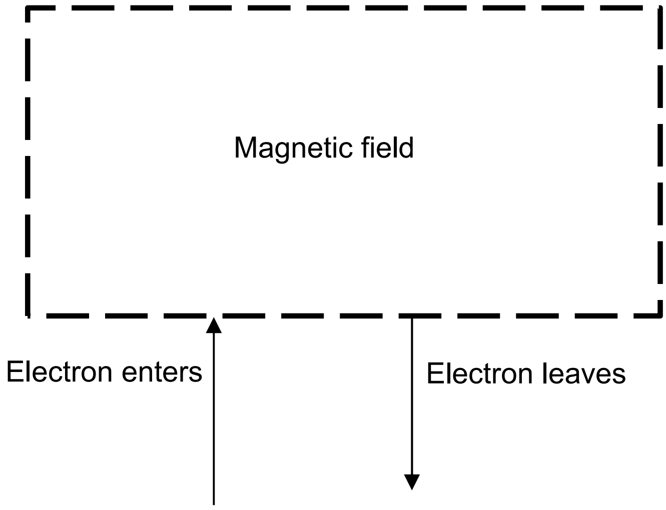
D The potential difference across R_2 is now greater than the potential difference across R_1.

22 An electric kettle, designed for travelers, can be used with different supply voltages. It is rated at 600 W for a 240 V r.m.s. alternating supply. What will be its power output if it is connected to a 120 V direct supply?

A 150 W **B** 300 W

C 600 W **D** 1.20 kW

23 An electron travelling at a speed of 5.0×10^7 m s^{-1} enters perpendicularly into a rectangular region of uniform magnetic field of strength 3.0 T, as shown below. The field is perpendicular to the page:



How much time does the electron spend inside the magnetic field?

A	2.3×10^{-31} s	**B**	1.1×10^{-23} s
C	1.2×10^{-19} s	**D**	6.0×10^{-12} s

24 A straight wire XY 2.0 cm long carrying a current of 1.5 A is placed at the centre of a solenoid 1.2 m long with 20 000 turns of wire and carrying a current of 3.0 A, so that the wire XY is perpendicular to the magnetic field produced by the solenoid.

What is the magnetic force acting on the wire XY?

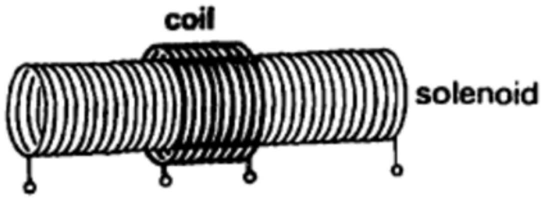
A	6.0×10^{-4} N	**B**	7.2×10^{-4} N
C	1.9×10^{-3} N	**D**	2.3×10^{-3} N

25 A copper disc of area A rotates at angular frequency ω at the centre of a long solenoid of length L and having N turns. The solenoid carries a current I. The plane of the disc is normal to the magnetic flux. The rotation rate is adjusted so that the e.m.f. generated between the centre of the copper disc and its rim is 10% of the potential difference across the ends of the solenoid.

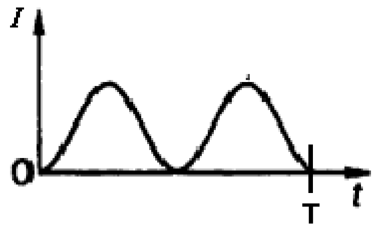
Which expression gives the potential difference across the ends of the solenoid?

A $10\mu_o NIA\omega$
B $1.6\mu_o NIA\omega/L$
C $0.1\mu_o NIA\omega$
D $0.016\mu_o NIA\omega/L$

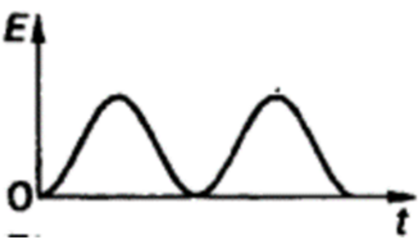
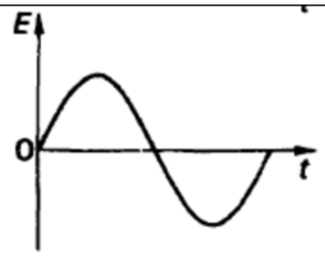
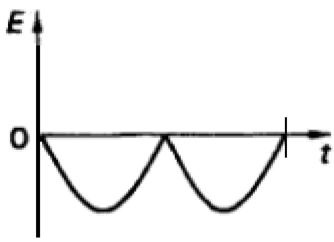
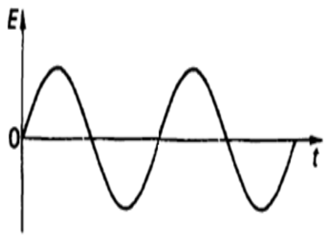
26 The diagram shows a short coil wound over the middle part of a long solenoid.



The solenoid current I is varied with time t as shown in the sketch graph. As a consequence, the flux density of the magnetic field due to the solenoid varies with time. The relation between B and I is $B = \mu_0 n I$ where n is the number turns per unit length.



Which graph shows how the e.m.f. E induced in the short coil varies with time t?

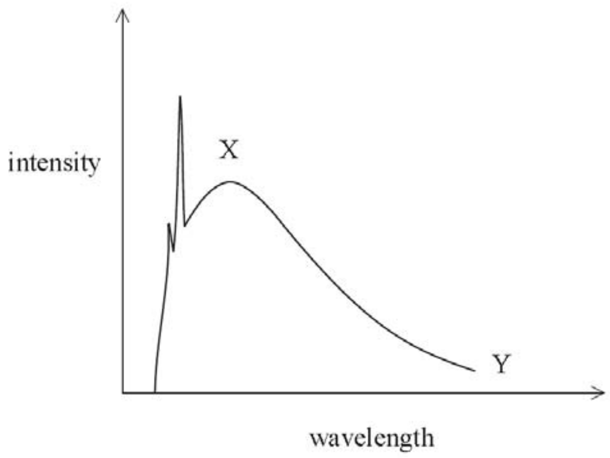
A		**B**	
C		**D**	

27 In a photoelectric effect experiment, ultraviolet light of wavelength 150 nm shines on a clean metal surface. The stopping potential was determined to be 2.1 V.

What is the work function of the metal used?

A 2.1 eV **B** 6.2 eV **C** 8.3.eV **D** 10.4 eV

28 The diagram shows a typical X-ray spectrum produced by the bombardment of a heavy metal target by high energy electrons.



Which of the following best explains the part of the spectrum labelled XY?

A The diffraction of the electrons striking the metal target.
B The acceleration of the electrons striking the metal target.
C Electron transitions between energy levels in the atoms of the metal target.
D The decrease in kinetic energy of photons.

29 Which of the following statements concerning nuclear properties is true?

A The greater the binding energy of a nucleus, the more stable it is.

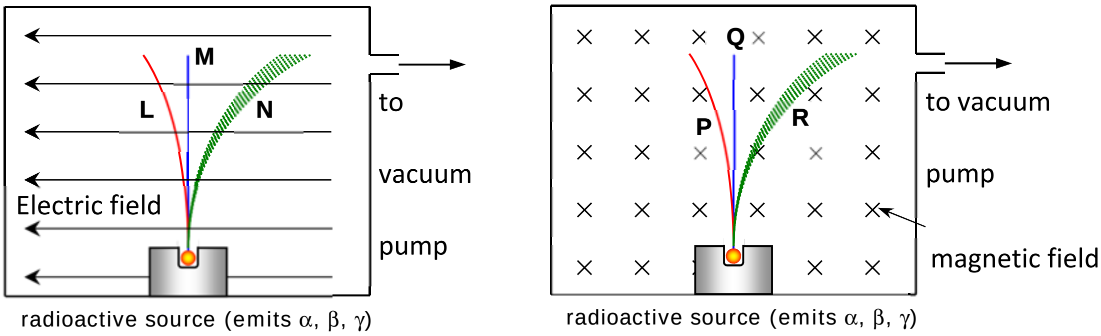
B If the total rest mass of the products of a reaction is greater than the total rest mass of the reactants, this reaction is impossible.

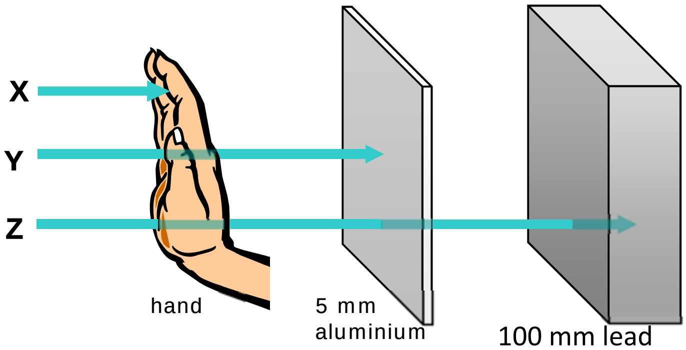
C The half-life of a radioactive substance can be changed by allowing the substance to react chemically to produce a new radioactive compound.

D When a stationary nucleus decays by emitting a γ-photon, the nucleus will move off in an opposite direction to the photon.

30 A radioactive source emits alpha, beta and gamma radiation. The three diagrams below illustrate the behaviours of the three radiations from this source.

Which three labels refer to the same kind of radiation?





A L, R, X **B** M, Q, X **C** L, P, Z **D** N, R, Y

Answers to JC2 Preliminary Examination Paper 1 (H2 Physics)

Suggested Solutions:

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

1 D

Resistivity, $\rho = \dfrac{RA}{l} = \dfrac{R\pi(d/2)^2}{l}$

$$\frac{\Delta\rho}{\rho} = \frac{\Delta R}{R} + 2\left(\frac{\Delta d}{d}\right) + \frac{\Delta l}{l} = \frac{1}{68} + 2\left(\frac{0.1}{5.0}\right) + \frac{1}{25}$$

$\Delta\rho = 0.5 \times 10^{-2}\ \Omega\text{ m}\quad(1\text{ s.f.})$

$\therefore\ \rho = (5.3 \pm 0.5) \times 10^{-2}\ \Omega$ m

2 C

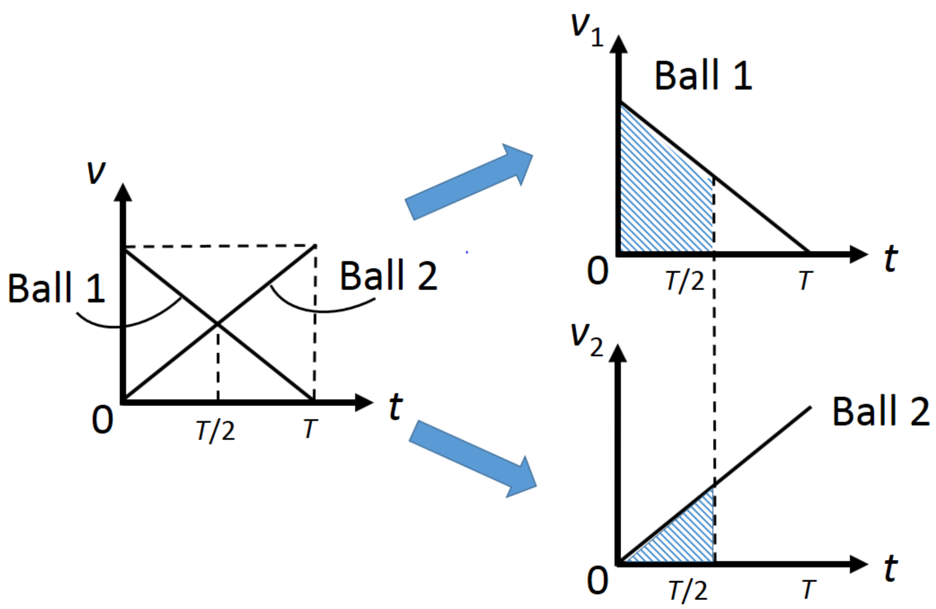
Method 1: Faster (guess & check using graphical method)

If Ball 1 doesn't collide with Ball 2, it will take time *T* to reach the top. Similarly, Ball 2 will take time *T* to reach the bottom.

Because both balls are experiencing the same gravitational acceleration ($g\sin\theta$), the initial speed of Ball 1 is the same as the final speed of Ball 2.

Guess: Is it possible that the balls collide at time = *T*/2?

Check: At time = *T*/2, apply the math of similar triangles to see that Ball 1 travels ¾ of the way up the slope (refer to the shaded area under Ball 1's curve). At time = *T*/2, Ball 2 travels ¼ of the way down the slope (refer to the shaded area under Ball 2's curve). So the balls do indeed collide at time = *T*/2, and Ball 1 travels 3 times further than Ball 2.



Method 2: Slower (using equations and graphs of kinematics)
Apply "$s = ut + (1/2)\,at^2$" and let t be the time of collision:

For Ball 1: $s_{AC} = ut + \frac{1}{2}(-a)t^2 = ut - \frac{1}{2}at^2$

For Ball 2: $s_{BC} = (0)t + \frac{1}{2}at^2 = \frac{1}{2}at^2$

$s_{AB} = s_{AC} + s_{BC} = ut - \frac{1}{2}at^2 + \frac{1}{2}at^2$

$\therefore s_{AB} = ut$ --- (1)

Suppose there is no collision. Let T be the time taken by either ball to travel the entire length of the slope s_{AB}.

Apply "$s = \left(\frac{u+v}{2}\right)t$" to Ball 1 gives: $s_{AB} = \left(\frac{u+0}{2}\right)T$

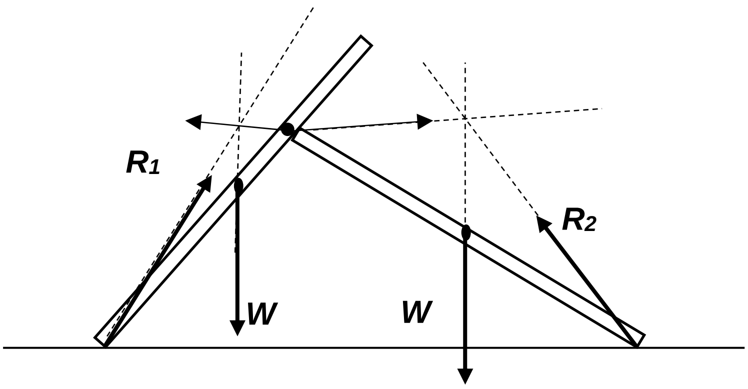
$\therefore s_{AB} = \frac{uT}{2}$ --- (2)

Equating (1) and (2) gives $t = \frac{T}{2}$

Refer to the previous v-t graphs for Balls 1 & 2. After time $T/2$, apply the math of similar triangles to see that Ball 1 travels ¾ of the way up the slope (refer to the shaded area under Ball 1's curve). After $T/2$, Ball 2 travels ¼ of the way down the slope (refer to the shaded area under Ball 2's curve). So the balls collide after $T/2$, and Ball 1 travels 3 times further than Ball 2.

3 **D**

The system is in equilibrium. Extrapolated lines of action of all 3 forces acting on each of the rods must intersect at a common point.



4 **A**

Forces on all 3 masses: $F_{\text{floor on Z}} - (m_X + m_Y + m_Z)g = (m_X + m_Y + m_Z)a$

$F_{\text{floor on Z}} - 9mg = 9ma$

$F_{\text{floor on Z}} = 9mg + 9ma$

Forces on Z alone: $F_{\text{floor on Z}} - F_{\text{Y on Z}} - m_Z g = m_Z a$

$$F_{\text{floor on Z}} - F_{\text{Y on Z}} - m_Z g = m_Z a$$
$$F_{\text{Y on Z}} = F_{\text{floor on Z}} - m_Z g - m_Z a$$
$$F_{\text{Y on Z}} = 9mg + 9ma - 5mg - 5ma = 4mg + 4ma$$

5 **C**

By considering conservation of energy,
gain in KE = work done by force – work done against frictional forces

$$\frac{1}{2}mv^2 = Fd_{total} + fd_{10}$$

$$\frac{1}{2}(100)v^2 = (320)(30) - (30)(10)$$

$v = 13.6$ m s^{-1}

6 **D**

Find driving force: $F_D - f = ma$

$F_D = (3500 \times 0.35) + 3250 = 4425$ N

Power supplied by engine: $P = Fv$

$P = 4425 \times 16 = 70800$ W

At maximum speed, driving force = frictional force.
Since power supplied is constant,

$70800 = 3250v$

$v = 21.8$ m s^{-1}

7 **D**

Deduce that *L* is tilted at 32° to the vertical, so

$L\sin 32^\circ = \dfrac{mv^2}{r}$ --- (1)

and $L\cos 32^\circ = mg$ --- (2)

(1) ÷ (2) gives: $\tan 32^\circ = \dfrac{v^2}{rg}$

When *r* is halved to *r*/2 and *v* is doubled to 2*v*, let the angle be ϕ.

We now have: $\tan\phi = \dfrac{(2v)^2}{\left(\dfrac{r}{2}\right)g} = 8\left(\dfrac{v^2}{rg}\right) = 8\left(\tan 32^\circ\right)$

$\therefore\ \phi = 78.7^\circ$

8 B

Apply Newton's second law to a geostationary satellite of mass *m*:

$$F = \frac{GM_E m}{r^2} = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2$$

$$\frac{GM_E}{r^3} = \frac{4\pi^2}{T^2} = \frac{4\pi^2}{(24\text{ hours})^2}$$

Notice that *m* cancels out, so the geostationary orbit is independent of the mass of the satellite.
But the period and radius of orbit have unique values.

9 C

Total initial energy of the satellite:

$$E_i = GPE_i + KE_i = -\frac{GMm}{r_i} + \frac{1}{2}mv_i^2$$

$$= -\frac{(6.67\times10^{-11})(6.0\times10^{24})(690)}{7.2\times10^6} + \frac{1}{2}(690)(7.5\times10^3)^2$$

$$= -1.895\times10^{10}\text{ J}$$

Total final energy of the satellite:

$$E_f = GPE_f + KE_f = -\frac{GMm}{r_f} + \frac{1}{2}mv_f^2$$

$$= -\frac{(6.67\times10^{-11})(6.0\times10^{24})(690)}{6.5\times10^6} + \frac{1}{2}(690)(7.9\times10^3)^2$$

$$= -2.095\times10^{10}\text{ J}$$

$E_f < E_i$, so the satellite loses total energy.

Change in total energy = $E_f - E_i$ = –2.0 × 10^9 J

In other words, the satellite loses approximately 2 × 10^9 J.

10 B

Using $P_{input} = \frac{m}{t}c\Delta T + h$

$$10 = \frac{m}{t}c\Delta T + h \quad \ldots\ldots (1)$$

$$18 = \frac{3m}{t}c\Delta T + h \quad \ldots\ldots (2)$$

Solving (1) and (2), rate of heat loss to the surrounding, h = 6.0 W

11 D

From the kinetic theory of gases, $p = \frac{1}{3}\rho\langle c^2\rangle$

Therefore, root-mean-square speed, $C_{r.m.s.} = \sqrt{\frac{3p}{\rho}} = \sqrt{\frac{3(150\text{x}10^3)}{0.178}} = 1600\text{ m s}^{-1}$

12 C

Using $y = 5\sin(20\pi t)$

At position of maximum displacement, $5 = 5\sin(20\pi t_1)$

$$\Rightarrow 20\pi t_1 = \frac{\pi}{2}$$

$$\Rightarrow t_1 = 0.025\,\text{s}$$

At position half way between maximum displacement and the equilibrium position,

$$2.5 = 5\sin(20\pi t_2)$$

$$\Rightarrow 20\pi t_2 = \frac{5\pi}{6}$$

$$\Rightarrow t_2 = 0.042\,\text{s}$$

Required time taken, $t = t_2 - t_1 = 0.042 - 0.025 = 0.017\,\text{s} = 17\ \text{ms}$

13 C

From the graph, period of oscillation, $T = 2.0\,\text{s}$

Maximum velocity, $V_{\max} = wx_0$, where x_o is the amplitude of the oscillation.

$$= \frac{2\pi}{T} x_o = \frac{2\pi}{2.0}\left(3.0\times10^{-2}\right) = 0.094\,\text{ms}^{-1}$$

14 C

Intensity at dish from antenna I = $\frac{P_{antenna}}{4\pi d^2}$

Power received = I A_{dish}

$$= \frac{P_{antenna}}{4\pi d^2} \pi\, r_{dish}^2$$

$$= \frac{240}{4\pi(750)^2} \pi\, (1.5)^2$$

$$= 2.4 \times 10^{-4}\ \text{W}$$

15 A

The wave takes 4 s to go from P to Q.

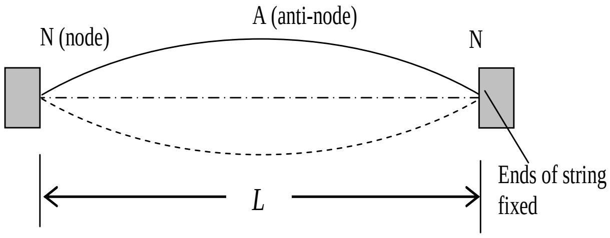
Look at the graph for P, at t = 0, for example. It starts from 0, and becomes more positive as time progresses.

So for Q, the same thing should happen at t = 4 s.

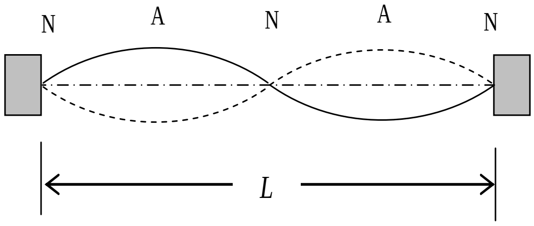
Looking at the 4 options, only A satisfies this requirement.

16 C

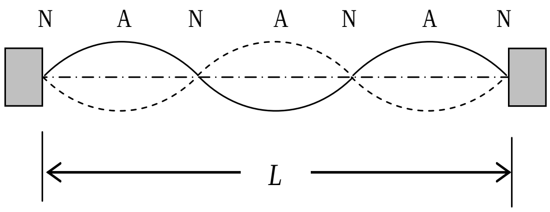
For a string fixed at both ends, these are the 1st few modes of vibration:



λ = 2.0 m



λ = 1.0 m

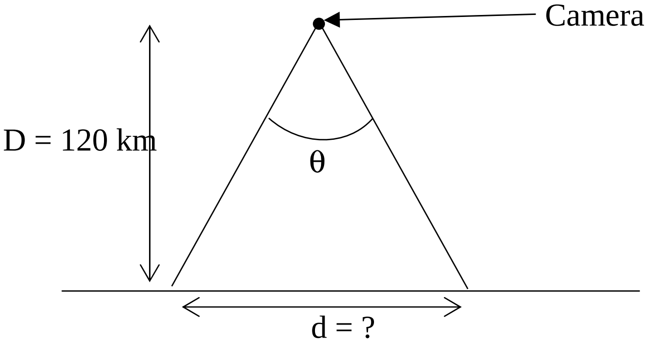


λ = 0.67 m

λ = 1.3 m is impossible.

17 B

Rayleigh's criterion



Just resolved: $\theta = \frac{\lambda}{a} \approx \frac{d}{D}$ when θ is very small.

$$d = \frac{\lambda D}{a}$$

$$= \frac{5.5\times10^{-7}\times120\times10^{3}}{2.5\times10^{-2}}$$

= 2.6 m

18 A

$$E_q = k\frac{q}{r_q^2} = k\frac{q}{0.40^2} = 12\text{ N C}^{-1}$$

$$kq = 1.92$$

$$\begin{aligned}E_{\text{total}} &= E_q + \left(-E_{-q}\right)\\ &= k\frac{q}{r_q^2} + \left(-k\frac{-q}{r_{-q}^2}\right)\\ &= \frac{1.92}{0.40^2} + \frac{1.92}{0.60^2}\\ &= 17.3\text{ N C}^{-1}\end{aligned}$$

19 A

From work energy theorem:

$W = \int Fdr = q\int Edr$

Hence work done is the area under E-field distance graph.

20 A

Power in R in circuit (i) $= I^2R = \left(\frac{3E}{3r+R}\right)^2 R = \left(\frac{3(1.5)}{3\times2+4}\right)^2 \times 4 = 0.81\ W$

Power in R in circuit (ii) $= I^2R = \left(\frac{E}{3r+R}\right)^2 R = \left(\frac{1.5}{3\times2+4}\right)^2 \times 4 = 0.09\ W$

$\frac{power\ in\ R\ in\ circuit\ (i)}{power\ in\ R\ in\ circuit\ (ii)} = \frac{0.81}{0.09} = 9$

21 C

When a 500 Ω resistance is connected in parallel with the 1000 Ω R_2, the effective resistance of these two resistors become smaller than 500 Ω. Hence the p.d across R_2 will become smaller than before, while the p.d across R_1 will be larger than before.

22 A

Power, $P = \frac{V^2}{R}$

For the same kettle, R is constant.

Therefore, $P \propto V^2$

$$\Rightarrow \frac{P_2}{P_1} = \left(\frac{V_2}{V_1}\right)^2$$

$$\Rightarrow \frac{P_2}{600} = \left(\frac{120}{240}\right)^2$$

$$\Rightarrow P_2 = \left(\frac{120}{240}\right)^2 600 = 150\,\text{W}$$

23 D

Find period of electron:

Centripetal force = magnetic force

$$m\omega v = Bev$$

$$m\left(\frac{2\pi}{T}\right)v = Bev$$

$$T = \frac{2\pi m}{Be}$$

$$= \frac{2\pi\times 9.11\times 10^{-31}}{3.0\times 1.60\times 10^{-19}}$$

$$= 1.192 \times 10^{-11}\ \text{s}$$

But the electron only travels half a circle, so time spent = T/2 = 6.0×10^{-12} s.

24 C

Wire XY is perpendicular to the magnetic field of the solenoid, so magnetic force acting on XY = $B_{solenoid}\, I_{XY}\, L_{XY}$

$$= (\mu_0\, n_{solenoid}\, I_{solenoid})\, I_{XY}\, L_{XY}$$

$$= (4\pi \times 10^{-7} \times \frac{20000}{1.2} \times 3.0) \times 1.5 \times 2.0 \times 10^{-2}$$

$$= 1.9 \times 10^{-3}\ \text{N}$$

25 B

For a solenoid, the internal B-field is: $B = \mu_0 \frac{N}{L} I$

Using Faraday's Law, the induced emf between the rim and center of the disk is:

$$E = \frac{d\Phi}{dt}$$

$$= B\frac{dA}{dt}$$

$$= \mu_0 \frac{N}{L} I \frac{A}{T}$$ (A radius on the disc will sweep out an area *A* in time *T*)

$$= \mu_0 \frac{N}{L} IA\frac{\omega}{2\pi}$$

$$= 0.16\mu_0 NIA\omega / L$$

Since the emf between the ends of the solenoid is 10 times larger than the induced emf,

$$E_{\text{solenoid}} = 1.6\mu_0 NIA\omega / L$$

26 D

Calculus method:

For a solenoid with a current *I*, and *I* varies with time as given:

$B \propto I = I_0 \sin^2 \omega t$

Hence using Faradays law to find the emf in the smaller coil:

$$E = A\frac{dB}{dt} = kI_0 \sin 2\omega t = E_0 \sin \omega' t$$

The result is a graph with twice the frequency of the graph given.

Reasoning method:
For a solenoid with a current *I*, $B \propto I$
Consider the **first half period**: the current increases then decreases, so the magnetic flux experienced by the smaller coil also increases and decreases,
Applying Faraday's Law and Lenz's Law, the emf induced will be in opposite directions during the increase compared to the decrease.
Thus for one complete period as shown in the graph, the emf induced will be positive, then negative then positive then negative again.

27 B

Using Einstein's Photoelectric equation, $\frac{hc}{\lambda} = \phi + eV_S$

$$\phi = \frac{hc}{\lambda} - eV_S$$
$$= \frac{(6.63\times10^{-34})(3.00\times10^{8})}{150\times10^{-9}} - (1.60\times10^{-19})(2.1)$$
$$= 9.9\times10^{-19}\text{ J}$$
$$= 6.2\text{ eV}$$

28 B

The spectrum labelled XY is due to "bremsstrahlung" radiation or braking radiation which refers to the acceleration of the electrons striking the metal target.

29 D

Option D is true. Conservation of momentum: Total Initial momentum = 0.
Hence, when γ-photon emitted in one direction, the nucleus must recoil with an equal magnitude momentum in the opposite direction such that the total momentum remains 0.

Option A is not true. The greater the binding energy *per nucleon*, then the more stable the nucleus.

Option B is not true. The reaction is still possible with the provision of input of energy to the reactants.

Option C is not true. The half-life of a radioactive substance cannot be changed chemically.

30 D

Alpha particles are L, P and X.
Beta particles are N, R and Y.
Gamma particles are M, Q and Z.

Name : ______________________________ CT group: ____________

VICTORIA JUNIOR COLLEGE
2018 JC2 PRELIMINARY EXAMINATIONS

PHYSICS **9749/02**

Higher 2 **12 Sep 2018**

Paper 2 Structured Questions **WEDNESDAY**

8 am – 10 am

2 Hours

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

READ THESE INSTRUCTIONS FIRST

Write your name and CT group 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 or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

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

Answer **all** questions.

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

For Examiner's Use	
1	
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units	
Total (max. 80)	

This document consists of **18** printed pages.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1} $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_{\mathrm{e}} = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_{\mathrm{p}} = 1.67 \times 10^{-27}$ kg
molar gas constant,	$R = 8.31$ J mol^{-1} K^{-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,	$s = ut + (½)\, at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\dfrac{GM}{r}$
temperature	$T / K = T / °C + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \dfrac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_o \sin \omega t$
velocity of particle in s.h.m.,	$v = v_o \cos \omega t$ $= \pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = Q/4\pi\varepsilon_o r$
alternating current/voltage,	$x = x_o \sin \omega t$
Magnetic flux density due to a long straight wire	$B = \dfrac{\mu_0 I}{2\pi d}$
Magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_0 NI}{2r}$
Magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_o \exp(-\lambda t)$
decay constant,	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

Answer all questions in the spaces provided

1(a) When an object is placed in water, it experiences an upthrust.

(i) Explain what is meant by upthrust. [1]

(ii) A container contains two liquids A and B which do not mix. The densities of liquids A and B, denoted by ρ_A and ρ_B , are 1.30×10^3 kg m^{-3} and 0.900×10^3 kg m^{-3} respectively. A cubical solid of side 0.200 m and mass 9.20 kg stays upright in equilibrium in between the two liquids as shown in Fig. 1.1. The depth of the solid submerged in Liquid A is denoted by *x*.

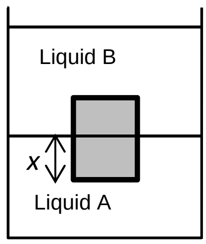


Fig. 1.1

1. Write down an expression for the upthrust exerted on solid by Liquid A in terms of *x*, ρ_A and *g*. [1]

2. Write down an expression for the upthrust exerted on solid by Liquid B in terms of *x*, ρ_B and *g*. [1]

3. Hence, or otherwise, determine *x*. [2]

(b) A hungry bear walks out from a cave onto a horizontal uniform beam of length L, supported on the left by a hinge attached to a wall, in an attempt to retrieve some "goodies" hanging at the right end (Fig. 1.2). The total weight of the bear and the beam is 900 N. The goodies weigh 80.0 N. Fig. 1.3 gives the tension T in the cable as a function of the bear's position given as a fraction x/L of the beam length.

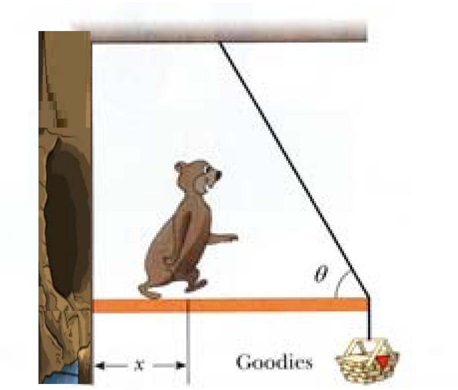


Fig. 1.2

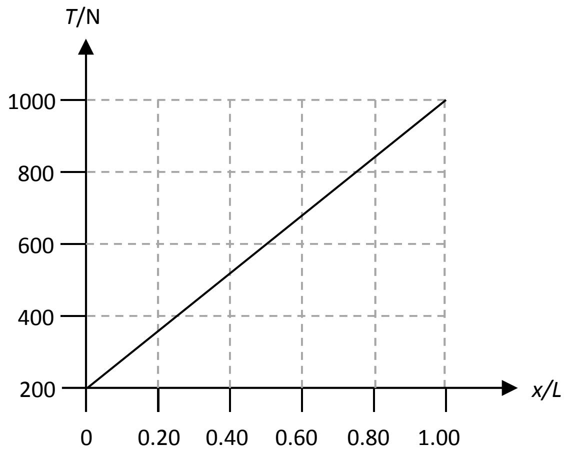


Fig. 1.3

(i) By considering the bear standing at the centre of the beam, calculate the angle θ.[2]

(ii) Suggest where, on the beam, the bear should stand so that his weight does not produce a moment on the beam. [1]

(iii) Calculate the mass of the beam. [2]

2(a) Explain the various energy conversions that occur during each of the following events:

(i) A car moving on a rough horizontal road coming to a stop. [2]

(ii) A mass is attached to the bottom of a vertical spring. The mass is lowered slowly until it reaches an equilibrium position and remains stationary at that position. [3]

(b) The skateboarder in Fig. 2.1 below is 55 kg. She enters the ramp of height *h* at point A with a speed of 6.5 m s^{-1} and leaves the ramp vertically upwards at point B. The skateboarder experiences an average frictional force of 2.0 N by the ramp. The distance travelled between A and B is 2.0 m and *h* is 1.3 m.

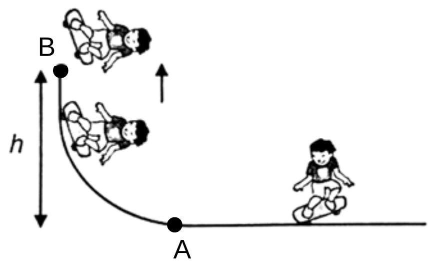


Fig. 2.1

(i) Determine the speed of the skateboarder as she exits point B. [3]

(ii) State and explain whether your answer to b(i) will be different if the ramp is replaced by the one shown in Fig. 2.2 below. The average frictional force by the ramp is still 2.0 N. The points A and B are in the same positions as in Fig. 2.1. [2]

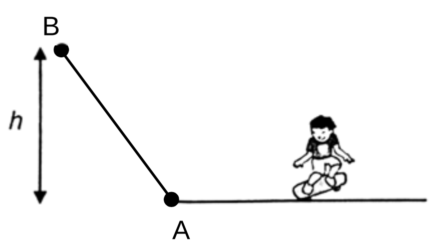
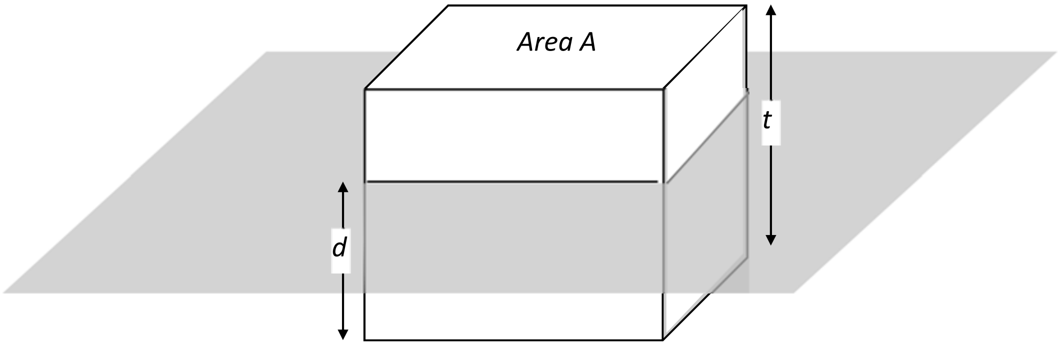


Fig. 2.2

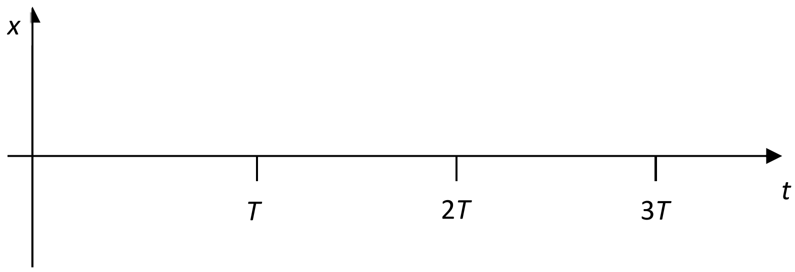
3(a) A rectangular block of wood of cross-section *A* and thickness *t* floats horizontally in water as shown in the figure below.



When the block is pushed downwards and then released, it undergoes ***damped*** harmonic motion.

(i) Explain why the motion of the block undergoes damping. [1]

(ii) Sketch a labelled graph showing the variation of displacement *x* with time *t* for a time interval over three periods. [2]



(b) Surface water waves from a constant amplitude wave generator are incident on the block. These causes ***forced oscillations*** in the motion of the block. The frequency of the wave generator is varied and ***resonance*** was observed at a particular frequency.

(i) Explain the terms ***'forced oscillations'*** and ***'resonance'*** with reference to the motion of the block. [2]

(ii) Resonance occurs when the water waves incident on the block has a speed of 0.90 m s^{-1} and wavelength 0.30 m.

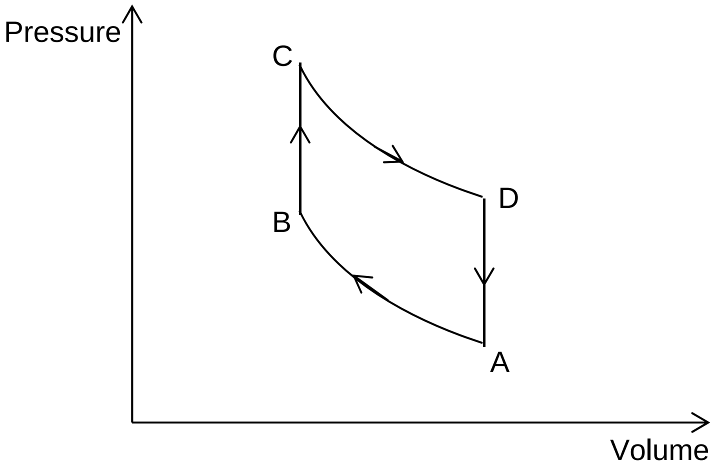
1. Calculate the frequency of the water waves. [1]

2. Given that the expression for the natural frequency of the oscillating block is given by $f = \frac{1}{2\pi}\sqrt{\frac{28}{m}}$ where f is in Hz and m in kg, calculate the mass of the block. [1]

3. Describe and explain what happens to the amplitude of vertical oscillations of the block after the block has absorbed some water. [2]

4(a) State the First Law of Thermodynamics in words. [1]

(b) A gas in an engine undergoes a cyclic process ABCD, as shown in the pressure – volume diagram below:



AB and CD are adiabatic processes, while BC and DA are isochoric processes.

(i) For process AB, the work done is 10 J. Calculate the change in internal energy of the gas. State whether it is an increase or decrease. [2]

For process BC, 70 J of heat is supplied to the gas, while for process CD, 25 J of work is done.

(ii) Calculate the heat flow during process DA. State whether it is into or out of the gas. [3]

(iii) Calculate the efficiency of the engine. [2]

(iv) The engine executes 3000 cycles per minute. Calculate its useful power output. [2]

5(a) State Lenz's law and explain how you would use a coil and a magnet to demonstrate the law. Make clear the use of any other apparatus in your explanation. [4]

(b) An instrument based on induced electromotive force (e.m.f.) is used to measure the speed of a projectile.

A small, strong but light magnet is imbedded in the projectile as shown in Fig. 5.1. The projectile passes through the two identical coils with *N* turns each, separated by a distance *d* with constant speed. As the projectile passes through each coil, a pulse of e.m.f. is induced in the coil. The time interval between the pulses can be measured accurately with an oscilloscope.

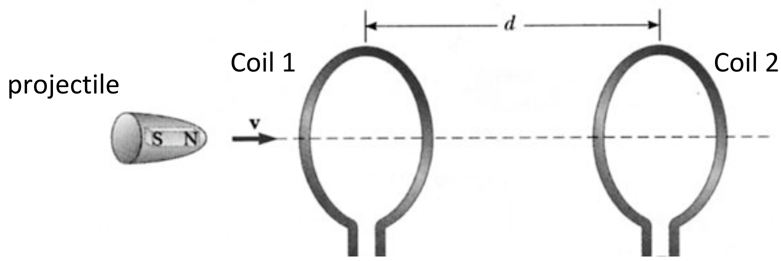


Fig 5.1

(i) Use the laws of electromagnetic induction to explain why an e.m.f. is induced in the coils. [2]

(ii) In Fig. 5.2, draw clearly a graph of the variation of induced e.m.f. against time for the arrangement shown in Fig. 5.1.

On your graph, label clearly which pulse is from coil 1 and which is from coil 2.

Fig. 5.2

(iii) If the pulse separation is 2.40 ms and *d* is 1.50 m, calculate the speed of the projectile. [1]

(iv) State and explain how the graph in Fig. 5.2 will differ if the speed of the projectile is increased. [2]

6. Radioactive decay is the *spontaneous* and random emission of radiation from a radioactive source. Radioactive nuclide ${}^{131}_{52}\text{Te}$ decays by β emission to form ${}^{131}_{53}\text{I}$. ${}^{131}_{53}\text{I}$ is not stable, and decays by β emission to the stable isotope ${}^{131}_{54}\text{Xe}$. The *half-life* for this second decay is very much longer than that for the decay of ${}^{131}_{52}\text{Te}$. A sample of pure ${}^{131}_{52}\text{Te}$ is prepared at time $t = 0$. Fig 6.1 shows the activity *A* of the sample over a period of 10 hours.

***t*/hr**	***A*/Bq**
0	1.00×10^{12}
1	1.94×10^{11}
2	3.95×10^{10}
3	1.08×10^{10}
4	2.66×10^{9}
5	2.27×10^{9}
6	2.12×10^{9}
7	2.12×10^{9}
8	2.12×10^{9}
9	2.12×10^{9}
10	2.12×10^{9}

Fig. 6.1

(a) Explain the meaning of the terms *spontaneous* and *half-life*. [2]

(b) The relation between activity A and time t follows the expression

$$A = A_0 e^{-\lambda t}$$

where A_0 is the initial activity and λ is a constant.

Data from Fig. 6.1 is used to obtain values for ln A. The variation with time t of ln A is plotted on the graph of Fig 6.2.

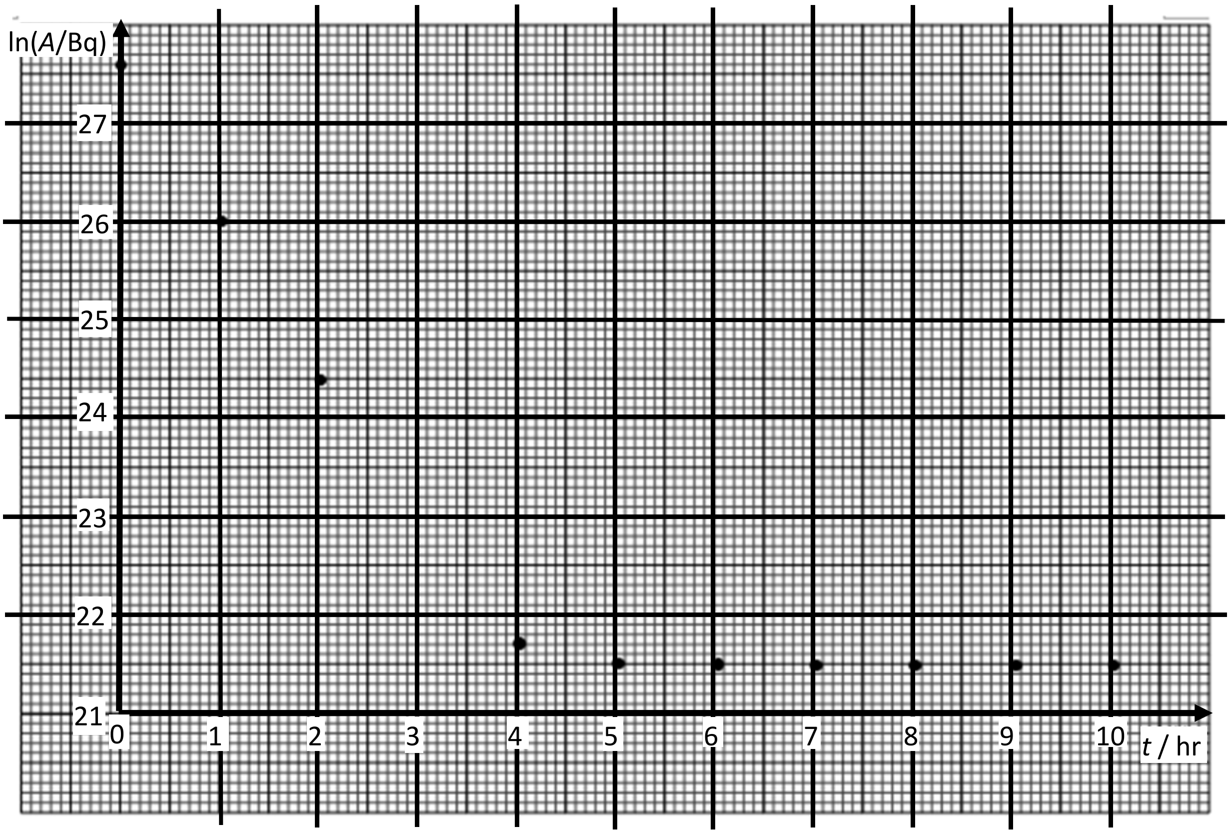


Fig. 6.2

(i) Determine ln A for t = 3 hr. [1]

(ii) On Fig. 6.2,

1. plot the point corresponding to t = 3 hr,
2. draw the line of best fit for all the points. [2]

(iii) Explain the shape of the line drawn in **(ii)**. [2]

(iv) Using the line drawn in **(ii)**, show that the decay constant of $^{131}_{52}Te$ is approximately 1.5 hr^{-1}. [2]

(v) Hence, or otherwise, deduce the initial number of $^{131}_{52}Te$ nuclei. [2]

(vi) Explain why the amount of $^{131}_{53}I$ in the sample first increases and then decreases. [2]

(vii) Assume that all the $^{131}_{52}Te$ has been converted to $^{131}_{53}I$ after about 6 hours. Calculate the half-life of $^{131}_{53}I$. [3]

7. Bats emit high frequency sound waves and receive reflected echoes. They use the echoes to locate their position. This process is called echolocation.

Sound waves emitted by the bat travel at 340 m s^{-1}. Their typical frequency range is 20 kHz to 80 kHz.

(a) Calculate the range of wavelengths for this frequency range. [2]

(b) Bats emit two waveforms, wave B and wave P, which superpose to form wave E.

Wave B (shown in Fig. 7.1) gives information about the surrounding background.

Wave P (not shown in Fig. 7.1) enables the bat to detect insect prey.
Wave E (shown in Fig. 7.1) is the superposition of wave B and wave P.

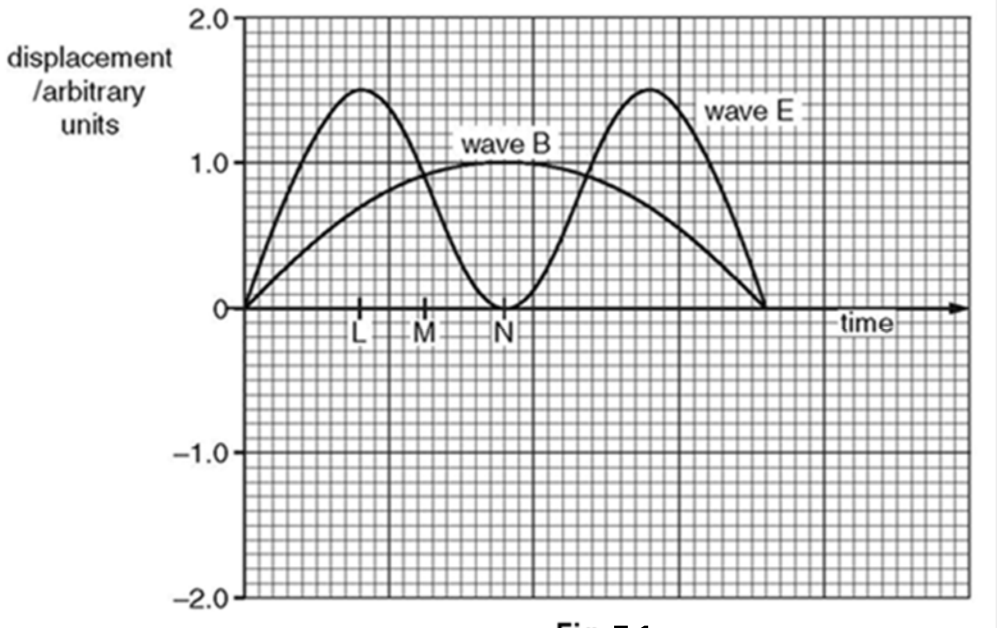


Fig. 7.1

(i) Use the principle of superposition to determine the displacement of wave P at times corresponding to points L, M and N on the time axis.

Write the displacement values in the spaces provided. [3]

displacement of wave P at L = ... units

displacement of wave P at M = ... units

displacement of wave P at N = ... units

(ii) Hence draw the waveform for wave P on Fig. 7.1. [1]

(c) An effect known as the Doppler effect uses changes in frequency to determine speeds.

The change in frequency, Δf, shown by wave P when it is reflected by an insect travelling with speed v is given approximately by the formula

$$\frac{\Delta f}{f} = \frac{2v}{c}$$

where c represents the speed, 340 m s^{-1}, of sound waves emitted by the bat.

(i) Wave P has a frequency of 50.80 kHz. Its apparent frequency after reflection is 51.25 kHz.

Calculate the speed of the insect. [2]

(ii) The bat best discriminates small insect prey when the wavelength of the reflected wave P is similar in size to the insect.

State the wave property that is being demonstrated in this situation. [1]

(d) The bat's high frequency waves are strongly attenuated in air. Fig. 7.2 shows the variation of intensity *I* with range in air *x* for the high frequency waves.

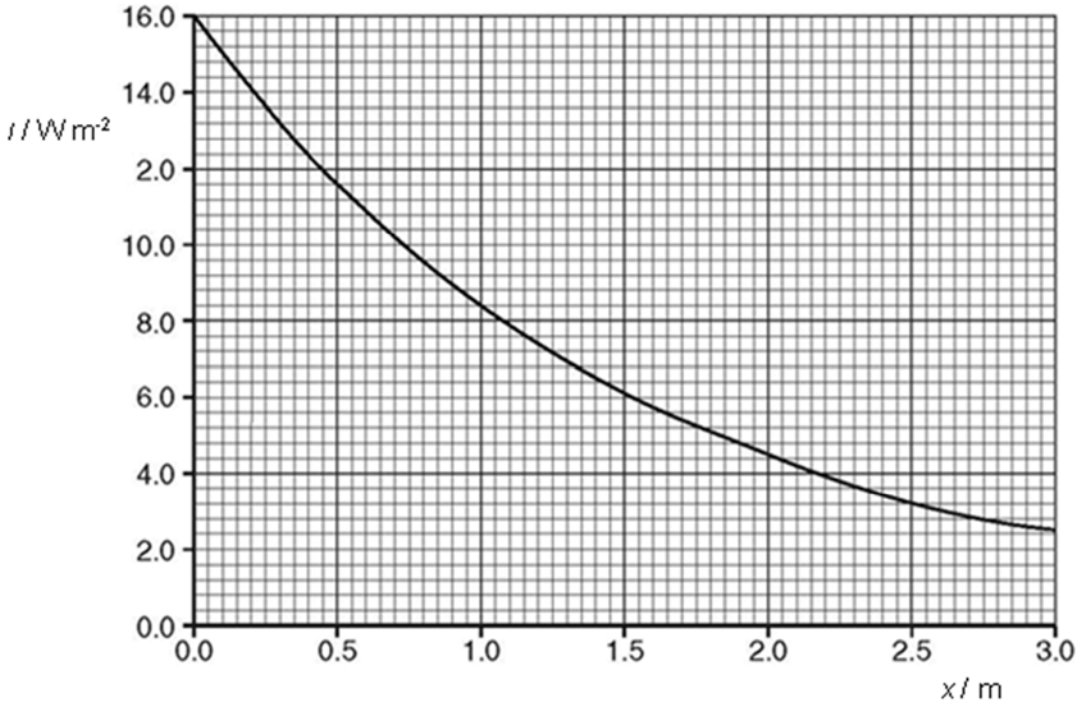


Fig. 7.2

The shape of the curve in Fig. 7.2 suggests that the decrease of the intensity *I* with range in air *x* could be exponential. In order to test this suggestion, a graph of ln *I* against *x* is plotted. This is shown in Fig. 7.3.

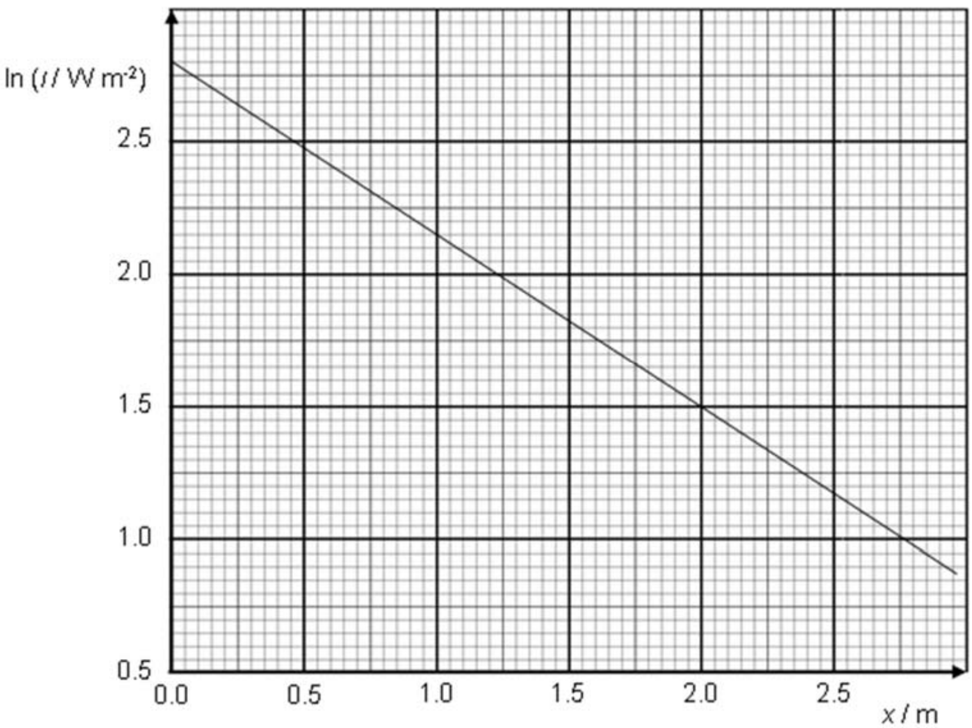


Fig 7.3

(i) Show that Fig. 7.3 indicates a relationship of the form

$$I = I_o e^{-\alpha x}$$

where α is a constant. [3]

(ii) The constant α is known as the attenuation coefficient.

1. State the SI unit of α. [1]

2. Use Fig. 7.3 to show that the value of α is about 0.7 units. [1]

(iii) On the axes of Fig. 7.3, sketch a graph to show a possible variation with range in air *x* of the intensity *I* of this high frequency wave if the value of α is 1.4. [2]

End of paper

2018 Physics prelim exam H2 P2 suggested answers

1(a)(i) Upthrust on an object immersed in a fluid is the net upward force acting on the object by the fluid due to the pressure difference acting on the top and bottom of the object.

(ii) Upthrust by liquid A = weight of liquid A displaced

$= V_A \rho_A g$

$= (0.200^2)(x)\rho_A g$

(ii) Upthrust by liquid B = weight of liquid B displaced

$= V_B \rho_B g$

$= (0.200^2)(0.200 - x)\rho_B g$

(iii) Weight of container = Upthrust by Liquid A + Upthrust by Liquid B

(9.20)(9.81) = $(0.200^2)(x)\rho_A g$ + $(0.200^2)(0.200 - x)\rho_B g$

(9.20)(9.81) = $(0.200^2)(x)(1.30\times10^3)(9.81)$ + $(0.200^2)(0.200 - x)(0.900\times10^3)(9.81)$

19.62 = 156.96 *x*

x = 0.125 m

(b)(i) When the bear is at the centre, the tension in the cable is 600 N.

Taking moments about the hinge,
Sum of clockwise moments = sum of anticlockwise moments,

$$(0.5L)(900) + (L)(80.0) = (600\sin\theta)(L)$$

$$\sin\theta = \frac{530}{600}$$

$$\theta = 62.0°$$

(ii) The bear should be standing on the hinge.

(iii) When the bear is standing on the hinge, the tension in the cable is 200 N.

Taking moments about the hinge,
By conservation of moments, the sum of clockwise moments = sum of anticlockwise moments,

$(0.5L)(m_b g) + (L)(80.0) = (200 \sin 62.0°)(L)$

$m_b g = 193$ N

$m_b = 19.7$ kg

2(a)(i) The kinetic energy of the car is used to do work against resistant forces such as friction on the road.

(ii) As the mass moves downwards, it loses gravitational potential energy. This loss in gravitational potential energy is converted to elastic potential energy stored in the stretched string and work done against the force exerted by the hand.

(b)(i) By conservation of energy,

Loss in KE = gain in GPE + word done against friction

$$\frac{1}{2}m(v_i^2 - v_f^2) = mgh + fd$$

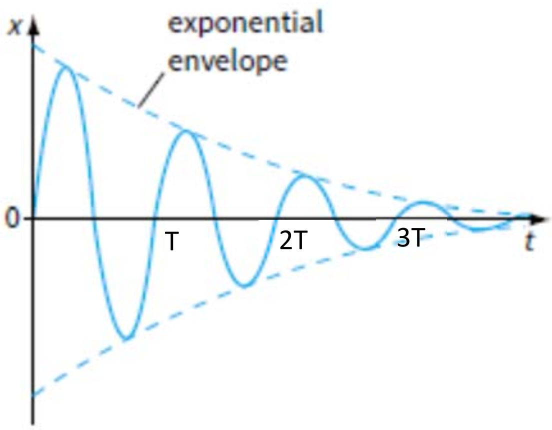
$$\frac{1}{2}(55)(6.5^2 - v_f^2) = (55)(9.81)(1.3) + (2.0)(2.0)$$

$$v = 4.1 \text{ m s}^{-1}$$

(ii) If the ramp is replaced by the one shown in the figure, the distance travelled will be shorter and hence the work done against friction will be smaller. Therefore, the speed the skateboarder exits at point B will be higher.

3(a)(i) As the block oscillates in the liquid, energy is needed to overcome the resistive (viscous) forces present in the liquid. Energy of the oscillating system thus decreases, resulting in damped oscillations.

(ii)



(b)(i) The motion of the block is in **forced oscillation** as the water waves provides the external periodic driving force to continuously supply energy to the block to compensate for the loss of energy due to damping. The block will therefore oscillate with a constant amplitude and at the frequency of the water waves.

When the driving frequency of the water waves matches the natural frequency of the block in the water, **resonance** occurs. At this particular frequency, there is maximum transfer of energy from the water waves to the block, so the block oscillates with the maximum amplitude.

(ii) 1. $v = f\lambda \Rightarrow f = \frac{v}{\lambda} = \frac{0.90}{0.30} = 3.0\,\text{Hz}$

2. $f = \frac{1}{2\pi}\sqrt{\frac{28}{m}} \Rightarrow m = \frac{28}{4\pi^2 f^2} = \frac{28}{4\pi^2(3.0)^2} = 78.8\,\text{g}$

3. When the block has absorbed some water, its mass increases, so its natural frequency becomes lower, so resonance no longer occurs. Hence the amplitude of vertical oscillation will be lower.

4(a) The increase in internal energy of a system is equal to the sum of the heat supplied to the system and the work done on the system.

(b)(i) AB: volume is compressed, so $(W_{on})_{AB}$ is positive.
Adiabatic: $Q_{AB} = 0$

$\Delta U_{AB} = Q_{AB} + (W_{on})_{AB}$
$= 0 + 10$
$= 10$ J [A1] (Increase)

(ii) For a complete cycle, $\Delta U_{AB} + \Delta U_{BC} + \Delta U_{CD} + \Delta U_{DA} = 0$

$\Delta U_{AB} + [Q_{BC} + (W_{on})_{BC}] + [Q_{CD} + (W_{on})_{CD}] + [Q_{DA} + (W_{on})_{DA}] = 0$
$10 + [70 + 0] + [0 – 25] + [Q_{DA} + 0] = 0$
$Q_{DA} = -55$ J
So 55 J of heat leaves the gas.

(iii) Efficiency $= \frac{\text{Net useful work done by gas}}{\text{Heat input}}$

$= \frac{[(W_{by})_{CD} - (W_{by})_{AB}}{Q_{BC}}$

$= \frac{25 - 10}{70}$

$= 21\ \%$

(iv) Useful power output
= (Net useful work done by gas per cycle) x (No. of cycles per second)
$= (25 - 10) \times \frac{3000}{60}$
= 750 W

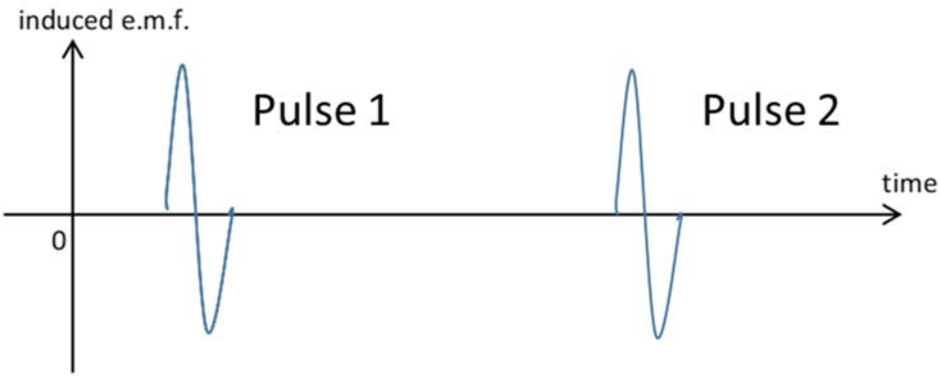
5(a) Lenz's law states that the induced emf and hence current in conductor will be such that it opposes the change causing it.

Using a clamp and retort stand, rigidly hold a coil connected to a galvanometer in a closed circuit with a switch. Freely hang a magnet as an oscillating pendulum from another retort stand and allow the magnet to oscillate such that its plane of oscillation brings the magnet closer and further from one end of the coil.

As the magnet approaches, an induced current will flow in the coil, producing a magnetic field that opposes the motion of the magnet, slowing it down, this can be seen as a deflection in the galvanometer. As the magnet oscillates away, the induced current will flow in the coil in the opposite direction to produce a magnetic field that attracts the magnet, further slowing it down.

(b)(i) As the projectile approaches the coils, the magnetic field experienced at each coil becomes larger, the closer the projectile is. The coils thus experience changing magnetic flux and hence according to Faraday's law, experience an emf.

(ii)



(iii) $v = \frac{d}{t} = \frac{1.50}{2.40 \times 10^{-3}} = 625 \text{ m s}^{-1}$

(iv) The pulses will be closer together as the bullet takes a shorter time to travel between the coils.

The amplitude of the induced emf of each pulse will be larger as the coils will experience a higher rate of change of magnetic flux linkage.

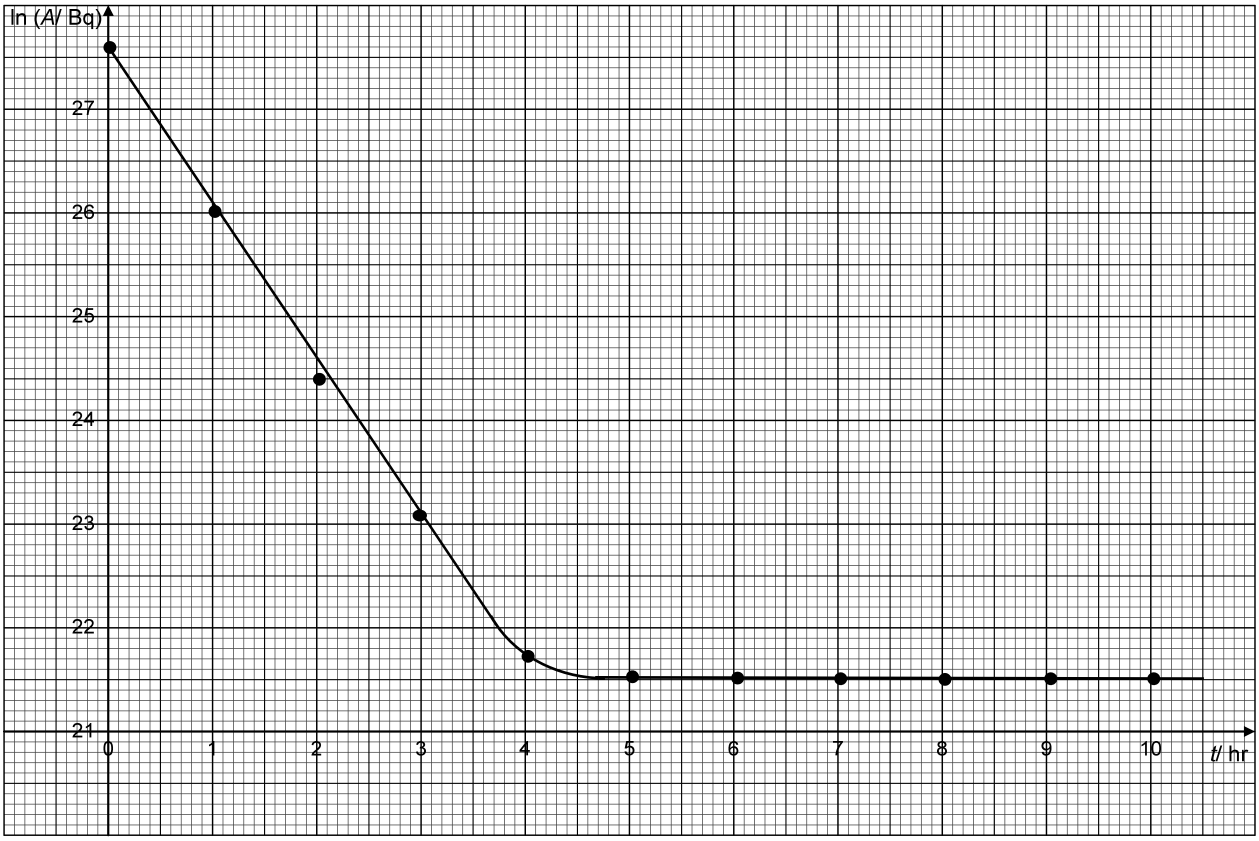
6(a) Spontaneous means that the decay process occurs on its own accord and are unaffected by physical or chemical means.

Half-life of a radioactive element is the *average* time taken for half the original number of the radioactive nuclei to decay.

(b)(i) From the table, at t = 3 hr, $A = 1.08 \times 10^{10}\ Bq$

$\Rightarrow \ln A = \ln(1.08 \times 10^{10}) = 23.103$

(ii)



(iii) From 0 to 3 hrs, the graph is linear with a negative slope. This is because the activity is predominantly that of $^{131}_{52}Te$ as there are only small amounts of $^{131}_{53}I$. So the combined activity follows the linear equation: $\ln A = -\lambda t + \ln A_0$ for $^{131}_{52}Te$.

From 3 to 6 hrs, the graph is a curve as the activity of $^{131}_{53}I$ nuclei grows and the activity of $^{131}_{52}Te$ decreases. So the resultant activity is due to two different nuclides, and doesn't follow the linear equation above.

From 6 to 10 hrs, the line is horizontal due mainly to the activity of $^{131}_{53}I$ which has a very long half-life as compared to $^{131}_{52}Te$. A long half-lfe means a low decay rate, which means that the activity hardly changes.

(iv) Decay constant of $^{131}_{52}Te$ can be obtained from the *gradient* of the linear part of the graph from 0 to 3 hrs.

$$\therefore \lambda = -\frac{27.60 - 23.40}{0.00 - 2.80} = 1.50\,\text{hr}^{-1}$$

(v) From the table, at *t* = 0 hr, $A_0 = 1.00 \times 10^{12}\ Bq$

Since, $A = \lambda N$

$$\Rightarrow N_0 = \frac{A_0}{\lambda} = \frac{1.00\times10^{12}}{1.5/(60\times60)} = 2.40\times10^{15}$$

(vi) Initially the rate of production of $^{131}_{53}\text{I}$ is much *higher* than the rate of its decay to $^{131}_{54}\text{Xe}$, hence the amount of $^{131}_{53}\text{I}$ increases.

Later, most of the $^{131}_{52}\text{Te}$ would have decayed, resulting in the rate of production of $^{131}_{53}\text{I}$ to be *lower* than its rate of decay to $^{131}_{54}\text{Xe}$. Hence, the amount of $^{131}_{53}\text{I}$ will then decrease.

(vii) Assuming that all the $^{131}_{52}\text{Te}$ has been converted to $^{131}_{53}\text{I}$, the number of $^{131}_{53}\text{I}$ isotopes after 6 hours is 2.40 x10^{15} and its activity is 2.12 x10^{9} Bq (*from table*).

Since, $A = \lambda N = \frac{\ln 2}{t_{1/2}} N$

$$\Rightarrow t_{1/2} = \frac{\ln 2}{A} N = \frac{\ln 2}{2.12\times10^{9}}\left(2.40\times10^{15}\right) = 7.85\times10^{5}\ \text{s}$$

7(a) $\lambda = v/f$

$$\lambda_1 = \frac{340}{20000} = 0.017\ \text{m}$$

$$\lambda_2 = \frac{340}{80000} = 0.0043\ \text{m}$$

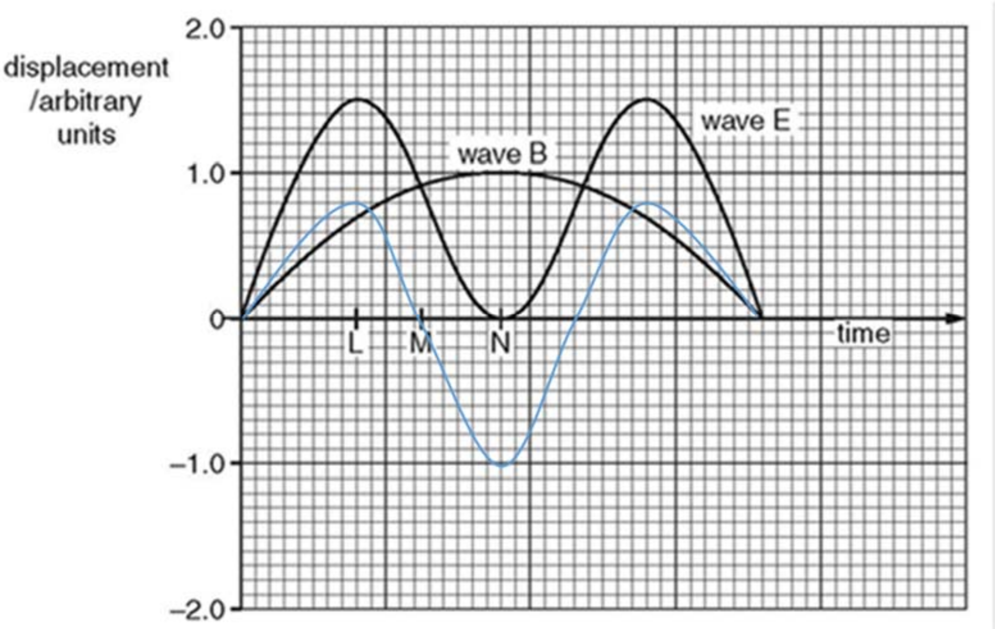
Range: 0.0043 to 0.017 m.

(b)(i) $x_L = 1.5 - 0.70 = 0.80$

$x_M = 0.90 - 0.90 = 0.00$

$x_N = 0.0 - 1.0 = -1.00$

(ii)



[A1]

(c)(i) $\frac{51.25-50.8}{50.8}=\frac{2v}{340}$

$v=1.51\text{ m s}^{-1}$

(ii) Diffraction

(d)(i) The graph is linear with a negative gradient. Its y intercept = 2.8 ≈ ln16.

So the graph supports the equation ln$I$ = -αx + ln16

$I = 16e^{-\alpha x}$

$= I_0 e^{-\alpha x}$

(ii) 1. m^{-1}

2. gradient= $\frac{2.80-0.85}{0.0-3.0}=-0.65\text{ m}^{-1}$

$\therefore \alpha \approx 0.7\text{ m}^{-1}$

(iii) Draw a graph with a constant more negative (steeper) gradient.

The y-intercept should be the same as before.

Name : ______________________________ CT group : ____________

VICTORIA JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATIONS 2018

PHYSICS **9749/03**

Higher 2 **18 Sep 2018**

TUESDAY

Paper 3 Longer Structured Questions **2 pm – 4 pm**

2 Hours

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

READ THESE INSTRUCTIONS FIRST

Write your name and CT group 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 staples, paper clips, highlighters, glue or correction fluid.

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

Section A
Answer **all** questions.

Section B
Answer **one** question only.

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

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

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

For Examiner's Use	
Section A	
1	
2	
3	
4	
5	
6	
7	
Section B	
8	
9	
Units	
sf	
g	
Total	

This question set consists of a total of **22** printed pages.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1} $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant,	$R = 8.31$ J mol^{-1} K^{-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,	$s = ut + (½)\,at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\dfrac{GM}{r}$
temperature	$T / K = T / °C + 273.15$
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \dfrac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_o \sin \omega t$
velocity of particle in s.h.m.,	$v = v_o \cos \omega t$ $= \pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = Q/4\pi\varepsilon_o r$
alternating current/voltage,	$x = x_o \sin \omega t$
Magnetic flux density due to a long straight wire	$B = \dfrac{\mu_0 I}{2\pi d}$
Magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_0 NI}{2r}$
Magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_o \exp(-\lambda t)$
decay constant,	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1. (a) Group the following terms into pairs, so that in each pair a quantity is given followed by its corresponding unit.

power, volt, watt, magnetic flux, magnetic flux density, potential difference, tesla, weber. [2]

(b) Explain why it is technically incorrect to define speed as distance travelled per second. Include in your answer the correct statement defining speed. [2]

(c) An archer fires an arrow with an initial velocity *v* and hits a target which is a distance *d* away and on the same horizontal level as the bow, as illustrated in **Fig. 1**. The arrow is aimed so that, on release, it makes an angle θ with the horizontal.

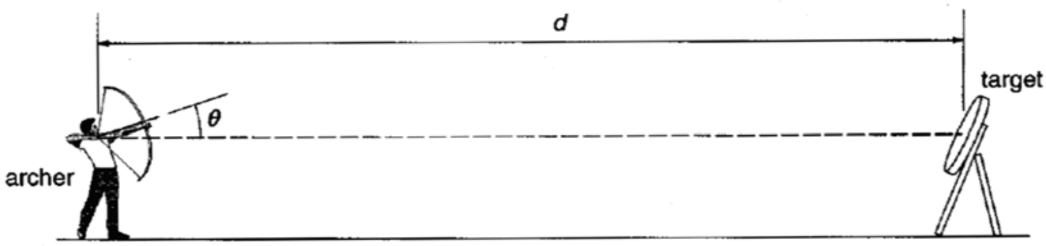


Fig. 1

(i) Assuming air resistance is negligible, write down an expression for *d* in terms of *v*, θ, and the time of flight *t*. [1]

(ii) Write down an expression for the time of flight t in terms of v, θ and the acceleration of free fall g. [1]

(iii) The distance d is given by the expression

$$d = \frac{v^2 \sin 2\theta}{g}.$$

Calculate two possible angles, θ_1 and θ_2, for an arrow with initial velocity v = 32 m s^{-1} and a target at a distance d of 94 m from the bow. [3]

2(a)(i) A man pushes a heavy rock resting on the ground, but it does not move. A student says that this is because the pushing force is balanced by the reaction to this force. Explain why the student's argument is wrong. [2]

(ii) Draw a labelled diagram to show the forces acting on the rock. [2]

(b) Block A of mass 2.0 kg moves with a velocity 10 m s^{-1} to the right on a smooth horizontal table. Block B of mass 3.0 kg moves with a velocity of 5.0 m s^{-1} in front of A in the same direction. A light spring of force constant 500 N m^{-1} is attached to B as shown in **Fig. 2.1** below.

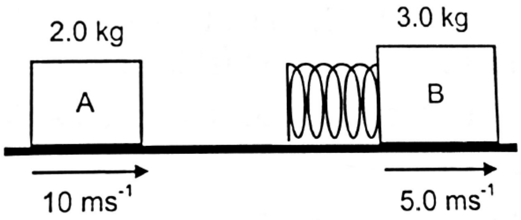


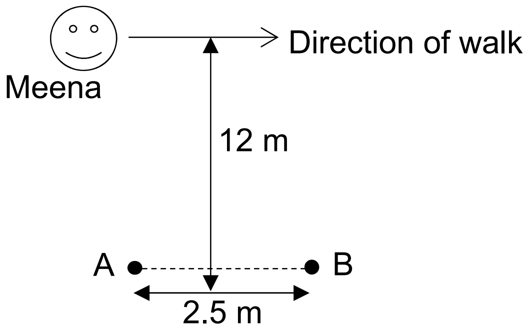
Fig. 2.1

(i) When A collides with B, there will be an instant when the spring experiences maximum compression. Describe the motion of A and B when maximum compression of the spring takes place. [1]

(ii) Calculate the final velocity of the two blocks at the instant the spring is at its maximum compression. [2]

(iii) Hence calculate the maximum compression of the spring. [2]

3 Two identical sound speakers placed at positions A and B are connected to the same signal generator, 2.5 m apart. Meena walks in a direction parallel to AB, 12 m away, as shown in the figure below:



As she walks, she detects a series of loud and soft sounds.

(a) Adjacent loud regions are 0.60 m apart. Calculate the frequency of the sound used. The speed of sound is 340 m s^{-1}. [3]

(b) At one of the loud regions, Meena detects an intensity of *I*. The amplitude of each wave from each speaker is *A*.

(i) State the resultant wave amplitude at Meena's location. [1]

The power output of one of the speakers is reduced to half its original value, while the other speaker remains unchanged.

(ii) For the speaker with the reduced power output, state the amplitude of its wave at Meena's location in terms of *A*. [1]

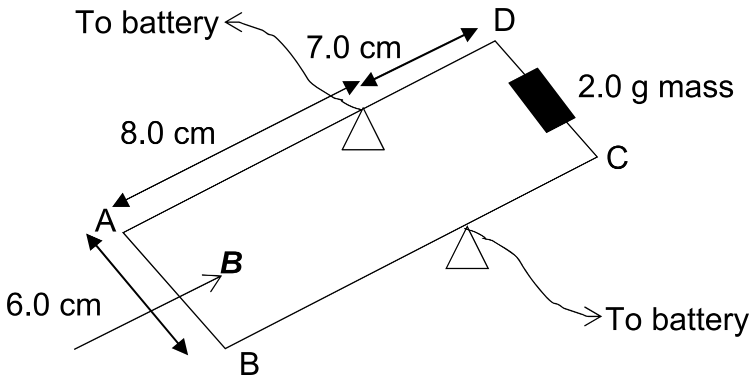
(iii) Calculate the new resultant wave amplitude at Meena's location in terms of *A*. [1]

(iv) Calculate the new intensity detected by Meena in terms of *I*. [2]

4. A light rectangular wire frame ABCD is used as a current balance. It has the following dimensions:

AB = CD = 6.0 cm
BC = DA = 15.0 cm

The wire frame is pivoted such that the pivot is 8.0 cm from AB, and 7.0 cm from CD. A 2.0 g mass is attached to CD. Side AB is entirely immersed in a uniform horizontal magnetic field ***B*** which is perpendicular to AB, as shown in the diagram below:



A current of 3.0 A flows through the wire frame, and as the result, the frame is found to come to a rest in the horizontal orientation.

(a) State the direction (AB or BA) of the current. [1]

(b) Calculate the magnetic field, ***B***. [3]

(c) Explain why such a current balance cannot be used to measure the strength of a magnetic field that is not horizontal. [3]

5. A stream of electrons travelling at a speed of 6.8×10^6 m s^{-1} and making an angle of 30° to the horizontal enters the region between two horizontal parallel plates at point P. The electrons are deflected and exit horizontally at point Q as shown in **Fig. 5.1**.

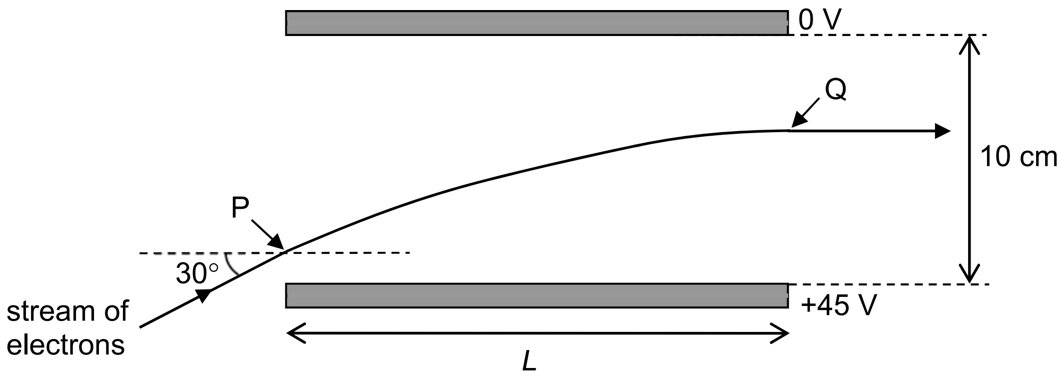


Fig. 5.1

The length of the plates is *L* and their separation is 10 cm. The potential of the lower plate is +45 V with respect to the upper plate.

(a) Show that the magnitude of the acceleration of an electron between the plates is 7.9×10^{13} m s^{-2}. [2]

(b) Determine the length L of the plates. [3]

(c) Charged particles travelling horizontally at a speed of 6.8×10^6 m s^{-1} are now entering the region between the plates at point Q as shown in **Fig. 5.2**.

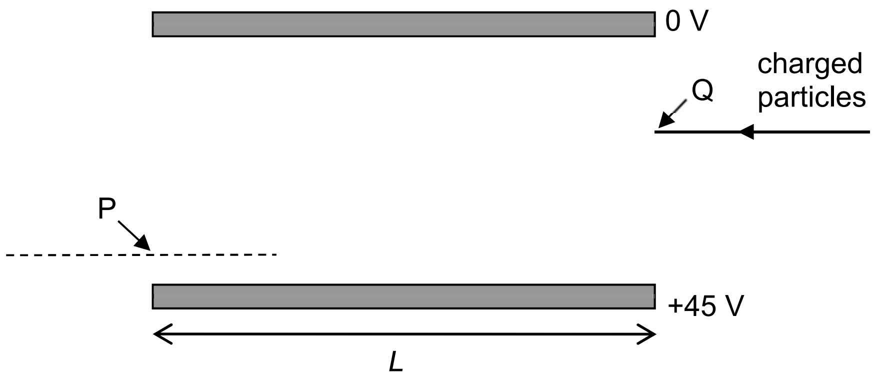


Fig. 5.2

(i) On **Fig 5.2**, sketch the path of the charged particles between the plates if they were electrons. Label this path A. [1]

(ii) On **Fig 5.2**, sketch the path of the charged particles between the plates if they were protons. Label this path B. [1]

(iii) Explain two differences between paths A and B. [2]

I.

II.

6. Fig. 6.1 shows the variation of binding energy per nucleon for nuclides with a nucleon number greater than 40.

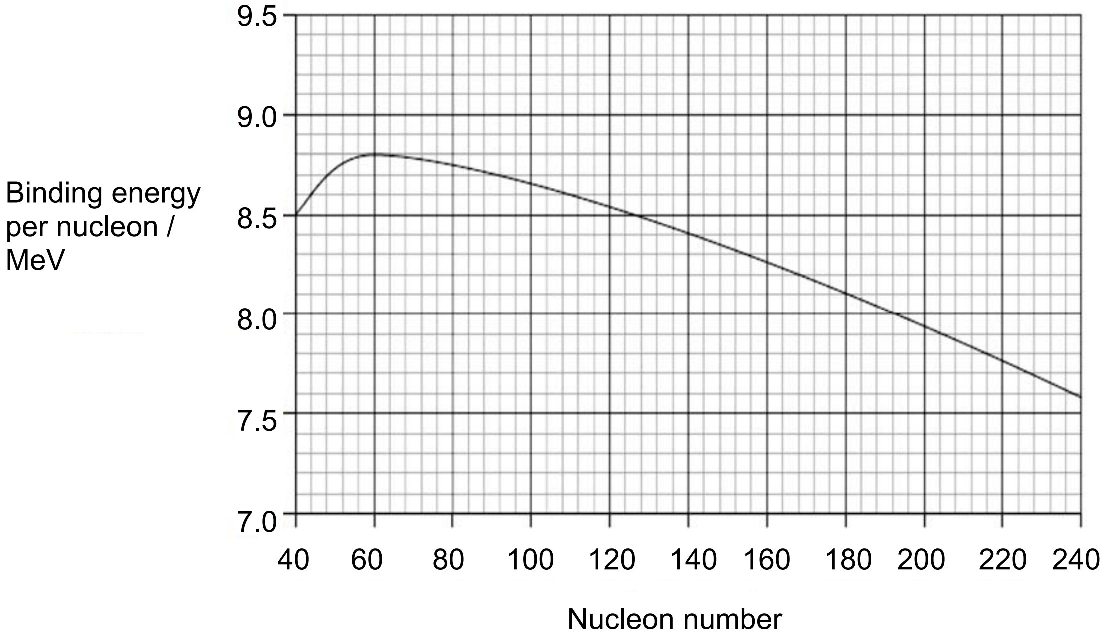


Fig 6.1

The following nuclear reaction occurs when a slow moving neutron is absorbed by an isotope of uranium-235.

$$^{1}_{0}n+^{235}_{92}U\rightarrow^{141}_{56}Ba+^{92}_{36}Kr+\text{neutrons}$$

(a) Determine the number of neutrons produced in this reaction. [1]

(b) Explain how this reaction is able to produce energy. [2]

(c) Use the graph in **Fig. 6.1** to determine the energy released in the above reaction. [3]

(d) Suggest why the neutron is not included in the calculation above. [1]

7(a) In an electron microscope, electrons are accelerated by an electric field in order to investigate the structure of matter. This is done by analyzing the diffraction pattern produced when the accelerated electron beam is passed through the arrangement of atoms in solids. This technique is possible due to the phenomenon known as wave–particle duality.

(i) Explain what is meant by the term *wave–particle duality* as applied to this technique. [1]

(ii) Estimate the kinetic energy of electrons such that they can be used to measure the distance between adjacent atoms in crystals, which is typically about 0.1 nm. [4]

(iii) The percentage uncertainty in measuring the electron's velocity is 10%. Calculate the minimum uncertainty in a simultaneous measurement of the electron's position. [2]

(iv) Calculate the energy of a photon which has the same wavelength as the electron. [2]

(b) Scientists suggests the use of *protons* to replace the electrons in the electron microscope in part (a).

(i) Determine the associated wavelength of protons with the same kinetic energy as the electrons in part (a). [1]

(ii) State and explain whether the use of protons would make a better or less effective probe of small-scale structures. [1]

Section B

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

8(a) One end of a string is secured to the ceiling and a metal ball of mass 50 g is tied to its other end. The length of the string is 1.50 m. The ball is initially at rest in the vertical position. The ball is raised through a vertical height of 70 cm (see **Fig. 8.1** below). When the ball is released, it describes a circular arc as it passes through the vertical position.

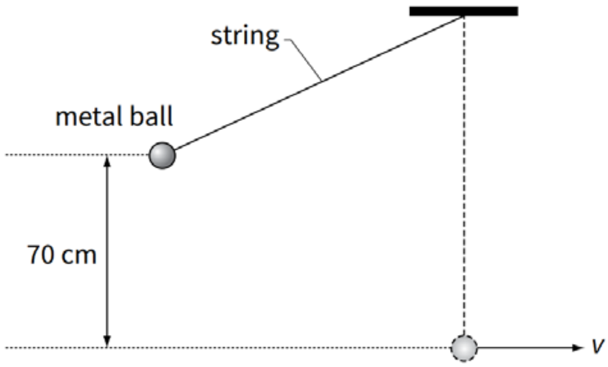


Fig. 8.1

(i) Ignoring the effects of air resistance, show that the speed v of the ball is $3.7\ \text{m s}^{-1}$ as it passes through the vertical position. [1]

(ii) Draw a labelled force diagram to show all the forces acting on the ball when the string is in the vertical position. [2]

(iii) Calculate the centripetal force on the ball when it is in the vertical position. [2]

(iv) Explain why the tension in the string when it is vertical is not equal to the weight of the ball. [2]

(v) Calculate the tension in the string when it is vertical. [2]

(b) **Fig. 8.2** shows the dwarf planet, Pluto, and its moon, Charon. These can be considered to be a double planetary system orbiting each other about their joint centre of mass. To simplify the situation, assume that Pluto has a circular orbit of radius r_P and Charon has a circular orbit r_C. The distance between the centres of mass of Pluto and Charon is 1.96×10^4 km.

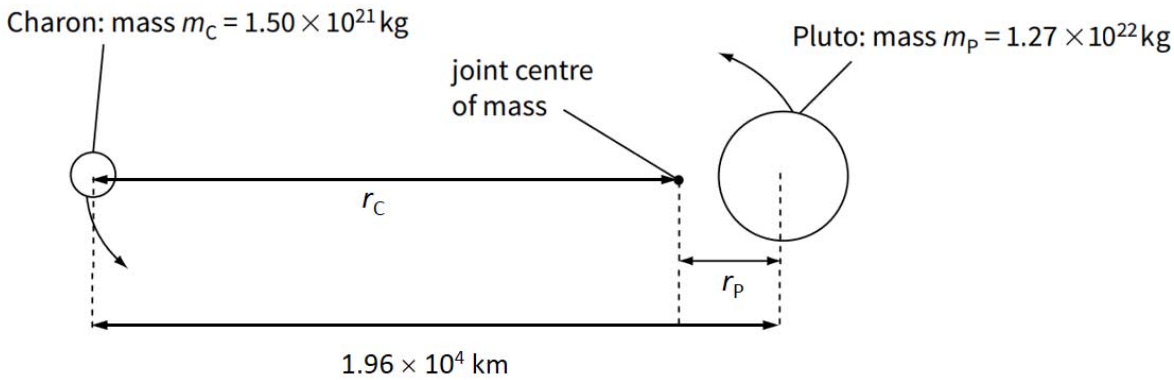


Fig. 8.2

(i) Explain what is meant by the gravitational field strength at a point. [1]

(ii) Calculate the gravitational field strength at the centre of Charon due to Pluto alone, and state its direction. [3]

(iii) Both Pluto and Charon have the same angular speed about their joint centre of mass. Show that the ratio of the masses is given by the expression: [3]

$$\frac{m_P}{m_C} = \frac{r_C}{r_P}.$$

(iv) Calculate the radius r_C of Charon's orbit. [2]

(v) Calculate Charon's orbital period. [2]

9(a) (i) Define the *ohm*. [1]

(ii) On **Fig 9.1** below, sketch a graph to show how you would expect the current in a tungsten filament lamp to change as the potential difference across the lamp increases slowly from $-V$ to + V.

[1]

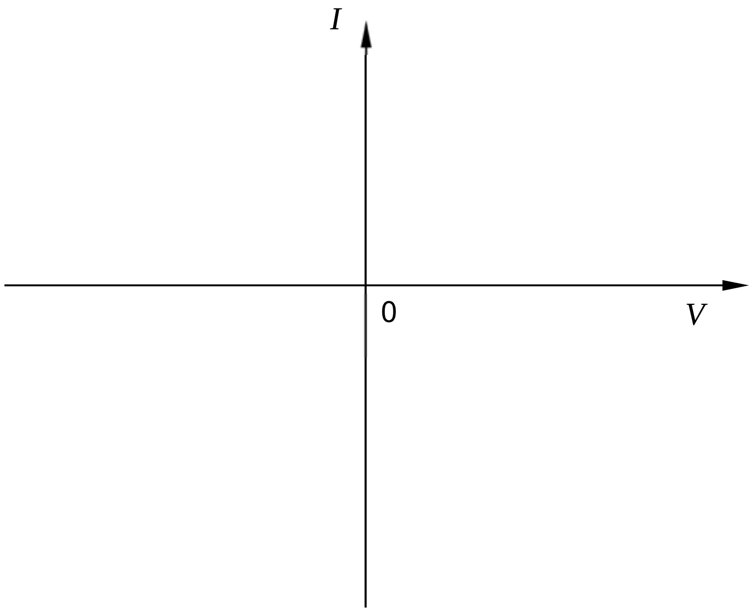


Fig 9.1

(iii) State how you would obtain the resistance of the lamp from your graph at a particular potential difference across the lamp. [1]

(iv) Draw a circuit set-up that could be used to investigate the *I*-*V* characteristics of a lamp as shown in **Fig 9.1**. [2]

(b) A circuit is setup as shown below in **Fig 9.2**. A cell *E* with internal resistance *r* is connected to a network of resistors.

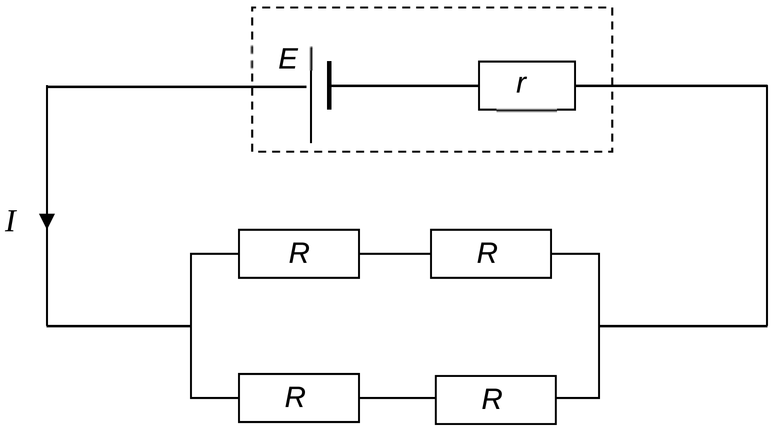


Fig 9.2

(i) Find the current I in the circuit, in terms of *R*, *r* and *E.* [2]

(ii) Show that the fraction of power dissipated in the external resistors by the battery is $\frac{R}{R+r}$. [2]

(iii) Suggest a reason for having 4 resistors connected in a network as shown in **Fig 9.2** instead of just using a single resistor of resistance *R*. [1]

(c) A resistor of resistance of $8.2\ \text{k}\Omega$ and a LDR (light dependent resistor) are connected in series, as shown below in **Fig 9.3**. The resistance of the LDR when light is shone on it is $420\ \Omega$ and when dark is 134 kΩ.

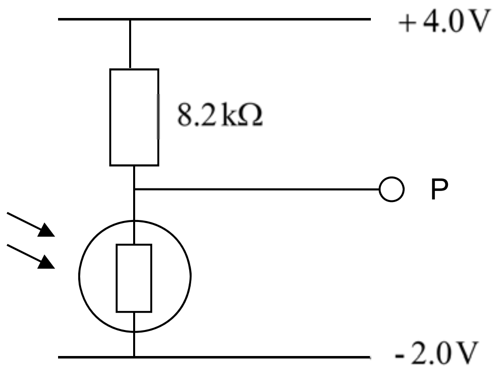


Fig 9.3

Calculate the potential at point P when

(i) light is shone on the LDR, [2]

Potential at P = ________ V

(ii) no light is shone on the LDR (dark). [1]

Potential at P = _________ V

(iii) An alarm is now connected in parallel with the LDR in **Fig 9.3** and a laser beam is directed at the LDR in a simple burglar alarm system. When a burglar blocks the laser that is shining continuously on the LDR, the alarm is triggered. Assume that the resistance of alarm is very large. Explain clearly how the LDR is used to turn on/off the alarm in such a system. [2]

(d) A circuit is set up as shown in **Fig 9.4** below. The resistance of the potentiometer wire has a resistance of 1.5 Ω and is 1.00 m long. The movable contact J can be connected to any point along wire XY.

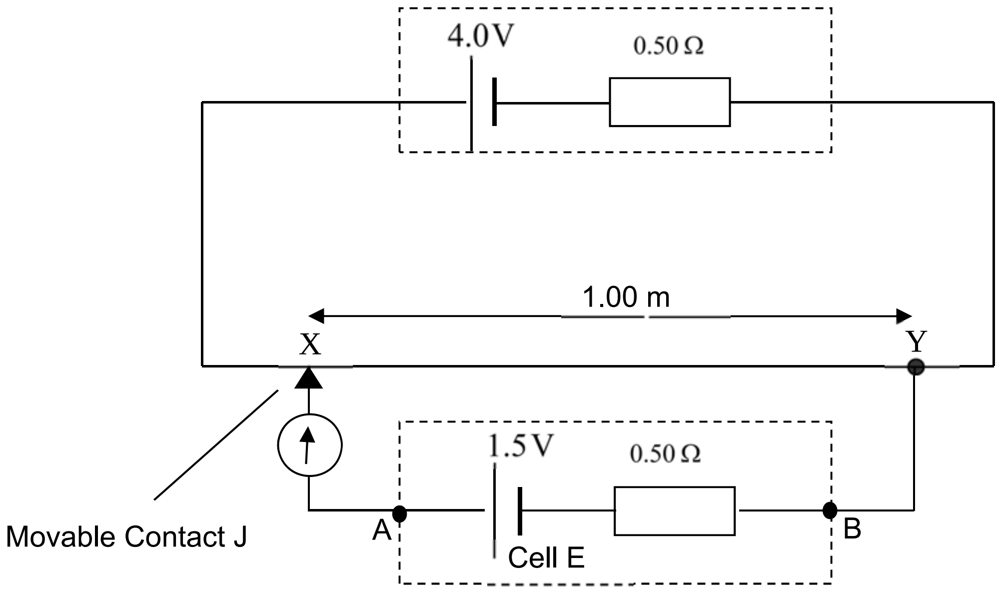


Fig 9.4

(i) Determine the distance of the contact J from X, such that there is no deflection in the galvanometer. [2]

(ii) A 1.50 Ω resistor is connected across points A and B (in parallel with cell E). Determine the new distance of the contact J from X, such that there is no deflection in the galvanometer. [3]

End of paper

VJC Prelim 2018, H2 Physics, Paper 3 – Suggested Solutions

Section A

1(a) power, watt
potential difference, volt
magnetic flux, weber
magnetic flux density, tesla

(b) Speed is a quantity, so it should be defined in terms of other quantities. But <u>"second" is a unit (or second isn't a quantity)</u>, so the statement is incorrect.
Speed is the distance travelled per <u>unit time</u>.

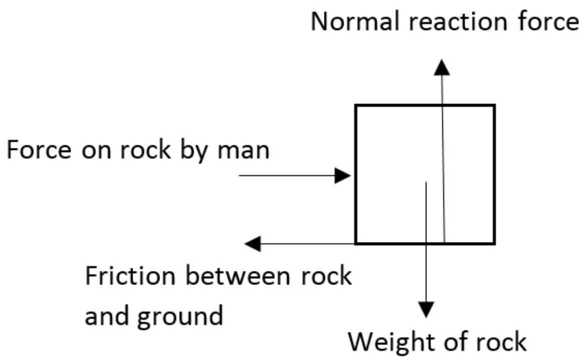
(c)(i) horizontal component of the velocity, $v_x = v\cos\theta$
Range, $d = (v\cos\theta)t$

(ii) vertical component of the velocity, $v_y = v\sin\theta$
$s_y = u_y t + (1/2)at^2$
$0 = (v\sin\theta)t + (1/2)(-g)t^2$
$t = \dfrac{2v\sin\theta}{g}$

(iii) $\sin 2\theta = \dfrac{dg}{v^2} = \dfrac{(94)(9.81)}{(32)^2}$
$= 0.9005$
$2\theta = 64.23°$ or $115.8°$
$\theta_1 = 32.1° = 32°$
$\theta_2 = 57.9° = 58°$

2(a)(i) The student's argument is not correct because the reaction force acts on the man, i.e. the reaction force on the man and the force the man exerts on the rock are acting on two different bodies, so they do not cancel out.

(ii)



Note: The normal reaction force and weight of rock must form an anticlockwise couple, to balance the clockwise couple from the horizontal forces.

2(b)(i) Block A and B moves with the same velocity when maximum compression of the spring takes place.

(ii) By the conversation of momentum,
total initial momentum = total final momentum

$m_A u_A + m_B v_B = (m_A + m_B)v$

$(2.0)(10) + (3.0)(5.0) = (2.0 + 3.0)v$

$v =$ 7.0 m s^{-1}

(iii) Let maximum compression be *x*.
By conservation of energy,
loss in KE of block A = gain in EPE in the spring + gain in KE of block B

$\frac{1}{2}m_A(u_A^2 - v_A^2) = \frac{1}{2}kx^2 + \frac{1}{2}m_B(v_B^2 - u_B^2)$

$\frac{1}{2}(2.0)(10^2 - 7.0^2) = \frac{1}{2}(500)x^2 + \frac{1}{2}(3.0)(7.0^2 - 5.0^2)$

$x =$ 0.24 m

3a. $\Delta y = \frac{\lambda D}{d}$

$= \frac{vD}{fd}$

Frequency of sound, $f = \frac{vD}{d\Delta y}$

$= \frac{340 \times 12}{2.5 \times 0.60}$

= 2720 Hz

bi. 2*A*

ii. $\frac{A}{\sqrt{2}}$ = 0.707 *A*

iii. $\left(A + \frac{A}{\sqrt{2}}\right)$ = 1.7071*A*

≈ 1.71*A*

iv. Old intensity: $I = k(2A)^2$, k = constant

$= 4kA^2$

New intensity: $I' = k(1.7071A)^2$

$= 2.91kA^2$

$= 0.729\, I$

4a. (Reasoning: the magnetic force must be downward, to balance the weight of the mass on the other end. Use Fleming's left-hand rule.)

B to A

b. Take moments about pivot

Anticlockwise moment = clockwise moment

BIL x 8.0 x 10^{-2} = mg x 7.0 x 10^{-2}

$$B = \frac{mg \times 7.0 \times 10^{-2}}{IL \times 8.0 \times 10^{-2}}$$

$$= \frac{2.0 \times 10^{-3} \times 9.81 \times 7.0 \times 10^{-2}}{3.0 \times 6.0 \times 10^{-2} \times 8.0 \times 10^{-2}}$$

$= 9.5 \times 10^{-2}$ T

c.

- A non-horizontal field will generate a magnetic force with a horizontal component.
- This horizontal component force will not generate any moment about the pivot.
- So you can't tell what is its magnitude (and therefore you won't know what is the total value of the magnetic field).

5 **(a)** $E = \frac{V}{d} = \frac{45}{0.10} = 450 \text{ V m}^{-1}$ or $F_E = qE = (1.60 \times 10^{-19}) \times 450 = 7.2 \times 10^{-17}$ N

$F_E = m\,a$

$e\,E = m\,a$

$(1.60 \times 10^{-19}) \times 450 = (9.11 \times 10^{-31}) \times a$

$a = 7.903 \times 10^{13}$ m s^{-2} or 7.9×10^{13} m s^{-2}

(b) $v_y = u_y + a_y\,t$

$0 = (6.8 \times 10^6 \times \sin 30°) + (-7.9 \times 10^{13})\,t$

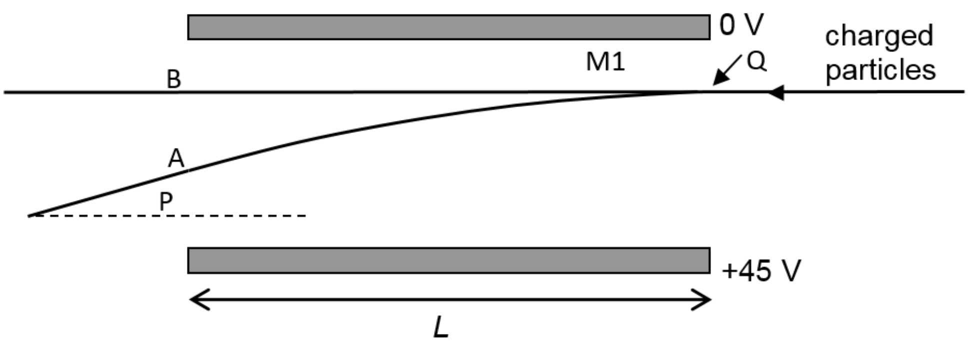
$t = 4.304 \times 10^{-8}$ s

$s_x = u_x\,t + ½\,a_x\,t^2$

$L = (6.8 \times 10^6 \times \cos 30°) \times (4.304 \times 10^{-8}) + 0$

$L = 0.253$ m or 0.25 m

(c)



(i) Electrons from Q will have a smaller vertical displacement than previously as its horizontal speed now is higher. Path A exits above point P.

(ii) Mass of protons is 1800 times more than electrons. Vertical displacement of protons will be 1800 times less than that of electrons. Path B is almost straight and the upward vertical displacement is much less than Path A.

(iii) **I.** Path A and path B are deflected in opposite directions: due to opposite charges, the forces acting on electrons and protons are in opposite directions.

II. Path A shows a much greater deflection than Path B (Path B is nearly straight): Electrons and protons experience the same force. Due to the much smaller mass of electrons, they experience a much larger acceleration than protons and hence a larger vertical displacement.

6(a) $^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$

3 neutrons are produced.

(b) From the graph U has lower binding energy per nucleon than the products Ba and Kr. Multiplying by the number of nucleons, U has lower binding energy than both (Ba + Kr) together.
This means that U required less energy to break up the nucleus into its constituent nucleons, and more energy is being released when both Ba + Kr are formed from the constituent nucleons. Hence overall, there is a net release of energy.

(c) Energy required to break U = 7.63 x 235 = 1793 MeV
Energy released when Ba + Kr formed = 8.40 x 141 + 8.70 x 92 = 1985 MeV
Net energy released = 1985 – 1793 = 192 MeV.

(d) Neutron is a free particle and has no binding energy. Thus it is not included in the calculation.

7 (a)

(i) In this technique, particles of electron exhibit wave-like behaviour as evidenced by the diffraction pattern produced by the electron beam.

(ii) In order for diffraction to occur, the associated wavelength of the electrons is about 0.1 nm.

By de Broglie equation,

momentum of the electrons, $p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{0.1\times10^{-9}} = 6.63\times10^{-24}\text{ kg m s}^{-1}$

Kinetic energy of the electrons,

$$KE = \frac{p^2}{2m} = \frac{\left(6.63\times10^{-24}\right)^2}{2\left(9.11\times10^{-31}\right)} = 2.4\times10^{-17}\text{ J} \approx 2\times10^{-17}\text{ J}$$

(iii) Momentum, $p = mv$

$$\Rightarrow \frac{\Delta p}{p} = \frac{\Delta v}{v} = 10\%$$

Uncertainty in electron's momentum,

$$\Delta p = \frac{10}{100}\left(6.63\times10^{-24}\right) = 6.63\times10^{-25}\ \text{kg m s}^{-1}$$

Using Heisenberg's uncertainty principle, $\Delta x \Delta p \geq h$

uncertainty in electron's position, $\Delta x \geq \dfrac{h}{\Delta p} = \dfrac{6.63\times10^{-34}}{6.63\times10^{-25}} \approx 1\times10^{-9}\ \text{m}$

(iv) Energy of photon,

$$E = \frac{hc}{\lambda} = \frac{\left(6.63\times10^{-34}\right)3.0\times10^{8}}{0.1\times10^{-9}} = 2.0\times10^{-15}\ \text{J} \ \approx\ 2\times10^{-15}\ \text{J}$$

(b)

(i) Using $KE = \dfrac{p^2}{2m}$

momentum of the protons,

$$p = \sqrt{2m(KE)} = \sqrt{2\left(1.67\times10^{-27}\right)\left(2.4\times10^{-17}\right)} = 2.8\times10^{-22}\ \text{kg m s}^{-1}$$

associated wavelength of the protons, $\lambda = \dfrac{h}{p} = \dfrac{6.63\times10^{-34}}{2.8\times10^{-22}} \approx 2\times10^{-12}\ \text{m}$

(ii) The use of protons would make a *more* effective probe because its associated wavelength is *smaller* than that of the electrons, thus producing images of higher resolution.

Section B

8(a)(i) The loss in GPE of the ball is converted into its KE.

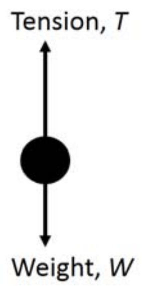
mgh = (1/2)*mv*^{2}

$v = \sqrt{2gh} = \sqrt{2(9.81)(0.70)}$

= 3.706 m s^{-1}(For 'Show' questions, must show substitution and unrounded answer first)

= 3.7 m s^{-1}

(ii)



(iii) Centripetal force, $F_c = \frac{mv^2}{r} = \frac{(0.050)(3.706)^2}{(1.50)}$

= 0.4578 N = 0.458 N

(iv) The ball is moving in a circular path, so it is experiencing an acceleration. According to Newton's first law, there must be a resultant force on the ball. So $T \neq W$, otherwise there will be no resultant force on the ball.

(v) Applying Newton's second law,

$F_{net} = ma = F_c$

$T - W = F_c$

$T = W + F_c = (0.050)(9.81) + 0.4578$

$= 0.9483 = 0.948$ N

(b)(i) The gravitational field strength at a point is the gravitational force per unit mass acting at that point.

(ii) $g = \frac{GM}{d^2}$, where d is the distance between the COMs of Charon and Pluto

$$g = \frac{(6.67\times10^{-11})(1.27\times10^{22})}{(1.96\times10^{7})^2}$$

$= 2.205 \times 10^{-3}$ m s^{-2}

$= 2.21 \times 10^{-3}$ m s^{-2}

g points towards the centre of Pluto.

(iii) ω is the angular speed about the joint centre of mass.

Centripetal force on pluto, $F_P = m_P r_P \omega^2$ & centripetal force on Charon, $F_C = m_C r_C \omega^2$

The centripetal force is provided by the gravitational force on each body, and the gravitational forces have the same magnitude, according to Newton's third law.

So $m_P r_P \omega^2 = m_C r_C \omega^2$

$\therefore \frac{m_P}{m_C} = \frac{r_C}{r_P}$

(iv) $r_P = \left(\frac{m_C}{m_P}\right) r_C$

$r_P + r_C = 1.96\times10^7$ m

$\left(\frac{m_C}{m_P}\right) r_C + r_C = 1.96\times10^7$ m

$$r_C = \frac{1.96\times10^7 \text{ m}}{1+\left(\frac{m_C}{m_P}\right)} = \frac{1.96\times10^7 \text{ m}}{1+\left(\frac{1.50\times10^{21} \text{ kg}}{1.27\times10^{22} \text{ kg}}\right)}$$

$= 1.753 \times 10^7$ m $= 1.75 \times 10^7$ m

(v) gravitational field strength experienced by Charon = centripetal acceleration experienced by Charon

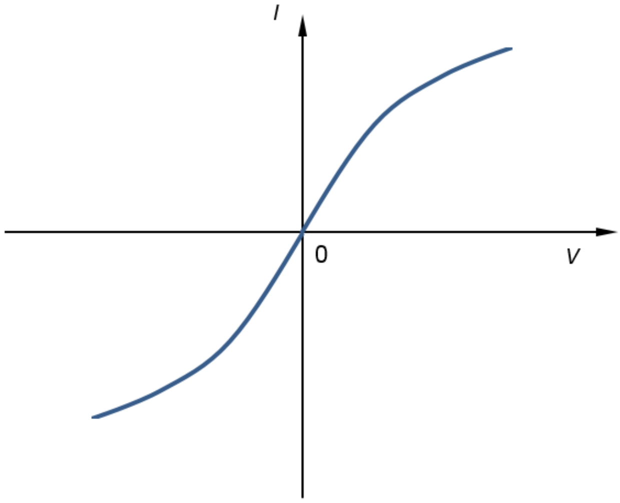
$$g = r_C \omega^2 = r_C \left(\frac{2\pi}{T}\right)^2$$

$$T = \sqrt{\frac{4\pi^2 r_C}{g}} = \sqrt{\frac{4\pi^2(1.753\times10^7)}{2.205\times10^{-3}}}$$

$= 5.60 \times 10^5$ s

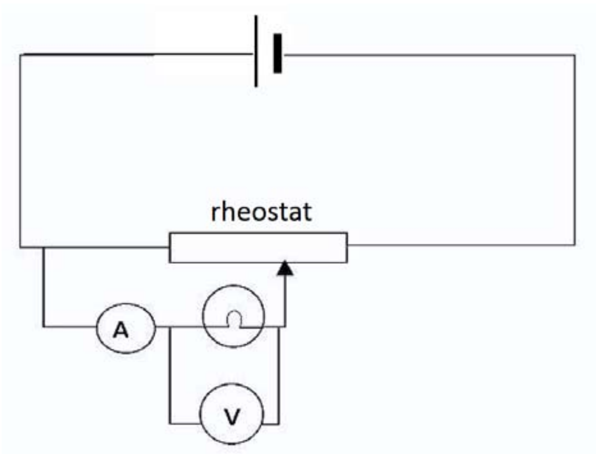
9(a)(i) The ohm is the unit of resistance such that 1 Ω is the resistance where the potential difference between 2 points across a conductor is 1 V produces a current of 1 A flowing through it.

(ii)



(iii) Resistance R is the ratio of the p.d V to the current I at that particular p.d on the graph.

(iv)



b(i) Total resistance of the 4 parallel resistors = $(1/2R + 1/2R)^{-1}$ = R.
I = E/(R + r).

(ii) Power in the 4 parallel resistors = I^2 R, where I = E/(R+r)
Power in the battery = IE

$$\frac{power\ in\ external\ resistors}{power\ by\ batter} = \frac{I^2R}{IE}$$

$$= \frac{I\ R}{E}$$

$$= \frac{E\ R}{R+r}\ \frac{1}{E}$$

$$= \frac{R}{R+r}$$

(iii) Having 4 resistors in parallel, each resistor only dissipates ¼ of the power compared to a single resistor.
Hence 4 resistors in parallel can have a higher power rating than just a single resistor.

(c)(i) When light shone on LDR, resistance of LDR is 420 Ω.
p.d across LDR $= \frac{420}{420+8200} \times 6.0 \ = \ 0.29\ V$

Hence potential at P, V_P = 0.29 – 2.0 = -1.71 V

(ii) When LDR in the dark, resistance of LDR = 134 kΩ.
p.d across LDR $= \frac{134\ \text{k}\Omega}{134\ \text{k}\Omega+8.2\ \text{k}\Omega} \times 6.0 \ = \ 5.65\ V$

Hence potential at P, V_P = 5.65 – 2.0 = 3.65 V.

(iii) The alarm is placed in parallel with the LDR.
When the laser beam is shining on the LDR, the resistance of the LDR will be low. By potential divider principle, the p.d. across the LDR and alarm will be low. The alarm will remain turn off.
When the burglar blocked the laser beam, the resistance of the LDR will be high. Hence the p.d across the LDR and alarm will be high. This will turn on the alarm.

(d)(i) There will be no deflection in the galvanometer when the p.d across JY = 1.5 V.
Let the balance length (between J and Y) be *L*. Then

$$V_{JY} = \frac{L \times 1.50}{(1.50+0.50)} \times 4.0 \ = 1.5$$

L = 0.500 m.

Hence distance from X = 1.00 – L_{JY} = 0.50 m.

(ii) When 1.50 Ω connected with the 1.5 V cell, the terminal p.d across the 1.50 Ω is

$$V = \frac{1.50}{1.50+0.50} \times 1.5 = 1.13\ V$$

There will null deflection when V_{JY} = 1.13 V. Then

$$V_{JY} = \frac{L' \times 1.50}{(1.50+0.50)} \times 4.0 = 1.13$$

L' = 0.377 m.

Hence distance from X = 1.00 – 0.377 = 0.62 m.