VICTORIA JUNIOR COLLEGE

2017 JC2 PRELIMINARY EXAMINATIONS

PHYSICS	**9749/01**
Higher 2	**21 Sep 2017**
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.
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.

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.

This document consists of **16** printed pages.

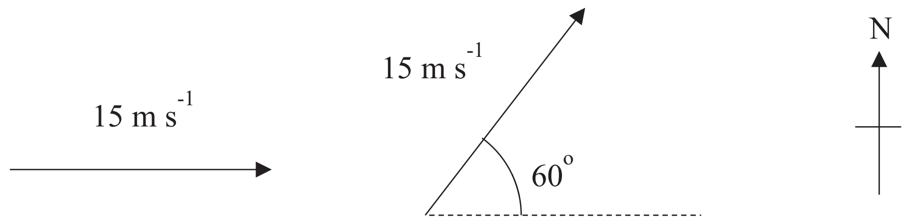
Data

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,	$\phi = -\frac{GM}{r}$
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 A car is initially travelling with a velocity of 15 m s^{-1} eastwards. At a later time, its velocity is 15 m s^{-1}, 60° north of east. The change of velocity of the car is



A zero

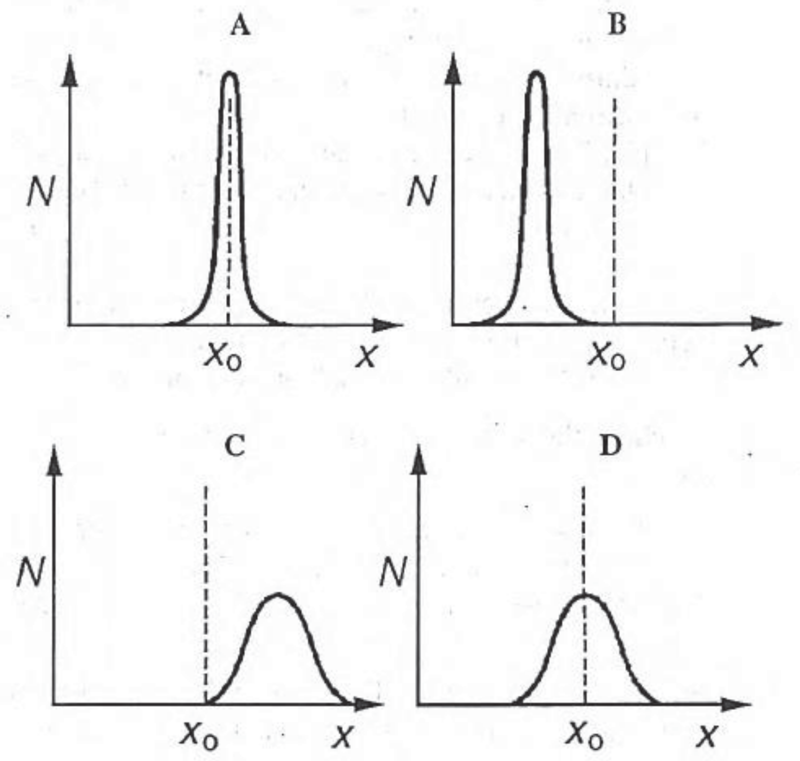
B 26 m s^{-1} , 30° north of east

C 15 m s^{-1} , 60° north of west

D 13 m s^{-1} , northwards

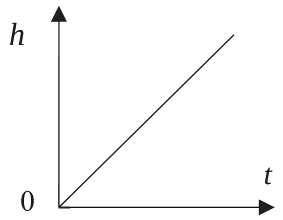
2 A quantity x is measured many times and the number N of measurements giving a value x is plotted against x. The true value of the quantity is x_o.

Which graph best represents precise measurements with poor accuracy?

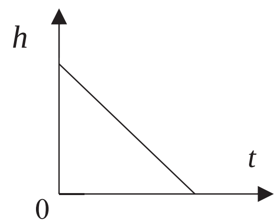


3 A brick falls vertically downwards from a tall building. Which of the following graphs represents the variation with time t of its height h **above** the ground if air resistance is negligible?

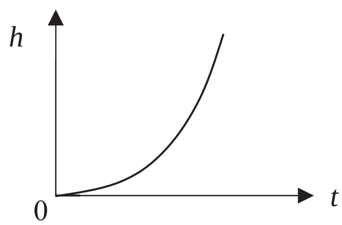
A



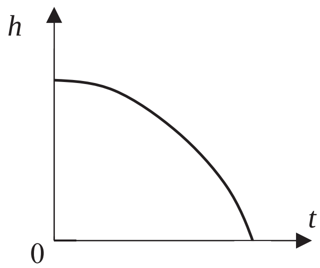
B



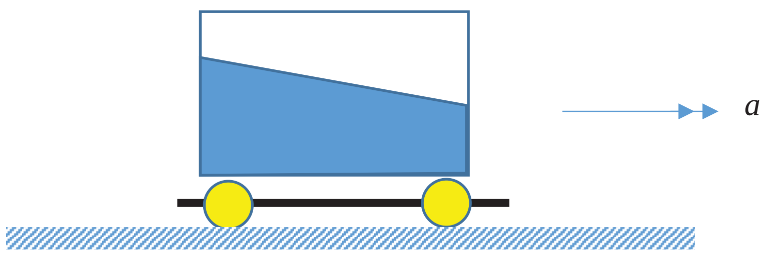
C



D



4 An aquarium partly filled with water accelerates along a level surface as shown below. The water surface makes an angle θ with respect to the horizontal. If the aquarium's acceleration is a while that due to gravity is g, deduce which of the following equations is correct. (Hint: consider forces acting on a single molecule at the water surface)



A $a = g\tan\theta$ **B** $a = g\sin\theta$ **C** $a = g\cos\theta$ **D** $a = g\cot\theta$

5 A spring obeying Hooke's Law has an unstretched length of 50 mm and a spring constant of 500 N m^{-1}. What is the energy stored in the spring when its overall length is 70 mm?

A 0.100 J **B** 0.600 J **C** 1.23 J **D** 100 kJ

6 An object, immersed in a liquid in a tank, experiences an upthrust. What is the physical reason for this upthrust?

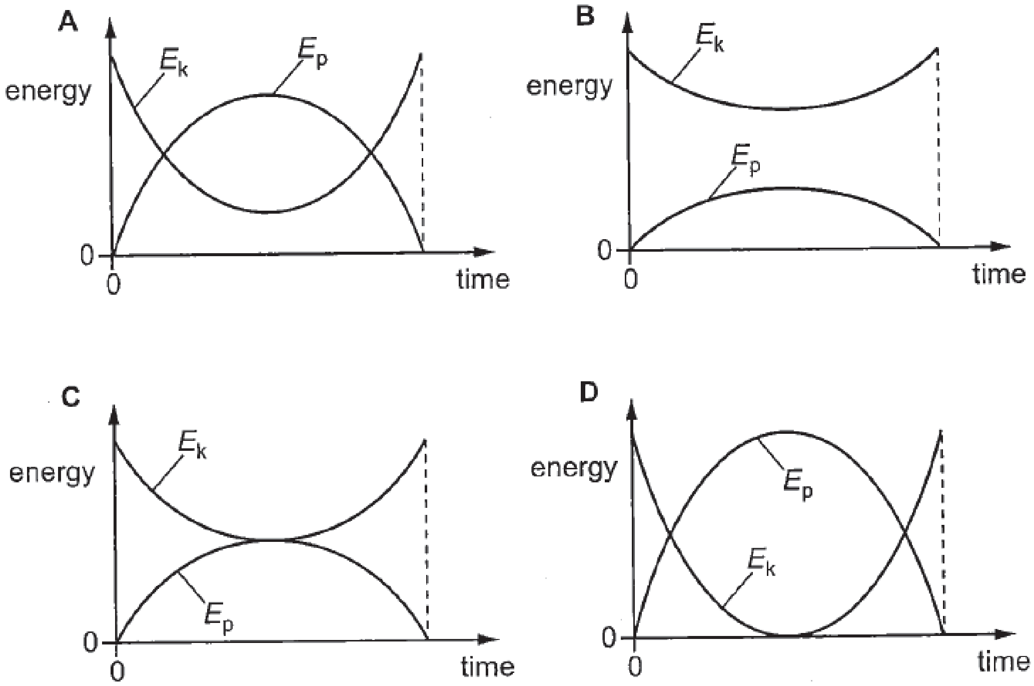
A The object has a uniform cross-sectional area.

B The object is denser than the liquid.

C The density of the object increases with depth in the liquid.

D The pressure in the liquid increases with depth.

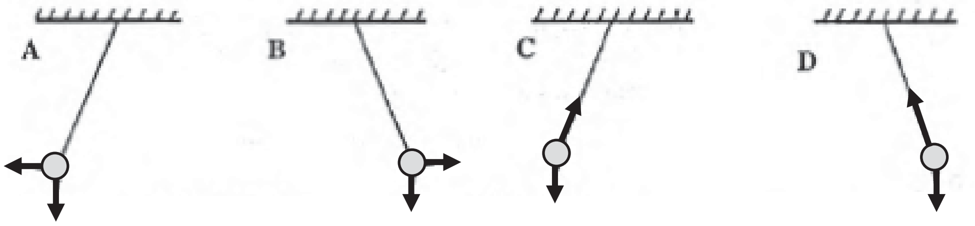
7 A soccer ball is kicked at an angle of 60° above the horizontal. Which graph shows how the kinetic energy E_k and the gravitational potential energy E_p of the ball vary with time from the instant of impact until just before it reaches the ground? Ignore effects of air resistance.



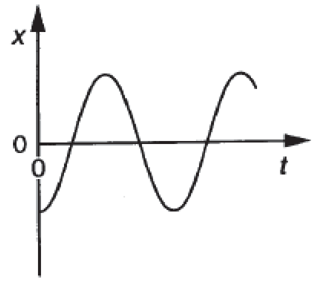
8 A satellite of mass m is moving in a circular orbit of radius r about the earth of mass M. Which of the following is correct? G is the universal constant of gravitation.

	Total Energy	Kinetic energy
A	$-\dfrac{GMm}{2r}$	$\dfrac{GMm}{2r}$
B	$-\dfrac{GMm}{2r}$	$\dfrac{GMm}{r}$
C	$\dfrac{GMm}{2r}$	$\dfrac{GMm}{r}$
D	$\dfrac{GMm}{r}$	$\dfrac{GMm}{2r}$

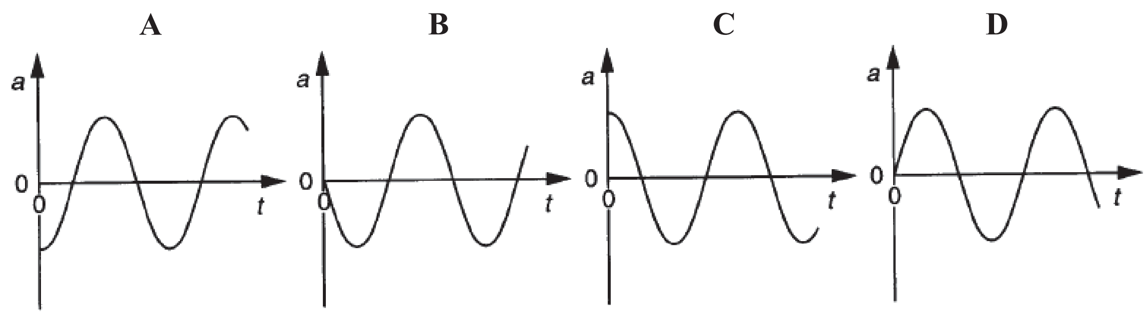
9 A passenger is sitting in a bus facing the direction in which the bus is travelling. A pendulum hangs down in front of him from the ceiling of the bus. The bus makes a turn to the right. Which of the following diagrams shows the position of the pendulum as seen by the passenger and the directions of the forces acting on it?



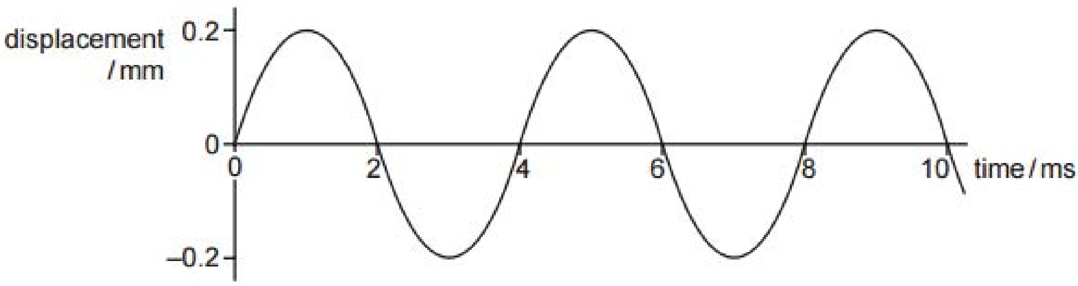
10 A body moves with simple harmonic motion about a point P. The graph shows the variation with time t of its displacement x from P.



Which graph shows the variation with time t of its acceleration a?



11 A sound wave moves through air. The variation with time of the displacement of an air particle due to this wave is shown in the graph below.



Which statement about the sound wave is correct?

A The frequency of the wave is 500 Hz.

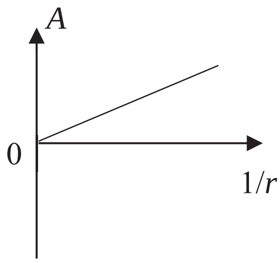
B The graph shows that sound is a transverse wave.

C The intensity of the wave will be doubled if its amplitude is increased to 0.4 mm.

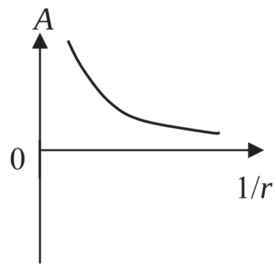
D The wavelength of the sound wave is about 1.32 m.

12 A point source of sound emits waves equally in all directions. Which graph shows the variation with $1/r$ of the amplitude A of the sound, where r is the distance from the source?

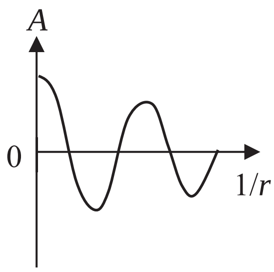
A



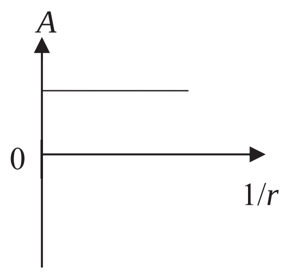
B



C



D



13 An ideal gas of volume 1.5×10^{-3} m^3 and at pressure 1.0×10^5 Pa is supplied with 70 J of heat energy. The volume increases to 1.7×10^{-3} m^3, the pressure remaining constant. The internal energy of the gas is

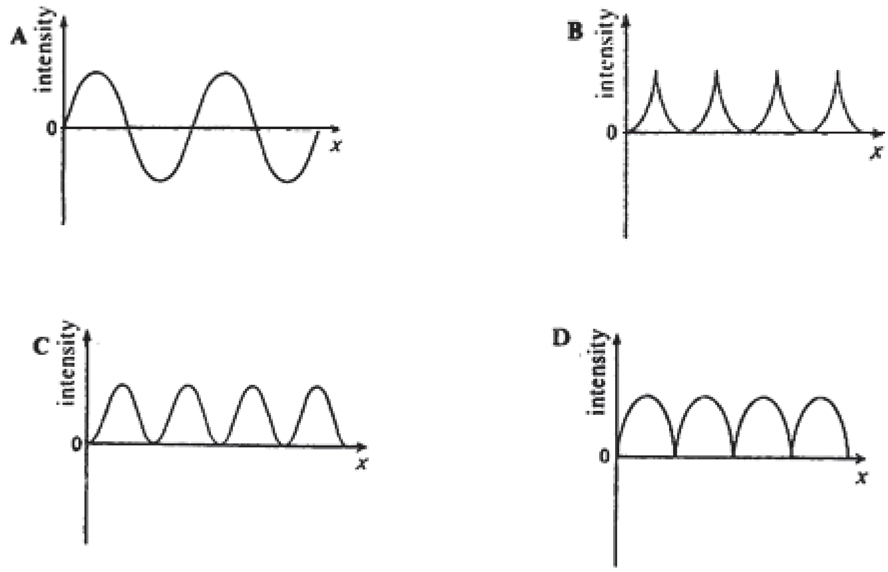
A decreased by 50 J.

B increased by 50 J.

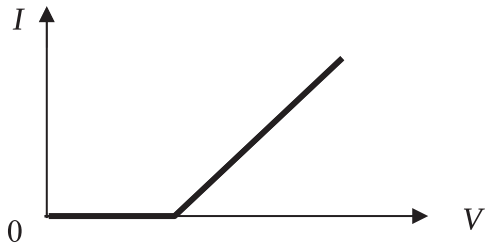
C increased by 70 J.

D increased by 90 J.

14 Two coherent monochromatic waves of equal amplitude are brought together to interfere on a screen. Which one of the following graphs correctly represents the variation of intensity with position *x* across the pattern of fringes?

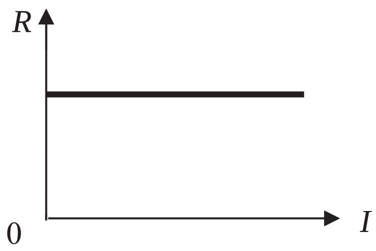


15 The diagram shows the relation between the current I in a certain conductor and the potential difference V across it.

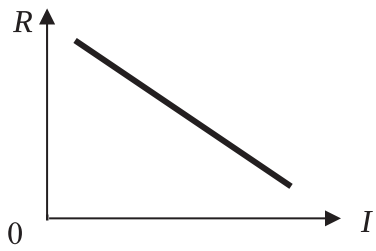


Which graph shows the correct relation between its resistance R and current I?

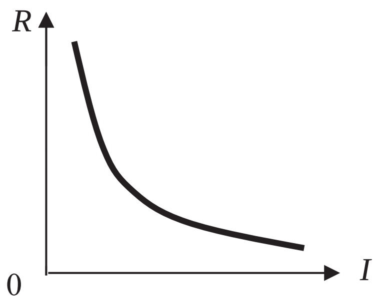
A



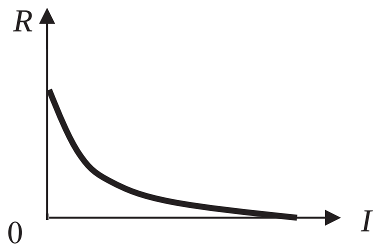
B



C



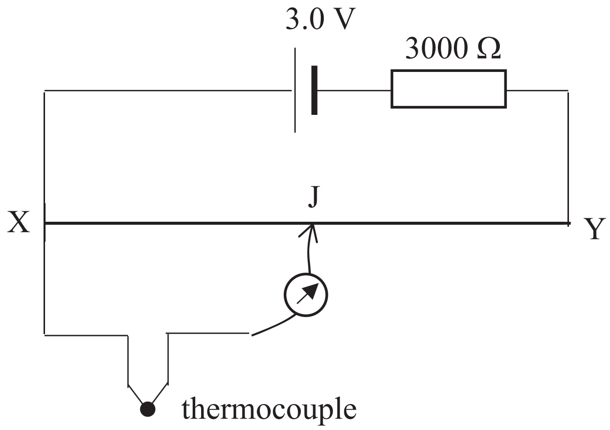
D



16 A copper wire has 2.0×10^{21} free electrons in 1.0 cm of its length. The drift speed of the electrons along the wire is 0.050 cm s^{-1}. What is the current in the wire?

A 0.16 A **B** 16 A **C** 160 A **D** 320 A

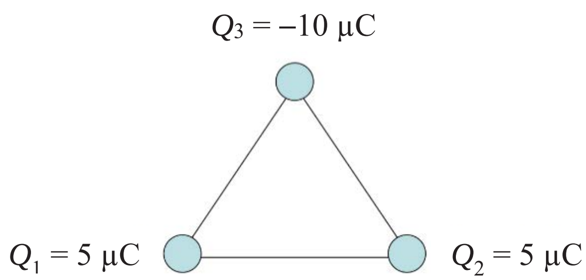
17



A thermocouple is connected across a potentiometer, and the jockey is slid along the metre bridge wire XY until balance point is reached. The balance length XJ is 80.1 cm. If the resistance of the bridge wire is 2.00 Ω, what is the e.m.f. of the thermocouple?

A 0.82 mV **B** 1.6 mV **C** 2.2 mV **D** 9.7 m

18 Three ping-pong balls are electrically charged and arranged in the plane of the page in an equilateral triangle as shown below. What is the direction of the force acting on the ping-pong ball charged with $Q_3 = -10\ \mu C$?



A Towards the top of the page.

B Towards the bottom of the page.

C Towards the left.

D Towards the right.

19 A linear conductor with current I_1 is placed along the axis of a solenoid, which carries current I_2. The magnetic force acting on the conductor is:

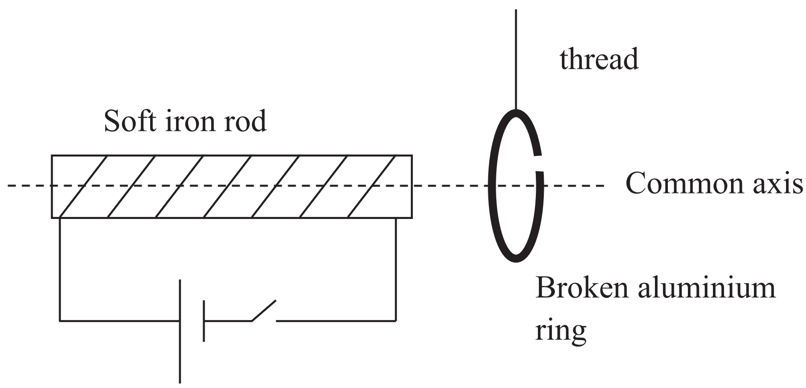
A zero;

B directly proportional to the product of currents I_1 and I_2, and inversely proportional to the radius of the solenoid;

C directly proportional to the product of currents I_1 and I_2, and inversely proportional to the square of the radius of the solenoid;

D directly proportional to the product of current I_1, current I_2, and the area of the solenoid

20 A solenoid is connected to a cell and switch. A soft iron rod is inserted into the solenoid. A broken aluminium ring is suspended from the thread with its axis aligned with that of the solenoid.



What will happen to the aluminium ring when the switch is closed?

A It will be repelled away from the solenoid.

B It will be attracted towards the solenoid.

C It will remain at rest.

D It will be repelled away from the solenoid before being attracted to it.

21 An alternating potential difference is connected across a pure resistor and the frequency of the supply is varied, keeping the r.m.s voltage constant. The mean rate of production of heat in the resistor is

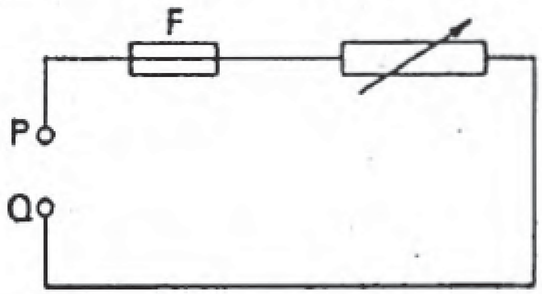
A proportional to frequency

B proportional to (frequency)$^{1/2}$

C inversely proportional to frequency

D independent of frequency

22 When an a.c. supply of 240 V r.m.s is connected to the terminals PQ in the circuit shown below, the fuse F breaks the circuit if the current just exceeds 13 A r.m.s.



When the a.c. supply is replaced with a 120 V d.c. source, an identical fuse breaks the circuit if the current just exceeds

A $\frac{13}{\sqrt{2}}$ A **B** 13 A **C** $13\sqrt{2}$ A **D** 26 A

23 Which of the following statements, referring to photoelectric emission, is always true?

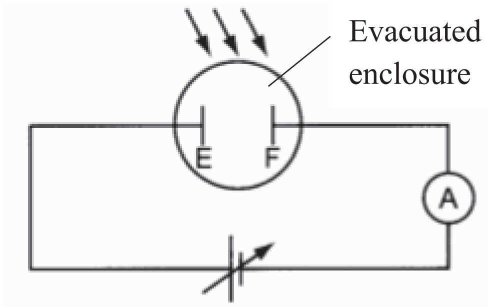
A No emission of electrons occurs for very low intensity illumination.

B The number of electrons emitted per second is proportional to the frequency of the incident radiation.

C The number of electrons emitted per second is proportional to the product of the frequency of the incident radiation and the intensity of the incident radiation.

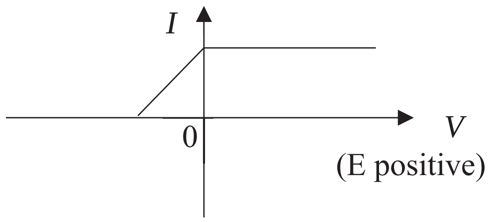
D No electrons will reach the collector if the magnitude of the decelerating potential difference between the emitting electrode and the collector is greater than the stopping potential.

24 The diagram shows a circuit used for photoelectric emission experiments.



The two electrodes E and F are made of different metals. The work function of electrode E is ϕ_E, and the work function of electrode F is ϕ_F.

Current-voltage (I-V) characteristics are obtained when both electrodes are illuminated with monochromatic light.



Which of the following statements is correct?

A Electrons are emitted from E.

B Electrons are emitted from F.

C Electrons are emitted from both E and F.

D $\phi_E < \phi_F$

25 White light from a tungsten filament lamp is passed through sodium vapour and viewed through a diffraction grating. Which of the following best describes the spectrum which would be seen?

A Coloured lines on a black background

B Coloured lines on a white background

C Dark lines on a coloured background

D Dark lines on a white background

26 An electron has an uncertainty of 5.0×10^{-12} m in its position. If its momentum is measured with an uncertainty of 1.00 %, what is its minimum kinetic energy?

A 3.8 MeV

B 6.6 MeV

C 38 MeV

D 66 MeV

27 All living matter contains carbon-14, which decays, according to the equation:

$$^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + \mathrm{X} + \bar{\nu}$$

where $\bar{\nu}$ is an antineutrino. Identify X.

A electron **B** neutrino **C** proton **D** gamma ray

28 Two deuterium nuclei fuse together to form a Helium-3 nucleus, with the release of a neutron. The reaction is represented by

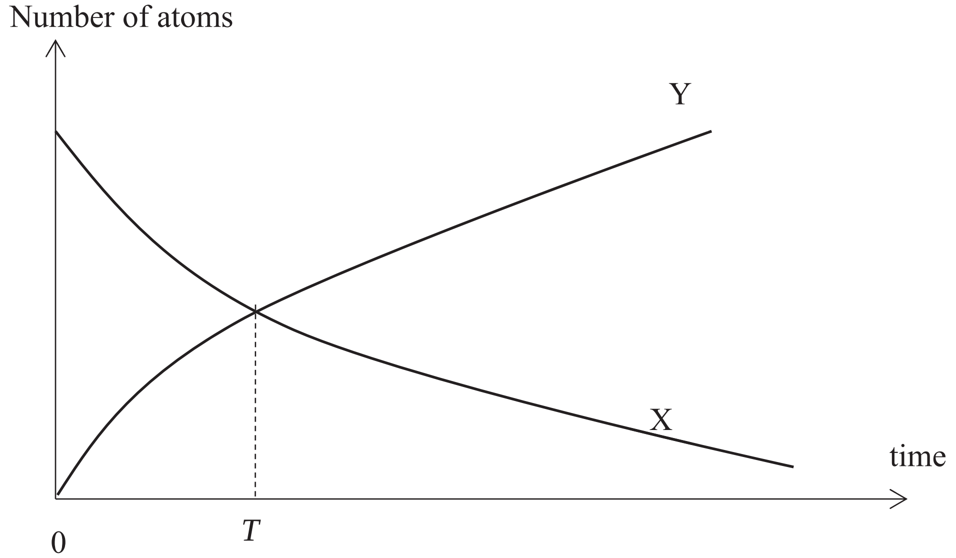
$$^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + \text{energy.}$$

The binding energies per nucleon are:
for $^{2}_{1}\mathrm{H}$ 1.09 MeV,
for $^{3}_{2}\mathrm{He}$ 2.54 MeV,

How much energy is released in this reaction?

A 0.36 MeV **B** 1.45 MeV **C** 3.26 MeV **D** 5.44 MeV

29 The graphs below represent the decay of a newly- prepared sample of radioactive nuclide X as it decays to a stable nuclide Y. The half-life of X is τ. The growth curve for Y intersects the decay curve for X at time T.



What is T?

A $\tau/2$ **B** $\ln(\tau/2)$ **C** τ **D** $\ln(2\tau)$

30 Which of the following samples of radioactive materials has the smallest rate of decay?

Sample	Half life / year	Amount / 10^{-7} mol
A	0.42	0.02
B	5.3	0.4
C	620	80
D	6200	200

********* END ********

Name : ______________________________ CT group: ___________

VICTORIA JUNIOR COLLEGE
2017 JC2 PRELIMINARY EXAMINATIONS

PHYSICS	**9749/02**
Higher 2	**12 Sep 2017**
Paper 2 Structured Questions	**TUESDAY**
	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	
2	
3	
4	
5	
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7	
8	
Total (max. 80)	

This document consists of **21** printed pages.

Data

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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
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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,	$W = p\Delta V$
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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,	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

1 A student set up the circuit shown in **Fig. 1** in order to determine the resistivity of the metal of the wire.

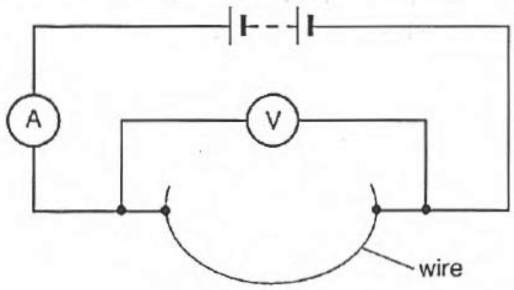

Fig. 1

(a) State a possible systematic error in this experiment and suggest a method to overcome this error.

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [2]

(b) The following readings were obtained:

Reading of voltmeter, V	Reading of ammeter, I	Length of Wire, L	Diameter of Wire, d
1.50 ± 0.01 V	0.82 ± 0.01 A	63.2 ± 0.1 cm	0.48 ± 0.02 mm

(i) Show that the resistivity is given by $\rho = \dfrac{V\pi d^2}{4IL}$.

[1]

(ii) Hence, or otherwise, calculate the resistivity of the metal of the wire together with its associated uncertainty.

Resistivity = (..……. ± ………) ……….. Ω m [4]

(c) Suggest why an alloy of two metals has a higher resistivity than any of the two metals used in the alloy.

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

2 A cricketer throws a ball with an initial velocity *u* at an angle of 30° above the horizontal, at a height of 1.5 m above the ground. The ball returns to its initial height 3.0 s later.

(a) Neglecting air resistance, calculate

(i) the initial velocity *u* of the ball,

u = ……………. m s^{-1} [2]

(ii) the maximum height *above* the ground to which it rises.

Maximum height = ……………… m [3]

(b) In the space below, sketch a graph to show how the vertical component of the velocity of the ball varies with time during its flight, taking the upward direction as positive.
Mark on the graph the times at which

(i) the ball leaves the cricketer's hands (t_1),

(ii) it reaches its maximum height (t_2),

(iii) it returns to its initial height above the ground (t_3).

[2]

(c) Without carrying out any calculations, explain how air resistance would affect the maximum height reached by the ball if it was projected with the same initial velocity.

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……………………………………………………………………………………….

………………………………………………………………………………….[2]

3 A 0.050 kg mass is attached to one end of an elastic string of unstretched length 0.50 m. The other end of the string is attached to a fixed support. The force constant of the elastic string is 40 N m^{-1}. The mass is rotated steadily on a smooth table in a horizontal circle of radius 0.70 m as shown in **Fig. 3.1**.

Plan View

Fig. 3.1

Fig. 3.2 shows the side view of the string and mass.

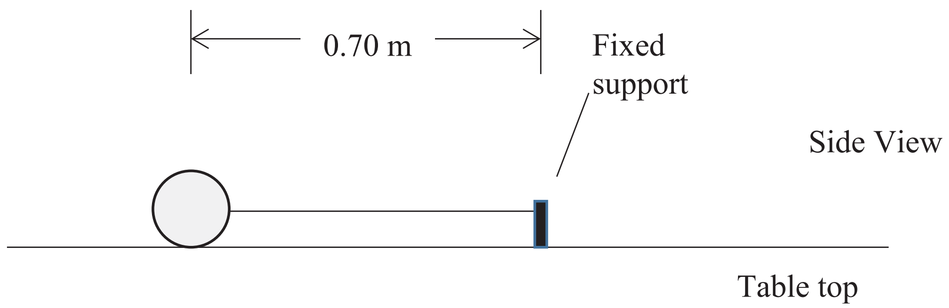

Fig. 3.2

(a) On **Fig. 3.2**, draw and identify the forces acting on the mass. [2]

(b) Calculate the magnitude of the resultant force acting on the mass.

Resultant force = ……………. N [2]

(c) Calculate the linear speed of the mass.

Linear speed = ………….. m s^{-1} [2]

(d) Calculate the time taken for one revolution of the mass.

Time taken = ………….. s [1]

(e) The mass is now rotated at a speed v in a vertical plane of radius r. Derive an expression for the minimum speed at the highest point of the circular path at which the string *just* becomes slack.

[2]

4 **(a)** State why the interference that occurs between the light waves from identical filament lamps does not result in observable interference fringes.

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…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(b) Two identical radio aerials P and Q are separated by a distance D. A sinusoidal radio signal of wavelength λ is received from an aircraft passing directly overhead at a speed v and height h along a line parallel to that between the aerials as shown in **Fig. 4**. The signals from the two aerials are added together and the resultant is recorded.

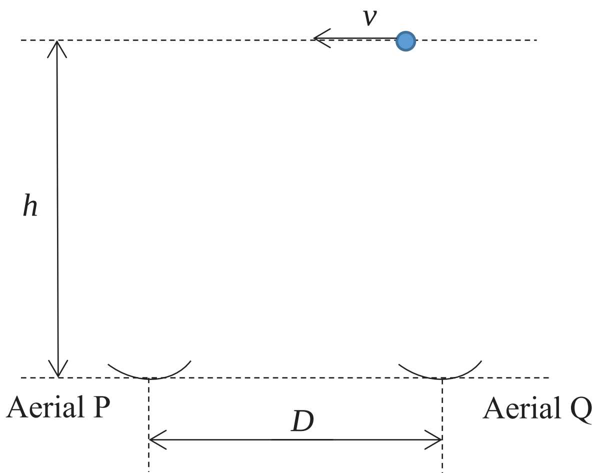

Fig. 4

(i) Explain why the intensity of the resultant signal fluctuates.

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…………………………………………………………………………………[2]

(ii) Deduce an expression for the minimum distance travelled by the aircraft in order to receive two successive maximum signals. Your expression should only contain the terms given in **(b)**. Assume that the height h is much larger than the distance D between the aerials.

[2]

(iii) Suggest two things which might interfere with the signals received by the aerials.

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……………………………………………………………………………………

…………………………………………………………………………………… [2]

5 The magnetic field in **Fig. 5** spans an area 1.50 m by 0.50 m. It points into the plane of the paper with a magnitude of 0.25 T. A metal rod RS slides to the left on a frictionless, fixed, light, conducting loop with a speed of 2.0 m s^{-1}. The resistance of the metal rod is 0.50 Ω, while the loop has negligible resistance.

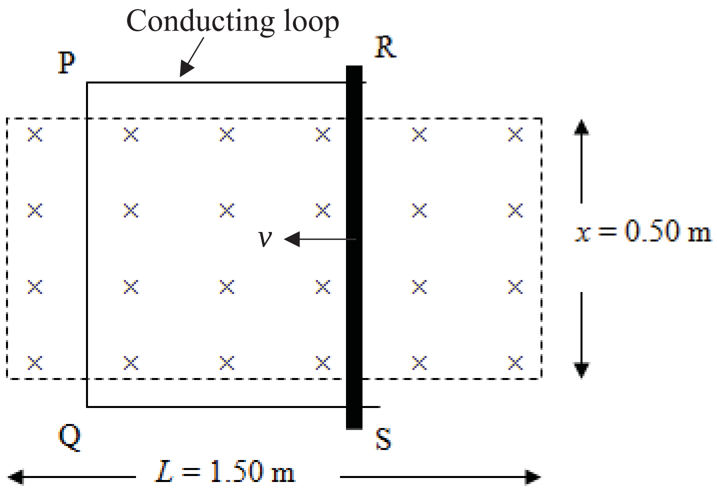

Fig. 5

(a) Calculate the induced e.m.f. in the moving rod.

Induced e.m.f. = ……………. V [2]

(b) Calculate the induced current in the circuit and state its direction (clockwise or anti-clockwise) around the loop.

Induced current = …………….. A [1]

Direction: ……………….. [1]

(c) Explain why the conducting loop has to be fixed in position for your answer to **(b)** to be valid.

…………………………………………………………………………………………

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…………………………………………………………………………………………

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

(d) Suppose now the loop is fixed in position. Suppose also that the resistance of the circuit is a very small value such that the induced current is very large, and that the position of RS and PQ are extremely close to each other. The other quantities are unchanged. Explain

(i) why your answer to **(a)** is no longer valid,

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

(ii) whether the induced e.m.f. will be larger or smaller than that in **(a)**.

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…………………………………………………………………………………………

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

6 X-rays are produced when electrons are accelerated through a potential difference towards a metal target such as tungsten. **Fig. 6** shows a typical X-ray intensity spectrum that can be produced from an X-ray tube.

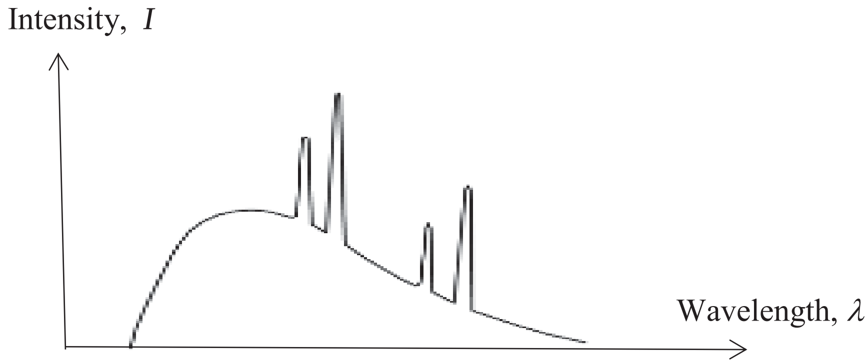

Fig. 6

(a) Explain the origins of the following features of **Fig. 6**:

(i) Characteristic lines

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

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……………………………………………………………………………………

…………………………………………………………………………………… [3]

(ii) Cut-off wavelength

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [1]

(b) If the electrons are accelerated through a potential difference of 75.0 kV, determine the cut-off wavelength of X-rays that can be produced by the tube.

Cut-off wavelength = …………………. m [2]

(c) Suppose now the potential difference used to accelerate the electrons is decreased. Sketch, in **Fig. 6**, the new spectrum obtained. [2]

7 A head-on collision takes place between an α-particle and a stationary nitrogen nucleus. It results in the following nuclear reaction.

$$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$$

The masses of the **nuclei** involved are listed below.

$^{14}_{7}N$	13.9993u
$^{4}_{2}He$	4.0015u
$^{17}_{8}O$	16.9947u
$^{1}_{1}H$	1.0073u

(a) Name the particles represented by $^{4}_{2}He$ and $^{1}_{1}H$ respectively.

$^{4}_{2}He$: …………………………….. ; $^{1}_{1}H$: ………………………………. [1]

(b) Calculate the small change in mass, in kilograms, which takes place in this nuclear reaction.

Change in mass = …………………… kg [1]

(c) Use your answer to **(b)** to calculate the theoretical minimum kinetic energy needed by the α-particle to enable the nuclear reaction to proceed. Show your calculations clearly.

Minimum kinetic energy needed = ……………….. J [2]

(d) Given that the masses of the proton and neutron are 1.0073 u and 1.0087 u respectively, calculate the binding energy per nucleon (in MeV) of the helium nucleus.

Binding energy per nucleon = ………………….. MeV [3]

(e) **(i)** Sketch a graph to show the variation with mass number of the binding energy per nucleon of different radioactive isotopes.

[1]

(ii) Use your graph in (e)(i) to explain how fission of heavy nuclei can lead to more stable nuclides.

……………………………………………………………………………………...…

……………………………………………………………………………………...…

……………………………………………………………………………………...…

……………………………………………………………………………………...…

……………………………………………………………………………………...…

……………………………………………………………………………………… [1]

8 Last year, Ah Beng and Ah Lian tried to compare two cars. A manufacturer of the USA car claims fuel efficiency of 30 mpg (miles per gallon). The manufacturer of the European car states the fuel efficiency of 7.80 *l* /100 km (litres per hundred kilometers). (One kilometre is equivalent to 0.621 mile while a gallon is equal to 3.79 litres.)

(a) Determine which car is more efficient and by how much. Make your comparison in terms of litres per 100 km (*l* /100 km)

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

This year, still undecided, Ah Beng noticed that the manufacturer of the European car improved the car's fuel efficiency so that it is now 15.38 km / *l*.

(b) Determine the percentage improvement in the European car's fuel efficiency.

Percentage improvement = ………………….. % [3]

Fig. 8.1 shows the variation with time of the speed of his car during a trip.

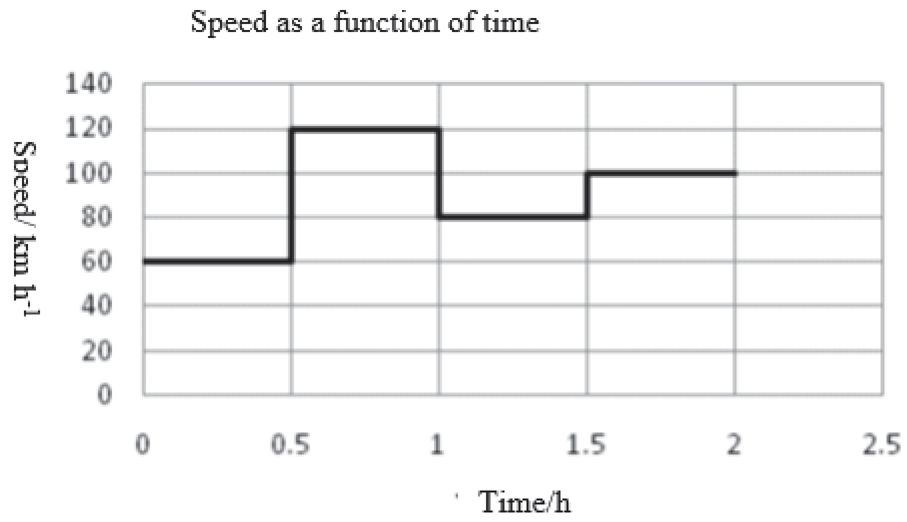

Fig. 8.1

(c) **(i)** Determine the total distance travelled during this two hour trip.

Total distance travelled = ……………………. km [2]

(ii) Ah Lian says a feature of the graph does not appear to agree with reality. Identify it and explain why.

……………………………………………………………………………...

……………………………………………………………………………...

……………………………………………………………………..…[2]

Fig. 8.2 displays the air drag force on the car as a function of its speed.

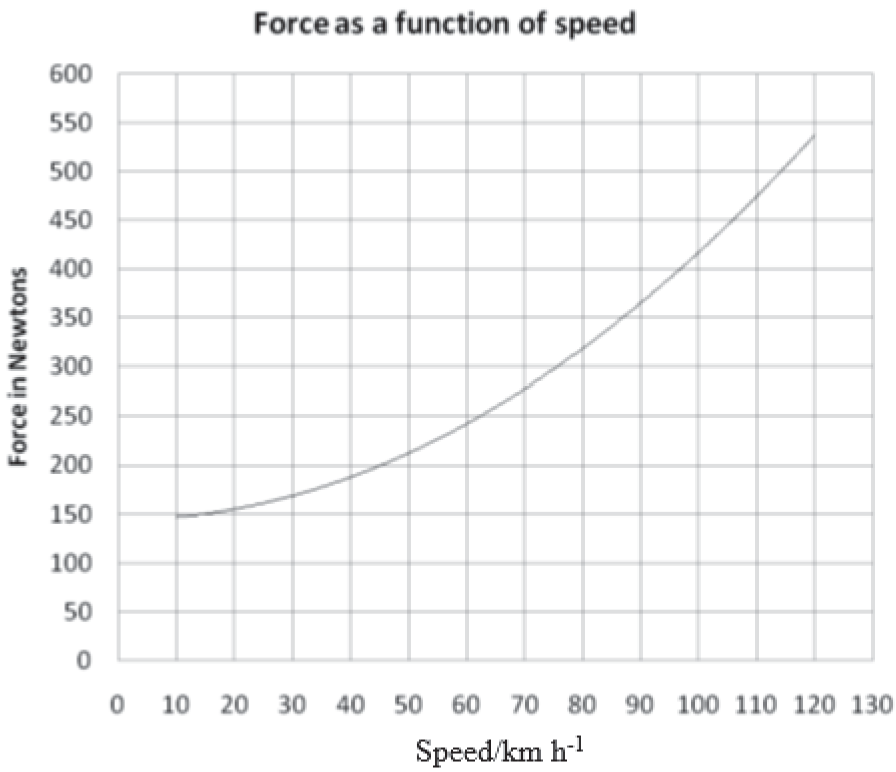

Fig. 8.2

(iii) Estimate the total work done against the drag force on the car during the **first hour** of the trip.

Work done = ……………………. J [3]

Each litre of petrol has 35 MJ of energy. The engine efficiency as a function of the car's speed is shown on **Fig. 8.3**. Engine efficiency is defined as the ratio of work done to overcome air drag to the energy that can be generated from fuel consumed by the car.

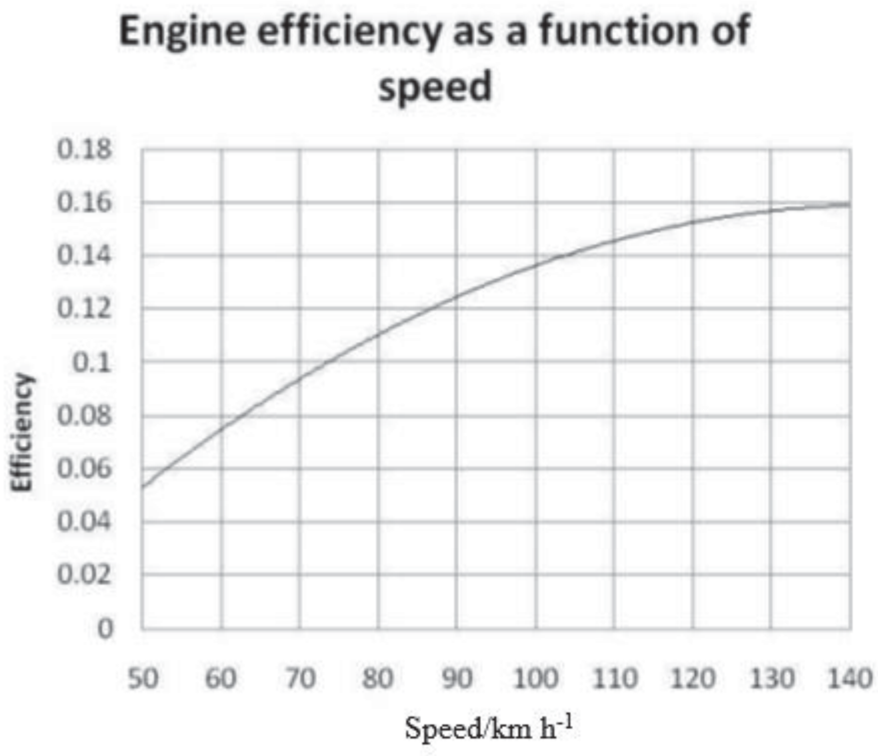

Fig. 8.3

(iv) Calculate the total amount of petrol in litre used to overcome the air drag **during the first hour** of the trip.

Amount of petrol used = ……………….. *l* [3]

(v) Determine which part of the trip **over the first hour** the fuel was used more efficiently (least petrol used per kilometer travelled).

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

*******END ******

Name : ________________________________ CT group : ______________

VICTORIA JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATIONS 2017

PHYSICS **9749/03**

Higher 2 **18 Sep 2017**

MONDAY

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	
Total	

This question set consists of a total of **21** 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,	$R = R_1 + R_2 + \dots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \dots$
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

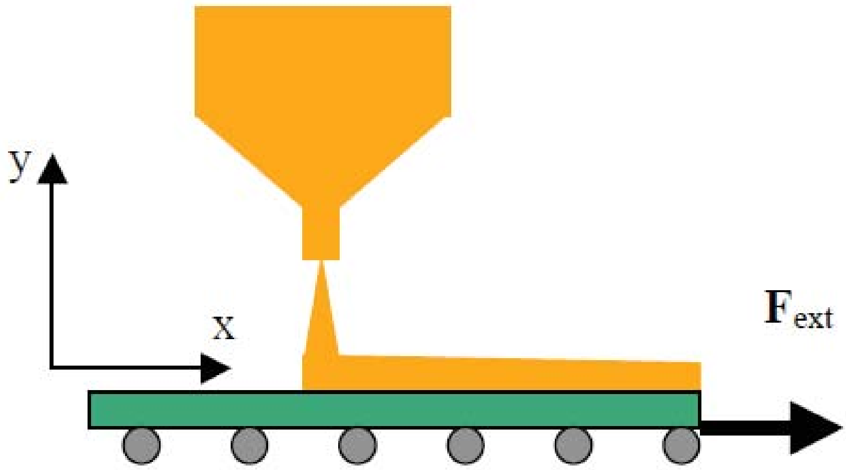

Fig. 1

Sand from a stationary hopper falls onto a moving conveyor belt at a rate of 5.00 kg s^{-1} as shown in **Fig. 1**. The conveyor belt is supported by frictionless rollers and moves at a constant speed of 0.75 m s^{-1} under the action of a constant horizontal external force $\boldsymbol{F}_{ext}$ supplied by the motor that drives the belt.
Calculate:

(a) the force of friction exerted by the belt on the sand;

Frictional force = …………………. N [2]

(b) the external force $\boldsymbol{F}_{ext}$;

F_{ext} = …………………. N [1]

(c) the power due to $\boldsymbol{F}_{ext}$;

Power = ……………….. W [2]

(d) the rate of change of kinetic energy of the sand due to the change in its horizontal motion;

Rate of change of kinetic energy = ………………. J s^{-1} [2]

Compare and analyse the answers to **(c)** and **(d)**.

……………………………………………………………………………………….

……………………………………………………………………………………….[2]

2 The Prius is a hybrid car that runs on both petrol and electricity. It has a mass of 1300 kg.

(a) Calculate the kinetic energy of a Prius that is moving at a speed of 60 kmh^{-1}.

Kinetic energy = ……………………… J [2]

(b) The power P required to overcome external forces opposing the motion of the Prius is given by the expression

$$P = 240v + 0.98v^3$$

(i) Calculate the magnitude of the external forces opposing the motion of the car when it is moving at a constant speed of 60 km h^{-1}.

Resistive forces = ………………… N [2]

(ii) Hence or otherwise, calculate the work done in overcoming the force in **(b)(i)** during a time of 3.0 minutes.

Work done = ……………… J [2]

Prius' technology allows the hybrid car to convert the kinetic energy during braking into electrical energy and store it in a battery for use during acceleration.

(c) Suggest one advantage and one disadvantage of a fully electric car compared with a hybrid car.

……………………………………………………………………………………..

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…………………………………………………………………………………… [2]

3

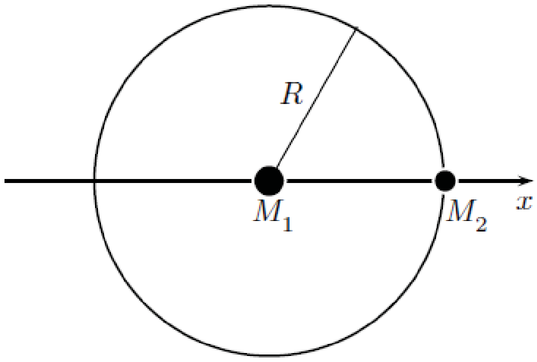

Fig. 3

M_1 and M_2 refer to masses of the Sun and the Earth respectively. Both orbit around their common centre of mass at angular velocity ω and with a period T. These orbits are *circular* to a good approximation, and the distance R between the Sun and the Earth is taken to be constant.

(a) Explain why the centre of the Earth's orbit can be assumed to be effectively the centre of the Sun.

…………………………………………………………………………………………

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

(b) Estimate a numerical value for ω.

$\omega \approx$ …………………… rad s^{-1} [2]

(c) Show that ω and R are related by $\omega \propto R^{-\frac{3}{2}}$. Deduce an expression for the constant of proportionality.

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

(d) **(i)** An object of mass m is located on the line joining the Sun and the Earth so that it also orbits the centre of the Sun with the *same* constant angular velocity ω. By considering forces acting on the mass m, write down two possible equations for the motion of the mass m about the centre of the Sun. Take the distance of the mass m from the Sun to be x. Express your answers in terms of M_1, M_2, R, x, G and ω where G is the universal gravitation constant.

[2]

(ii) State an assumption made when deriving the equations in **(i)**.

……………………………………………………………………..…………

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

4 Consider a cubical box of side l which contains N molecules, each of mass m, all moving horizontally with speed u at right angles to wall A. See **Fig. 4**.

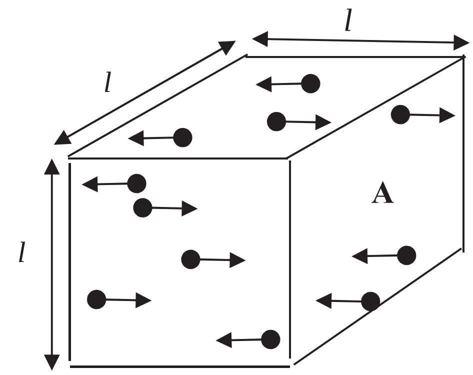

Fig. 4

When a molecule hits a wall, it bounces off with no loss of speed and travels in the opposite direction.

(a) Deduce

(i) the change in momentum of a molecule when it collides with a wall,

Change in momentum = ………………………….. [1]

(ii) the time taken by one molecule between collisions with wall A,

Time taken = ……………… [1]

(iii) the force due to all the molecules colliding with wall A.

Total change in momentum per unit time = ……………………….. [3]

(b) Use your answer in **(a)** to show that the pressure p on wall A is given by $p = \dfrac{Mu^2}{V}$ where M is the total mass of all the molecules and V is the internal volume of the box.

[1]

(c) Give two reasons why the expression in **(b)** is not valid.

……………………………………………………………………..……………..

……………………………………………………………………..……………..

……………………………………………………………………..……………..

……………………………………………………………………..…………[2]

5 **(a)**

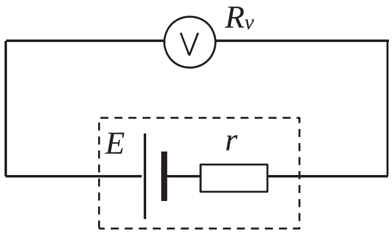

Fig. 5.1

A voltmeter is connected across the terminals of a cell of e.m.f. E = 2.0 V and internal resistance r. See **Fig. 5.1**. If the resistance of the voltmeter is R_v, write down an expression for the voltmeter's reading. Express your answer in terms of R_v, r and E.

………………………………………………………………………………… [1]

(b) If r = 0.10 Ω, determine the minimum resistance that the voltmeter must have for its reading to be within 0.10 % of the e.m.f. E.

Minimum resistance required = ……………… Ω [2]

(c) **(i)**

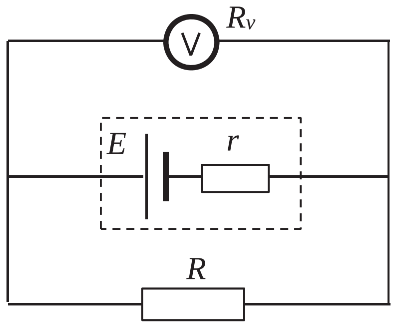

Fig. 5.2

The cell is now connected across a resistor R. (See **Fig. 5.2**).
Derive an expression for the reading of the voltmeter. Express your answer in terms of R_v, r, R and E.

……………………………………………………………………………………. [3]

(c) **(ii)** Calculate the voltmeter's reading if it just fulfills the condition in **(b)** and $R = 0.90\ \Omega$.

Voltmeter reading = ……………. V [2]

6 A flat metal coil used to produce a magnetic field for an electron beam experiment has 200 turns and a radius of 12.0 cm. The density D and resistivity ρ of the metal of the wire are 1.0×10^4 kg m^{-3} and 2.0×10^{-8} Ω m respectively. The wire has a radius of cross-section of 0.457 mm.

(a) Calculate the resistance of the coil.

Resistance = ……………… Ω [3]

(b) Determine the magnitude of a p.d. that is required to be applied across the ends of the flat coil to produce a magnetic field with a magnitude of 5.0×10^{-3} T at the centre of the coil.

p.d. required = ……………… V [3]

(c)

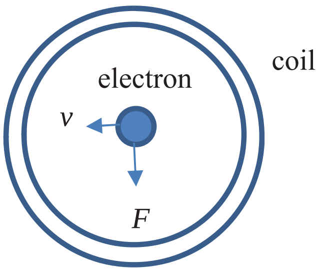

Fig. 6

Fig. 6 shows an electron travelling at 4.0×10^5 m s^{-1} being deflected as it moves through the coil. Calculate the magnetic force acting on the electron and deduce the direction of the magnetic field at the centre of the coil.

Magnetic force = ……………… N [2]

Direction of magnetic field = ……………….. [1]

7 (a) 1.0 g of radioactive magnesium ${}^{23}_{12}\mathrm{Mg}$ undergoes decay into sodium ${}^{23}_{11}\mathrm{Na}$ with a half life of about 11.3 s.

(i) By writing down a nuclear equation for the decay, identify all the particles that are produced in this decay.

……………………………………………………………………………………. [2]

(ii) Calculate the initial rate of decay of magnesium nuclides .

Initial rate of decay = ………………… s^{-1} [2]

(b) To illustrate the effect of an electric field on the paths of α, β and γ radiations when travelling in a cloud chamber, a book contains a diagram similar to **Fig. 7**.

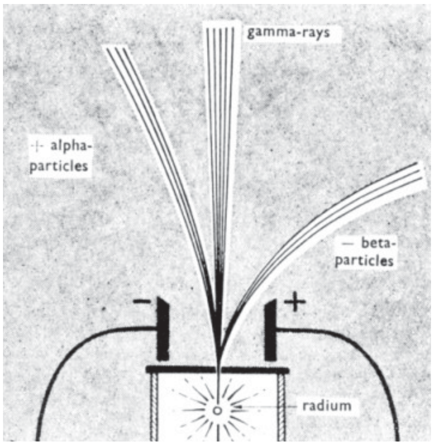

Fig. 7

Explain why

(i) no curvature of gamma radiation takes place.

……………………………………………………………………………………. [1]

(ii) the paths of the α and β curve when in the electric field. Identify the nature of the curve.

…………………………………………………………………………………….

……………………………………………………………………………………. [2]

(iii) a pattern of tracks, such as that shown in **Fig. 7,** is not correct.

…………………………………………………………………………………….

……………………………………………………………………………………. [2]

Section B

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

8

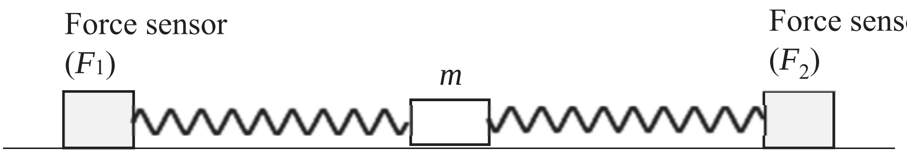

Fig. 8.1

A 0.200 kg mass is attached sideways to two electronic force sensors using identical springs of constant k. The force sensors are fixed in place. When the mass is at rest in the centre at equilibrium, each spring is stretched by a distance $e = 0.150$ m.
The mass is then displaced towards the right and then released, so that it oscillates horizontally on a frictionless surface.
The force sensor on the left side records the force F_1 exerted on it, which varies with time t according to **Fig. 8.2**.

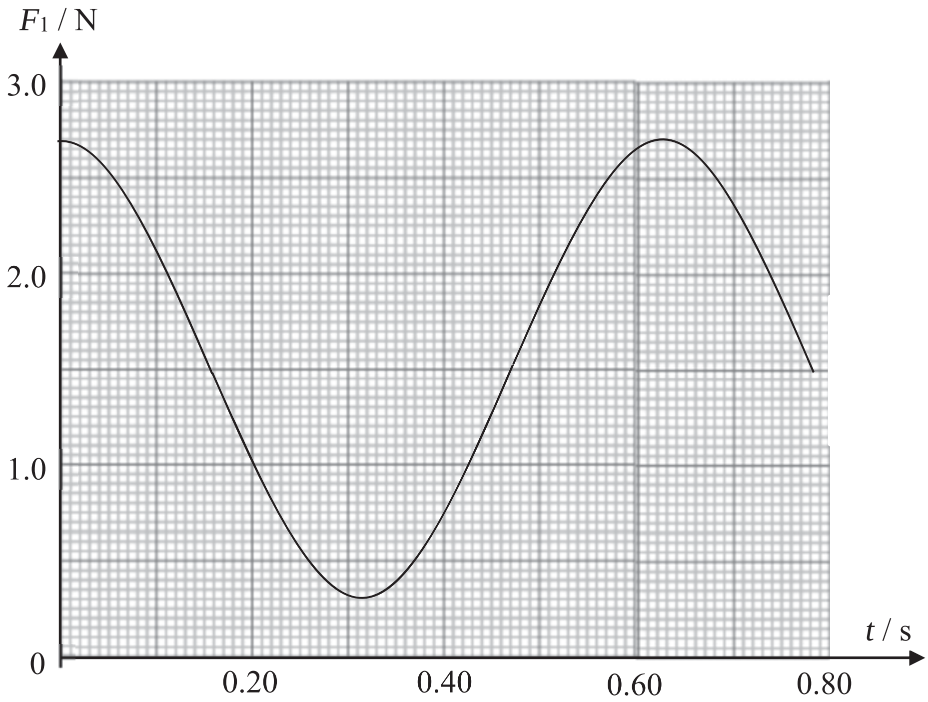

Fig. 8.2

(a) On **Fig. 8.2**, sketch the variation with time t of the force F_2 recorded by the sensor on the right.

[2]

(b) State the period T of the oscillation.

T = …………….. s [1]

(c) Calculate the effective force constant k_{eff} of the two spring system.

k = ………………. N m^{-1} [2]

(d) Prove that the system executes simple harmonic motion.

[2]

(e) Calculate the force constant k of each spring.

k = …………………. N m^{-1} [1]

(f) Determine the amplitude x_0 of the oscillation.

x_0 = ………………… m [2]

(g) Calculate the maximum speed of the mass.

v_0 = ………………… m s^{-1} [2]

(h) Calculate the maximum kinetic energy K_0 of the mass.

K_0 = ……………….. J [1]

(i) Sketch a graph to show the variation with displacement x of the kinetic energy of the mass.

[2]

(j) Calculate the minimum elastic potential energy of the system.

Minimum elastic potential energy = ………………… J [2]

(k) Sketch graphs to show the variation with time of the kinetic energy K, the elastic potential energy U and the total energy E of the system. Include appropriate numerical labels.

[3]

9 (a) **Fig. 9.1** represents the four lowest energy levels of an electron in the hydrogen atom.

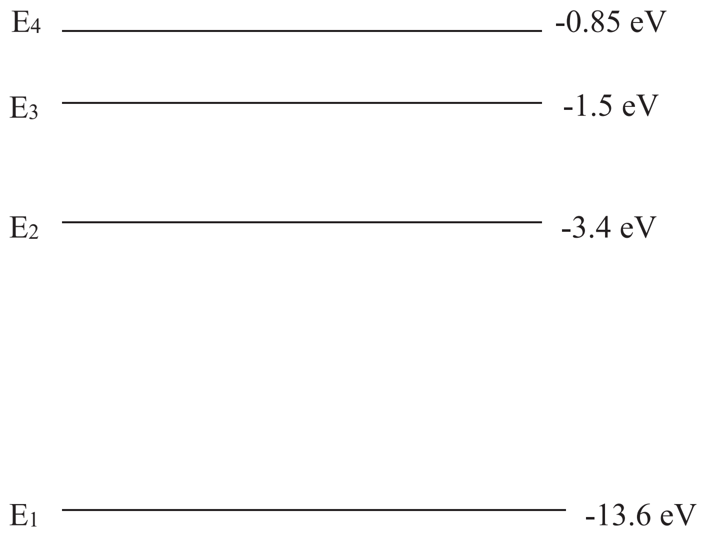

Fig. 9.1

(i) With the aid of a diagram, explain how an absorption line spectrum is produced.

....

....

....

....

....

....

....

.... [4]

(ii) If the hydrogen atoms are originally in the ground state, draw, on **Fig. 9.1**, all the possible transitions that produce the absorption spectrum. [1]

(iii) If the atoms are originally in excited states, draw, on **Fig. 9.2**, all the possible transitions that produce emission lines. [1]

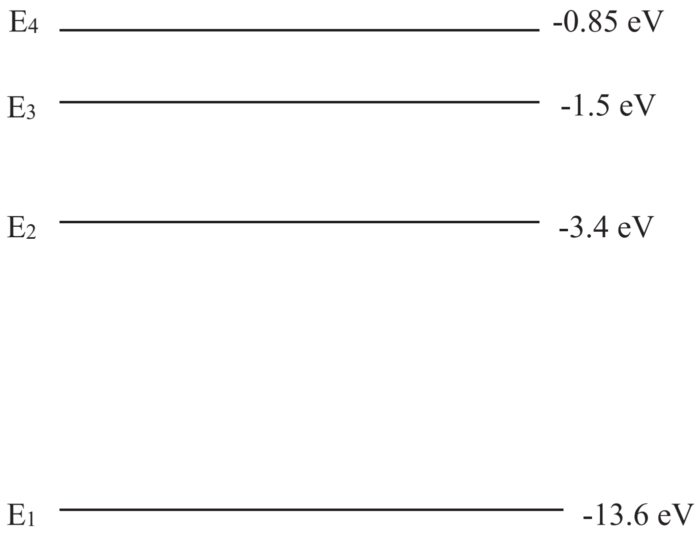

Fig. 9.2

(iv) State the ionisation energy of the hydrogen atom.

.... [1]

(v) State and explain what happens when mono-energetic electrons with energy greater than the ionisation energy in **(iv)** bombard hydrogen atoms originally in their ground state.

....

....

....

....

....

....

.... [2]

(b) **(i)** X-ray emission is often said to be the inverse of the photoelectric effect. Explain.

....

.... [1]

(ii) An X-ray spectrum of molybdenum is shown in **Fig. 9.3**.

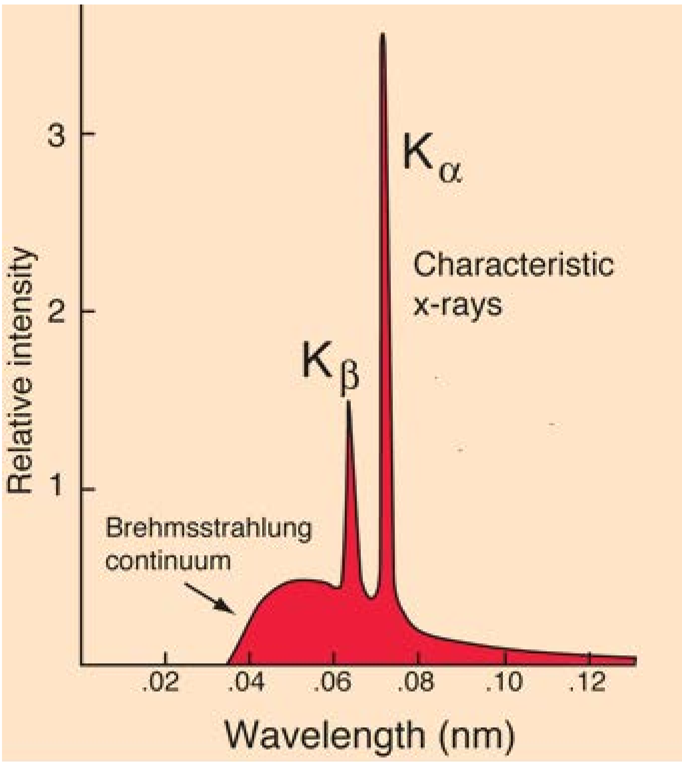

Fig. 9.3

1 Using **Fig. 9.3**, estimate a value for the wavelength that corresponds to the most energetic X-ray photon.

Estimated wavelength = ………………… nm [1]

2 Explain how the wavelength in **1** is different from that of the de Broglie wavelength of electrons that are used to produce the X-rays.

....

....

.... [1]

(c) The accelerating p.d. in an X-ray tube is increased. State and explain whether this will affect the following:

(i) Intensity of the X-radiation.

....

....

.... [2]

(ii) Wavelength of the characteristic lines.

....

....

.... [2]

(d) State and explain whether the following will affect the intensity of X-radiation:

(i) Increasing the tube current.

....

....

.... [2]

(ii) Increasing the time taken to heat up the filament of the X-ray tube (This is called the exposure time. Note that X-ray tubes are usually switched on for a very short time).

....

....

.... [2]

Apparatus for Question 1

1. retort stand with boss and clamp
2. brick
3. spring
4. 450 g mass (inclusive of holder)
5. stopwatch
6. meter rule

Apparatus for Question 2

1. Retort stand with two bosses
2. Two smooth nails with split corks
3. 50g slotted mass hanger
4. Spring
5. Wooden beam with holes drilled at the middle and one end.
6. Metre rule and set square
7. Brick to stabilise the retort stand
8. 20 cm string
9. Two 50 cm strings
10. Scissors

Apparatus for Question 3

1. Resistor labelled R1 (47 Ω)
2. Resistor labelled R2 (220 Ω)
3. Nine carbon film resistors, each with resistance value shown (33 Ω, 47 Ω, 100 Ω, 150 Ω, 220 Ω, 330 Ω, 470 Ω, 560 Ω, 680 Ω)
4. One dry cell (1.50 V)
5. Digital voltmeter capable of measuring voltages in the range 0–2 V
6. Milliammeter capable of measuring currents in the range 0–20 mA
7. Eight connecting leads with crocodile clips

Name : ________________________________ CT group : ______________

VICTORIA JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATIONS 2017

PHYSICS **9749/04**

Higher 2 **29 Aug 2017**

TUESDAY

Paper 4 Practical Test **2 hours 30 minutes**

Candidates answer on the Question Paper.
Additional Materials: As listed on the Confidential Instructions.

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.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

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.

Shift
Laboratory

For Examiner's Use	
1	
2	
3	
4	
Total	

This question set consists of a total of **12** printed pages.

1 This investigation is on the oscillation of a mass on a spring.

(a) (i) Stabilise the base of the retort stand with the brick provided. Attach a spring to the clamp. Measure and record the natural length of the spring using the meter rule.

L = ………………… [1]

(ii) Attach the 450 g mass inclusive of mass holder to the other end of the spring vertically and lower it gently until the equilibrium position is attained. Measure and record the length of the extended spring.

L' = ……………...... [1]

(iii) Calculate the spring constant k.

Spring constant k = ………………..[2]

(iv) Displace the mass slightly downwards and release it so that it performs small oscillations. You will have to get a good set of timings in order to determine the period of oscillation T.

T = ……………………………… [2]

(v) Using **(a)(iii)**, **(a)(iv)**, calculate a value for the mass.

Calculated mass = ……………………. [2]

(vi) Suggest why there is a discrepancy in the result obtained in **(a)(v)** when compared with the stated value of 450 g of the mass.

……………………………………………………………………..

……………………………………………………………………..

……………………………………………………………………..

……………………………………………………………………. [2]

(vii) State and explain one positive and one negative effect on the experimental results of oscillating a mass significantly greater than 450 g.

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

……………………………………………………………………………… [2]

(b) A meter rule is clamped vertically using another retort stand. The mass, which is suspended at the bottom of a different spring, is displaced downwards from its equilibrium position and then released so that it performs vertical oscillations next to the meter rule.

As time passes, the amplitude of oscillations is observed to decrease. The amplitude *A* of oscillations is measured in relation to *n*, the number of oscillations.

The graph of how ln *A* varies with the number of oscillations *n* is shown in **Fig. 1**. Using the graph, *estimate* the number of oscillations that corresponds to the amplitude that has reduced to half of the original value. [3]

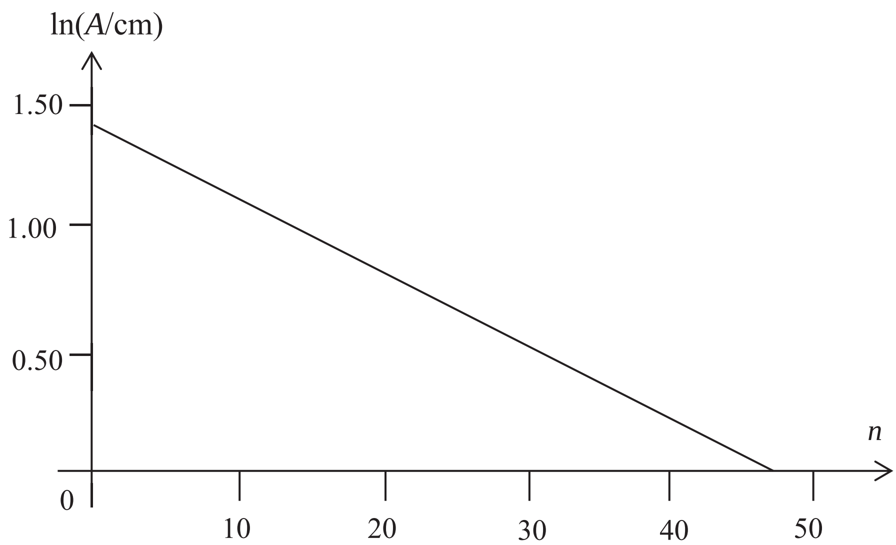

Fig. 1

[Total: 15 marks]

2 This investigation considers the equilibrium of forces acting on a wooden beam.

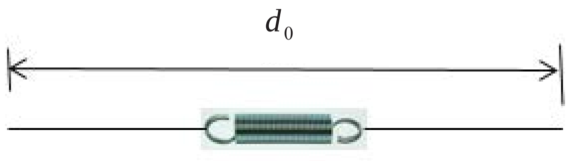

Fig. 2.1

(a) Tie the two strands of 50 cm thread to the two ends of the spring as shown in **Fig. 2.1**. The length of d_0 should be about 60 cm. Measure d_0.

d_0 = ... [1]

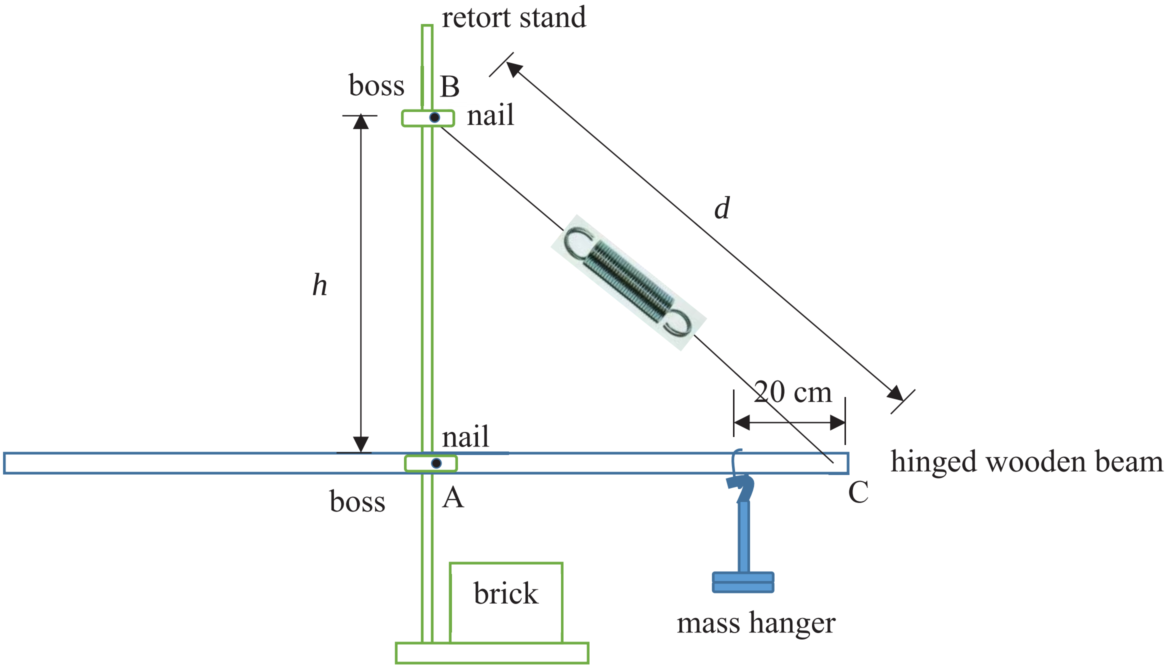

Fig. 2.2

(b) Set up the apparatus shown in **Fig. 2.2**, taking care to stabilise the retort stand with a brick.

(c) Suspend the 50 g mass hanger from a loop of string at 20 cm from C on the wooden beam. Carefully move the boss at B up or down the retort stand until the wooden beam is horizontal. Measure and record *d*, the distance BC, in **Fig. 2.2**.

d = ... [1]

(d) Using your answers from (a) and (c), calculate the percentage uncertainty in $\frac{d_0}{d}$.

Percentage uncertainty = ………………….. [1]

(e) Measure and record height h from the nail at point A to the nail in the boss at B as shown in **Fig. 2.2**.

h = …………………………… [1]

(f) Steps **(c)** and **(e)** are repeated for a further six values of m, the total mass of the hanger and slotted weights. These six readings have been measured and are recorded in the table below.

Calculate and fill in the table, the value of $(1-\frac{d_0}{d})h\,/\,\mathrm{cm}$ for the 100 g mass. Take d_0 = 58.5 cm.

m/g	h/cm	d/cm	$(1-\frac{d_0}{d})h\,/\,\mathrm{cm}$
350	55.0	69.5	8.71
300	53.5	68.0	7.47
250	52.2	66.5	6.28
200	49.2	65.0	4.92
150	45.5	63.9	3.85
100	44.0	62.5	

[1]

(g) The equation that relates h, d, d_0 and m is

$$\left(1-\frac{d_0}{d}\right)h = mk$$

where k is a constant.

(i) Plot the point corresponding to the mass m = 100 g obtained from **(f)** on the graph in **Fig. 2.3**. [1]

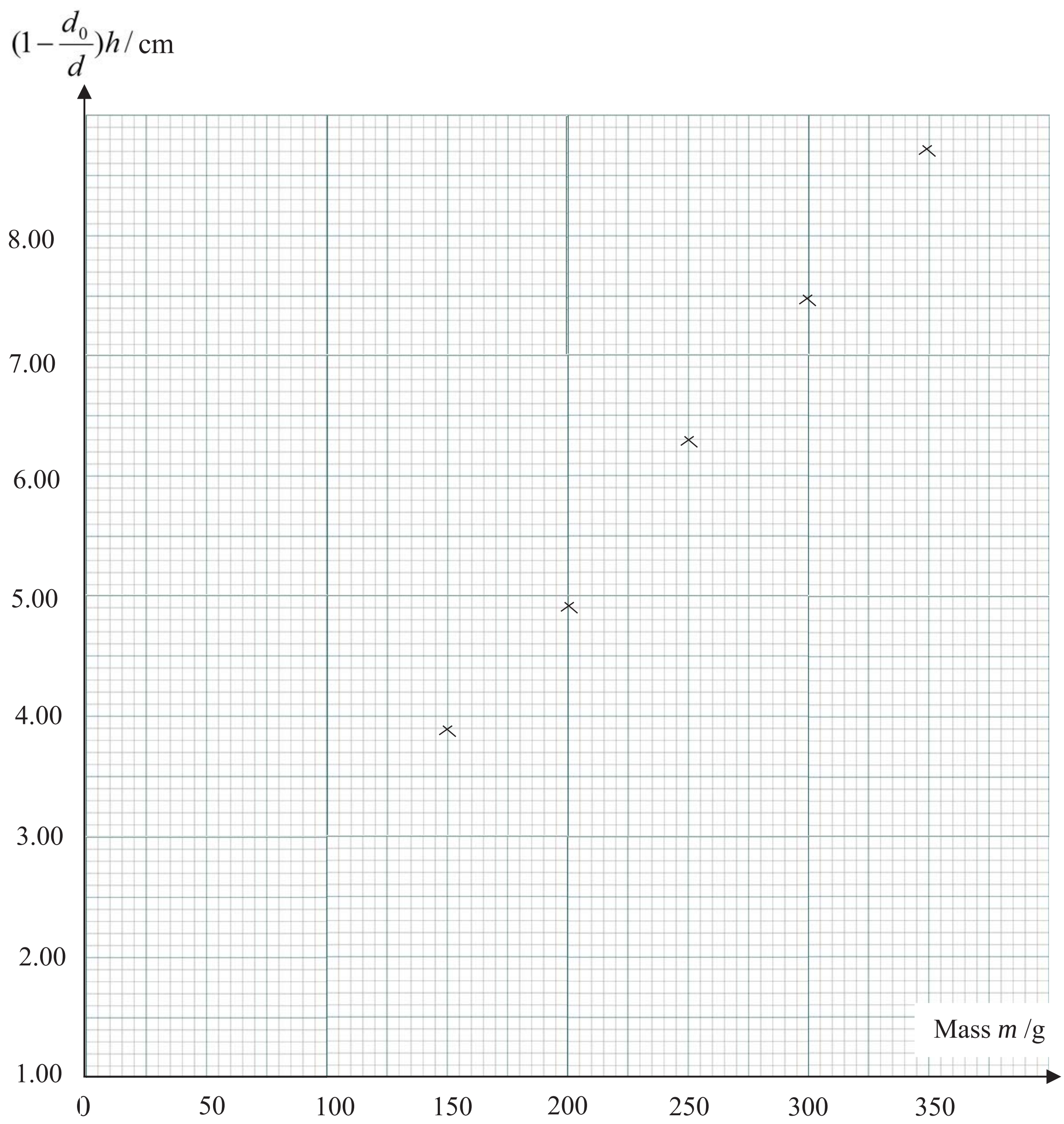

Fig. 2.3

(ii) Calculate the value of k, giving its unit.

k = ………………………………. [2]

[Total: 8 marks]

You may not need to use all of the materials provided.

3 In this experiment you will measure the current I through a resistor $\mathbf{R_3}$ as its resistance is changed.

(a) (i) Use the voltmeter to measure the e.m.f. E of the power supply.

E = ... [1]

(ii) Connect the circuit shown in **Fig. 3.1**. $\mathbf{R_1}$ and $\mathbf{R_2}$ are labelled, and $\mathbf{R_3}$ may be chosen from any one of the remaining resistors. Each resistor carries a label indicating its resistance.

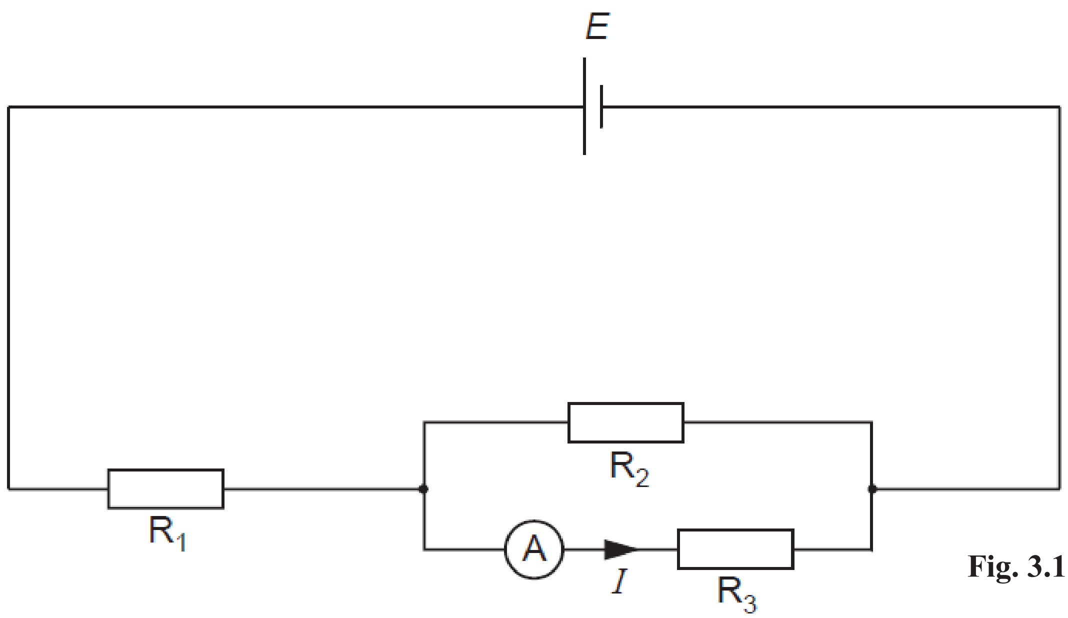

Fig. 3.1

(b) The relationship between I and R_3 is

$$\frac{1}{I} = \left(\frac{R_1 + R_2}{ER_2}\right)R_3 + \frac{R_1}{E}$$

where R_1 is the resistance of the resistor $\mathbf{R_1}$, R_2 is the resistance of the resistor $\mathbf{R_2}$, and E is the e.m.f. of the power supply.

By taking sufficient appropriate measurements, plot a suitable graph to determine the values of R_1 and R_2, showing all necessary calculations.

Records

[7]

Graph and calculations

R_1 = ………………..………………

R_2 = …………………………… [7]

(c) Comment with justification whether there are any anomalous data in your results.

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………

…………………………………………………………………………………… [1]

(d) **(i)** Identify a significant source of error. Explain how this error affects your results.

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

…………………………………………………………………………………… [1]

(ii) Suggest an improvement that could be made to the experiment and explain how it addresses the error/limitation in **(d)(i)**. You may suggest the use of other apparatus or different procedures.

……………………………………………………………………………………..

……………………………………………………………………………………..

…………………………………………………………………………………… [1]

(e) If R_1 and R_3 are constant and R_2 instead is the variable quantity, suggest the graph to plot to enable the values of R_1 and R_3 to be determined. Explain.

……………………………………………………………………………………..

……………………………………………………………………………………..

…………………………………………………………………………………… [2]

[Total: 20 marks]

4 Direct current (d.c.) motors are characterised by some specifications, such as their stall torque and no-load speed when operated at a nominal fixed supply voltage. Such a motor can be used to raise an appropriate mass over a certain height.

The stall torque is the maximum torque that the motor can exert, when its rotational speed is zero.

The no-load speed is the maximum rotational speed of the motor axle when no load is attached to it, i.e. when the torque is zero.

It is known that the torque τ and rotational speed ω of the motor axle are related linearly by the equation

$$\tau = -k\omega + \tau_S$$

where k is a constant and τ_S is the stall torque.

Design an experiment to determine the stall torque and no-load speed of a low-power d.c. motor operating on a fixed supply voltage. You are provided with some masses for the experiment. You may also use any of the other equipment usually found in a physics laboratory.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

(a) the identification and control of variables,
(b) the equipment you would use,
(c) the procedure to be followed,
(d) how the torque exerted by the motor axle and its angular speed are determined,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

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…………………………………………………………………………………………….. [12]

Oscillation of mass on a spring

Marking Scheme of Q1

Question	Answer	Code	Marks
1(a)(i)	MMO Value of L to 1 d.p. in cm	M1	1
1(a)(ii)	MMO Value of L' to 1 d.p. in cm	M2	1
1(a)(iii)	MMO $x = L' - L$ calculated, ACE $F = kx$, Value of k to 2 or 3 s.f. with unit	M3 A1	1 1
1(a)(iv)	MMO Time ≥ 10.0 s, with repetition PDO Period T calculated to the appropriate number of s.f. with unit	M4 P1	1 1
1(a)(v)	ACE $T = 2\pi\sqrt{\frac{m}{k}}$ ACE Mass m calculated correctly to the appropriate number of s.f. (2 or 3 s.f.) with unit	A2 A3	1 1
1(a)(vi)	ACE Any two of the following: -Uncertainty in measurement of extension leading to inaccurate k -Spring may not obey Hooke's law hence affect k -Period T inaccurate due to human errors	A4 A5	1 1
1(a)(vii)	ACE A heavier mass will cause the oscillations to be slower, yielding a smaller percentage uncertainty in the period. However, it may extend the spring to the point where Hooke's Law is not obeyed.	A6 A7	1 1
1(b)	ACE $ln(A_0/2) = mn + ln(A_0)$ *where* m = *gradient* PDO $lnA_0 - ln2 = mn + lnA_0$ gradient calculated and y-intercept from graph ACE $n = 23$ n to nearest integer (accept between 20 and 26) or to 1 decimal place	A8 P2 A9	1 1 1

MARKING SCHEME FOR QUESTION 2

Question	Answer	Code	Marks
2(a)	MMO d_0 recorded to 1 d.p. in cm (d_0 = 58.5 cm)	M1	1
(c)	MMO d recorded to 1 d.p. in cm with unit (d = 60.0 cm to 64.0 cm)	M2	1
(d)	ACE Percentage uncertainty of d_0/d correctly calculated to 2 s.f. 2 mm $\leq \Delta d \leq$ 5 mm but Δd_0 = 1 mm or 2 mm	A1	1
(e)	MMO h recorded to 1 d.p. in cm with unit (h = 40.0 cm to 44.0 cm)	M3	1
(f)	ACE Value of $(1- d_0/d)h$ correctly calculated to 3 s.f. for 100 g mass	A2	1
(g)(i)	PDO Point plotted correctly	P1	1
(g)(ii)	ACE Gradient – the hypotenuse of the triangle sufficiently large (i.e. must be greater than half the length of the drawn line.) Read-offs must be accurate to half a small square. Check for $\Delta y/\Delta x$ (i.e. do not allow for $\Delta x/\Delta y$).	A3	1
	ACE Value of k calculated correctly with units. k = (0.0218 to 0.0254) cm g^{-1} = (0.218 to 0.254) m kg^{-1}	A4	1

MARKING SCHEME FOR Qn 3

Question	Answer	Code	Marks
3(a)(i)	MMO Measurement of e.m.f. of power supply with unit	M1	1
3(b)	MMO Measurements Two marks for six sets of readings for I and R_3, 1 mark for 5 sets and zero marks for 4 sets or fewer	M2	2
	MMO Repetition of measurements for current	M3	1
	MMO Quality of data (Graph) Judge by scatter of points about the best fit line. Trend must be correct. At least 5 plots are needed for this mark to be scored.	M4	1
	PDO Column headings Each column heading must contain a quantity and a unit where appropriate. Ignore units in the body of the table. There must be some distinguishing mark between the quantity and the unit (i.e. solidus is expected, but accept, for example, I (A)). .	P1	1
	PDO Consistency of presentation of raw readings All values of I must be given to the same number of decimal places.	P2	1
	PDO Table: calculated quantities Significant figures Apply to $\frac{1}{I}$ only. If I is given to 3 sf, then accept $\frac{1}{I}$ to 3 sf. If I I is given to 4 sf, then accept $\frac{1}{I}$ to 4 sf.	P3	1

Question	Answer	Code	Marks
	PDO (Graph) Axes Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed. There should not be more than three large squares between axis labels. Scales must be chosen so that the plotted points must occupy at least half the graph grid in both x and y directions. Scales must be labelled with the quantity which is being plotted.	P4	1
	PDO Graph: plotting of points All observations must be plotted. Check 3 plots at random. Ring and check a wrong plot. Tick if correct. Work to an accuracy of half a small square.	P5	1
	PDO Graph: trend line Line of best fit (must be 5 or more plots) Judge by scatter of points about the candidate's line. There must be a fair scatter of points either side of the line.	P6	1
	ACE Gradient The hypotenuse must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square. Check for $\Delta y/\Delta x$ (i.e. do not allow $\Delta x/\Delta y$).	A1	1
	ACE y-intercept The value must be read to the nearest half square. The value can be calculated using $y = mx + c$.	A2	1
	ACE R_1 must be in range 40.0 to 90.0 Ω. Value for R_1 obtained from y-intercept x E. 2 or 3 sf. Unit required	A3	1
	ACE Should be (220 ± 80) Ω for R_2. Method of working must be correct. 2 or 3 sf. Unit required.	A4	1

Question	Answer	Code	Marks
3(c)	MMO Anomalous data/results, if any, must be identified. Appropriate justification must be given. Otherwise, comment on absence of anomalous data.	M5	1
3(d)(i)	ACE 1 point for each significant source of error and explanation. (resistor value of R_3 may not be exactly as stated on label; overheating of circuit affecting resistor values; possible fluctuation of current values)	A5	1
3(d)(ii)	ACE Improvements must be related to chosen source of error. (pre-determine R_3 values before experimentation; switch off circuit when measurements are not being made; ensure no loose connections or use a cell that is not too new or too old so that electrical discharge is more regular)	A6	1
3(e)	ACE $\frac{1}{I} = \left(\frac{R_1 + R_2}{ER_2}\right)R_3 + \frac{R_1}{E}$ can be rewritten as $\frac{1}{I} = \frac{R_1 R_3}{E}\left(\frac{1}{R_2}\right) + \left(\frac{R_3}{E} + \frac{R_1}{E}\right)$. A graph of $\frac{1}{I}$ can be plotted against $\frac{1}{R_2}$ which will yield $\frac{R_1 R_3}{E}$ as the gradient and $\left(\frac{R_3}{E} + \frac{R_1}{E}\right)$ as the vertical intercept. R_1 and R_3 can then be solved using simultaneous equations. *[1 mark for rewriting correct equation and another for determining the gradient and vertical intercept]*	A7	2

Planning Question for 2017 Preliminary Exam 9749/4.

Direct current (d.c.) motors are characterised by some specifications, such as their stall torque and no-load speed when operated at a nominal fixed supply voltage. Such a motor can be used to raise an appropriate mass over a certain height.

The stall torque is the maximum torque that the motor can exert, when its rotational speed is zero.

The no-load speed is the maximum rotational speed of the motor axle when no load is attached to it, i.e. when the torque is zero.

It is known that the torque τ and rotational speed ω of the motor axle are related linearly by the equation

$$\tau = -k\omega + \tau_S$$

where k is a constant and τ_S is the stall torque.

Design an experiment to determine the stall torque and no-load speed of a low-power d.c. motor operating on a fixed supply voltage. You are provided with some masses for the experiment. You may also use any of the other equipment usually found in a physics laboratory.

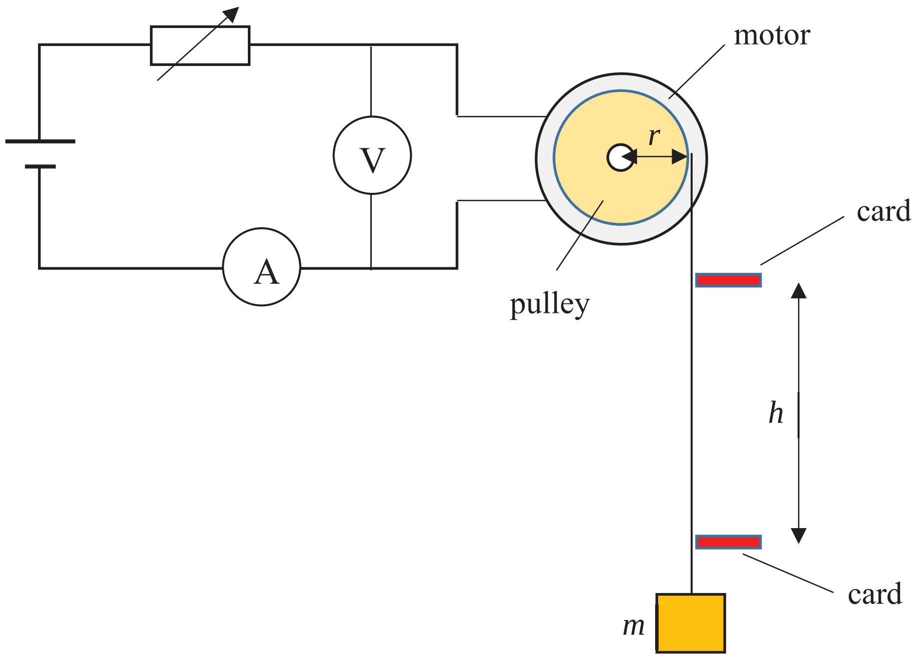
You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

(a) the identification and control of variables,
(b) the equipment you would use,
(c) the procedure to be followed,
(d) how the torque exerted by the motor axle and its angular speed are determined,
(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Suggested solution:

Diagram of apparatus:

Apparatus:



(a) Identification and control of variables:

The torque τ applied to the motor axle is varied, and the resulting angular speed ω is measured.

The voltage applied across the motor is kept constant, as a different voltage will give different values of the motor characteristics.

(b) Equipment:

Refer to equipment in the diagram.

(c) Procedure:

1. Use a retort stand to clamp the motor so that its shaft is horizontal.
2. Attach a pulley to the shaft of the motor. Wind a thin but strong string around the pulley groove and, using a metre rule, determine the circumference, and use it to determine the radius r of the pulley via "circumference = $2\pi r$.
3. Attach a string to the pulley.
4. Measure the mass m of the load using an electronic balance.
5. Attach the load to the lower end of the string.
6. Using another retort stand, mount two cards along the string to serve as the start and end points of the timing.
7. Measure the distance h between the two cards.
8. Turn on the motor so that its lifts the load.

9. Start the stopwatch as the load passes through the bottom card, and stop it when the load crosses the top card. Record this timing as t.
10. Calculate the torque τ and the angular speed ω of the motor using the method explained in section (d) below.
11. Repeat steps 2 to 10, in each case varying the mass m of the load. Obtain several sets of values of τ and ω.
12. Plot a graph of τ against ω. This graph would be a straight line graph with a negative gradient $(-k)$ and a positive y-intercept (τ_S).
13. The value of k is obtained from the gradient.
14. The stall torque τ_S is equal to the y-intercept.
15. The no-load speed ω_0 is obtained from the x-intercept (where $\tau = 0$) which is calculated using "$\omega_0 = \frac{\tau_S}{k}$".

<u>(d) Determination of torque and angular speed</u>:

- The torque τ exerted by the motor is calculated using "$\tau = mgr$".
- The linear speed of the rim of the pulley is calculated using "$v = \frac{h}{t}$".
- The angular speed ω is calculated using "$\omega = \frac{v}{r}$".

<u>(e) Precautions:</u>

(i) <u>Accuracy</u>:

- The height h the load is raised through should be sufficiently large to reduce the percentage uncertainty in the measurement of t.
- The measurement of the linear speed v should be repeated with a shorter h to ensure that it is the same as the previous value. This constancy ensures that the motor has accelerated to a constant speed before the timing is started.

(ii) <u>Safety:</u>

- Wear goggles as the rope might snap during the experiment.
- Ensure that the load is light enough so that the motor is able to move it, as a lot of heat will be generated and damage the motor if it is not able to turn while a current is supplied to it.

Marking Scheme:

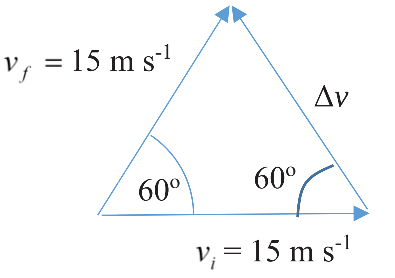
Item	**Marking requirement**	**Marks allocated**
Diagram / Apparatus A1	• Diagram to contain all essential details. • Suitable apparatus to be explained using either the diagram *or in writing*. Instruments for any measurement to be mentioned. • Missing or wrong apparatus used or lack of clarity will be penalised.	1
Control of variables B1	• Main variables (torque, angular speed) identified. • Quantity to be kept constant identified (e.g., voltage across motor) <u>with justification provided</u>.	1
Method C1 C2	• Workable method described. Missing essential details to be penalised. • Varying load to vary torque	2
C3	• Torque, $\tau = mgr$	1
D1 D2	• Angular speed, $\omega = \frac{v}{r}$ • $v = \frac{h}{t}$.	2
Graphs E1	• Graphs to be plotted are stated. (τ vs. ω)	1
Deducing results F1	• Identifying stall torque as y-intercept ($\omega = 0$),	1
F2	• Identifying the no-load speed as x-intercept ($\tau = 0$).	1
Precaution (accuracy) G1	Any valid precaution accepted.	1
Precaution (safety) G2	Any valid precaution accepted.	1

VICTORIA JUNIOR COLLEGE

SUGGESTED SOLUTIONS TO 2017 PHYSICS PRELIM EXAMS 9749 P1

1. Change in velocity

$\Delta\vec{v} = \vec{v}_f - \vec{v}_i$ or $\vec{v}_f = \Delta\vec{v} + \vec{v}_i$. Hence



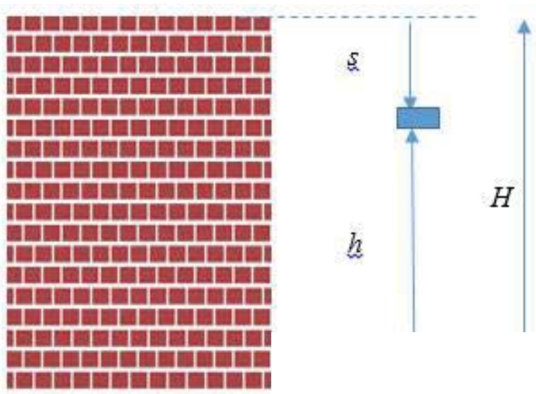
which shows an equilateral triangle, and Δv is 15 m s^{-1} , 60° north of west

Ans: C

2. B is precise because the values fall close to one another, but it is not accurate because the average value is far from x_o.

Ans: B

3.



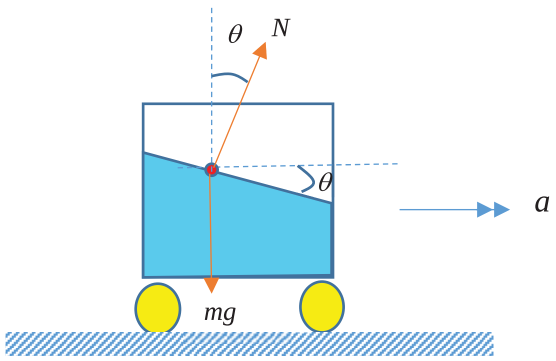
Using " $s = ut + \frac{1}{2}at^2$ ", we have

$$H - h = \frac{1}{2}gt^2 \text{ or } h = H - \frac{1}{2}gt^2$$

h decreases as t increases, and gradient increases as t increases.

Ans: D

4.



Forces acting on a molecule of mass m on the surface of the water are the weight mg and the normal reaction N.

For vertical equilibrium, $N\cos\theta = mg\ldots(1)$

For horizontal acceleration to the right,

$N\sin\theta = ma\ldots.(2)$

$\frac{(2)}{(1)}$ gives $\tan\theta = \frac{a}{g}$

Ans: A

5. Stored energy = ½ $k e^2$
= ½ (500) $(0.020)^2$ = 0.100 J

Ans: A

6. Upthrust on an object in a liquid is due to the pressure difference between the upper and lower parts of the object in the liquid.

Ans: D

7. When kicked at 60°, the soccer ball will still have a velocity at its highest point, hence D is not the answer. At the highest point, the velocity is $v = v_0 \cos 60^0 = \frac{v_0}{2}$.

Hence the final E_k must be

$E_k = \frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{m{v_0}^2}{4}\right)$ which is ¼ of the initial E_k. Hence answer is A.

Ans: A

8. For the satellite to move in a circle about the earth, $\frac{GMm}{r^2} = \frac{mv^2}{r}$ i.e. KE

$$K = \frac{1}{2}mv^2 = \frac{GMm}{2r}$$

Total energy is PE and KE. i.e.

$$E = -\frac{GMm}{r} + \frac{GMm}{2r} = -\frac{GMm}{2r}$$

Ans: A

9. Since the bus is turning to the right and the pendulum is in the bus, the resultant force of the tension in the string and the weight of the bob of the pendulum is to the right.

Ans: C

10. The x-t graph shows that:

$x = -x_o \cos \omega t$

$\therefore v = +\omega x_o \sin \omega t$

$\therefore a = +\omega^2 x_o \cos \omega t$

Ans: C

11. Period T = 4 ms, $f = 1/T$ = 250 Hz,
$v = f\lambda$,

Estimating the speed of sound in air to be 330 m s^{-1}, $330 = 250\lambda$

λ = 1.32 m.

Ans: D

12. $I = kA^2 = P/(4\pi r^2)$, or $A \alpha 1/r$

Ans: A

13. From the First Law of Thermodynamics, $\Delta U = \Delta Q + \Delta W$
= 70 – (1.0 x 10^5) (1.7 x 10^{-3} - 1.5 x 10^{-3})
= 50 J

Ans: B

14. **Ans: C**

15. When the current is zero, it is equivalent to saying resistance is infinitely big.
An imaginary line drawn from the origin of the *IV* graph to the line where current increases with p.d. *V* shows the gradient of the imaginary line increasing progressively as *V* increases. But the gradient of the imaginary line is the inverse of resistance. Hence resistance decreases as p.d. *V* increases.

Ans: C

16. The number density of electrons n in the wire = $2.0\times10^{21}/(A\times1.0 \text{ x}10^{-2})$ m^{-3}, where A is the cross sectional area of the wire. The current $I = nAve$

$$= \left(\frac{2.0\text{x}10^{21}}{A\text{x}1.0\text{x}10^{-2}}\right)A(0.050\text{x}10^{-2})(1.6\text{x}10^{-19})$$

= 16 A

Ans: B

17. At balance point,

e.m.f. of thermocouple = p.d. across XJ

$$= \frac{R_{XJ}}{R_{XY} + 3000} \times E$$

$$= \frac{\frac{80.1}{100} \times 2.00}{2.00 + 3000} \times 3.0$$

= 0.00160 V = 1.60 mV

Ans: B

18. Both Q_1 and Q_2 will exert a force of the same magnitude on Q_3 towards themselves. Resolving these two forces horizontally and vertically, the two horizontal force components will cancel each other out. The vertically downward force components will add up to give a net force towards the bottom of the page.

Ans: B

19. The magnetic force acting on the conductor is zero because the magnetic field due to the current in the solenoid is either parallel or anti-parallel to the current in the linear conductor.

Ans: A

20. No induced current can flow in the broken ring with a gap. Hence Lenz's Law does not operate and the ring remains stationary.

Ans: C

21. As $P = I_{rms}{}^2 R = \dfrac{I_0{}^2 R}{2}$

Frequency plays no part in affecting the mean rate of production of heat in the pure resistor.

Ans: D

22. A fuse breaks when the power through it exceeds a certain value. Since its resistance is assumed constant, the only factor that needs to be considered is the current. An a.c. supply breaks this fuse at 13 A r.m.s, and hence a d.c. of 13 A will break it too. *Recall the definition of r.m.s current.*

Ans: B

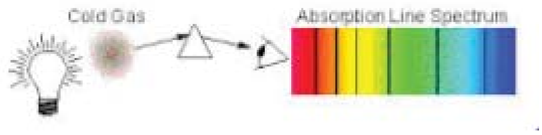
23. If the decelerating p.d. is greater than the stopping potential, not even the electron with the largest kinetic energy can reach the collector.

Ans: D

24. When electrode E is positive, electrons are accelerated from F to E. As long as the frequency of light is fixed and light intensity is constant, the photocurrent will be constant. When E is negative, the photocurrent decreases finally to zero when stopping potential is attained. There is no photoelectric emission from E, implying the work function of E is greater than for F.

Ans: B

25.



This is the arrangement for the production of an absorption spectrum.

Ans: C

26. From the Uncertainty Principle,

$$\Delta p \Delta x \geq \frac{h}{4\pi}$$

Thus $\Delta p \geq \dfrac{h}{4\pi \Delta x}$

Given $\dfrac{\Delta p}{p} = \dfrac{1}{100} \therefore\ p = 100\Delta p$

Hence $p_{\min} = 100\dfrac{h}{4\pi \Delta x}$

$\text{KE}_{\min} = \dfrac{p^2_{\min}}{2m} = (\dfrac{25h}{\pi \Delta x})^2 / 2m$

$= [\dfrac{(25)(6.63\times10^{-34})}{\pi(5.0\times10^{-12})}]^2 /[2(9.11\times10^{-31})]$

$= 6.11 \text{ x } 10^{-13}\text{ J} = \dfrac{6.11\text{x}10^{-13}}{1.6\text{x}10^{-13}}$ MeV

= 3.8 MeV

Ans: A

27. Conservation of mass number yields mass no. of X to be zero, while conservation of charge number yields charge no. of X to be −1. Hence X = ${}^{0}_{-1}e$.

Ans: A

28. Energy released = binding energy of product nuclei – binding energy of reactant nuclei

$= B_{\text{He}} - 2B_{\text{H}} = 2.54\times3 - 1.09\times2\times2$

= 3.26 MeV

Ans: C

29. When the parent nuclei have decreased by half its original number, the daughter nuclei would have increased from zero to half the original parent nuclei. This occurs after a half-life τ.

Ans: C

30. Rate of decay

$$A = \lambda N = \frac{\ln 2}{t_{1/2}} N = \frac{\ln 2}{t_{1/2}} (nN_A)$$ where n and N_A are number of moles and Avogadro's number respectively.

Hence $A \propto \frac{n}{t_{1/2}}$. The ratio $\frac{200}{6200}$ is the smallest.

Ans: D

******* **END** ******

VICTORIA JUNIOR COLLEGE

SUGGESTED SOLUTIONS TO 2017 PHYSICS PRELIM EXAMS 9749 P2

Q1. (a)
The voltmeter or ammeter might have a zero error.

To overcome this error, the meters should be adjusted to remove the zero error before the experiment.

1(b)(i) $R = \frac{V}{I}$ and $R = \frac{\rho L}{A}$, hence

$$\frac{V}{I} = \frac{\rho L}{A} \Rightarrow \rho = \frac{VA}{IL} = \frac{\pi V d^2}{4IL}$$

1(b)(ii)

$$\rho = \frac{\pi V d^2}{4IL} = \frac{1.50 \times \pi \times (0.48 \times 10^{-3})^2}{4 \times 0.82 \times 0.632}$$
$$= 5.23 \times 10^{-7}\,\Omega\text{ m}$$

$$\frac{\Delta\rho}{\rho} = \frac{\Delta V}{V} + \frac{\Delta I}{I} + \frac{\Delta L}{L} + 2\frac{\Delta d}{d}$$
$$= \frac{0.01}{1.50} + \frac{0.01}{0.82} + \frac{0.1}{63.2} + 2\frac{0.02}{0.48} = 0.1037$$

$$\Delta\rho = 0.1037\rho = 0.1037 \times 5.23 \times 10^{-7}$$
$$= 0.54 \times 10^{-7} \approx 0.5 \times 10^{-7}\,\Omega$$

Hence,
$$\boldsymbol{\rho = (5.2 \pm 0.5) \times 10^{-7}\,\Omega\text{ m}}$$

1(c)
The introduction of a second metal in an alloy distorts the lattice structure of the first metal, and vice versa, making it more difficult for electrons to move through the alloy, resulting in increased electrical resistivity.

Q2(a)(i)
Taking upwards positive,
$v_y = u_y + a_y t$

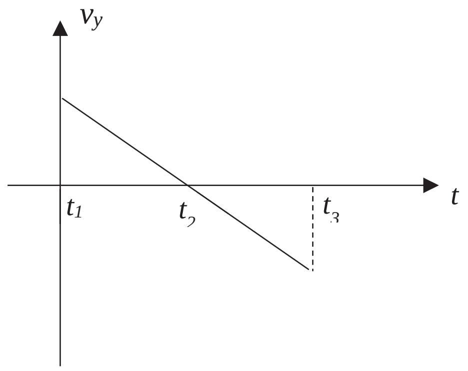
At the highest point,
$0 = u \sin 30^0 + (-9.81)(3.0 / 2)$
$\boldsymbol{u = 29.4}$ **m s^{-1}**

2(a)(ii)
$s_y = ½ (u_y + v_y)\, t$

$= ½ (29.4 \sin 30^0 + 0)(3.0 / 2)$
$= 11.0$ m

Maximum height above the ground
= 11.0 + 1.5 = **12.5 m**

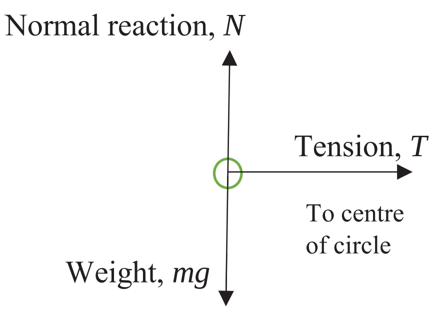
2(b)



2(c)
With air resistance, the deceleration of the ball as it rises is greater compared with the situation where air resistance is negligible. OR Work has to be done by ball to overcome air resistance as it rises above the ground.

Hence the maximum height reached will be smaller.

Q3(a)



Side view of forces acting on the mass.

3(b)

Resultant force = tension = kx

= (40) (0.70-0.50) = **8.0 N**

3(c)

Centripetal force = tension

$$\frac{mv^2}{r} = kx$$

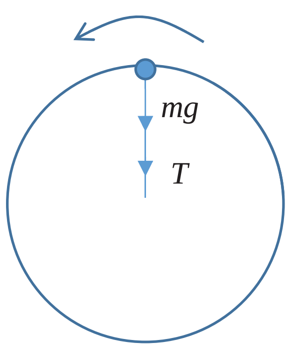
$$v = \sqrt{\frac{(8.0)(0.70)}{0.050}} = \mathbf{10.6\ m\ s^{-1}}$$

3(d)

$$v = \frac{2\pi r}{T}$$

$$T = \frac{2\pi(0.70)}{10.6} = \mathbf{0.42\ s}$$

3(e)



Consider the object moving in a circular path in a vertical plane. Fr circular motion of the object,

$T + mg = \dfrac{mv^2}{r}$ where T and m are the tension in the string and the mass of the object respectively.

To just become slack, the tension in the string just drops to zero. Hence $\boldsymbol{v_{min}} = \sqrt{\boldsymbol{rg}}$

Q4(a)

Lamps do not produce coherent light as the photons are emitted from different points on each lamp.

The light waves meeting at a point have random and rapidly changing phases resulting in only a bright patch.

4(b)(i)

The path difference between the two waves from the aircraft to aerials P and Q will change with time as the aircraft flies overhead.

The waves may be received by P and Q in phase (maximum signal) or out of phase (minimum signal).

4(b)(ii)

Minimum distance travelled by aircraft corresponds to the fringe separation y between two successive maxima (Analogy: Young's double-slit experiment)

$$\boldsymbol{y = \frac{\lambda h}{D}}$$

4(b)(iii)
Thick clouds

Tall buildings nearby.

Q5(a)
Induced e.m.f. = Bxv

$= (0.25)(0.50)(2.0) = \mathbf{0.25\ V}$

5(b)
Induced current =
Induced emf/Resistance
= 0.25/0.50 = **0.50 A**

in a direction clockwise around the loop.

5(c)
Arm PQ will experience a magnetic force as a result of the induced current. If it is not fixed, this will cause the loop to move to the left by FLHR.

Arm PQ will then have an induced e.m.f. which will oppose the e.m.f. in RS.

This will result in an induced current smaller than in (b).

5(d)(i)
The magnetic field due to the induced current in QP will be significant due to the large current. This would affect the magnitude of the original magnetic field on RS and hence the induced emf.

5(b)(ii)
Larger than in part (a). The induced magnetic field of QP in the region of RS points into the paper, and hence the resultant magnetic field acting on RS is now stronger. Hence the induced e.m.f. will be larger.

Q6(a) (i)
Energetic incoming electrons knock out the electrons in the inner shells of target atoms, leaving vacancies behind.

Electrons from the outer shells fall in to fill up the vacancies and X-ray photons are emitted.

The energy of an x-ray photon has a characteristic wavelength determined by the energy difference between the two energy levels involved in the downward transition.

6(a)(ii)
When an incoming electron loses practically all its kinetic energy in a single encounter with a target nucleus, the photon emitted has an associated wavelength corresponding to the cut-off wavelength.

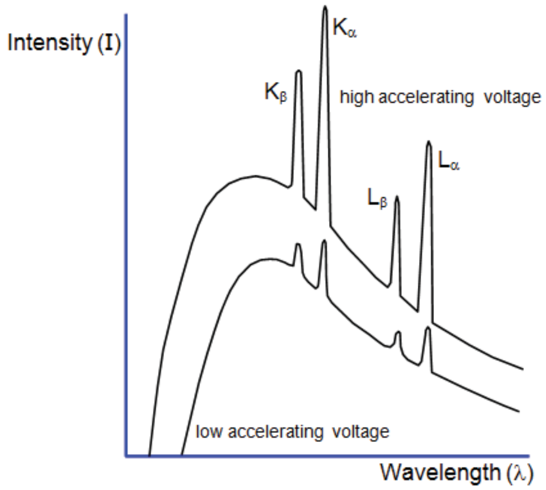
6(b)
Energy of incoming electron = energy of x-ray photon

$$qV = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{qV} = \frac{(6.63\times10^{-34})(3.0\times10^{8})}{(1.6\times10^{-19})(75000)}$$

$$= \mathbf{1.66\times10^{-11}\,m}$$

6(c)



Q7(a)
α-particle and proton.

7(b) $\Delta m = m_O + m_H - m_N - m_{He}$
$\Delta m = 16.9947u + 1.0073u - 13.9993u - 4.0015u$
$= 1.2\times10^{-3}\times1.66\times10^{-27}$
$=$ **1.99×10^{-30} kg**

7(c)
$(m_O + m_H - m_N - m_{He})c^2 = K_\alpha - K_O - K_H$

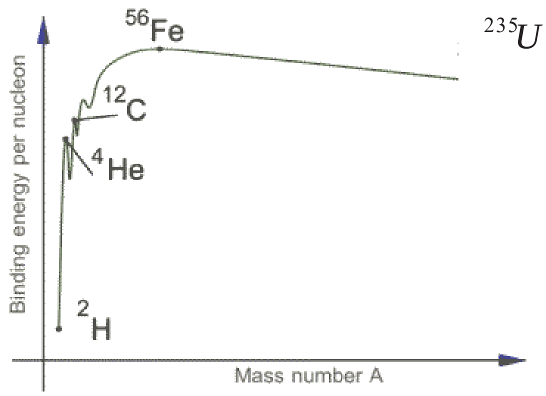
Minimum $K_\alpha = (m_O + m_H - m_N - m_{He})c^2$
$(\Delta m)c^2 = 1.99\times10^{-30}c^2 =$ **1.79×10^{-13} J**

7(d) Mass defect of helium nucleus = mass of 2 protons and 2 neutrons – mass of helium nucleus
Binding energy = mass defect x c^2

$= [2(1.0073)+2(1.0087)-4.0015]\text{x}1.66\text{x}10^{-27}\text{x}(3.0\text{x}10^{8})^2$
$= 4.5567 \text{ x } 10^{-12}$ J
$= \dfrac{4.5567\text{x}10^{-12}}{1.6\text{x}10^{-13}} \approx 28.479$ Mev

$= \dfrac{28.479}{4} \approx$ **7.12 MeV per nucleon.**

7(e)(i)



7(e)(ii) The fission of a heavy nucleus such as ^{235}U will lead to two daughter fragments, each with a mass number smaller than that of the parent nucleus.
The binding energy per nucleon of the daughter fragments will be higher up the binding energy per nucleon graph, corresponding to increased stability.

Q8(a)
USA car: 30 mpg = $\dfrac{30}{0.621}$ km per 3.79 litres.

Hence 100 km corresponds to
$\dfrac{3.79}{\left(\dfrac{30}{0.621}\right)}\text{x}100 = 7.85$ litres of fuel.

European model: 7.80 *l*/100 km. The European model is more fuel-efficient by **0.05 litre/100 km**.

8(b)
European car: original fuel efficiency is 7.80 litres for every 100 km. Hence distance covered per litre is $\frac{100}{7.80}$ km/*l*. =12.8 km/*l*

Percentage increase in fuel efficiency is
$$\frac{15.38-12.8}{12.8}\text{x}100$$

≈ 20% improvement.

8(c)(i)
Total distance travelled = area under *v*-*t* graph over 2 hr
s = 60x0.5 +120x0.5 +80x0.5+100x0.5
=**180 km.**

8(c)(ii)
The gradient of the *v*-*t* graph at 0.5 hr, 1.0 hr and 1.5 hr is infinite.

This is unrealistic because a car cannot achieve infinite acceleration.

8(c)(iii)
The total work done against air drag is the product of force and distance travelled for each time interval over the first hour.

$W = 245\text{x } 30 \text{ x } 10^3 + 540 \text{ x } 60\text{x}10^3$

≈ 3.98 x 10^7 J

8(c)(iv)
Let work done to overcome air drag be *W*.
Then efficiency $\eta = \frac{W}{EV}$ where E = 35 MJ per litre, and V is the volume of fuel required.

$V = \frac{W}{\eta E}$. The total volume of fuel must be calculated for each velocity of the car over the first one hour since efficiency η is velocity-dependent.

$$V = \frac{1}{35\text{x}10^6}\left(\frac{245\text{x}30\text{x}10^3}{0.076}+\frac{540\text{x}60\text{x}10^3}{0.152}\right)$$

≈ 8.9 litre

8(c)(v)
Fuel used per kilometre for the first half hour is $\frac{245\text{x}30\text{x}10^3}{35\text{x}10^6\text{x}0.076}\left(\frac{1}{30}\right) = 9.21\text{x}10^{-2}$ litre

Fuel used per kilometre for the second half of the first hour is $\frac{540\text{x}60\text{x}10^3}{35\text{x}10^6\text{x}0.152}\left(\frac{1}{60}\right)$
≈ 10.2 x 10^{-2} litre

Hence fuel is used more efficiently in the first half of the first hour.

********* END ********

VICTORIA JUNIOR COLLEGE

SUGGESTED SOLUTIONS TO 2017 PHYSICS PRELIM EXAMS 9749 P3

Section A

Q1(a). When the sand impacts on the conveyor belt, it has zero initial horizontal velocity. Friction drags the sand particles along the surface of the conveyor belt, causing the sand to attain a final horizontal velocity of v = 0.75 m s^{-1}. Hence

From N2L, $f = ma = \dfrac{m(v-0)}{t}$

= (5.00)(0.75) = **3.75 N**

1(b) The external force is opposed by the force exerted on the conveyor belt by the sand particles. By Newton's 3rd Law, this force is numerically 3.75 N**.**

Hence F_{ext} = 3.75 N

1(c) Power due to F_{ext} is

$P = F_{ext}\, v$

= 3.75 (0.75) ≈ **2.81 J s^{-1}**

1(d) Rate of change of kinetic energy is

$$\frac{dK}{dt} = \frac{d}{dt}\left(\frac{1}{2}mv^2\right) = \frac{1}{2}v^2\left(\frac{dm}{dt}\right)$$

$$= \frac{1}{2}(0.75^2)(5.00) \approx \mathbf{1.41\ J\ s^{-1}}$$

The rate of change of kinetic energy of the sand is half of the power due to F_{ext}.

Half of the work done by the external force is due to work done to overcome friction between the sand and the conveyor belt.

Q2(a) $KE = \dfrac{1}{2}mv^2 = 0.5 \times 1300 \times (16.7)^2$

$= \mathbf{1.81 \times 10^5\ J}$

2(b)(i) Let total external forces opposing motion of car be R. Then driving force $F = R$ since velocity is constant.

$P = Fv = (240 + 0.98v^2) \times v$

$R = 240 + 0.98v^2 = 240 + 0.98(16.7)^2$

= **513 N**

2(b)(ii) Work done = Force x Distance

= R x velocity x time

= 513 x 16.7 x (3x 60) = $\mathbf{1.54 \times 10^6\ J}$

2(c) Advantage: Electric cars are non-polluting unlike hybrid cars which emit fumes from consumption of petrol.

Disadvantage: Because electric vehicles use electric power alone, there's no backup engine when the batteries run out of energy.

Q3(a) The earth effectively orbits about the centre of the sun because the sun has a much bigger mass compared to the earth.

3(b)

$$\omega = \frac{2\pi}{T}$$

$$\approx \frac{2\pi}{(365)(24)(60)(60)} \approx \mathbf{2.0 \times 10^{-7}\ rad\ s^{-1}}$$

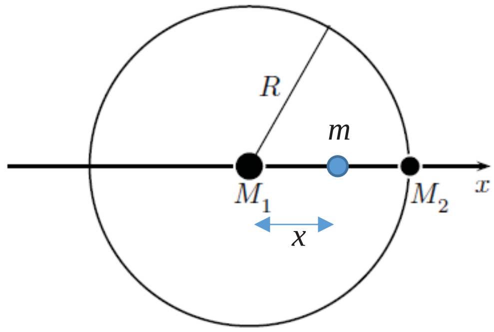
3(c) For circular motion of the earth about the sun, we have

$$\frac{GM_1M_2}{R^2} = M_2R\omega^2$$

$$\omega^2 = \frac{GM_1}{R^3} \text{ or } \omega \propto R^{-\frac{3}{2}}$$

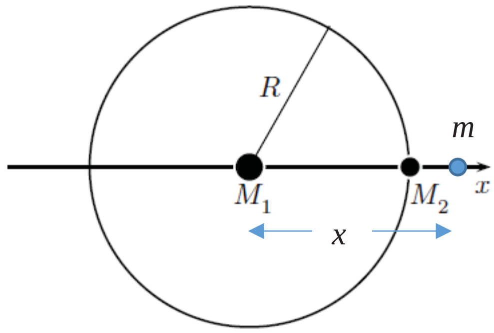
The constant of proportionality is $\sqrt{\boldsymbol{GM_1}}$

3(d)(i)



First possible equation:

$$\frac{GM_1m}{x^2} - \frac{GM_2m}{(R-x)^2} = mx\omega^2$$



Second possible equation:

$$\frac{GM_1m}{x^2} + \frac{GM_2m}{(x-R)^2} = mx\omega^2$$

3(d)(ii) The assumption is that there are no massive celestial objects in the vicinity of mass *m*.

Q4(a)(i) Initial momentum, $p_i = m\,u$
(taking right as positive direction)
Final momentum, $p_f = -\,m\,u$
Change in momentum of a molecule = $\boldsymbol{-\,2\,m\,u}$

4(a)(ii) Time taken by one molecule between collisions with wall A, $\boldsymbol{t = \frac{2l}{u}}$

4(a)(iii) Rate of change of momentum for all molecules colliding with wall A

$$= N\left|\frac{-2mu}{\left(\frac{2l}{u}\right)}\right|$$

$$= \boldsymbol{\frac{Nmu^2}{l}}$$

By N2L, force = rate of change of momentum

Or $\boldsymbol{F = \frac{Nmu^2}{l}}$ (force exerted on wall by N3L)

4(b) Pressure = Force / Area

Pressure, $p = \frac{Nmu^2}{l^3}$

$\boldsymbol{P = \frac{Mu^2}{V}}$ (shown)

4(c) The expression in (b) assumes that all the molecules move in only one dimension when in fact, they move in three dimensions.

The expression also assumes that all the molecules move with only one speed when they actually move with a range of speeds.

Q5(a) p.d. across voltmeter is

$$\boldsymbol{V = \frac{R_v}{R_v + r}E}$$

5(b) If the voltmeter reading is within 0.1 % of the e.m.f.,

$$\frac{E-V}{E} \le 0.001$$

$1 - \frac{V}{E} \le 0.001$ or $1 - \frac{R_v}{R_v+r} \le 0.001$

$\therefore \frac{r}{R_v + r} \le 0.001$

$\therefore 1000r \le R_v + r$

$\therefore R_v \ge 999r = 999 \times 0.10 = 99.9$

$\therefore R_{v(min)} = \boldsymbol{99.9\ \Omega}$

5(c)(i) The voltmeter and the resistor R form a parallel load resistance that the cell is connected across. The equivalent resistance of the voltmeter and resistor R in parallel is:

$$R_{\parallel} = \frac{R_v \times R}{R_v + R}$$

By the voltage divider rule, the voltmeter reading is

$$V = \frac{R_{\parallel}}{R_{\parallel} + r} \times E$$

$$V = \frac{\frac{R_v \times R}{R_v + R}}{\frac{R_v \times R}{R_v + R} + r} \times E$$

$$\boldsymbol{V = \frac{R_v R}{R_v R + rR_v + rR} \times E}$$

5(c)(ii)

$$V = \frac{\boldsymbol{R}}{\boldsymbol{R + r + \frac{rR}{R_v}}} \times \boldsymbol{E}$$

If $R_v = 99.9\ \Omega$, $r = 0.10\ \Omega$ and $R = 0.90\ \Omega$,

$$V = \frac{0.90}{0.90 + 0.10 + \frac{0.10 \times 0.90}{99.9}} \times 2.0$$

$\therefore\ V =$ **1.80 V**

Q6 Let $N = 200$, $r_1 = 12.0$ cm, $D = 1.0 \times 10^4$ kg m^{-3}, $\rho = 2.0 \times 10^{-8}\ \Omega$ m, $r_2 = 0.457 \times 10^{-3}$ m

6(a) Resistance of the coil is

$$R = \rho\frac{L}{A} = \rho\frac{2\pi r_1}{\pi r_2^2}N$$

$$R = \frac{(2.0\text{x}10^{-8})(2)(12.0\text{x}10^{-2})(200)}{(0.457\text{x}10^{-3})^2}$$

$\approx$ **4.60 Ω**

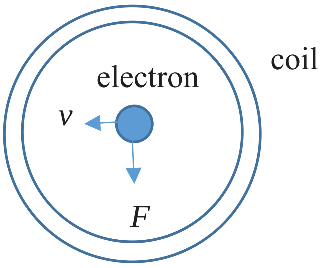
6(b) Magnetic field at the centre of the coil is $B = \frac{\mu_0 NI}{2r_1}$

Applying Ohm's Law,

$$B = \frac{\mu_o NV}{2r_1 R} \text{ or } V = \frac{2Br_1 R}{\mu_0 N}$$

$$= \frac{2(5.0\text{x}10^{-3})(12.0\text{x}10^{-2})(4.60)}{(4\pi\ \text{x}10^{-7})(200)} \approx \mathbf{22.0\ V}$$

6(c)



The force acting on the electron is

$F = Bev$

$= (5.0\text{x}10^{-3})(1.6\text{x}10^{-19})(4.0\text{x}10^{5})$

$=$ **3.2 x10^{-16} N**

By Fleming's LHR, the magnetic field at the centre of the coil is directed **out of the plane of the paper.**

Q7(a)(i) ${}^{23}_{12}Mg \rightarrow {}^{23}_{11}Na + {}^{0}_{1}e + \upsilon$

Products of the decay: Na-23 nucleus, positron and neutrino.

7(a)(ii) From $A = \lambda N = \left(\frac{\ln 2}{t_{\frac{1}{2}}}\right)\left(\frac{M}{M_m}N_A\right)$

Initial rate of decay

$$A = \left(\frac{\ln 2}{11.3}\right)[(\frac{1}{23})(6.02 \times 10^{23})]$$

$= \mathbf{1.61 \times 10^{21}\ Bq}$

7(b)(i) Gamma radiation is uncharged and is thus unaffected by an electric field.

7(b)(ii) α and β particles are charged particles and they will be deflected when travelling perpendicular to the electric field.

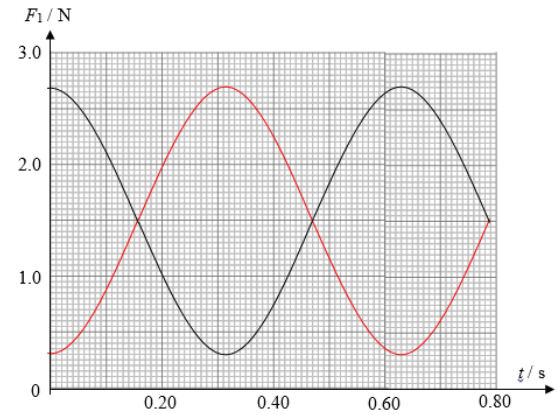
The particles curve in parabolic paths.

7(b)(iii) Tracks are not drawn to scale. The β particles should curve very much more than for the α particles because they are so much lighter.

The charged particles should be travelling straight after exiting the electric field and not continue in a curved path.

Section B

8(a)



(b) T = **0.63 s**.

(c) $\omega^2 = \dfrac{k_{eff}}{m}$

$$\therefore \left(\frac{2\pi}{T}\right)^2 = \frac{k_{eff}}{m}$$

$$\therefore \left(\frac{2\pi}{0.63}\right)^2 = \frac{k_{eff}}{0.200}$$

$\therefore$ k_{eff} = **20.0 N m^{-1}**.

(d) When the mass is displaced by x to the right,

Net force = $T_2 - T_1$

$$\therefore ma = k(e-x) - k(e+x)$$

$$\therefore ma = -2kx$$

$$\therefore a = -\frac{2k}{m}x \propto -x$$

$\therefore$ the motion is simple harmonic.

(e) Net force = $F = -2kx$

$\therefore$ $k_{eff} = 2k$

$\therefore$ force constant for each spring = k = 20.0/2 = **10.0 N m^{-1}**.

(f) From the graph, it is seen that

When $x = x_0$, F_1 = 2.70 N.

$$\therefore k(e + x_0) = 2.70$$

$$\therefore 10.0(0.150 + x_0) = 2.70$$

$\therefore$ amplitude = x_0 = **0.120 m**.

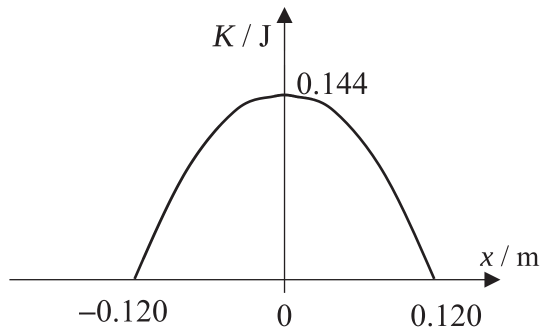
(g) Maximum speed = $v_0 = \omega x_0$

$$\therefore v_0 = \frac{2\pi}{T} \times x_0$$

$$\therefore v_0 = \frac{2\pi}{0.63} \times 0.120 = \mathbf{1.20\ m\ s^{-1}}$$

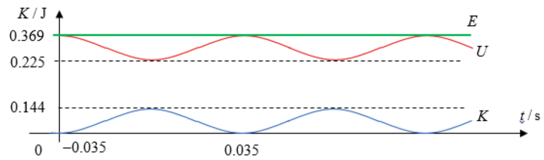
(h) $$K_0 = \frac{1}{2}mv_0^2 = \frac{1}{2} \times 0.200 \times 1.20^2$$
$$= \mathbf{0.144\ J}$$

(i)

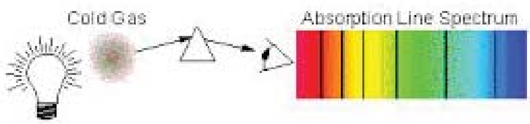


(ii) The PE is minimum at the equilibrium position.

$$\text{Minimum PE} = \frac{1}{2}ke^2 + \frac{1}{2}ke^2 = ke^2$$
$$= 10.0 \times 0.150^2$$
$$= \mathbf{0.225\ J}$$



Q9(a)(i)

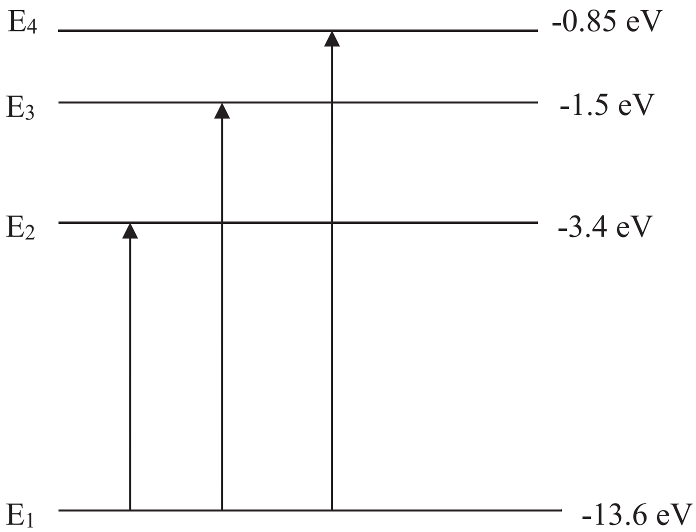


White light is sent through a cool gas. The gas atoms absorb certain characteristic frequencies from the white light and get excited to higher energy states in the process.

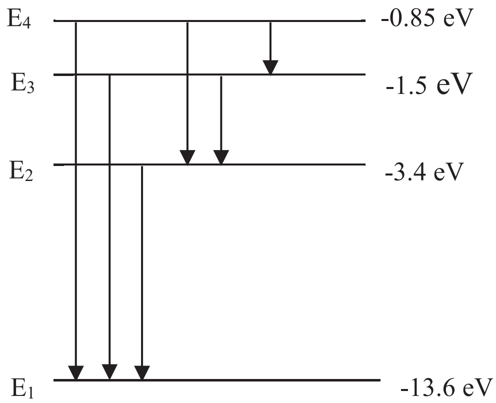
As the atoms de-excite, they re-emit the light in all possible directions.

These frequencies will therefore be practically missing on the spectral photograph. They correspond to dark lines against a coloured background.

9(a)(ii)



9(a)(iii)



9(a)(iv) **13.6 eV**

9(a)(v) The hydrogen atom can get ionised with the excess kinetic energy of the bombarding electron shared between the bombarding electron and the electron that is ejected from the atom due to an effective collision.

The hydrogen atom can also get excited to any other excited state with the bombarding electron carrying away the excess kinetic energy due to a not-so-effective collision.

9(b)(i)1. In the photoelectric effect, bombarding photons produce electrons, while in X-ray production, bombarding electrons produce photons of X-rays.

9(b)(ii)1. **0.035 nm**

9(b)(ii)2. The wavelength in 9(b)(ii)1 is due to a photon travelling at the speed of light, while the de Broglie wavelength of the bombarding electron is associated with wave nature of the moving electron.

9(c)(i) If the accelerating p.d. is increased, the bombarding electrons will have sufficient kinetic energy to interact with more target nuclei, causing the release of more photons.

Hence the intensity of x-radiation will increase.

9(c)(ii) The wavelengths of the characteristic x-ray spectrum are unique to the nature of the target metal.

Since the target remains the same during the increase in p.d, , the wavelengths of the characteristic spectrum will not change.

9(d)(i) Increasing the tube current increases the number of electrons per unit time striking the target metal.

This will lead to more interactions with target atoms, leading to increased intensity in x-radiation.

9(d)(ii) Increasing the exposure time leads to longer time for heating of the filament, leading to greater temperature of the filament in the x-ray tube. The result is more electrons will be produced per second from thermionic emission.

This will lead to more interactions with target atoms, leading to increased intensity in x-radiation.

********* END **********