H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATIONS

Higher 2

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS **9749/01**

Paper 1 Multiple Choice

11 Sep 2018

Additional Materials: Multiple Choice Answer Sheet

1 hour

READ THE INSTRUCTION FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, Subject Class and index number on the Answer Sheet in the spaces provided unless this has been done for you.
DO **NOT** WRITE IN ANY BARCODES.

The Index Number is a 5 digit format, which is made up of the 2nd digit and the last four digits of the student's Registration Number. For e.g. If student's Reg Number is 0905123, then the OAS registration number will be 95123.

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.

Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of 13 printed pages.

Data

speed of light in free space	$c = 3.00 \times 10^{8}\ ms^{-1}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\ Hm^{-1}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ Fm^{-1} = (1/(36\pi)) \times 10^{-9}\ F\ m^{-1}$
elementary charge	$e = 1.60 \times 10^{-19}\ C$
the Planck constant	$h = 6.63 \times 10^{-34}\ Js$
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	$R = 8.31\ JK^{-1}mol^{-1}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\ mol^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\ JK^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11}\ Nm^{2}kg^{-2}$
acceleration of free fall	$g = 9.81\ ms^{-2}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = - GM/r$
temperature	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ and $v = \pm\omega\sqrt{x_0{}^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \cdots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 The diameter of a wire, known to be 0.27 mm at room temperature, is measured with an instrument that gives readings to 0.001 mm.
Readings are taken, at room temperature, at three different points along the wire. Two perpendicular values are taken at each point.
The six readings obtained, in mm, are 0.247, 0.247, 0.248, 0.248, 0.249 and 0.247.

Which statement is true?

A The readings are accurate since the spread of the values is within 0.002 mm.
B The readings are precise since all the values are recorded to the third decimal place.
C The readings are inaccurate since the readings are consistently less than the actual value.
D The readings are not precise since the readings are consistently less than the actual value.

2 A radio antenna of length *L* emits electromagnetic waves of wavelength λ and power *P* when an alternating current I flows through it. These quantities are related by the expression

$$P = kI^2L^2\lambda^{-2}$$

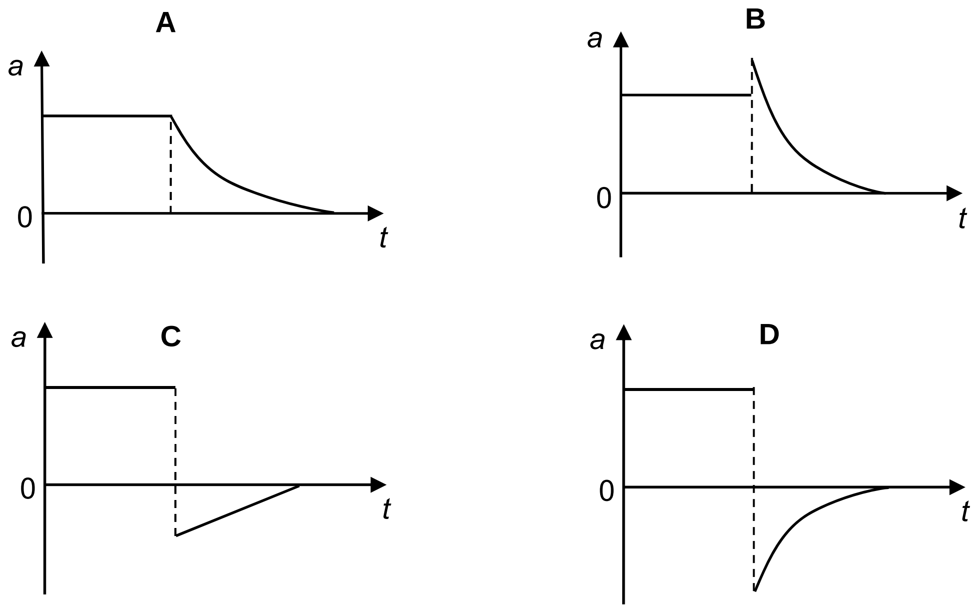
where *k* is a constant.

What is the S.I. base unit of the constant *k*?

A kg m^2 s^{-3} A^{-1}
B kg m^2 s^{-3} A^{-2}
C kg m^2 s^{-3}
D no unit

3 A small metal sphere is released from rest one metre above the surface of a viscous fluid. The sphere experience a viscous force that is proportional to its velocity when moving in the fluid.

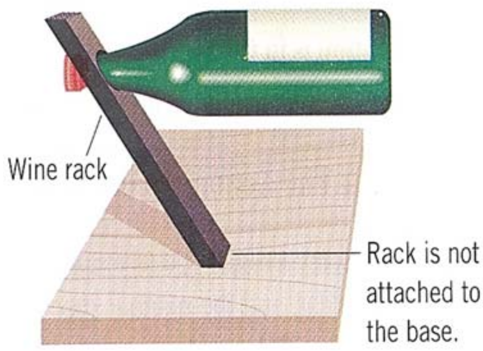
Which of the following graphs best represents the variation of the acceleration *a* of the sphere with time *t*?



4 In an ice-hockey match, two players skated towards each other. After colliding head-on, only one of them was thrown backward.
The player was thrown backwards because he

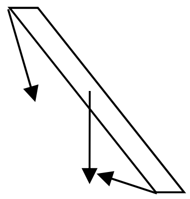
A exerted a smaller force on the other player.
B had a smaller initial momentum.
C had a lower initial speed.
D had a smaller mass.

5 The diagram shows a wine rack with a bottle of wine that is balanced on the table.

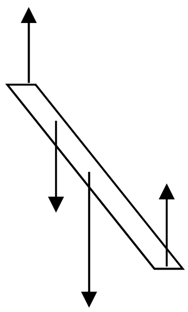


Which of the following diagrams correctly shows the directions of the forces acting on the wine rack?

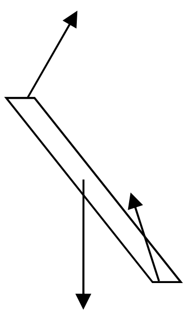
A



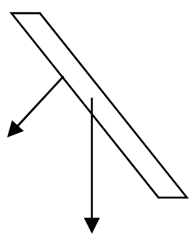
B



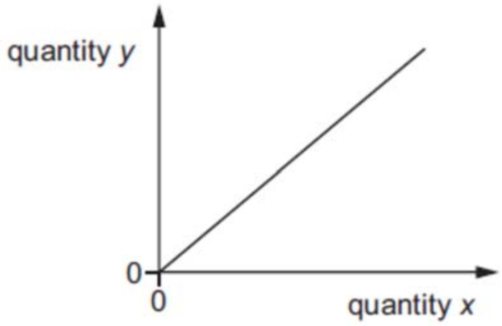
C



D



6 The graph shows the variation of a quantity *y* with a quantity *x* for a body that is falling in air at terminal velocity in a uniform gravitational field.



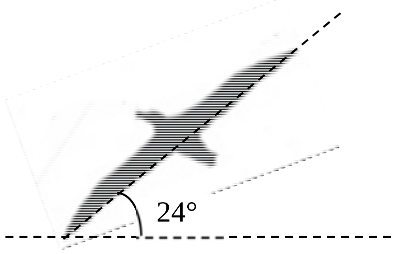
Which quantities could *x* and *y* represent?

	x	*y*
A	air resistance	acceleration
B	loss of height	gain in kinetic energy
C	loss of potential energy	work done against air resistance
D	time	velocity

7 A stone is attached to one end of a light inextensible string. The other end of the string is attached to a fixed point and the stone moves in a vertical circle.
Which of the following statements is false?

A The angle of the string to the vertical cannot be zero as it rotates.
B The velocity of the stone is the same as long as the stone is at the same height from the ground.
C The magnitude of the tension is increasing when the stone moves from the highest position to the lowest position.
D The difference in the tension when the stones is at the top and the bottom of the circle is proportional to the mass of the stone.

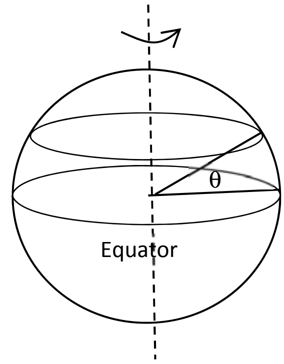
8 A bird is soaring in a horizontal circular path of radius 2.0 m. Its bank angle relative to the horizontal is 24° as shown in the diagram below.



What is the speed of the bird?

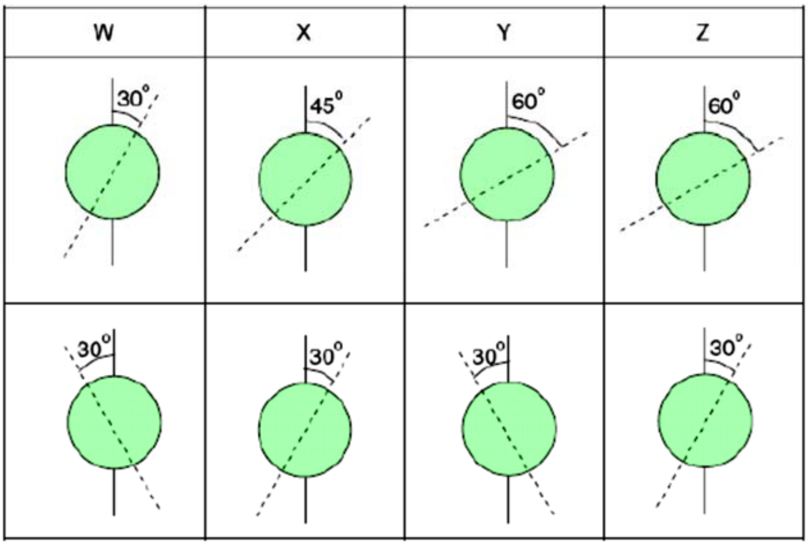
A 1.5 m s^{-1} **B** 3.0 m s^{-1} **C** 6.6 m s^{-1} **D** 8.7 m s^{-1}

9 The Earth has a radius of 6.38 × 10^6 m, and rotates on its axis once every 24 hours. At what latitude (i.e., the angle in the drawing) is the tangential speed of a person one third that of a person living at the equator?



A 20.5° **B** 30.5° **C** 60.5° **D** 70.5°

10 The table below shows four pairs of polarizers W, X, Y and Z. Each pair is mounted so that they overlap exactly. A beam of unpolarised light is then incident normally onto the surface of each pair of polarizers. The polarizing direction of each polarizer is indicated by the dotted line.



Which of the following gives the correct order for the intensity of the emergent light in decreasing order?

A XYZW **B** YWZX **C** XZWY **D** YXWZ

11 A student sets up a simple harmonic oscillator comprising a mass *m* and a light spring with force constant *k* which oscillates with a period *T*. At equilibrum, the extension of this spring is x_0.

To overcome air resistance, the length of the spring is halved and the oscillator is attached to an actuator (driver). At the new equilibrium point, the extension of this spring is now ½x_0.

What frequency should the actuator be set so that the oscillator can achieve maximum amplitude?

A $\frac{1}{T\sqrt{2}}$ **B** $\frac{\sqrt{2}}{T}$ **C** $\frac{1}{T}$ **D** $\frac{2}{T}$

12 Body X and body Y have the same temperature. Body Y is in thermal equilibrium with body Z. The three bodies are of different materials. Body X has the largest mass and body Z has the least mass.

Which one of the following statements is correct?

A X and Y have the same internal energy
B Y and Z have the same specific heat capacity.
C If X is placed in thermal contact with Z, there is no net transfer of heat.
D If X is placed in thermal contact with Z, heat will be transferred from X to Z.

13 A mole of monatomic ideal gas has pressure P_A and volume V_A initially. The gas undergoes a change to a final pressure P_B and volume V_B such that $V_B > V_A$.

Which of the following statements is true?

A The heat supplied to the gas during the process can be determined using only the values P_A, V_A, P_B and V_B.
B The change in the internal energy of the gas during the process can be determined using only the values P_A, V_A, P_B and V_B.
C The work done by the gas during the process can be determined using only the values P_A, V_A, P_B and V_B.
D None of the above.

14 A boy blows gently across the top of a piece of glass tubing the lower end of which is closed by his finger so that the tube gives its fundamental note of frequency- f. While blowing, he removes his finger from the lower end. The note he then hears will have a frequency of approximately

A $f / 4$ **B** $f / 2$ **C** $2f$ **D** $4f$

15 Light of wavelength λ is incident on a pair of slits, forming fringes 3.0 mm apart on a screen.

What is the fringe spacing when light of wavelength 0.5λ is used and the slit separation is doubled?

A 0.75 mm **B** 1.5 mm **C** 3.0 mm **D** 6.0 mm

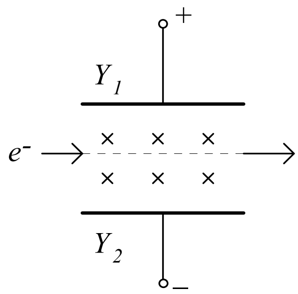
16 A beam of monochromatic light is incident normally on a diffraction grating with number of lines per millimetre N_1. The second order diffracted beam makes an angle of 45° with the grating.

The grating is then replaced by one a different number of lines per millimetre N_2. The third order diffracted beam is now observed at the same angle.

What is the ratio of N_1/N_2?

A 0.47 **B** 0.67 **C** 1.1 **D** 1.5

17 An electron is accelerated from rest through a potential difference V (not shown in the diagram). It then passes without any deflection through a region with mutually perpendicular electric and magnetic fields.



The electric field is provided by a pair of deflecting plates Y_1 and Y_2 with potential difference V and separation d. The applied uniform magnetic field is B. The charge to mass ratio of an electron is given by

A $\dfrac{2B^2d^2}{V}$ **B** $\dfrac{V}{2B^2d^2}$ **C** $\dfrac{B^2d^2}{2V}$ **D** $\dfrac{2V}{B^2d^2}$

18 *A*, *B*, *C* and *D* are four points on a straight line as shown.

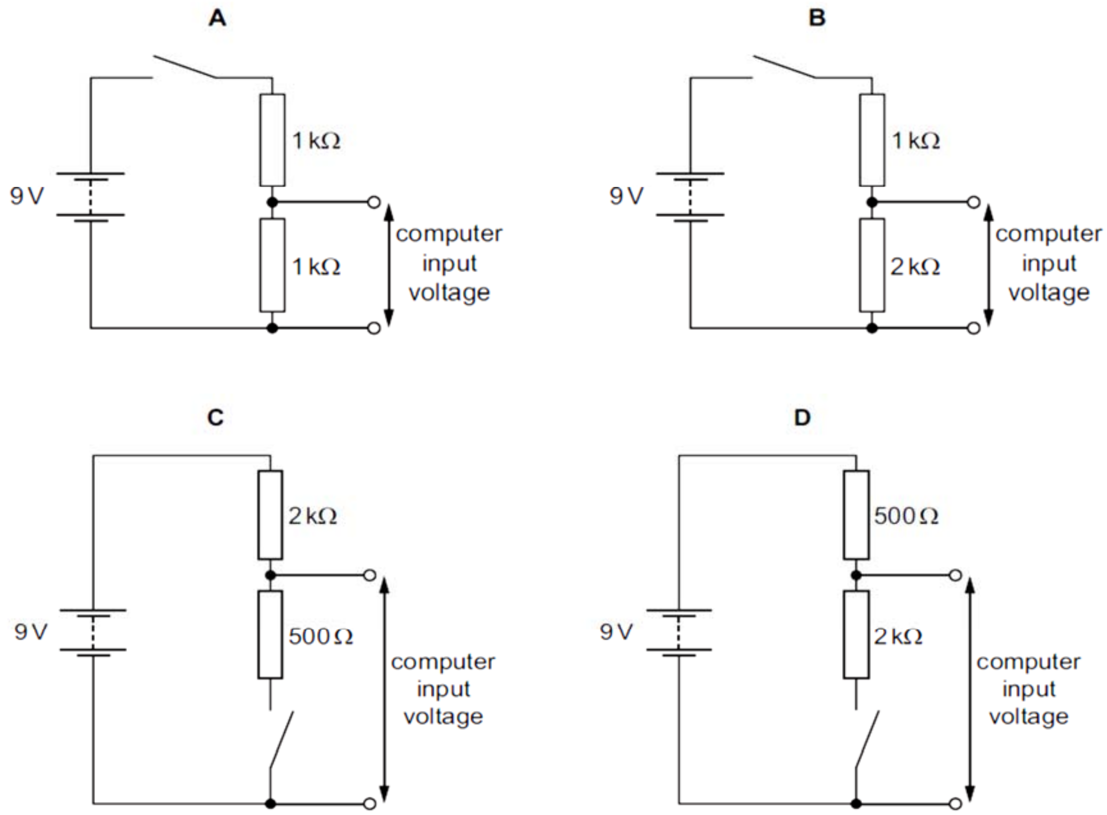
A point charge $+Q$ is fixed at A and a point charge $-Q$ is moved from B to C.

Which of the following statements is false?

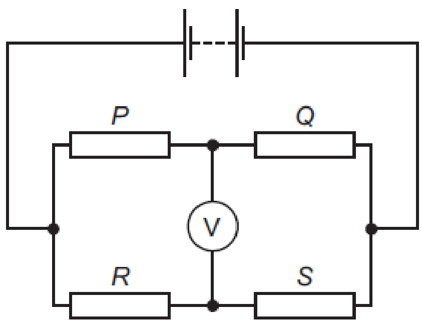
A The electric potential at point *D* increases.
B The magnitude of the electric field strength at point *D* increases.
C The electric potential energy of the system of two charges increases.
D The electric field strength at the mid-point between point *A* and point *B* decreases.

19 A computer is used to detect the change of position of a switch. To detect the change of position, the computer requires a potential difference (p.d.) of 0 V to its input at one switch position and a p.d. between 5 V and 7 V for the other switch position.

Which of the following circuits provides an input voltage to the computer that enables it to detect the change of position of the switch? (The battery and computer in each circuit has negligible internal resistance and infinite resistance respectively.)



20 The diagram shows a circuit with four resistors with resistance *P*, *Q*, *R* and *S* connected to a battery.

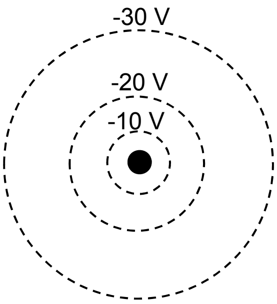


The voltmeter reading is zero. Which of the following equations is correct?

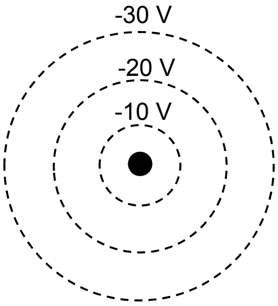
A $P - Q = R - S$
B $P - S = Q - R$
C $PQ = RS$
D $PS = QR$

21 Which of the following diagrams best represents the equipotential lines around a negative point charge?

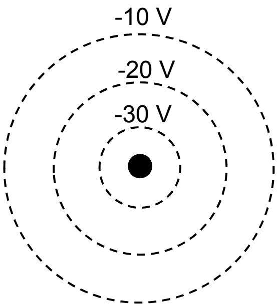
A



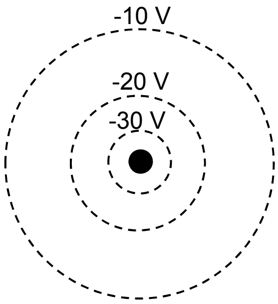
B



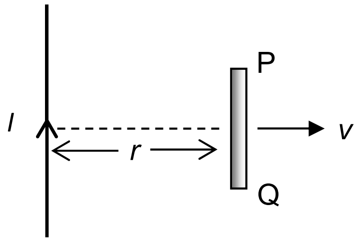
C



D



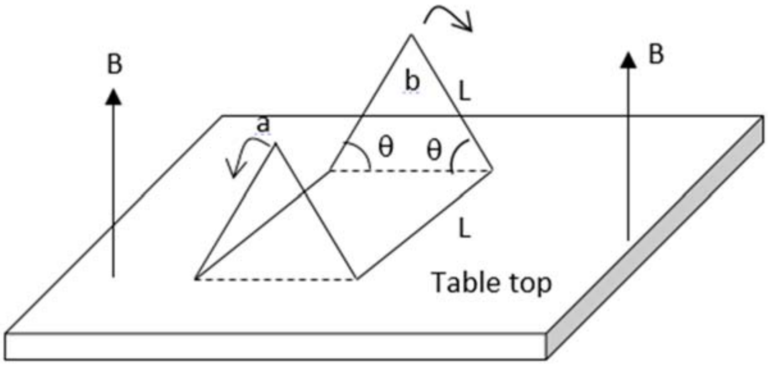
22 The diagram shows a wire carrying a current I and a straight conductor PQ is placed on the same vertical plane as the wire. PQ is moved at constant speed v away from the wire.



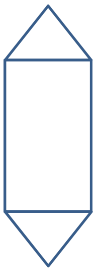
How will the magnitude of the induced e.m.f. in PQ vary and which end will be at a higher potential?

	magnitude of induced e.m.f.	end at higher potential
A	decrease	P
B	decrease	Q
C	increase	P
D	increase	Q

23 The wire shown in the figure below is bent into the shape of a tent, with θ = 60° and L = 1.5 m, and is placed in a 0.30 T magnetic field directed perpendicular to the table-top.

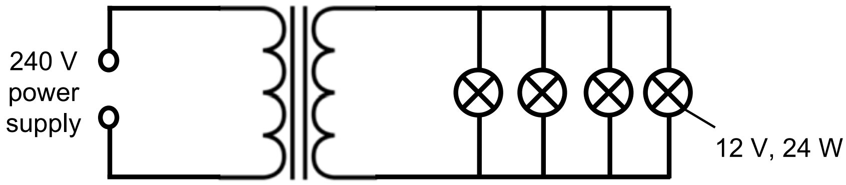


If the tent is flatten out on the table in 0.10 s as shown below (top view), what is the average e.m.f. induced in the wire during this time?



A 2.92 V **B** 5.85 V **C** 7.15 V **D** 9.21 V

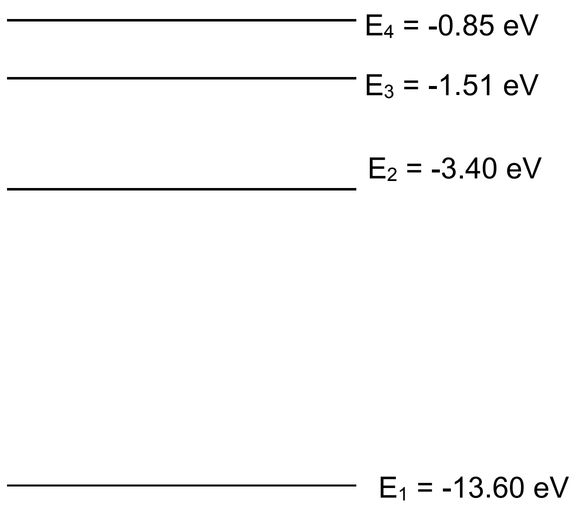
24 The primary coil of a transformer is connected to a 240 V supply. Four identical lamps are connected to the secondary coil as shown below. The lamps are rated 12 V and 24 W and are operating at normal brightness and the transformer is not 100% efficient.



What could be the possible value of the current that can be drawn from the power supply?

A 0.10 A **B** 0.20 A **C** 0.40 A **D** 0.45 A

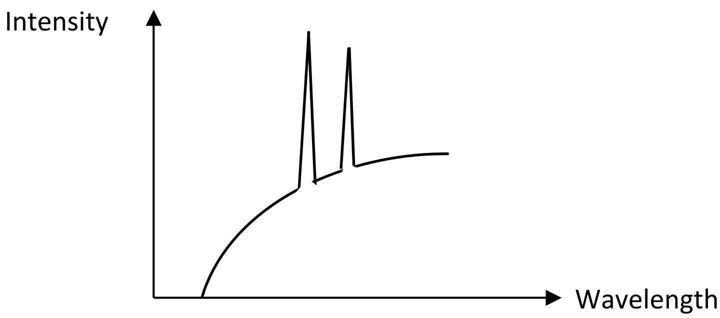
25 The diagram shows some of the energy levels (not drawn to scale) of hydrogen atom. Four photons of wavelength 7.5 nm, 8.0 nm, 11.4 nm and 74.6 nm respectively, strike a sample containing these hydrogen atoms in their ground state.



Calculate the maximum speed of the ejected electron.

A 1.04×10^6 m s^{-1}
B 2.36×10^6 m s^{-1}
C 7.31×10^6 m s^{-1}
D 7.61×10^6 m s^{-1}

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



1 The wavelengths at which the peaks appear are independent of the voltage across the tube.

2 The minimum (cut-off) wavelength is independent of the atomic number of the target in the X-ray tube.

3 The continuous part of the spectrum is due to the very high temperature attained by the target in the X-ray tube.

Which of the above statement(s) is/are correct?

A 1 only **B** 2 only **C** 1 and 2 only **D** 1 and 3 only

27 In the lungs, there are tiny sacs of air known as alveoli. The average diameter of an alveolus is 0.250 mm. Consider an oxygen molecule of mass 5.30×10^{-26} kg that is trapped in an alveolus. What is the order of magnitude of the uncertainty in the velocity of this oxygen molecule?

A 10^{-5} m s^{-1}
B 10^{-8} m s^{-1}
C 10^{-10} m s^{-1}
D 10^{-12} m s^{-1}

28 The number of radioactive nuclides in two different samples *P* and *Q* are initially 4*N* and *N* respectively. If the half-life of *P* is *t* and that of *Q* is 2*t*, the number of radioactive nuclides in *P* will be the same as the number of radioactive nuclides in *Q* after a time of

A $t / 2$ **B** $2t$ **C** $4t$ **D** $8t$

29 A parent nucleus, initially at rest, decays into two particles of masses m_1 and m_2, moving away from each other in opposite directions. If the decay releases energy *E*, what is the kinetic energy of mass m_1?

A $\frac{m_1}{m_2}E$ **B** $\frac{m_2}{m_1}E$ **C** $\frac{m_2}{m_1 + m_2}E$ **D** $\frac{m_1}{m_1 + m_2}E$

30 Hydrogen bombs operate with tritium, a radioactive isotope of hydrogen with a half-life of 1.7×10^8 s. It has been proposed that if the production of tritium were halted, countries storing hydrogen bombs would have to replenish supplies from existing bombs. Eventually there would not be enough tritium to make any bombs.

A country has a stockpile of 2000 hydrogen bombs. What is the shortest duration that the world had to wait for the country to be unable to make a single bomb?

A 54 years **B** 59 years **C** 10 800 years **D** 1.7×10^9 years

END OF PAPER

Q1	C			Q16	D
Q2	B			Q17	B
Q3	D			Q18	A
Q4	B			Q19	B
Q5	B			Q20	D
Q6	C			Q21	D
Q7	B			Q22	A
Q8	B			Q23	B
Q9	D			Q24	D
Q10	C			Q25	C
Q11	B			Q26	C
Q12	C			Q27	A
Q13	B			Q28	C
Q14	C			Q29	C
Q15	A			Q30	B

H

NATIONAL JUNIOR COLLEGE
SENIOR HIGH 2 Preliminary Examination
Higher 2

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS **9749/02**
Paper 2 Structured Questions

23 August 2018
2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST
Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

Answers **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	**/ 10**
2	**/ 10**
3	**/ 10**
4	**/ 10**
5	**/ 9**
6	**/ 11**
7	**/ 20**
Total (80m)	

This document consists of 18 printed pages.

[Turn over

Data

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permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ Fm^{-1} = (1/(36\pi)) \times 10^{-9}\ F\ m^{-1}$
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the Avogadro constant	$N_A = 6.02 \times 10^{23}\ mol^{-1}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\ JK^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11}\ Nm^2kg^{-2}$
acceleration of free fall	$g = 9.81\ ms^{-2}$

Formulae

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work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = - GM/r$
temperature	$T/K = T/℃ + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ and $v = \pm\omega\sqrt{x_0{}^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \cdots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
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magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{ln2}{t_{\frac{1}{2}}}$

1 A disc moves on a smooth horizontal surface. Fig. 1.1 shows the top view of the disc moving from point P at $t = 0.0$ s with an initial velocity of 0.200 m s^{-1} in the north-east direction. From $t = 0.0$ s to $t = 10.0$ s, the disc has a constant acceleration of 0.100 m s^{-2} in the easterly direction.

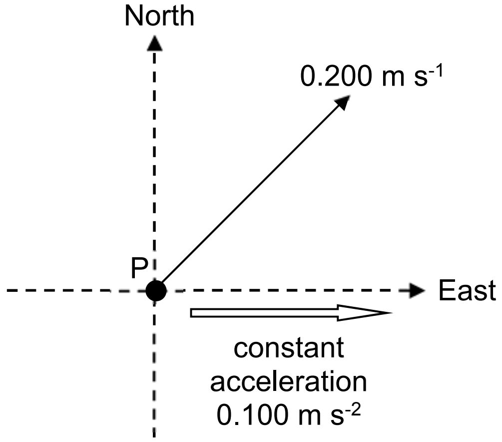


Fig. 1.1

(a) Determine the disc's velocity at t = 10.0 s.

speed = …………………. m s^{-1}

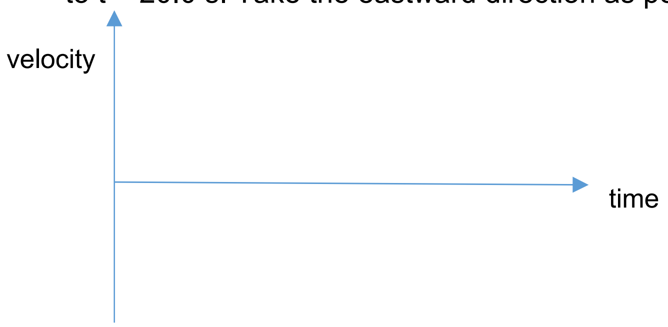
bearing = …………………. ° from north [3]

(b) Determine the distance of the disc from the point P at t = 10.0 s.

distance = ………………m [3]

(c) From $t = 10.0$ s to $t = 20.0$ s, the acceleration of the disc has a constant value of 0.100 m s^{-2} directed towards the west.

1. Sketch the velocity-time graph along the East-West direction between t = 10.0 to t = 20.0 s. Take the eastward direction as positive.



[2]

2. Sketch in Fig. 1.2 the path of the disc from t = 0.0 s to t = 20.0 s.

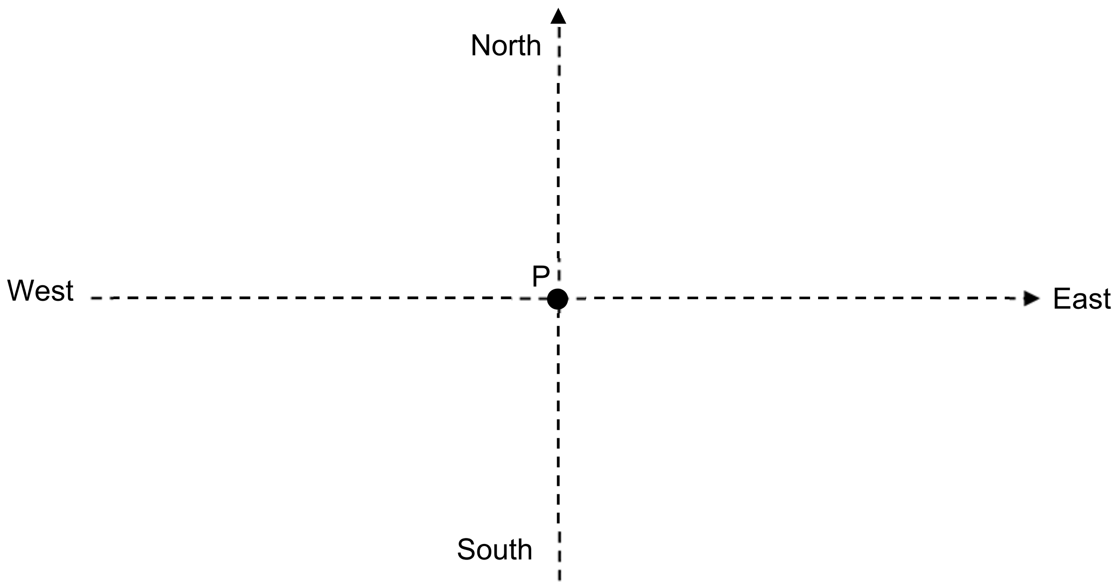


Fig. 1.2

[2]

[Turn over

2 **(a)** By reference to Newton's laws of motion, explain why when two particles, which are isolated, collide, the total momentum of the particles is conserved.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(b) A ferryboat of mass $M_1 = 7.0 \times 10^5$ kg moves toward a docking bumper of mass M_2 that is attached to a shock absorber, as shown in Fig. 2.1.

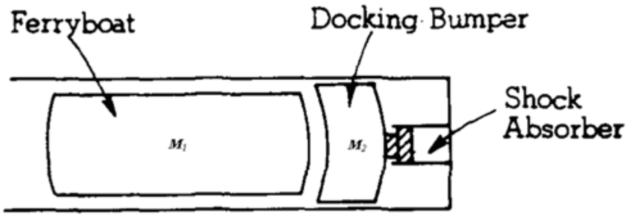


Fig. 2.1

Just before hitting the bumper, the ferryboat is travelling at a speed v = 3.0 m s^{-1}. After colliding inelastically with the bumper, the ferryboat and bumper move together with an initial speed of 2.0 m s^{-1}. The ferryboat comes to a complete stop 4.0 s after the collision. Fig. 2.2 shows the variation with time t of the velocity v of the ferryboat, where t = 0 s is the instant of collision.

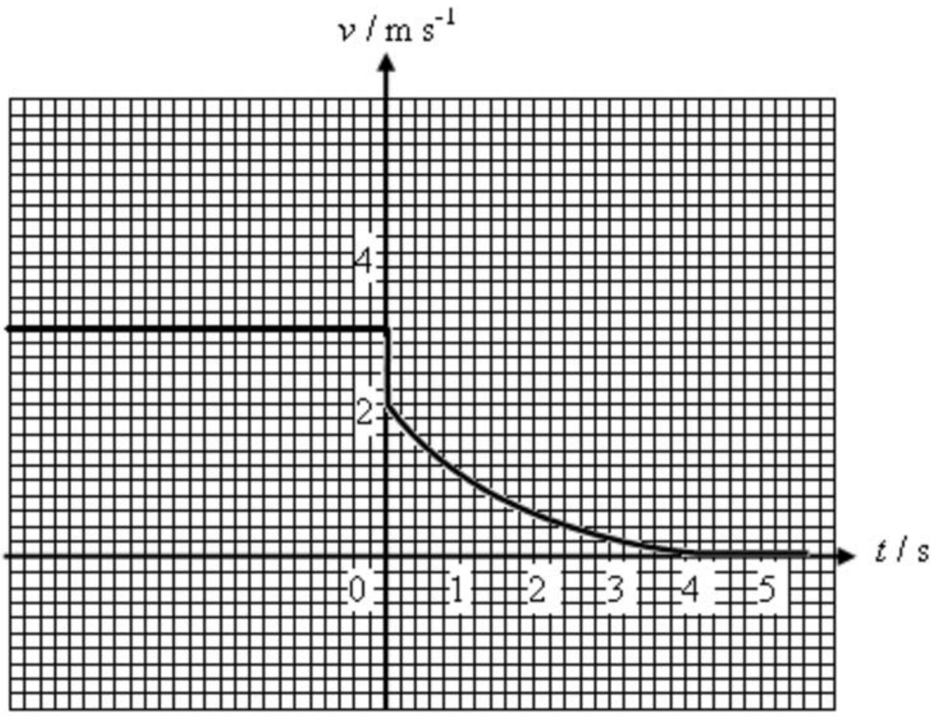


Fig. 2.2

(b) **(i)** Explain what is meant by *an inelastic collision*.

……………………………………………………………………………………………………

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

(ii) Calculate the mass of the bumper M_2. State an important assumption that you have made in the calculation.

mass = …………………. kg [2]

(iii) Use the graph to determine the acceleration of the ferryboat at t = 1.0 s. Show your working on the graph clearly. State the direction of the acceleration.

acceleration = …………………. m s^{-2}

direction = …………………. [3]

(iv) Hence calculate the retarding force on the ferryboat at t = 1.0 s.

force = …………………. N [1]

[Turn over

3 A boy fills a flask with fluid and places it on a mass balance. The boy records the reading on the mass balance x in grams. He inserts two similar cubes, one on top of the other, into the flask as shown in Fig. 3.1.

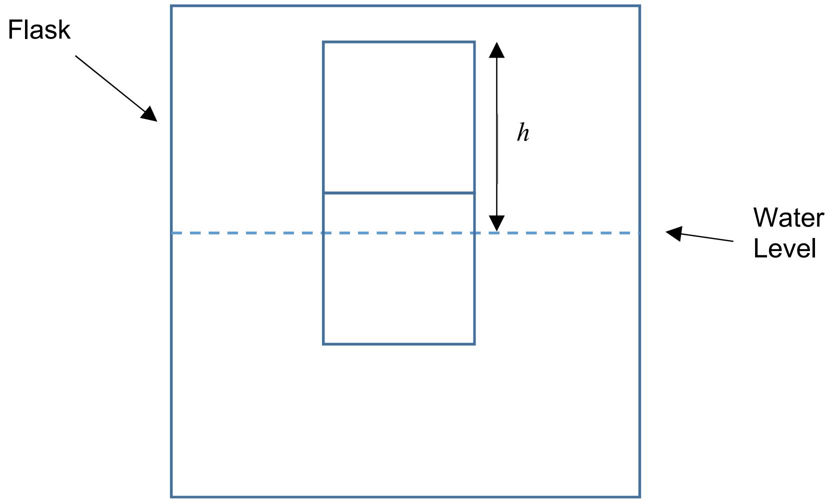


Fig. 3.1

Each side of the cube is r in cm. Both cubes stay afloat with one cube being partially immersed. After some time, the boy records that height of the two cubes above the fluid surface is h in cm while the reading on the mass balance is now y in grams.

(a) Express the density of the fluid in terms of x, y, r and h in g cm^{-3}.

[2]

(b) The cube on top is removed. Suggest and explain the subsequent motion of the cube in the fluid.

....

....

....

....

....

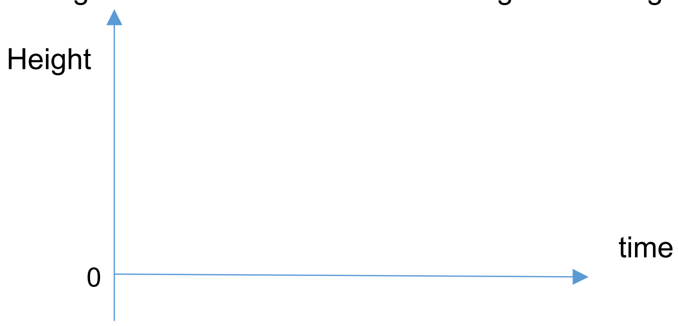
....

....

....[4]

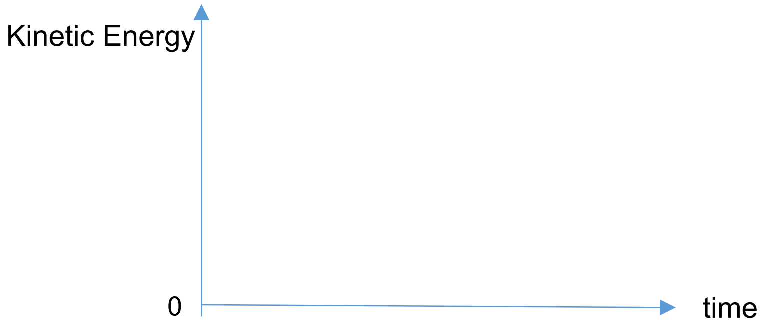
3(c) Given the values of r = 2.00 cm and h = 3.30 cm, sketch, without numerical values, the following graphs for the cube that remains in the fluid. Note that the bottom cube has a height of 1.30 cm above the fluid surface before the top cube is removed.

(i) Height of cube above fluid surface against time graph,



[2]

(ii) Kinetic Energy against time graph.



[2]

4 (a) The *I-V* characteristics of resistor **R** and resistor **X** are investigated. The results obtained are shown in Fig. 4.1.

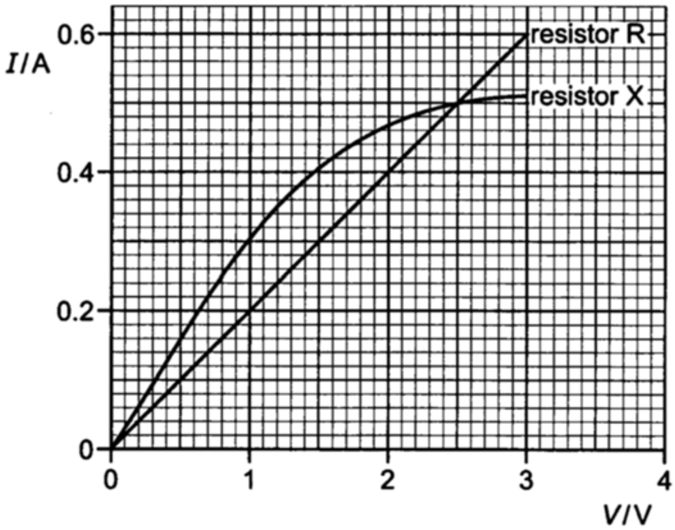


Fig. 4.1

(i) Student 1 sets up the circuit with resistors R and X in series across an unknown e.m.f. source with negligible internal resistance as shown in Fig. 4.2.

Fig. 4.2

Determine the value of the unknown e.m.f. source if the current through resistor X is 0.22 A.

Value of unknown e.m.f. source = …………….. V [2]

(ii) Student 2 sets up the circuit using a variable resistor, resistors R and X as shown in Fig. 4.3 using the same e.m.f. source.

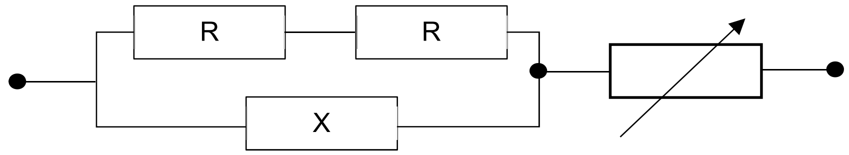


Fig. 4.3

Determine the resistance of the variable resistor given that the ratio of

$$\frac{\text{resistance of X}}{\text{resistance of R}} = 0.80$$

Resistance = ……………….Ω [3]

(iii) Student 2 modifies his circuit by adding an ideal ammeter and a voltmeter as shown in Fig. 4.4.

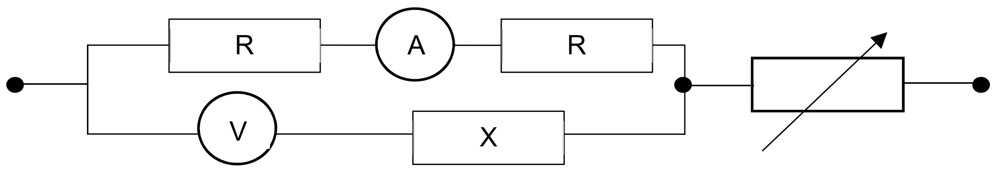


Fig. 4.4

Explain if this circuit is appropriate for determining the graphs over the range of V and I as shown in Fig. 4.1.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

4(b) A student uses the equation $I = Anvq$ to determine the drift velocity of the electrons, v, in the wire.
State, with a reason, whether this is the maximum velocity of the free electrons in the wire.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

5 **(a)** This question is about an americium-241 radionuclide source used in a smoke detector.

A smoke detector works by detecting a decrease in the arrival of alpha particles from the americium when they are absorbed by the smoke. It is advised that the smoke detector be replaced after five years.

Here are some data about the source:
activity of source = 3.3×10^4 Bq
decay constant = 4.8×10^{-11} s^{-1}

(i) Radioactive decay is *random* in nature. State what is meant by the word *random* in this context.

……………………………………………………………………………………………

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

(ii) Use the equation $\Delta N = -\lambda N \Delta t$ with N taken as the original number of nuclei to show that about 5×10^{12} nuclei decay in the five years of use.

[2]

(iii) Explain why it is reasonable to use the equation $\Delta N = -\lambda N \Delta t$ (as above) to estimate the number of nuclei decaying over a five year period, but not over a few hundred years.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(iv) A decrease in activity of the sample is not likely to be the reason that the smoke detector should be replaced after five years. Suggest a more likely reason that the detector might need replacing.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(b) Strontium-90 is a radioactive waste product of nuclear power stations. Strontium-90 emits beta particles of energy up to 0.54 MeV. Should any of this isotope get into our food, it would be quickly absorbed into bones and teeth.
Explain why these beta particles are more of a risk to humans than gamma photons of the same energy.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

6 **(a)** A dust particle is suspended in the air between two parallel plates with the direction of electric field shown in Fig. 6.1. The electric field strength between the two parallel plate is 3.0×10^3 Vm^{-1}. The particle has charges of $+1.4 \times 10^{-15}$ C and -1.4×10^{-15} C near its ends. The charges may be considered to be static point charges separated by a distance of 3.0 mm, as shown in Fig. 6.1.

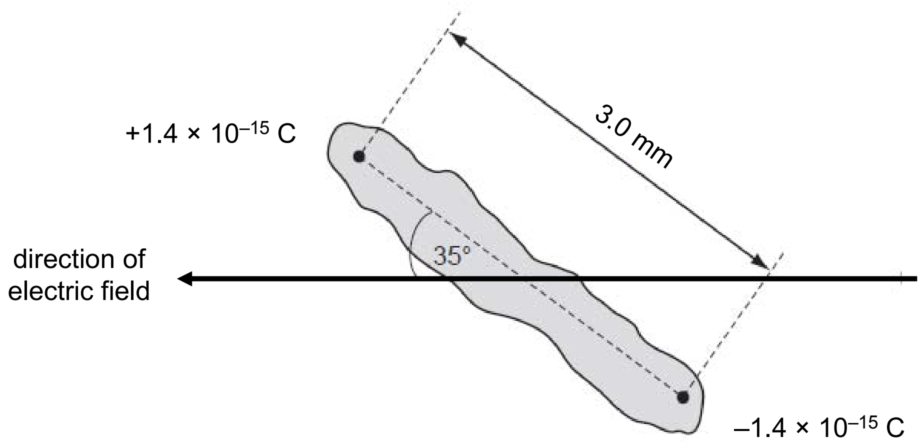


Fig. 6.1

The particle makes an angle of 35° with the direction of the electric field.

(i) Calculate the magnitude of the force on each charge due to the electric field.

force =…………………….. N [1]

(ii) Describe and explain the subsequent motion of the particle in the electric field.

……………………………………………………………………………………

……………………………………………………………………………………..

……………………………………………………………………………………

……………………………………………………………………………………

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

6 (b) Fig. 6.2 and Fig 6.3 show the electric field pattern near two point charges respectively.

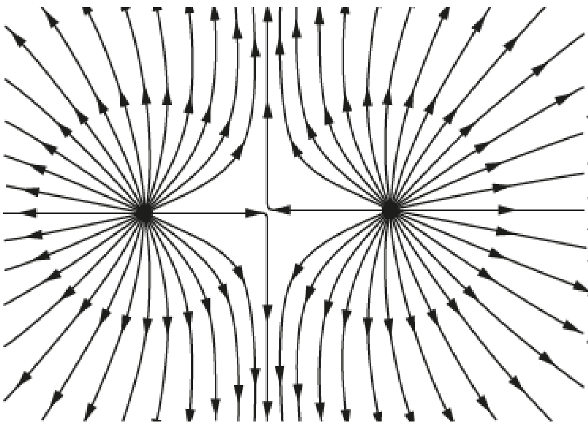


Fig. 6.2

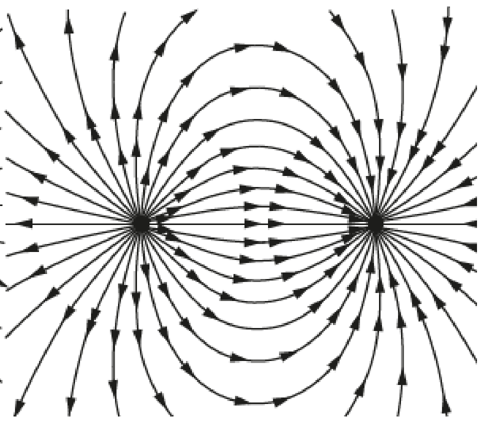


Fig. 6.3

(i) On the appropriate figure(s) mark the point(s)

1. with zero electric field and label it with the letter "N"

2. with zero electric potential and label it with the letter "E" [1]

(ii) On Fig. 6.2, draw **three** complete equipotential lines.

[2]

6 **(c)** Fig. 6.4 shows the electrical potential *V* and the magnitude of the electric field *E* against distance *R* for an isolated – 1.0 C charge.

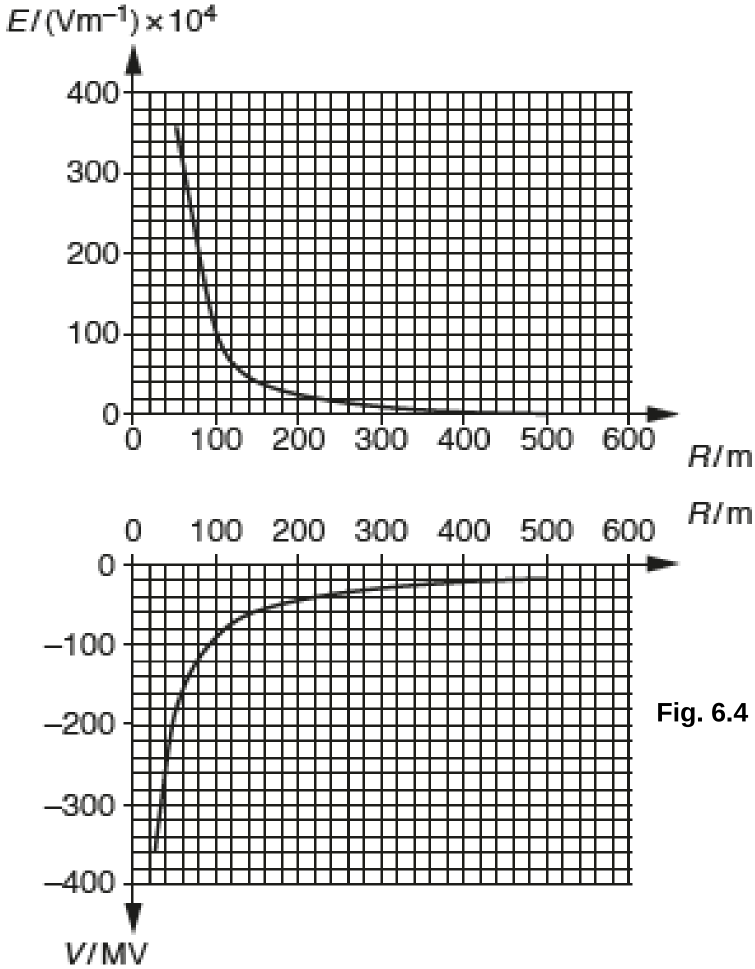


Fig. 6.4

Use Fig. 6.4 to explain the relationship between the electric field strength and the electric potential. (You may annotate on the figure and make clear reference to these annotations to support your answer.)

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

7 (a) In 1913, Niels Bohr combined Planck's quantum theory, Einstein's concept of the photon, Rutherford's planetary model of the atom and Newtonian mechanics to derive a new model for the hydrogen atom. Several postulates were put forth.

Postulate 1. The electron moves in circular orbit, with radius r, around the proton due to the electric force of attraction, as shown in Fig. 7.1. In his model, the proton was considered to be stationary because its mass was very large compared to that of the electron.

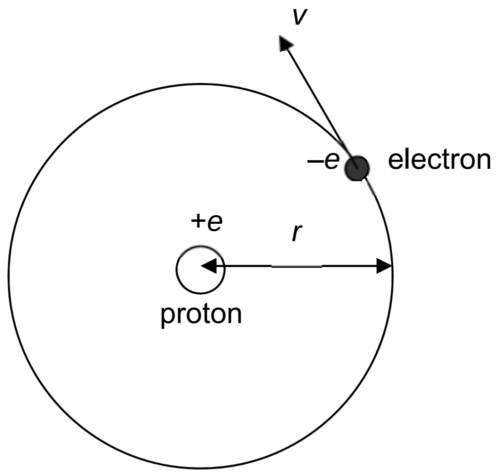


Fig. 7.1

Postulate 2. The angular momentum of the electron was quantised and this led to the hydrogen atom having allowable energies given by

$$E_n = -\frac{13.6}{n^2}$$ …… equation (1)

where n = 1, 2, 3, …

Postulate 3. The atom emits radiation or photon when the electron made a transition from a higher energy to a lower-energy orbit. The frequency f of the photon emitted is related to the change in the energy of the atom rather than the orbital motion of the electron.

(i) With reference to postulate 3, write a word equation relating the change in the energy of the atom and the energy of the photon emitted.

.... [1]

(ii) Hence, with reference to postulate 3, explain the characteristic emission spectrum of hydrogen atoms.

....

....

....[2]

(iii) By considering matter waves in the orbital motion of the electron, the radii of the orbits were found to be quantized. The smallest radius is 5.29×10^{-11} m.

1. By considering the forces acting on an electron, show that the momentum p of the electron in an orbit of radius r is given by

$$p = \sqrt{\frac{me^2}{4\pi\varepsilon_o r}}$$

where m is the mass of the electron.

[3]

2. Hence, determine the wavelength of the electron when $r = 5.29 \times 10^{-11}$ m.

wavelength = ……………….m [2]

(iv) Explain why this model of the hydrogen atom, where the electron orbits in a circular path with a fixed radius, will violate the Heisenberg uncertainty principle.

……………………………………………………………………………………………

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

(b) When high-energy electrons or any other charged particles bombard a metal target, x-rays are emitted.
The origin of the characteristic x-rays is due to the removal of the inner-shell electron from the atom by the bombarding electrons that have sufficient energies. The vacancy that is created in the inner shell is filled when an electron that is at a higher energy level in the atom transits into the energy level containing the vacancy. Fig. 7.2 shows the shells (*K*, *L*, *M*, *N* and *O*) present in the atom and how the characteristic x-rays, K-lines and other peaks, are obtained.

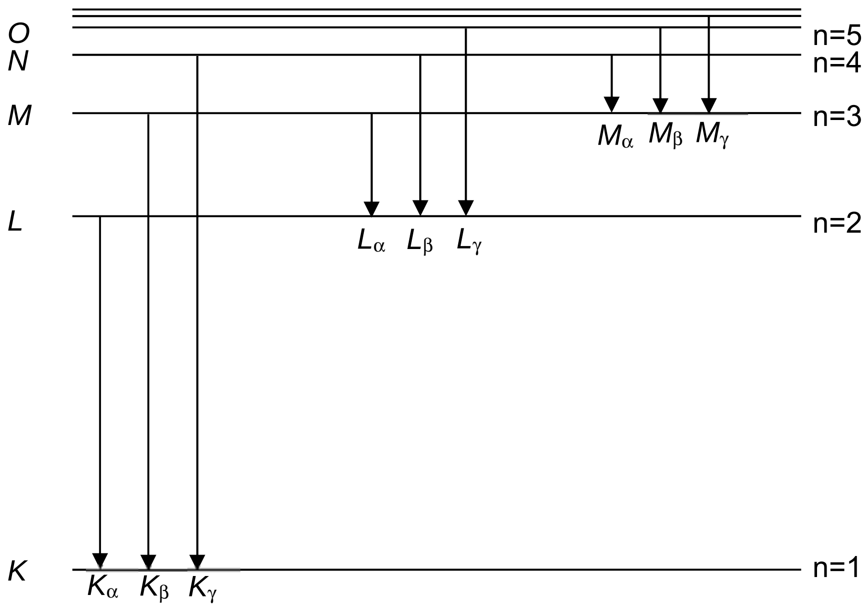


Fig. 7.2

Equation (1) in part **(a)** may be modified to describe the energy for the *L*-shell. Due to the presence of one *K*-shell electron, the other electron in *L*-shell will 'see' an effective nuclear charge of approximately (Z – 1)e, where e is the elementary charge and Z is the atomic number of the element.
As such equation (1) in part **(a)** can be approximated as

$$E_n = -\frac{(13.6\ eV)(Z-1)^2}{n^2}$$

(i) For an electron that makes a transition from the *L* shell (with n = 2) to the *K* shell (with n = 1), derive the relationship between the frequency f of the radiation and Z.

[3]

(ii) It is thought that the wavelength λ of K_α x-ray radiation, varies with atomic number of element *Z* according to the expression below as suggested by Mosley in 1914.

$$\sqrt{\frac{1}{\lambda}} = A(Z - B) \text{ where } A \text{ and } B \text{ are constants}$$

The frequency *f* of K_α x-ray radiation, of a few elements are given in Fig. 7.3.

Element	Atomic number Z	Frequency f / 10^{18} Hz	$\sqrt{\frac{1}{\lambda}}$ / 10^4 m$^{-1/2}$
Titanium	22	1.08	6.01
Chromium	24	1.30	6.59
Iron	26	1.54	7.16
Nickel	28	1.79	
Zinc	30	2.07	8.30
Gallium	31	2.21	8.59

Fig. 7.3

Complete Fig. 7.3 for Nickel. [1]

(iii) The data from Fig. 7.3 are used to plot the graph of Fig. 7.4.

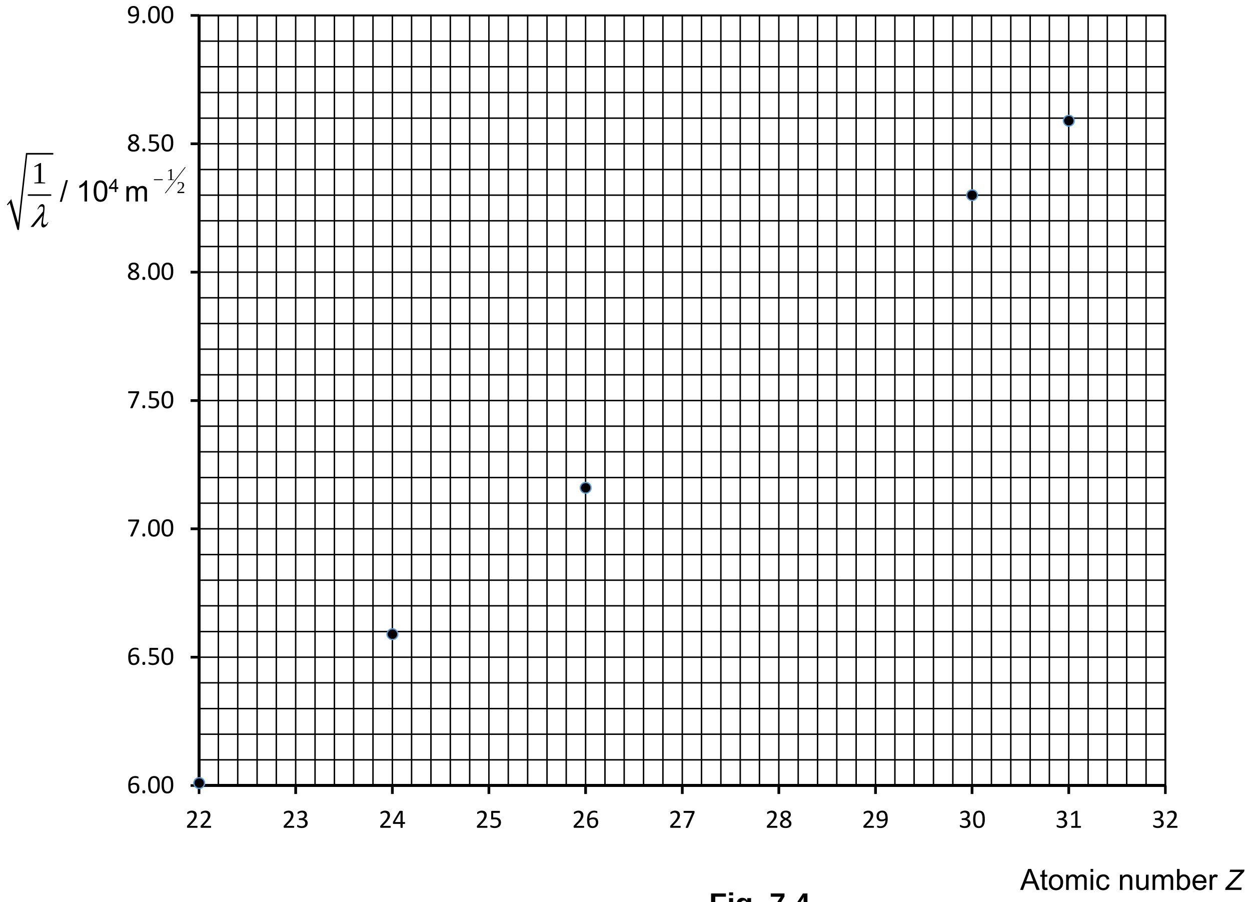


Fig. 7.4

On Fig. 7.4,

1 Plot the point corresponding to Nickel. [1]

2 Draw the best-fit line for all the points. [1]

(iii) Use the line drawn in **Fig. 7.4** to determine the magnitude of the constants *A* and *B* in the expression in **b(ii)**.

A = ………………..m$^{-1/2}$

B = …………………[3]

(c) One of the possible use for characteristic spectrum is to allow impurity in specimens to be detected by scientists. A cobalt target is bombarded with electrons, and the wavelengths of its characteristic x-ray spectrum are measured. There is also a second fainter characteristic spectrum, which is due to an impurity in the cobalt. The wavelengths of the K_α lines are 178.9 pm (cobalt) and 143.5 pm (impurity), and the atomic number *Z* for cobalt is 27.

Using Fig. 7.3, deduce the impurity in the cobalt.

[2]

END OF PAPER

2018 H2 Physics Prelim P2 Suggested Solution

1(a) at t = 10.0 s,

its velocity towards East $v_E = 0.141 + (0.100)(10) = 1.14\ m\ s^{-1}$

its velocity towards North = 0.141 m s^{-1}

its resultant velocity $v_R = \sqrt{(1.14)^2 + (0.141)^2} = 1.15\ m\ s^{-1}$

at $\theta = \tan^{-1}(1.14/0.141) = 82.9^o$

(b) displacement towards East,

$x = 0.200 \cos 45^o (10.0) + \frac{1}{2}(0.100)(10.0)^2 = 6.41\ m$

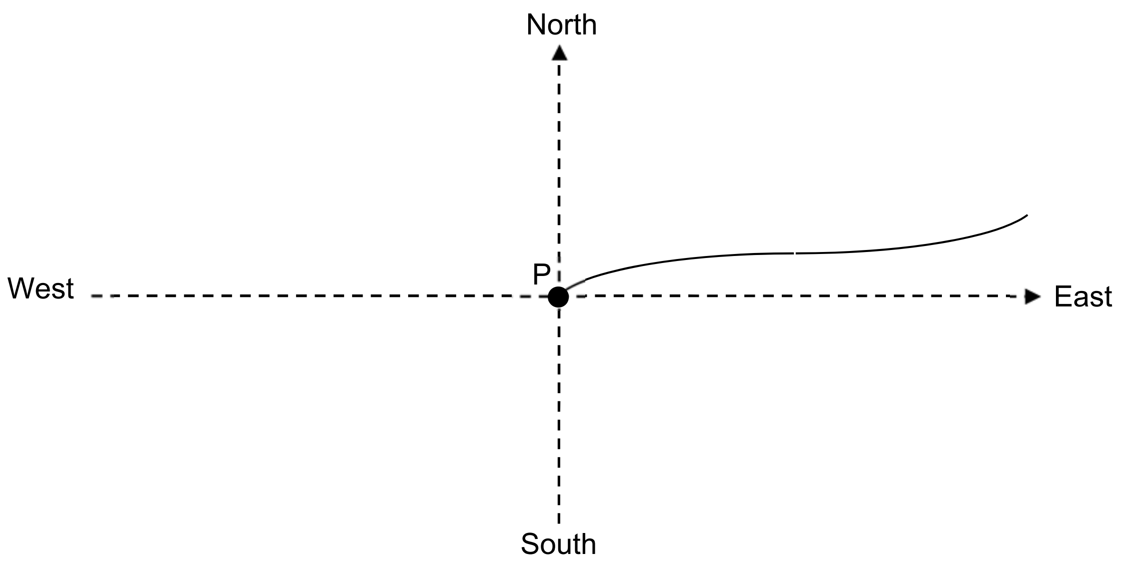
displacement towards North,

$y = 0.200 \sin 45^o (10.0) = 1.41 m$

Distance from point P , $r = \sqrt{(6.14)^2 + (1.41)^2} = 6.57 m$

(c) Straight-line with negative gradient. Non-zero ending.

(d)



2. (a) Taking the two particles as A and B, according to **Newton's 3rd law**, when the two particles collide, the force that A exerts on B is equal in magnitude but opposite in direction to the force that B exerts on A.

According to **Newton's 2nd law**, the net/resultant force on a particle is proportional to the rate of change of its momentum.

Since the **time of contact for A and B is equal**, the change in momentum of A is exactly equal in magnitude, and opposite in sign/direction, to the change in momentum of B.

Hence the total momentum is conserved.

(b) (i) **Total kinetic energy** of the **system** is not conserved in the collision. [1]

(ii) By the principle of conservation of momentum,

$M_1 u = (M_1+M_2) v$

$(7.0 \times 10^5)(3.0) = (7.0 \times 10^5 + M_2)(2.0)$

$M_2 = 3.5 \times 10^5$ kg.

(iii) Drawing of a suitable tangent at t = 1.0 s and showing of relevant working. (Tangent triangle should be as large as possible and coordinates read to half a small square).

Magnitude of acceleration = 0.65 m s^{-2}
Direction: left

(iv) Magnitude of retarding force = $7.0 \times 10^5 \times 0.65 = 4.6 \times 10^5$ N

3

(a) Since the system is in equilibrium, net force = 0

Upthrust on cube = Weight of two cubes

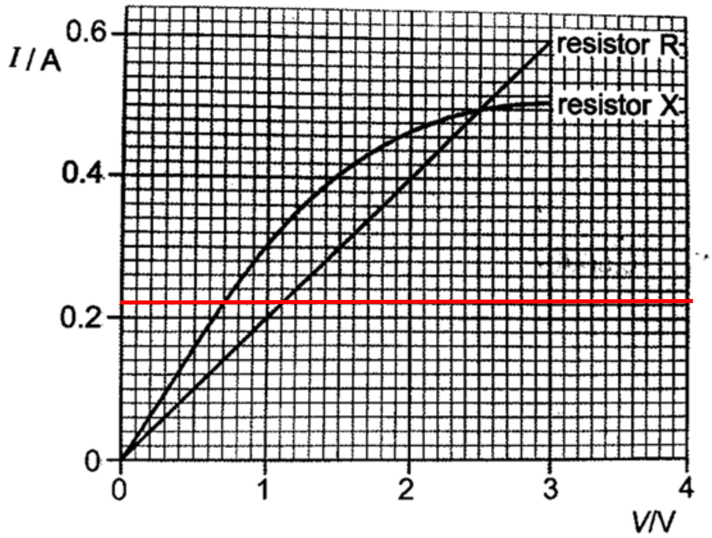
$$\rho_{fluid} r^2(2r-h)g = (y-x)g$$
$$\rho_{fluid} = \frac{(y-x)}{r^2(2r-h)}$$

(b) - The cube that remains in the fluid is at rest at the point when the top cube is removed. Since the upthrust at that instant is larger than the weight of the cube, the net force is upwards so the velocity starts to increase in the upward direction.
- As the cube moves upwards, the upthrust decreases till it is the same magnitude as the weight of the cube at equilibrium position where the magnitude of the velocity is maximum.
- The upthrust decreases further resulting in the net force being downwards as it moves further up. This results in the velocity decreasing as it reaches its highest position where the velocity comes to zero.
- This shows that the cube that remains in the fluid is in oscillating motion.

(c) (i) Height starts from lowest point (1.30 cm) to highest point (2.00 cm) with equilibrium position at 1.65 cm. Height at t=0 is 1.30 cm and increasing. Reaches 2.00 cm after half a period.
Sinusoidal
Label period and starts from lowest point

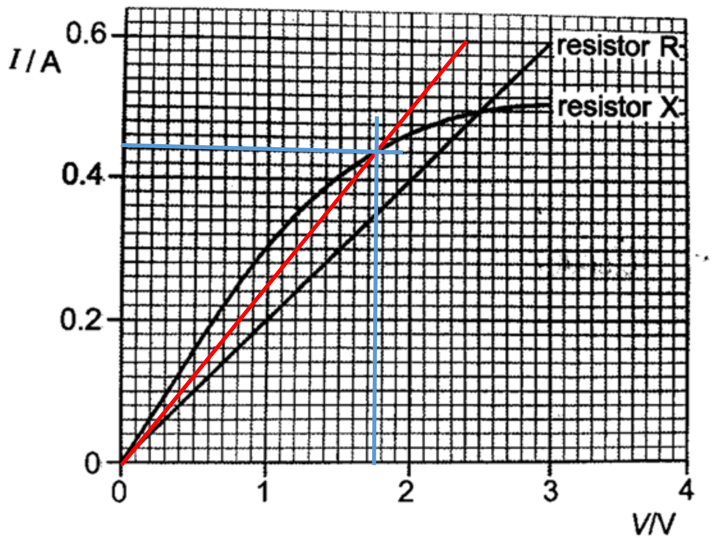
(ii) Kinetic energy graph is sinusoidal. 2 cycles shown within a period.KE is 0 at 0, T/2 and T. KE is max at T/4 and 3T/4.
Sinusoidal
2 maxima within one period and starts from zero

4(a)(i)



At I = 0.22 A, pd across X = 0.7 V while pd across R = 1.1 V.
Emf = 2*(1.1) + 0.7 = 2.9 V

4(a)(ii)
Resistance of R = 3/0.6 = 5 Ω
Resistance of X = 0.8(5) = 4 Ω



From graph, V_x = 1.75 V and I_x = 0.44A
Method 1:
Since parallel circuit, $I_R = V_x/10$ = 0.175 A
Effective resistance = 1.75/ (0.44 + 0.175) = 2.846 Ω

OR
Method 2
Effective resistance = 1/(1/4+1/10) = 2.857Ω

Applying potential divider rule, Vx/VT = Reff/RT
RT = Reff*VT/Vx = 2.857 *(2.9/1.75) = 4.734Ω
Variable resistance = RT – Reff = 4.734 – 2.857 = 1.9 Ω
(Range of 1.75-1.95 was allowed. Also ECF from previous part)

4(a)(iii)
Assuming voltmeter and ammeter are ideal, voltmeter has infinite resistance so no current will pass through resistor X. Hence, voltmeter will give a reading of the potential difference across 2 resistors R while the ammeter will show the reading of the current through R. Hence the graph for resistor X cannot be obtained.
However not the entire graph for resistor R as shown in Fig. 4.1 can be obtained since the potential difference across R can never be zero by potential divider rule.
Also since the voltmeter is placed across two identical resistors R, when the variable resistor is zero the maximum value for the potential difference across one resistor R can only be half of the value of the emf source which is 1.45 V. Hence the graph for resistor R from 1.45 V to 3V cannot be obtained.

4(b)
The drift velocity is an average not a maximum.
Since the derivation I = nevA is based on average current = total charge/total time. (Any indication that the electrons have a range of speeds/velocities

5ai Random means it is impossible to state exactly which nucleus or when a particular nucleus will disintegrate, but only the probability of decay in unit time interval for a particular radioactive isotope. [B1]

aii $\Delta N = -\lambda N \Delta t = 4.8 \times 10^{-11} \times 6.9 \times 10^{14} \times (5 \times 3.2 \times 10^{7})$
$= 5.2 \times 10^{12}$

aiii As the half life of americium is 458 years, N will not change much(remain constant) over 5 year period. N/t will remains constant over 5 years, thus this equation can be used.

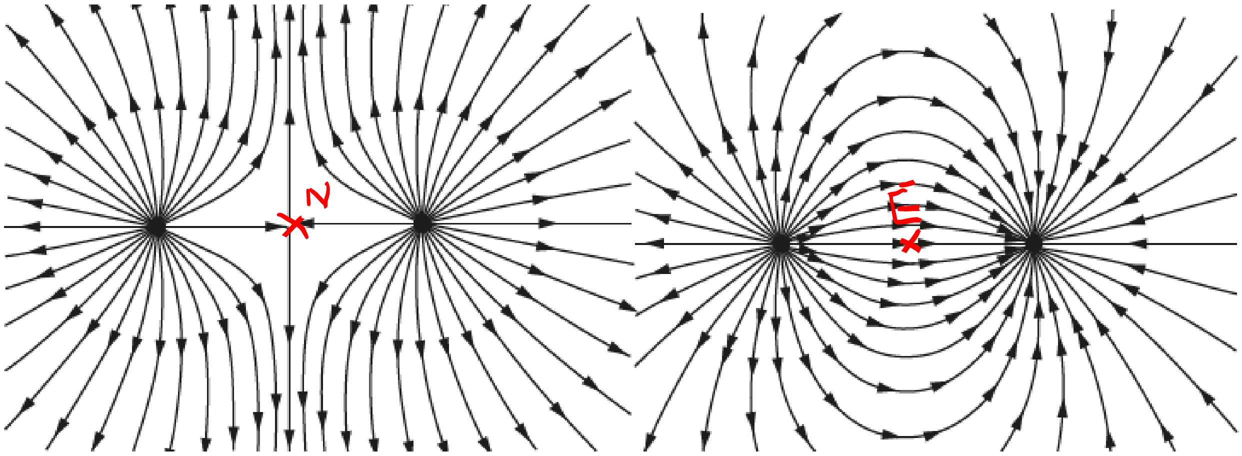
OR
As the half life of americium is 458 years, over a few hundred years, N will decreases significant. Since activity depends on number of nuclei present, N/t will also change significantly over a few hundred years. Thus this equation cant be used.

aiv
Over the five years, dust and other particles might have build up on the surface of the detector. This will affect the detector's ability to detect the incoming alpha particles which will trigger a false alarm. Thus a replacement must be done.
OR
Alpha particles has strong ionising power. Over the 5 years, the electronic component in the detector will be affected by this high ionising power, leading to electronic failure inside the detector. Thus a replacement must be done.

b
Beta particles have lower penetration (have a shorter range or less likely to escape from the body)/ are more highly ionising than gamma photons.
The body or cells will have a larger (absorbed) dose of beta particles which will increase the risk of Cancer (or higher of mutation of cells)
ACCEPT reverse argument for gamma photons

6(a)(i) Force = qE = $1.4 \times 10^{-15} (3.0 \times 10^{3}) = 4.2 \times 10^{-12}$ N
(ii)
A couple acts on the particle since two parallel forces of equal magnitude but in opposite directions acts on the particle, i.e positive charge experience a force to the left and the negative charge experience a force to the right.
The torque of the couple causes the particle to <u>rotates</u> anti-<u>clockwise</u> to align with the field.OR
The torque of the couple causes the particle <u>oscillates about a position</u> with the <u>positive charge in the direction of electric field.</u>

(b)(i)



(ii)

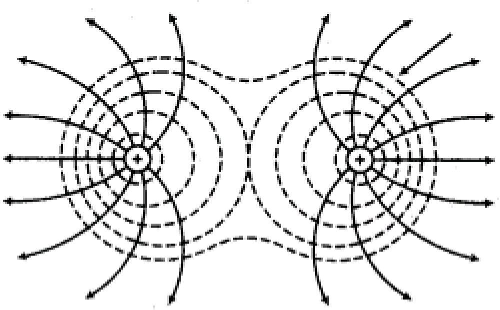
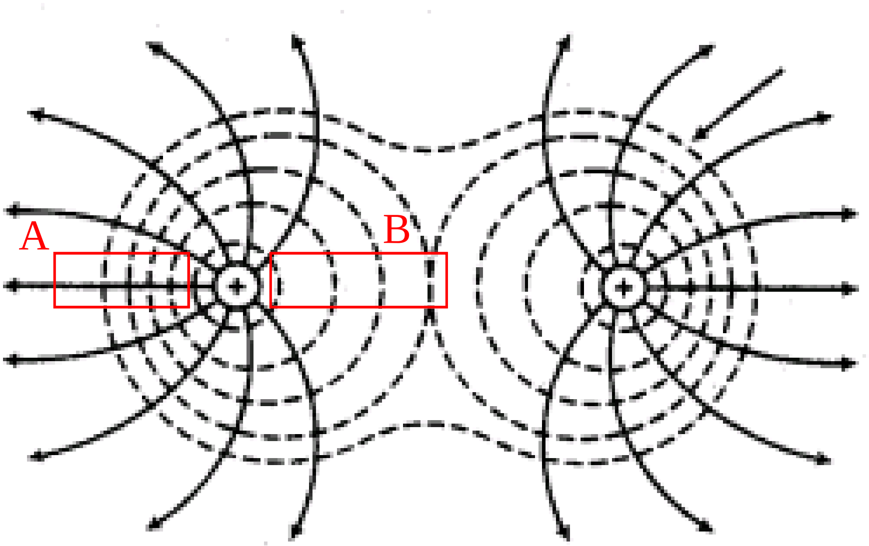


Fig 6.2: Dotted lines represent the equipotential lines.

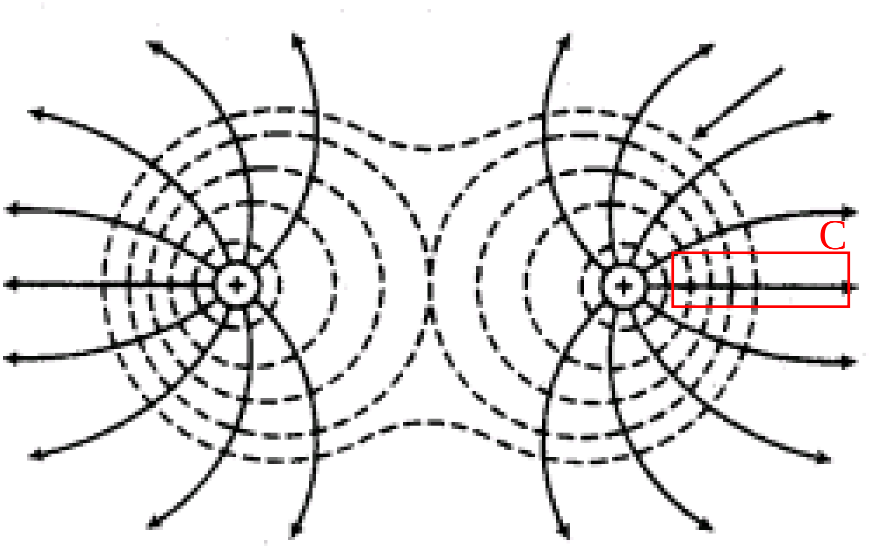
- 3 equipotential(labelled) of roughly correct shape (lines must be perpendicularly to the field lines)
- Spacing between each line is difference.

Case 1: 3 circles drawn on the same charge
See red rectangles A and B to check for spacing between each line. In rectangle A, spacing between each lines < spacing between each lines in rectangle B.



Case 2: 1 circle drawn on the same charge with 2 complete lines drawn surrounding both charges. Or
Case 3: 2 circles drawn on the same charge and 1 complete line drawn surrounding both charges. Or

See red rectangle C to check for spacing between each line. In rectangle C, spacing between each lines get wider.



6(c) Student's answer must include the following 4 points:

1) Area under E(R) electric field strength graph

- Area under E(R) field graph between 2 points gives the change in potential between the 2 points.

From E(R) graph, change in potential can be calculated using = 1 x 15sq (4 x 10^6 J per square)

= 60 MJ

From V-R graph, change in potential is from -90 MV to -30 MV.

2) Gradient of V(R) potential graph

- Electric field strength E is the negative potential gradient (OR negative gradient of V(R)) i.e $E = -dV/dR$ (MUST write in words)
- From the V-R graph, draw 1 tangent at R = 100 m. gradient (MUST show working).

Gradient = magnitude of the E-field strength = 100×10^{-4} Vm^{-1}

From E-R, ar R = 100m, the magnitude E-field strength is 100×10^{-4} Vm^{-1}

7

ai Energy of higher level – Energy of lower level = energy of photon emitted (or product of planck's constant and frequency of photon) .

aii The energy level (or orbit) of hydrogen are discrete. The energy of photon emitted is the energy difference between the two energy level which is distinct. (or a unique value). Hence, the emission line spectrum comprise of discrete lines.

7a iii 1 Electrostatic force provides the centripetal force

$$F_E = F_C$$
$$\frac{e^2}{4\pi\varepsilon_o r^2} = \frac{mv^2}{r}$$
$$\frac{me^2}{4\pi\varepsilon_o r} = m^2v^2$$
$$p = \sqrt{\frac{me^2}{4\pi\varepsilon_o r}}$$

2 P = 1.99 x 10^{-24} kg m s^{-1}, wavelength = 33 x 10^{-11} m

iv If momentum of electron in radial direction is fixed, then its uncertainty is zero. Using $\Delta\times\Delta p \geq \frac{h}{4\pi}$, $\Delta\times$ would be infinite. However the above model has a fixed radius.

bi)

$$\Delta E = E_1 - E_2$$
$$= \frac{-(13.60)(Z-1)^2}{1^2} - \frac{-(13.60)(Z-1)^2}{2^2}$$
$$= -(10.2)(Z-1)^2\, eV$$
$$f = \frac{E_2 - E_1}{h}$$
$$= \frac{(10.2\times1.6\times10^{-19})(Z-1)^2}{(6.63\times10^{-34})}$$
$$= (2.46\times10^{15})(Z-1)^2$$

(b)(ii) 7.72

(ii)1. Plot point at coordinates (28, 7.72) to half smallest square

2. Points evenly scattered on both sides of line

(iii) Knowing *A* = gradient

Correct value of *A* (= 0.286 x 10^4)

-AB = vertical intercept = -0.281 x 10^4

Correct value of *B* (= 0.98)

(c) Calculate

$\sqrt{\frac{1}{\lambda_\times}}$ To get the impurity as Zinc.

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATIONS

Higher 2

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS

9749/03

Paper 3 Longer Structured Questions **(Section A)**

28 Aug 2018
2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST
Write your subject class, registration number and name on all the work you hand in.
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.

Section A
Answers **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	**/ 10**
2	**/ 10**
3	**/ 10**
4	**/ 10**
5	**/ 10**
6	**/ 10**
Total	**/ 60**

This document consists of 14 printed pages.

[Turn over

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1} = $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho g h$
gravitational potential	$\phi = - GM/r$
temperature	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ and $v = \pm\omega\sqrt{x_0{}^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \cdots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{ln2}{t_{\frac{1}{2}}}$

Section A (60 marks)

1 **(a)** Distinguish between *gravitational potential energy* and *elastic potential energy*.

…………………………………………………………………………………………………

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

(b) A child's pogo stick comprises of a spring with spring constant of 1.50×10^4 N m^{-1}. The combined mass of the child and pogo stick is 25.0 kg.

Fig. 1.1 shows the various instances of a child jumping vertically on the pogo stick.

At instance **A**, the spring compression is a maximum and the child is momentarily at rest. The foot rest is 0.200 m below the reference level.

At instance **B**, the spring is relaxed and the child is moving upward.

At instance **C**, the child is again momentarily at rest and at the top of the jump.

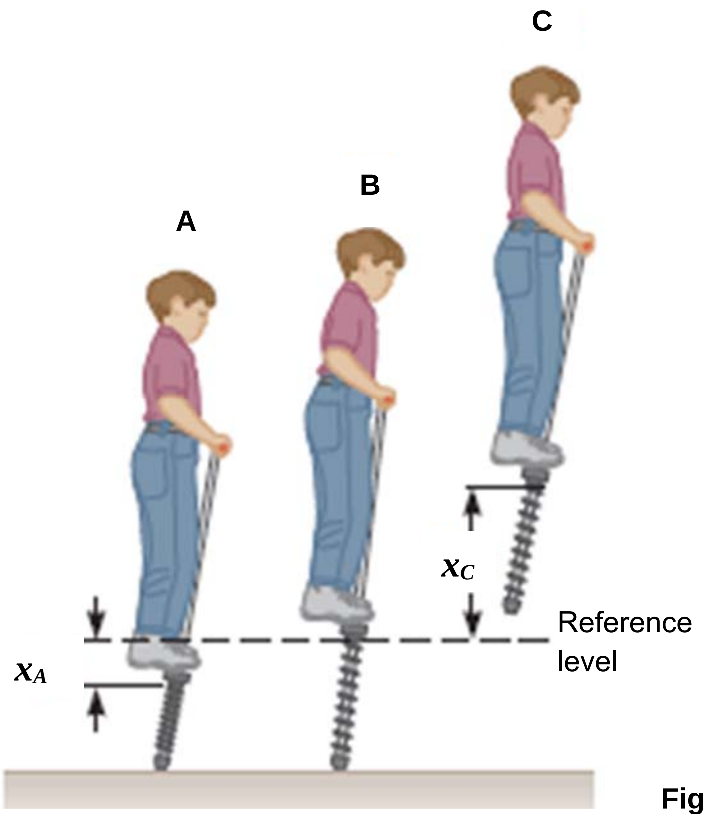


Fig. 1.1

(i) State the energy changes from instance A to C. Numerical values are not required.

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

[Turn over

(b) (ii) Determine the value for $\boldsymbol{x_C}$.

$\boldsymbol{x_C}$. =……………………m [2]

(iii) Determine the maximum speed of the child.

maximum speed = ……………….. m s^{-1} [3]

(iv) State and explain the position of the footrest, with respect to the reference level, when maximum speed is attained.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………[1]

2 An executive toy consists of five identical steel spheres of mass m suspended so that they are free to move in a vertical plane as shown in Fig. 2.1. Each sphere is suspended using thin inextensible strings of negligible mass.

You may assume that collisions between the spheres are perfectly elastic and air resistance is negligible

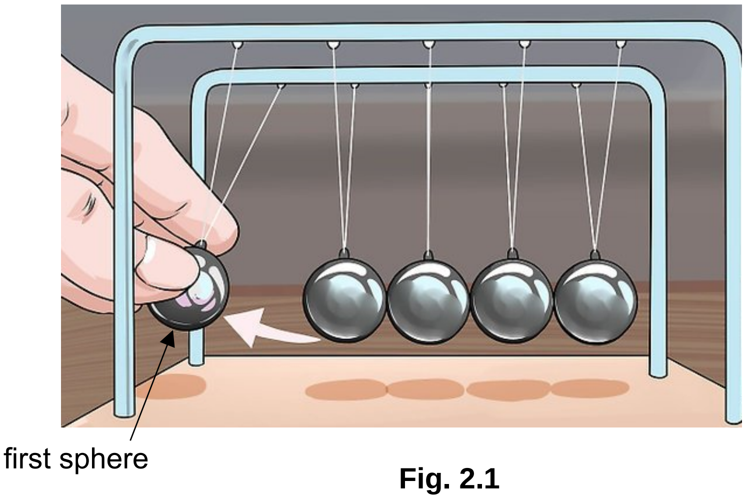

Fig. 2.1

(a) The first sphere is displaced to the left and then released. Describe and explain the resulting motion of the five spheres.

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

(b) **(i)** Object **A** has a velocity of u and moves horizontally towards Object **B** which is at rest. The collision between both objects is head-on and perfectly elastic.
The ratio of the mass of Object **A** to the mass of Object **B** is **1:2**.
Determine the ratio of the **final** velocity of Object **B** to the initial velocity of Object **A**.

ratio = …………………..[2]

[Turn over

(b) **(ii)** Object **C** has a velocity of u and moves horizontally towards Object **D** which is at rest. The collision between both objects is head-on and perfectly elastic.
The ratio of the mass of Object **C** to the mass of Object **D** is **2:1**.
Determine the ratio of the final velocity of Object **D** to the initial velocity of Object **C**.

ratio = ……………………[1]

(iii) Hence, if the **second and fourth spheres are replaced with steel spheres of mass 2*m*** of the executive toy in Fig. 2.1, determine the ratio of

$$\frac{\text{Maximum vertical displacement of the first sphere}}{\text{Maximum vertical displacement of the last sphere}}$$

Assume that the collision between both objects is head-on and perfectly elastic.

ratio = ……………………[2]

(c) The five identical steel spheres in Fig. 2.1 are of mass m.

State and explain one significant difference to the motion observed if all the thin inextensible strings are replaced by springs of negligible mass.

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

3 **(a)** Fig. 3.1 shows a circuit containing three identical lamps A, B and C. It also contains three switches, S_1, S_2 and S_3.

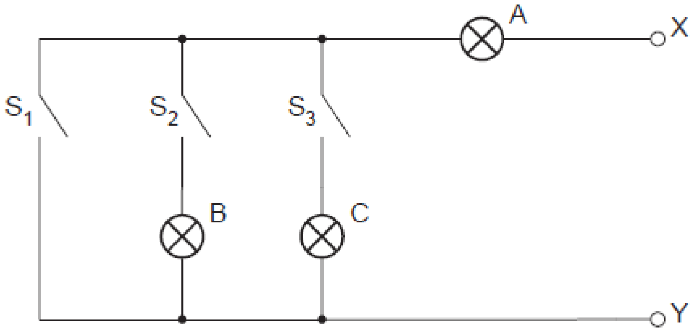

Fig. 3.1

One of the lamps is faulty. In order to detect the fault, an ohm-meter is connected between terminal X and Y. When measuring resistance with the ohm-meter, negligible current flows in the circuit.

Fig. 3.2 shows the readings of the ohm-meter for different switch positions.

switch S_1	S_2	S_3	meter reading / Ω
open	open	open	∞
closed	open	open	15 Ω
open	closed	open	30 Ω
open	closed	closed	15 Ω

Fig. 3.2

(i) Identify the faulty lamp, and the nature of the fault.

Faulty lamp: ………………………………………………………………………………

Nature of fault: …………………………………………………………………………[2]

(ii) Suggest why it is advisable to test the circuit using an ohm-meter rather than with a power supply.

……………………………………………………………………………………………

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

(a) **(iii)** Determine the resistance of the lamp when it is functioning properly.

resistance = ……………………Ω [1]

[Turn over

(b) A battery of e.m.f. 4.50 V and negligible internal resistance is connected to a fixed resistor of resistance 1200 Ω and a thermistor, as shown in Fig. 3.3.

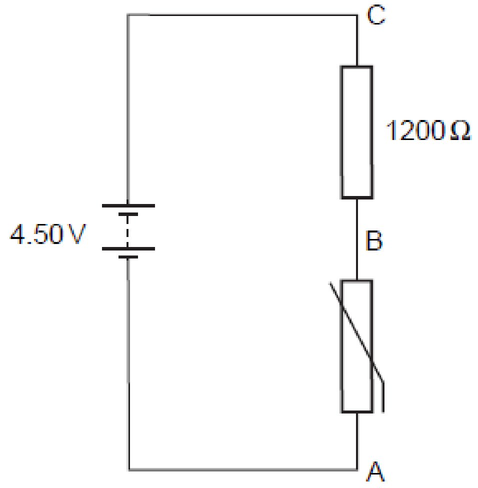

Fig. 3.3

At room temperature, the thermistor has a resistance of 1800 Ω.

A uniform resistance wire PQ of length 1.00 m is now connected to the resistor and the thermistor, as shown in Fig. 3.4.

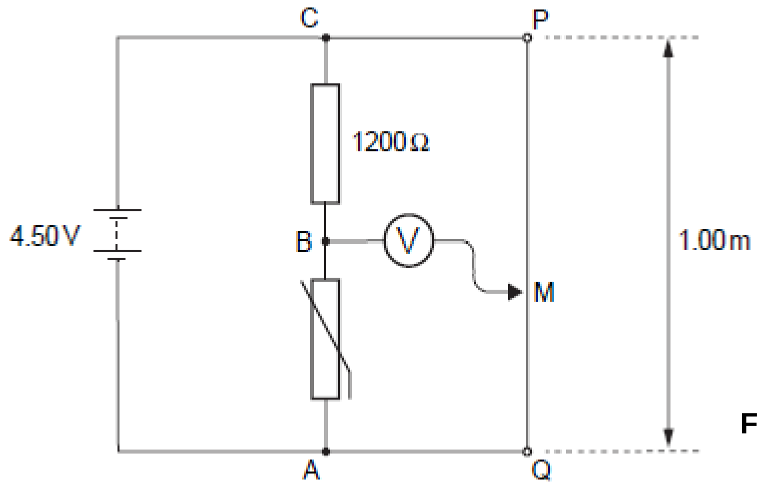

Fig. 3.4

A voltmeter is connected between point B and a movable contact M on the wire.

(i) Explain why, for constant current in the wire, the potential difference between any two points on the wire is proportional to the distance between the points.

....

....

....

....[2]

(b) **(ii)** The contact M is moved along PQ until the voltmeter shows zero reading. Calculate the length of the wire between M and Q.

length = ……………………m [2]

(iii) The temperature of the thermistor increases slightly during the measurement. Explain the effect on the length of wire between M and Q for the voltmeter to show zero reading.

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…………………………………………………………………………………………

………………………………………………………………………………………[2]

4 Fig. 4.1 shows a mass spectrometer comprising a velocity selector (Stage 1) and an ion separator (Stage 2). A stream of alpha particles is sent into the mass spectrometer.

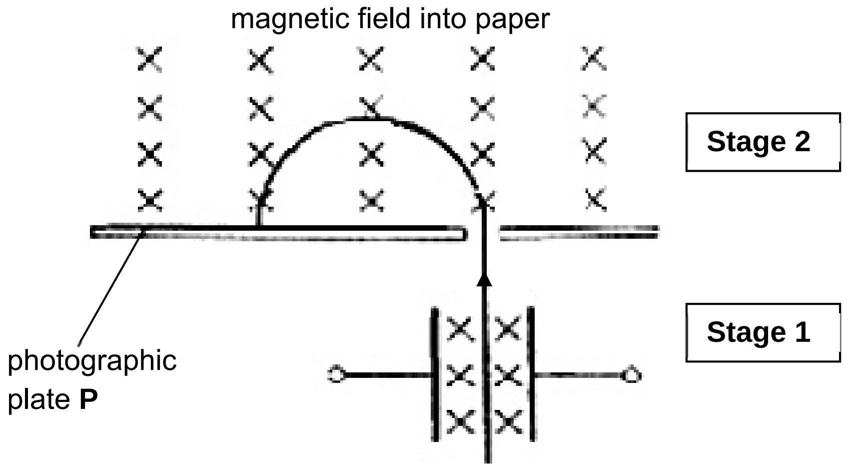
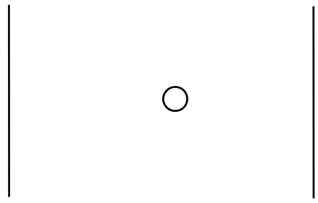


Fig. 4.1

(a) **Stage 1**
The alpha particles have a range of speeds enter Stage 1 which isolates particles with a specific speed, v. The plates producing the electric field have a separation of 1.0 cm. A uniform magnetic field is applied between the plates.

(a) **(i)** On the diagram below, draw arrows to represent the electric force F_E and the magnetic force F_B. [2]



(ii) Describe and explain the path of alpha particles with speed less than *v*.

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…………………………………………………………………………………………[2]

(b) **Stage 2**

After Stage 1, alpha particles of speed 1.00×10^5 m s^{-1} are sent into stage 2. The alpha particles are travelling at right angles to the uniform magnetic field and are detected using a photographic plate P placed at the appropriate position. Determine the distance between the point of entry and the point of impact of the alpha particles with the photographic plate when the magnetic flux density 0.050 T is used.

distance = ……………………m [2]

(c) A similar spectrometer can be used with beta particle. Beta particles typically travel more than 100 times faster than the alpha particles. State and explain the necessary modifications to the spectrometer for it to work with beta particles.

Stage 1:

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Stage 2:

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[4]

5 **(a)** **(i)** State what is meant by *a line of force in a gravitational field*.

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……………………………………………………………………………………………

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

(ii) By reference to the lines of force of the gravitational field near the surface of the Earth, explain why the acceleration of free fall near the surface of Earth is approximately constant.

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

(b) The table below shows some data for Mercury and Pluto.

	Mass/kg	Radius/m	Mean distance from Sun/m
Mercury	3.30×10^{23}	2.44×10^{6}	57.9×10^{9}
Pluto	0.131×10^{23}	1.19×10^{6}	5910×10^{9}

(i) Show that the escape velocity *v* of a gas molecule on the surface of Pluto is given by the equation

$$v = \sqrt{\frac{2GM}{r}}$$

where *M* is the mass of Pluto and *r* is its radius. [2]

(ii) Calculate the escape velocity of a gas molecule on the surface of Pluto.

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

(iii) Suggest, using data from the table, why Mercury has no detectable atmosphere while Pluto has a thin atmosphere.

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

6 **(a)** A mass of 24 g of ice at –15 °C is taken from a freezer and placed in an insulated container with 200g of water at 28 °C. Some data for the ice and the water are given in the table below.

	specific heat capacity / $J\,kg^{-1}\,K^{-1}$	specific latent heat of fusion / $J\,kg^{-1}$
ice	2.1×10^3	3.3×10^5
water	4.2×10^3	–

Calculate the final temperature of the water in the container.

final temperature = ………………………..°C [2]

(b) Some air, assumed to be an ideal gas, is contained within a cylinder. Initially, the volume of gas is 540 cm^3, its pressure is 1.1×10^5 Pa and its temperature is 27 °C. The air is compress to 30 cm^3 suddenly such that no heat enters or leaves the gas. The pressure of the gas is 6.5×10^6 Pa immediately after the compression.

(i) Determine the temperature of the gas immediately after the compression.

temperature = ………………………..°C [2]

(b) **(ii)** Explain, using the first law of thermodynamics, why the temperature of the air changes during the compression.

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……………………………………………………………………………………...

………………………………………………………………………………………[3]

(c) The first law of thermodynamics can be expressed in the form

$$\Delta U = q + w$$

where U is the internal energy of the system,
ΔU is the increase of the internal energy of the system,
q is the thermal energy supplied to the system,
w is the work done on the system.

The table below shows different processes. Complete the table with symbols '+' for an increase, '–' for a decrease and the symbol '0' for no change, for the respective quantities U, q and w. [3]

Process	U	q	w
the compression of an ideal gas at constant temperature			
the heating of a solid with no expansion			
The melting of ice at 0 ◦C into water at 0 ◦C. (Note: ice is less dense than water)			

End of Section A

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATIONS

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS

9749/03

Paper 3 Longer Structured Questions **(Section B)**

28 Aug 2018
2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

For Examiner's Use	
7	**/ 20**
8	**/ 20**
Total	**/ 20**

READ THE INSTRUCTION FIRST
Write your subject class, registration number and name on all the work you hand in.
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.

Section B
Answer any **one** question.

You are advised to spend 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.

This document consists of 11 printed pages.

[Turn over

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ Fm^{-1} = $(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$, $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -GM/r$
temperature	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ and $v = \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \cdots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{ln2}{t_{\frac{1}{2}}}$

Section B (20 marks)

7 **(a)** **(i)** State and explain the effect of the width of aperture on the diffraction of the wave.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………[2]

(ii) The band is practising in the band room down the corridor with the door left slightly ajar. Explain why notes of a certain range of frequencies can be heard more clearly than others at the other end of the corridor.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………[2]

(b) A plane diffraction grating is illuminated normally by a monochromatic light source of wavelength λ. Light rays from each slit travel a different distance before arriving at a particular point on the screen. In order to derive an expression for the path difference, the light rays that meet at the same point on the screen can be approximated as parallel rays.

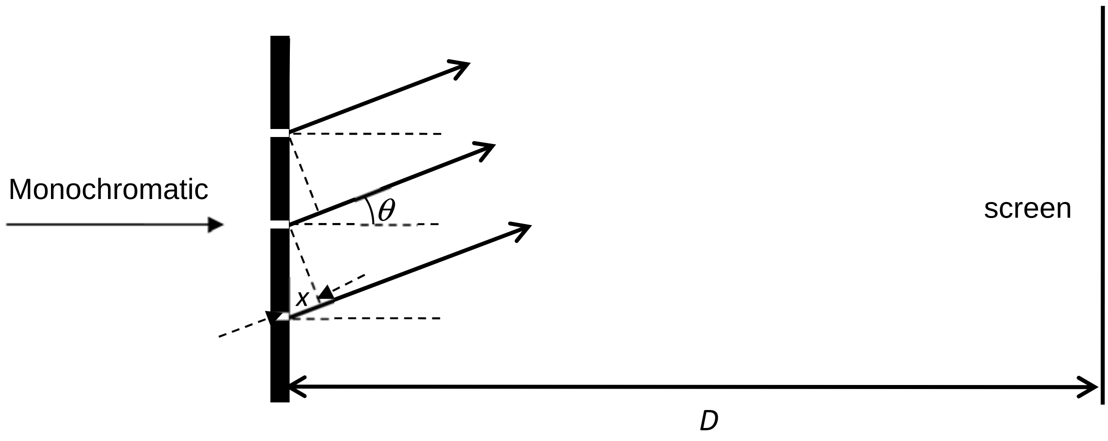


Fig. 7.1

(i) State the condition where the rays can be assumed to be parallel.

…………………………………………………………………………………………

………………………………………………………………………………………[1]

7 **(b)** **(ii)** Derive an expression for the path difference x between adjacent rays in terms of p and θ, where p is the number of lines per unit length of the grating, and θ is the angle between the emergent ray and the normal. [2]

(iii) Hence, derive an expression relating p and θ for the constructive interference of the rays. Define any additional symbol you use. [2]

7 **(c)** A diffraction grating is set up at the centre of a rotating table which completes a revolution every 3.0 s. The grating is illuminated normally by monochromatic light of wavelength λ from a source which is also mounted on the table, see Fig. 7.2.

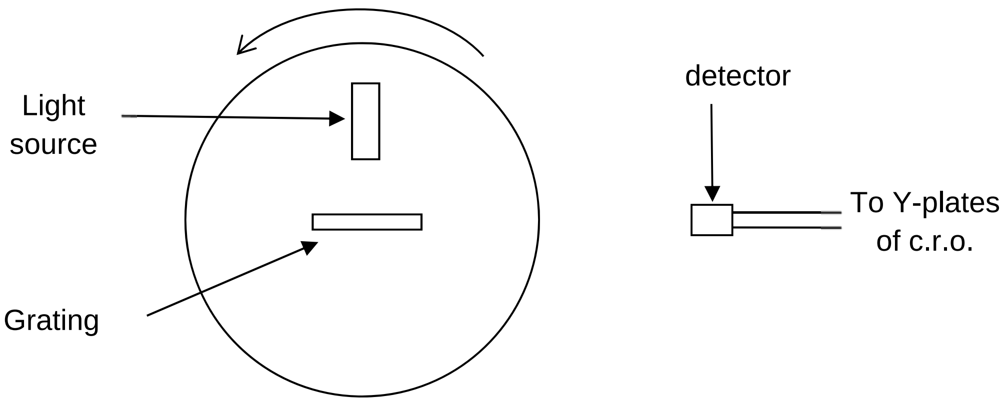


Fig. 7.2

The emergent beams of light from the grating are monitored by means of a stationary opto-electrical detector. The output from detector is displayed on a cathode ray oscilloscope (c.r.o.). With the time-base set at 0.10 s cm^{-1}, the trace obtained is shown in Fig. 7.3. The relative positions of the peaks are as indicated.

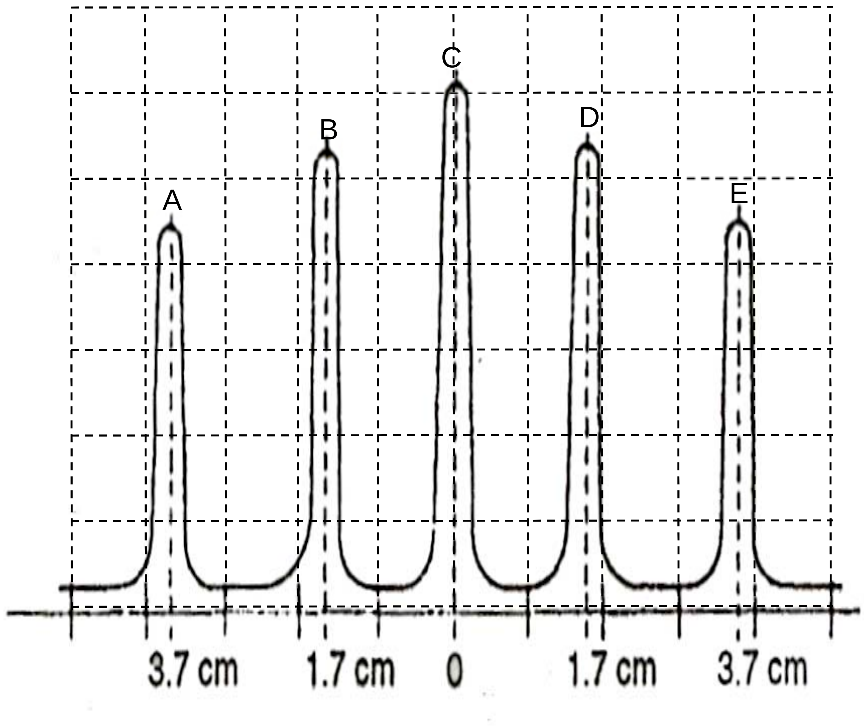


Fig. 7.3

7 **(c)** **(i)** Calculate the angular speed of rotation of the grating.

angular speed = …………………….rad s^{-1} [1]

(ii) Explain the appearance of the trace in Fig. 7.3.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………….[2]

(iii) Calculate the angle θ in radians, as defined in (b) (ii), for peaks D and E.

θ for D = …………….radians

θ for E = …………… radians

[3]

7 **(c)** **(iv)** Using peak E, calculate the wavelength of the light if the grating has 550 lines per mm.

wavelength = ……………………nm [2]

(v) Explain why it is preferable to calculate the wavelength using peak E rather than peak D.

……………………………………………………………………………………………

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

(vi) Sketch in Fig. 7.4, the c.r.o. display, if the diffraction grating is replaced by a double slit of the same slit separation as the diffraction grating. [2]

.

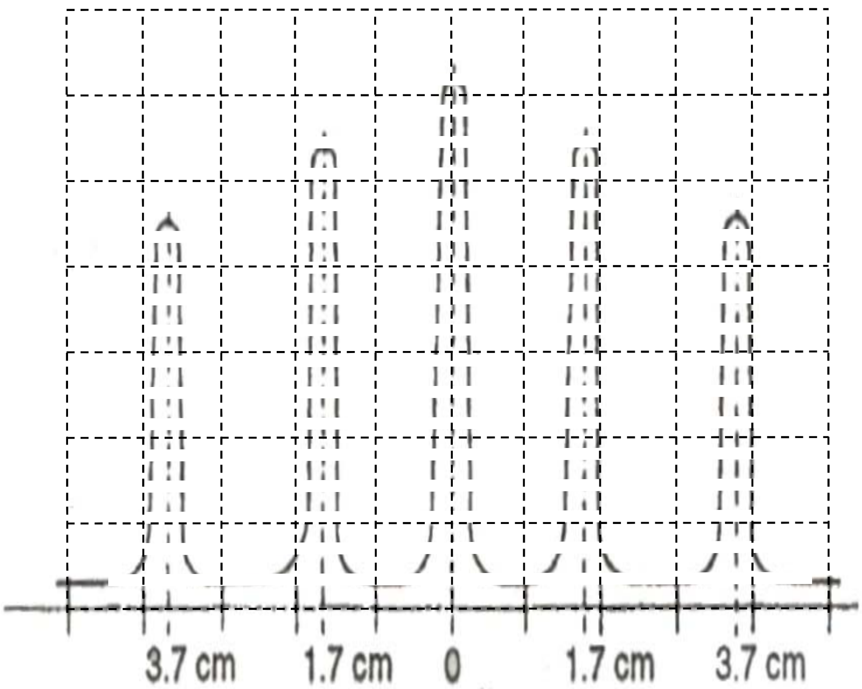


Fig. 7.4

(The original display from the grating is shown in dotted line)

8 **(a)** Describe how the alpha scattering experiment provides evidence for

(i) the small size of the nucleus,

………………………………………………………………………………………

……………………………………………………………………………………….[1]

(ii) a charged nucleus.

………………………………………………………………………………………

……………………………………………………………………………………….[1]

(b) In 1914, James Chadwick showed that the energies of the beta particles emitted for a radioactive source had a distribution of energies rather than with a distinct single value of energy.

Figure 8.1 shows the energy spectrum for beta particles emitted during the decay of Bismuth-210 ($^{210}_{83}Bi$). The intensity (vertical axis) indicates the number of beta particles emitted with each particular kinetic energy (horizontal axis).

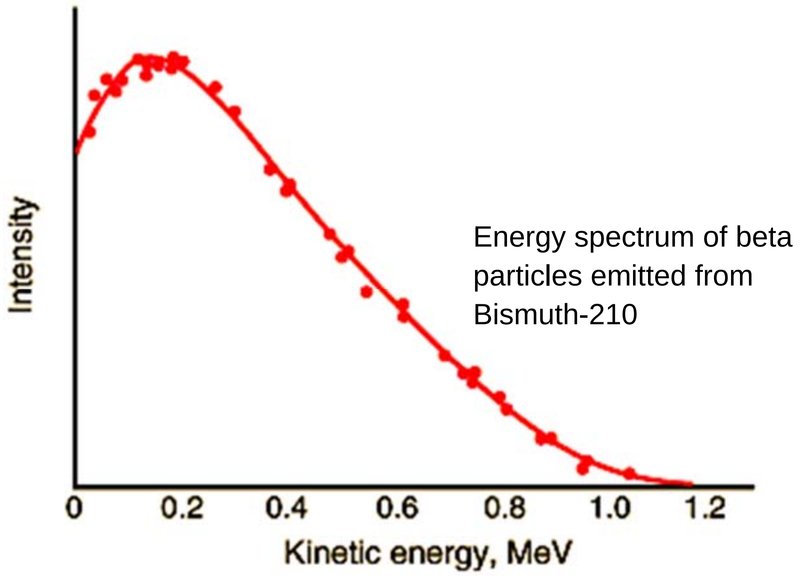


Fig. 8.1

(i) **1.** Determine, from Fig.8.1, Q, the maximum possible energy of the beta particle emitted.

Q =……………………… MeV [1]

2. Hence calculate the maximum speed of the beta particle.

Maximum speed =……………………… m s^{-1}

3. Comment on the value you obtained in **b(i)2**.

…………………………………………………………………………..…………….

…………………………………………………………………………..……….[2]

8 **(b)** **(ii)** The radioactive isotope of Bismuth, ${}^{210}_{83}\text{Bi}$, decays into Polonium (chemical symbol: Po) with the emission of a beta particle.

Determine the mass of the resultant Polonium nucleus, in terms of *u*, and express your answer to 3 decimal places. (mass of a ${}^{210}_{83}\text{Bi}$ nucleus is 209.939 *u*; mass of proton m_p is 1.00729 *u*; mass of neutron m_n is 1.00867 *u*).

mass=……………………. *u* [3]

(iii) From Fig. 8.1, identify the most probable energy for the beta particle.

most probable energy value = ………………… MeV [1]

(iv) It is noted that the stable isotopes of heavy elements have an optimal neutron to proton ratio. Unstable isotopes will undergo transmutation into another element through radioactive decay such that product achieve the optimal ratio.

Suggest, with a reason, whether Bismuth-210 has an excess of neutrons or protons, as compared to the optimal ratio.

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

……………………………………………………………………………………..[2]

(v) The continuous spectrum of kinetic energy values of the beta particle presented a problem to physicists up to 1930s. If a stationary nucleus decayed into a beta particle and a stable daughter nucleus only, it should lead to a distinct single value of energy.

Explain, using conservation of linear momentum and energy, how the continuous spectrum of beta particle energies gave rise to this problem.

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

……………………………………………………………………………………… [2]

8 **(b)** **(vi)** Suggest what was proposed by physicists to resolve the problem in **(v)**.

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

(c) In an experiment, a detector is held a fixed distance from a sample of a radioactive material and the data provided is used to plot a graph of count-rate against time, as shown in Fig 8.2.

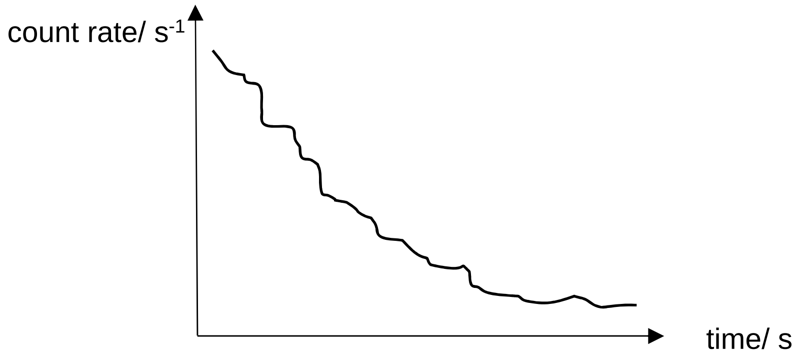


Fig. 8.2

(i) Explain why the data points on the graph do not lie on a smooth curve.

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

(ii) Suggest two reasons why the count-rate recorded is not equal to the activity of the radioactive sample.

1. ………………………………………………………………………………………
……………………………………………………………………………………………

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

(iii) The count rate from a counter near a radioactive source is 7.6×10^{8} s^{-1}. The decay constant of the source is 4.6×10^{-3} s^{-1}.

1. Calculate the time taken for the count rate to fall to 8.3×10^{3} s^{-1}.

time = …………………… s [1]

8 (c) (iii) 2. When the detector is at a distance y from the radioactive source, the count rate is 234 counts per minute.

Calculate the count rate when the detector is at a distance $3y$ from the source.

average count rate = …………………… counts per minute [2]

End of Section B

2018 H2 Physics Prelim P3 Suggested Solution

1(a) Gravitational potential energy of an object is the energy it possesses by virtue of its position in a gravitational field while elastic potential energy is the energy that is stored when a spring is stretched or compressed.

(b)(i) Taking the child and the pogo stick as a system.

At **A**, the gravitational potential energy is at a minimum while the elastic potential energy is at a maximum, since it is at rest, kinetic energy is zero.
From **A** to **B**, the gravitational potential energy has increased while the elastic potential energy is now zero since the spring is relaxed. Kinetic energy is non-zero at this point.
From **B** to **C**, the gravitational potential energy reaches its maximum, elastic potential energy is still zero while the kinetic energy is zero since it comes to rest.

(b)(ii) By conservation of energy,

Total energy at point A = Total energy at point C

$$\frac{1}{2}k{x_A}^2 = mg(x_A + x_C)$$
$$x_A + x_C = 1.22\ m$$
$$x_C = 1.02\ m$$

(b)(iii) Point of maximum speed is where the system is in equilibrium, net force = 0.

Mg – kx = 0
x = 0.01635 m

By conservation of energy,
Loss in EPE = Gain in KE + Gain in GPE

$$\frac{1}{2}k{x_A}^2 - \frac{1}{2}k(0.01635)^2 = Gain\ in\ KE +\ mg(x_A - 0.01635)$$

Gain in KE = 252.95 J

Maximum speed = 4.50 ms^{-1}

(b)(iv) Just below B, since x = 0.01635m. At B there is only weight OR at maximum speed elastic force upwards is equal to the weight downwards.

2.

(a)

By conservation of energy, the first sphere will accelerate as it loses gravitational potential energy and gains kinetic energy achieving maximum velocity, v, at the lowest position just before it with the second sphere.

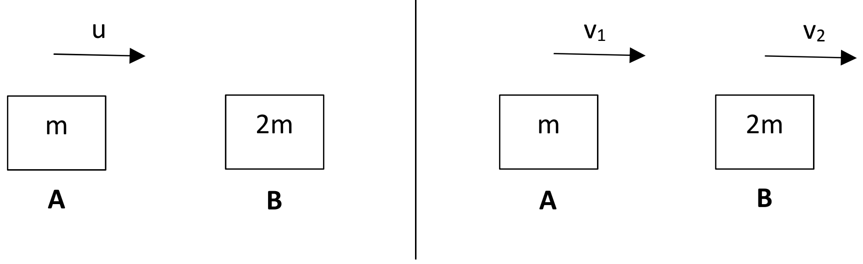
Since the spheres are identical, they have the same mass. By conservation of linear momentum, the first sphere with a velocity of v will collide with the next sphere which is at rest. After collision, the second sphere will move off with a velocity v, while the first sphere comes to rest. This continues on till the last sphere moves off with a velocity v.

Since the last sphere has the same velocity as the first sphere, it will rise to the same height as the first sphere where it was released by conservation of energy as the last sphere loses kinetic energy and gains gravitational potential energy.

The last sphere then reaches the same maximum height and comes to rest momentarily. Due to the tension of the string and weight of the sphere, the net force causes the last sphere to accelerate in the opposite direction before colliding with the neighbouring sphere. This motion then repeats itself in an oscillatory manner.

2(b)(i)

Before: After:



By PCLM,

$mu = mv_1 + 2mv_2$ --- (1)

Since collision is elastic, applying relative speed relation,

$u - 0 = v_2 - v_1$ --- (2)

Sub (2) into (1)

$m(v_2 - v_1) = mv_1 + 2mv_2$

$(v_2 - v_1) = v_1 + 2v_2$

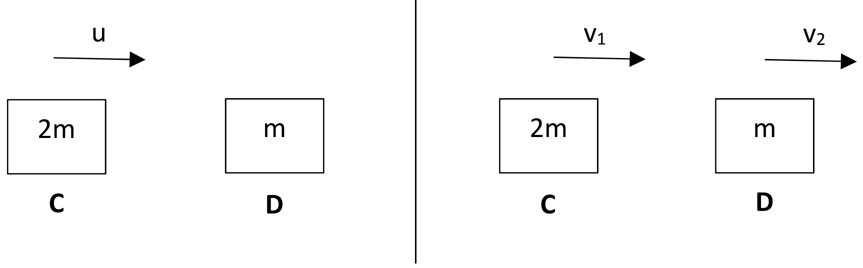
$v_2 = -2v_1$

Hence $v_1 = -\frac{u}{3}$ and $v_2 = \frac{2u}{3}$

$Ratio = \frac{2}{3}$ = 0.67

2(b)(ii)

Before: After:



By PCLM,

$2mu = 2mv_1 + mv_2$ --- (1)

Since collision is elastic, applying relative speed relation,

$u - 0 = v_2 - v_1$ --- (2)

Sub (2) into (1)

$2m(v_2 - v_1) = 2mv_1 + mv_2$

$(2v_2 - 2v_1) = 2v_1 + v_2$

$v_2 = 4v_1$

Hence $v_1 = \frac{u}{3}$ and $v_2 = \frac{4u}{3}$

$Ratio = \frac{4}{3}$ = 1.3

2(b)(iii)

Collision (i) occurs twice.

Collision (ii) occurs twice.

$$\frac{Max\ vert\ displacement\ of\ first\ sphere}{Max\ vert\ displacement\ of\ last\ sphere} = \frac{Change\ in\ GPE\ of\ first\ sphere}{Change\ in\ GPE\ of\ last\ sphere}$$

By CoE, since the ball comes to rest at max GPE,

$$\frac{Change\ in\ GPE\ of\ first\ sphere}{Change\ in\ GPE\ of\ last\ sphere} = \frac{Max\ KE\ of\ first\ sphere}{Max\ KE\ of\ last\ sphere} = \frac{0.5\ mv_i^2}{0.5\ mv_f^2}$$

Hence

$$\frac{Max\ vert\ displacement\ of\ first\ sphere}{Max\ vert\ displacement\ of\ last\ sphere} = \frac{v_i^2}{v_f^2} = \frac{u^2}{(\left(\frac{2}{3}\right)\left(\frac{4}{3}\right)\left(\frac{2}{3}\right)\left(\frac{4}{3}\right)u)^2}$$

Ratio = 1.60

2(c)

The tension of the spring for all the spheres except for the first sphere is equal to the weight of the sphere since net force = 0. The first sphere will have a greater tension since it undergoes centripetal acceleration, T = mg + mv^2/r. Hence extension for the first sphere is greater than that of the rest.

The first sphere and the second sphere no longer collide head-on.

3

(a)(i) Faulty Lamp: Lamp C
Nature of fault: Lamp is shorted(or short circuit).

(ii) Using a power supply might short Lamp A, high current pass through the circuit and would damage the power supply/lamps/blow fuse in supply.

(iii) 15 Ω

(b)(i) Potential difference across wire is V= IR where R is $\rho\frac{L}{A}$ where I is current in wire, R is resistance of wire, ρ is resistivity of wire, L is length of wire and A is cross-sectional area of wire. Since I, ρ and A are constant, therefore V is directly proportional to length of wire.

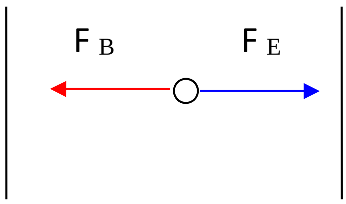
(ii) Potential across thermistor = pd across QM
= 1800/3000 (4.5) = 2.7 V

$\frac{L}{100} = \frac{2.7}{4.5}$

L = 60.0 cm

3(b)(ii) As temperature rises, thermistor resistance decreases. Pd across QM will be smaller, thus QM is shorter.

4.(a) (i)



(ii) The alpha particle would be deflected to the **right** along a **parabolic path.**

As the speed of the particle is less than v, the **magnetic force experienced is less than the electric force.** Hence the particles experience **a constant acceleration to the right.**

(b) Stage 2

By Newton's 2nd law, the magnetic force provides the centripetal force for electron to undergo circular motion

$Bqv = mv^2/r$

➔ $r = mv/Bq$ ------ (1)

$= (4 \times 1.67 \times 10^{-27} \times 1.00 \times 10^5) / (0.050 \times 2 \times 1.6 \times 10^{-19})$

$= 4.175 \times 10^{-2}$ m

Point of impact = 2 r = $2 \times 4.175 \times 10^{-2}$ m = 8.35×10^{-2} m

(c) Stage 1:

As the Beta particle velocity is 100 times faster, The magnetic force is now 100 times stronger than the electric force. Hence, an electric field strength 100 times the original one must be applied for it to remain undeflected.

For alpha particle,

$F_E = F_B$

qE = Bqv

v = E/B

Since beta particles travels 100 times faster,

F_B' = B(2q)(100v)

$F_E' = (2q)\,E'$

For Beta particle to remainl undeflected,

$F_B' = F_E'$

$E' = 100Bv = 100\,E$

Stage 2:

- While the speed of beta particles is 100 times faster, its mass is more than 1000 times smaller than alpha particle. Hence the position of photographic plate needs to be placed much closer to the entrance since the point of impact is much smaller now.
- Beta particle is negatively charge, the point of impact is on the right side of the entrance. Thus the position of the plate must be placed at the right side of the entrance instead of the left side.

From (1),

Radius of He particle, r = mv/Bq

Radius for Beta particles, r' = $m_e v_e/B2q$

$$= \frac{\frac{1}{1833}m\,(100v)}{2}B$$

$$= 0.0266\,\frac{mv}{Bq} = 0.0266\ r$$

5

(a)(i) It means direction of force on a (small test) mass/ direction of acceleration of a (small test) mass.

(ii) It is because field lines are radial. The lines near the surface are (approximately) parallel. With parallel lines, the field strength is constant, thus constant acceleration of free fall.

(b)(i) GPE at infinity is maximum at 0J and KE is minimum at 0J.

By conservation of energy,

Gain in GPE from surface to infinity = Lost in KE from surface to infinity

$\frac{GMm}{r} = 1/2\ mv^2$ where mass is the mass of one gas molecule

$v = \sqrt{\frac{2GM}{r}}$ (shown)

(ii) The escape velocity, $v = (2\mathrm{x}6.67\mathrm{x}10^{-11}\mathrm{x}0.131\mathrm{x}10^{23}/(1.19\mathrm{x}10^{6}))^{1/2}$

$= 1212 = 1200\ ms^{-1}$

(iii) Mercury has a higher escape velocity than Pluto which is 4248 ms^{-1}.

Mercury is closer to sun and Mercury is hotter.

Molecules on Mercury have speed higher than the escape speed, thus they are fast enough to escape from Mercury. Mercury has no atmosphere.

6

(a) By conservation of energy,

Thermal Energy gained by ice = Thermal energy lost by water

$0.024(2.1\mathrm{x}10^3)(15) + 0.024(330\mathrm{x}10^3) = 0.20(4.2\mathrm{x}10^3)(28\text{-}T)$

$T = 17.7\ ^\circ C$

(b)(i) PV/T = constant

$T = (6.5\times10^6 \times 30 \times 300)/(1.1\times10^5 \times 540)$

$= 985$ K

(ii) $\Delta U = Q + W$

Since Q =0, gas compress, W is positive. Thus ΔU must increases.

ΔU increases, kinetic energy of the atoms also increases.

KE of atoms is proportional to thermodynamic temperature, i.e KE =3/2kT

KE increase, thus temperature must increase.

6(c)

	U	*q*	*w*
the compression of an ideal gas at constant temperature	0	-	+
the heating of a solid with no expansion	+	+	0
The melting ice at 0 ◦C to give water at 0 ◦C. (Note: ice is less dense than water)	+	+	+

7(a)(i) When the wavelength of the wave is comparable to slit width, diffraction is most significant.

(ii) Low-pitched notes have longer wavelengths that's more comparable to the width of door gap and undergo more diffraction through the door.

(b)(i) Distance *D* must be much longer than distance two adjacent slits of the grating

(ii) Slit separation, $d = 1/p$

path difference $x = d \sin\theta = 1/p \sin\theta$

(iii) Hence Constructive interference occurs when

$$1/p \ \sin\theta = n\ \lambda \text{ where } n = 0,\ 1,\ 2, \ldots\ldots$$

Where *n* is the order of the spectrum and θ is the angle of diffraction between the diffracted ray and the direction of incident light.

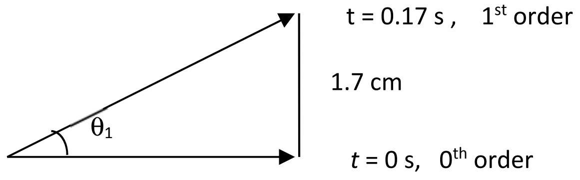
c (i) angular speed of grating, $\omega = 2\pi / T = 2\pi / 3 = 2.09 = 2.1$ rad.s^{-1}

(ii) Peak C corresponds to the zeroth order of the interference pattern whereas peaks B and D the first order and Peaks A and E the second order.

The height of each peak is due to diffraction effect.

(iii)

Hence, time to shift from zeroth order to the first order through 1.7 cm on the screen is 1.7 x 0.1 = 0.17s



θ_1 = $(2\pi / 3)$ 0.17 rad = 0,355 rad = 0.36 rad

Similarly time from the zeroth order to 2nd order = 3.7 x 0.1 = 0.37 s

θ = $(2\pi / 3)$ 0.37 rad = 0.773 rad = 0.77 rad.

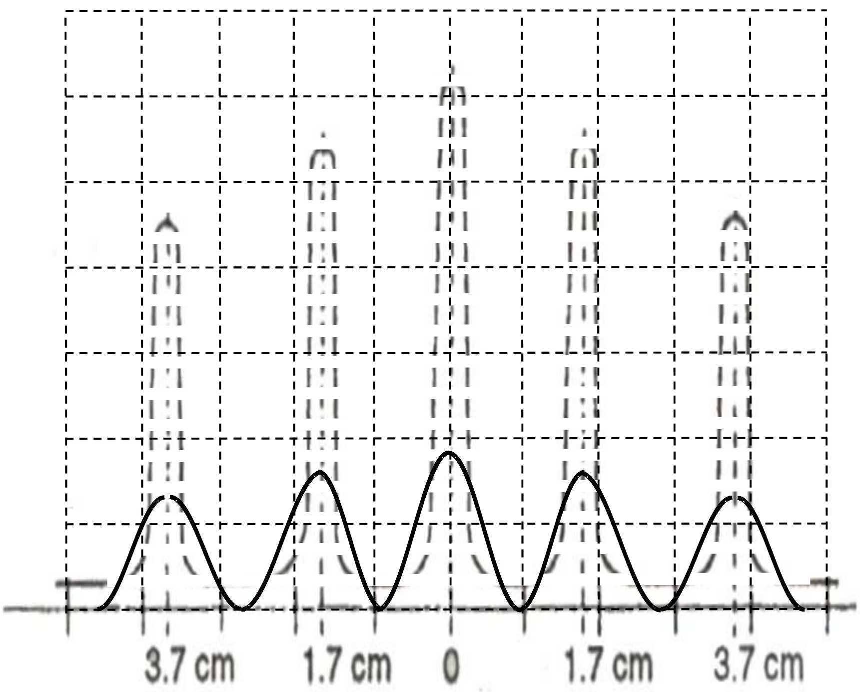
(iv) Using the grating equation

$\sin\theta_2 = 2 \times 5.5 \times 10^5 \times \lambda$

λ = 636 nm

(v) Peak E is preferred as the angle θ is larger and the percentage error for calculating the wavelength is smaller.

(vi) Since the slit separation remain the same, the fringe separation remains the same. However, the peaks are less intense (poorer contrast) and less sharp (broader and less defined).



8 (a) (i) most alphas have small deflection
so nucleus is small target
(ii) deflection too large to be gravitational
so must be electrostatic i.e. charged

(b) (i) 1. from the graph, Q = 1.2 MeV

2. $v = \sqrt{(E/(\frac{1}{2} m_e)}$
$= 6.5 \times 10^8 \text{ ms}^{-1}$

3. The calculated value of v is more than c, the speed of light.
(This suggests that the classical formula for kinetic energy $\frac{1}{2} mv^2$, is not valid in calculating the speed of the beta particle.)

(ii) $m(Po) = m(Bi) - m_e - Q/c^2$
$= [(209.939u) - (9.11 \times 10^{-31}/1.66 \times 10^{-27}) - (1.2\times10^6 \times 1.60\times10^{-19}/c^2)]/(1.66 \times 10^{-27} \text{ kg})$
$= 209.937$ u

(iii) Range of values accepted : 0.16 - 0.18 MeV

(iv) Since ^{210}Bi undergoes spontaneous beta decay, a process in which it increases its proton number by one
while decreasing its neutron number by one, it suggests that ^{210}Bi must have an excess of neutrons as compared to the optimal ratio.

(v) For a stationary nucleus decaying into the beta particle and daughter nucleus, the conservation of linear momentum requires that $\underline{p_1} = -\underline{p_2}$.
The sum of kinetic energies will thus be $(p_1)^2/2m_1 + (p_2)^2/2m_2 = E$, which ought to equal the energy released in the reaction, which, if equal to the increase in the total binding energy/decrease in total mass, ought to be constant.

The range of beta particle energies and thus the supposed energy released E, seem to suggest that the energy released was not constant, in contradiction to the principle of conservation of energy.

(vi)
- Energy was not conserved in a beta decay. (proven false)
- **The existence of another undetected particle.**
- (The actual reason. The undetected particle was the neutrino, and a 3 body interaction allowed for the beta particle to carry away a varying amount of KE whilst still ensuring COE)

(b) (i) random nature of emissions
(ii) e.g. self-absorption, detector not 100% efficient,
detector not surrounding source

ci
$R = R_o e^{-\lambda t}$ so $8.3 \times 10^3 = 7.6\times10^8 \times e^{-4.6\times10^{-3}t}$ t = 2480 s

ii Using inverse square law, answer is 26 counts per minute.