Physics

Hornsby Girls High School
2019
HSC Task 3
Trial Examination

Student Number

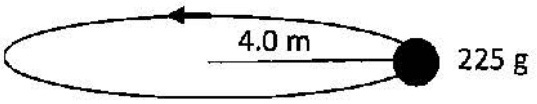
General Instructions:

- Reading time – 5 minutes
- Working time – 3 hours
- Write using **black pen**
- Draw diagrams using pencil
- NESA approved calculators may be used
- A data sheet, formulae sheet and Periodic Table are provided at the back of this paper
- For questions in Section II, show all relevant working in questions involving calculations
- Write your student number on this page, page 11 and page 19.

Total marks: 100

- Section I – 20 marks
- Attempt All Questions 1–20
- Allow about 35 minutes for this section
- Section II – 80 marks
- Attempt All Questions 21–34
- Allow about 2 hours and 25 minutes for this section

3. A 225 g mass is rotating at 75 revolutions per minute on a 4.0 m long string.



How would the angular velocity of this mass change if it continued to rotate with the same frequency, but the string was let out until it was 6.0 m long?

(A) The angular velocity would be 1.5 times greater.

(B) The angular velocity would decrease by one third.

(C) The angular velocity would decrease by two thirds.

(D) The angular velocity would not change.

4. Which identifies the characteristics of the motion of a projectile?

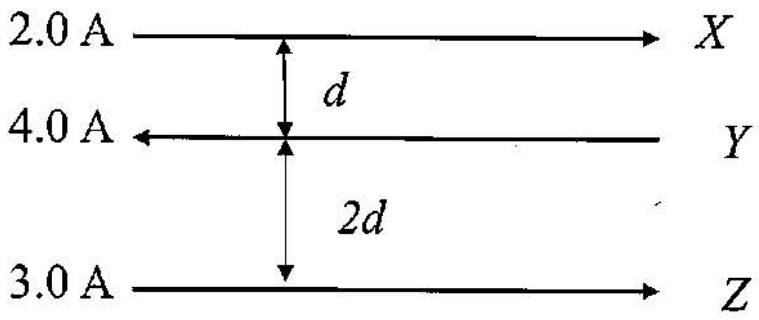
(A) The vertical velocity is greater than the horizontal velocity.

(B) Both the net velocity and acceleration are constant.

(C) It has constant horizontal motion and uniformly accelerated vertical motion.

(D) It has constant vertical motion and uniformly accelerated horizontal motion.

5. Three current-carrying wires are set up as shown. The force on wire Y due to the other two wires in this situation is F.



What will happen to the force on Y if the currents in X and Z are each doubled but the distances stay the same?

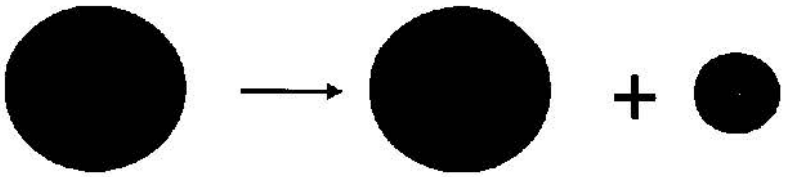
(A) It will halve to F/2.

(B) It will be the same value but in the opposite direction.

(C) It will double to 2F.

(D) It will quadruple to 4F.

8. Atom X undergoes alpha decay to form atom Y.



How will the nucleus of Y be different from that of X?

(A) The nucleus of Y will have 2 protons more than the nucleus of X

(B) The nucleus of Y will have 2 protons less but the same number of neutrons as the nucleus of X

(C) The nucleus of Y will have 2 protons and 2 neutrons more as the nucleus of X

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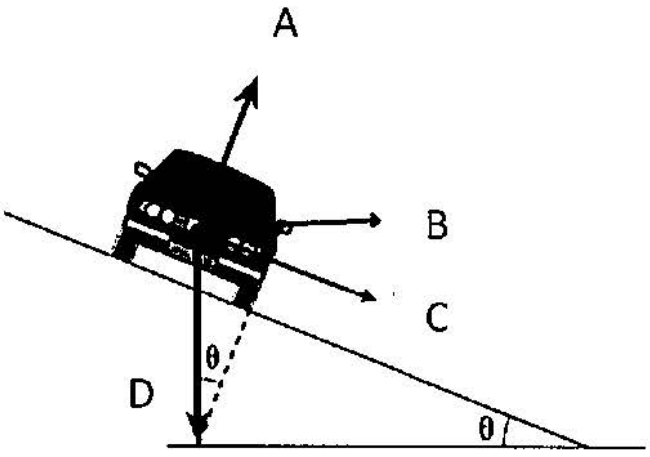
9. The figure below shows a vehicle travelling in a horizontal circle at constant speed on a frictionless banked track.



Which arrow, A, B, C, D, represents the **direction** of the net force on the vehicle?

10. A laptop charger with 1600 turns in the primary coil and 800 turns in the secondary coil draws a current of 3.34 A.

If the transformer is ideal, what is the current in the primary coil?

(A) 0.67 A

(B) 1.67 A

(C) 1.73 A

(D) 6.68 A

14. The absorption spectra of 4 metals and a star are shown below

Which metals are present in the star?

(A) calcium, sodium, iron, magnesium

(B) calcium, iron, magnesium

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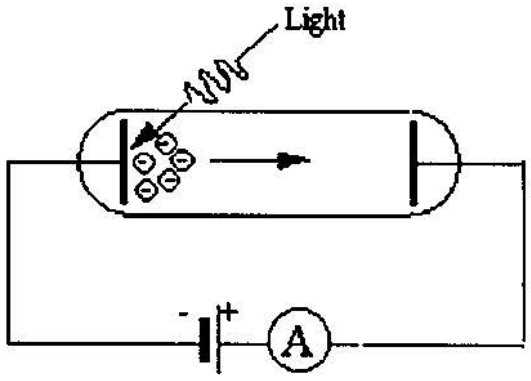
(D) sodium, iron, magnesium

15. The following experiment is set up to demonstrate the photoelectric effect. Light of a fixed frequency is directed onto a metal plate. The photocurrent is measured using the ammeter.



If the intensity of intensity of the light is increased, what other variable will also increase?

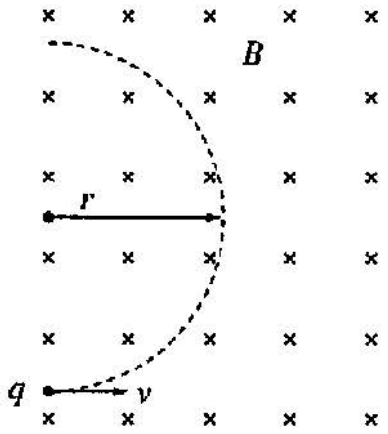
(A) maximum photon energy

(B) photon wavelength

(C) maximum electron kinetic energy

(D) photocurrent magnitude

18. A charged particle, q, enters a uniform magnetic field B at velocity v. The particle follows a circular path of radius, r as shown.



If the magnitude of the magnetic field was doubled and the other variables were kept constant, what would the new radius be?

(A) $\frac{r}{4}$

(B) $\frac{r}{2}$

(C) $2r$.

(D) $4r$

19. 'Prior to digital technology, the use of a pendulum was the most accurate method for determining the acceleration due to gravity in a school laboratory.'

Which explanation best justifies this statement?

(A) pendulums are very easy for students to set up

(B) the equations needed for calculations are easy to use

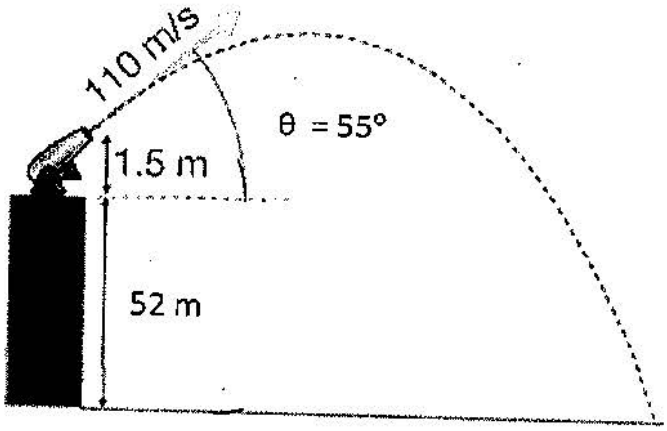
(C) measurement errors for the main variables can be minimised

(D) a stop watch can be used to measure the time for one swing

Student Number

Question 21 (6 marks)

A cannon fired a projectile from a cliff, with an initial velocity of 110 ms^{-1} at an angle of 55° as shown.



note: diagram not drawn to scale. Ignore the effect of air resistance in your calculations.

(a) What was the maximum height above ground level reached by the projectile? **3**

(b) What was the velocity of the projectile at the position of maximum height? **1**

(c) How far had the projectile travelled horizontally at the position of maximum height? **2**

Question 22 (8 marks)

The table displays data from the 8 planets in our solar system.

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
Mass (x 10^{24}kg)	0.33	4.87	5.97	0.642	1898	568	86.8	102
Diameter (km)	4879	12,104	12,756	6792	142,984	120,536	51,118	49,528
Density (kg/m3)	5427	5243	5514	3933	1326	687	1271	1638
Length of Day (hours)	4222.6	2802	24	24.7	9.9	10.7	17.2	16.1
Orbital Period (days)	88	224.7	365.2	687	4331	10,747	30,589	59,800
Average Distance from Sun (x10^6 km)	57.9	108.2	149.6	227.9	778.6	1433.5	2872.5	4495.1
Perihelion (x10^6 km)	46	107.5	147.1	206.6	740.5	1352.6	2741.3	4444.5
Aphelion (x 10^6 km)	69.8	108.9	152.1	249.2	816.6	1514.5	3003.6	4545.7

The mass of the Sun = 2.00×10^{30} kg.

(a) At what distance from the sun is Mercury travelling with its greatest orbital velocity? Which of Kepler's laws did you use to answer this? **2**

(b) What is the average gravitational force between the Sun and Mars? **2**

(c) What is the gravitational field strength on the surface of Saturn? **2**

Q22 continued

(d) What is the escape velocity from the surface of Saturn? **2**

Question 23 (5 marks)

Students carried out an experiment to determine the relationship between the radius and velocity for a 42 g mass moving with a uniform circular motion. The centripetal force was kept constant for each variation in radius. The time for 10 complete cycles was measured. The results are shown in the table below.

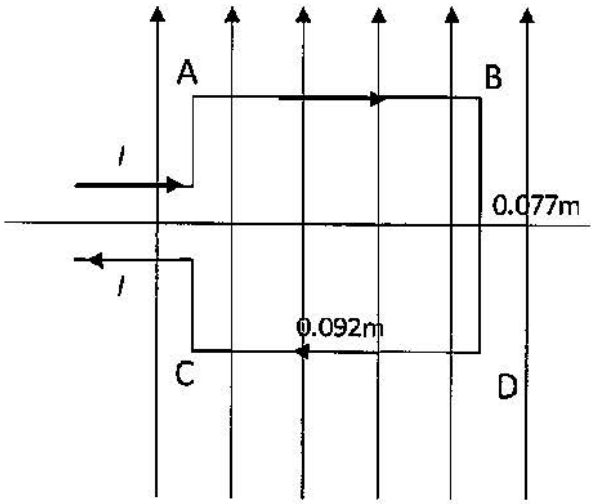
Radius of turn (cm)	time for 10 cycles (s)
10	4.3
20	6.1
30	7.3
40	8.5
50	9.5
60	10.1

They were asked by their teacher to use all the results to determine the magnitude of the constant centripetal force.

List and explain the steps of the analysis required to calculate the centripetal force. (You are not required to calculate the force.)

Question 24 (6 marks)

A motor uses a coil with 80 turns that has dimensions of 0.092 m by 0.077 m, as shown in the diagram. A current of 1.5 A flows through the coil in the direction shown. The coil is vertical and is in a magnetic field of 5.1×10^{-2} T directed upwards.



(a) What is the magnitude and direction of the magnetic force exerted on side AB? **3**

(b) What is the magnitude and direction of the torque experienced by the coil in this position? **2**

(c) The coil rotates as a result of the applied torque. What would happen to the magnitude of the torque as the coil rotates through 90°? **1**

Question 25 (4 marks)

A rectangular loop of wire is moved at a constant velocity across a magnetic field as shown in the diagram. The plane of the coil is perpendicular to the field lines at all times.

A current flows in the direction shown in Fig 1. and the coil experiences a force in the opposite direction to the motion. However, when the coil is entirely inside the field, Fig. 2, there is no current and no opposing force.

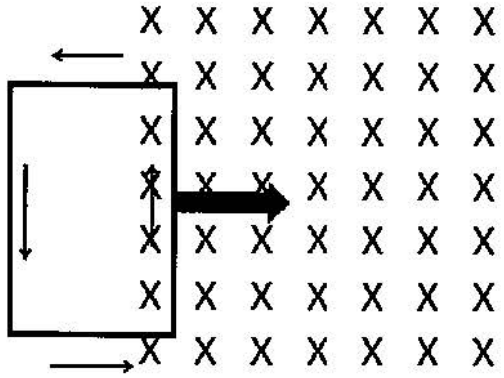


Fig. 1

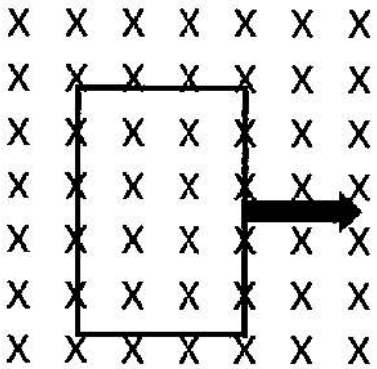


Fig. 2

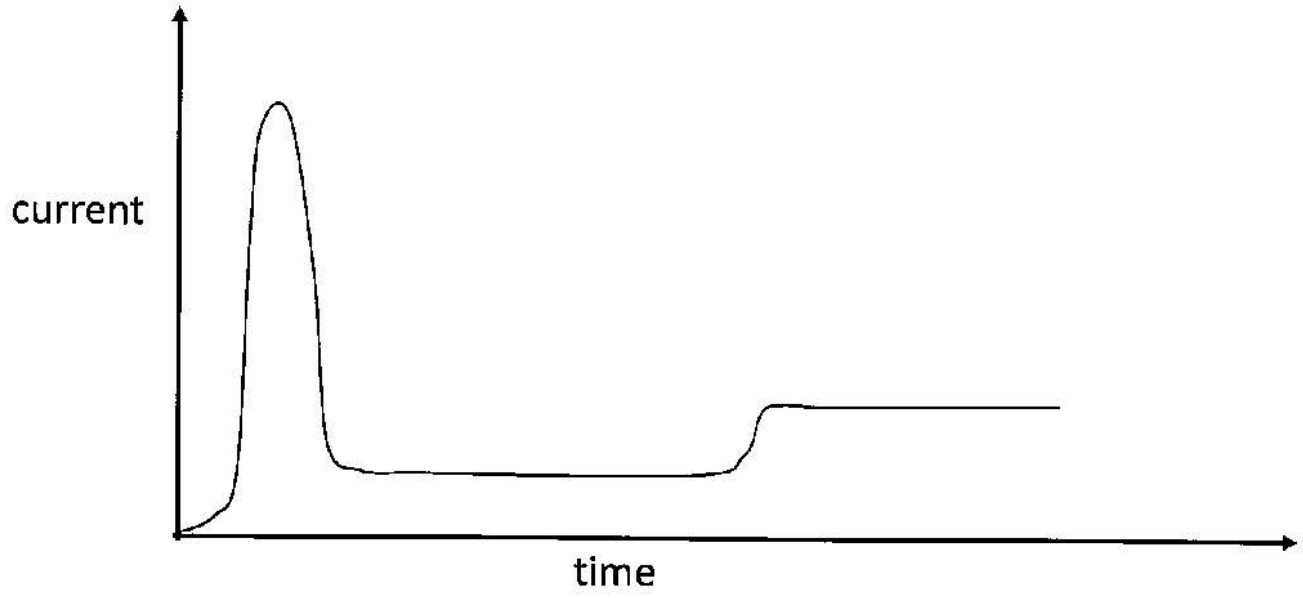
Use your understanding of Faraday's law and Lenz's law to explain this scenario.

Question 26 (5 marks)

A battery operated electric drill was connected to an ammeter to measure the current in the rotor.

When the drill was switched on, the current rapidly increased to 5.5 A and then reduced quickly to a steady value of 0.9 A.

The drill was then used to drill a hole, placing a load on the motor. The current went up to 2.1 A while it was drilling.



Explain why the current changed like this.

Question 27 (6 marks)

Throughout history, light has been a mystery that scientists have tried to explain. During the 1700s, the two prominent scientists Newton and Huygens proposed very different hypotheses on the nature of light.

(a) Compare Newton's and Huygens' models of light, including ONE similarity and ONE difference between them. **4**

(b) Huygens' model was accepted over Newton's largely due to the experimental work of Thomas Young. What did Young's work show and how did it support Huygens over Newton? **2**

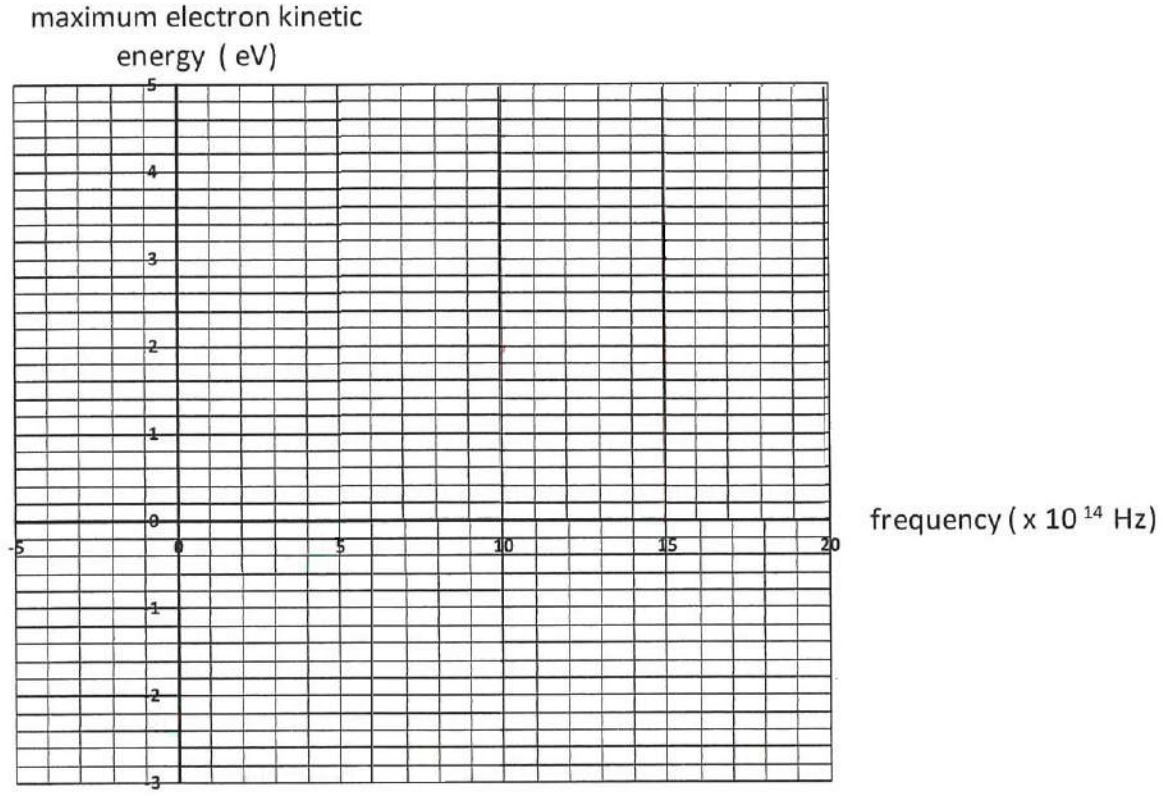
Student Number

Question 28 (5 marks)

Photoelectric effect data using sodium as a target metal is given below.

Light (photon) frequency (x 10^{14} Hz)	Electron kinetic energy (eV)
6.0	0.18
8.8	1.32
12.5	2.85
15.0	3.81
16.4	4.65

(a) Plot a graph of this data. Draw a line of best fit. **2**



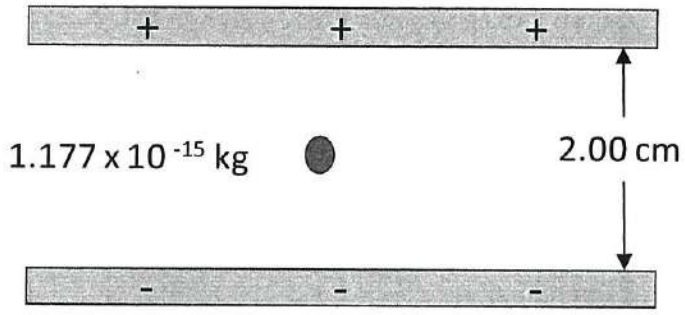
(b) Use the graph to:

(i)derive a value for Planck's constant 'h' with unit eVs. Show working on the graph. **2**

(b) find the work function for sodium metal. **1**

Question 29 (4 marks)

An oil drop of mass 1.177×10^{-15} kg falls vertically into the evacuated space between two parallel charged plates, which are 2.00 cm apart. The oil drop is negatively charged.

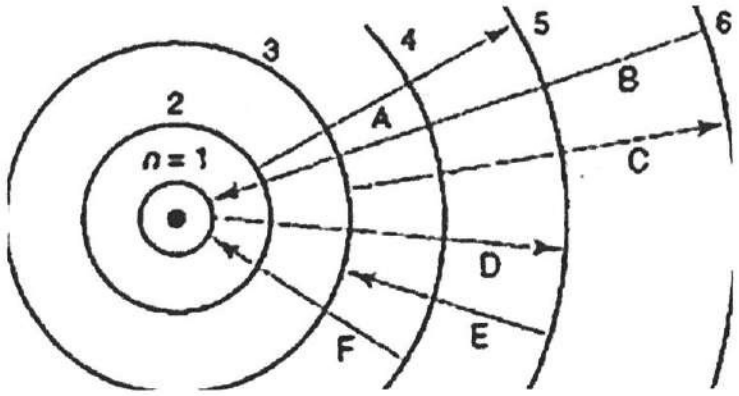


(a) The voltage is altered so that it slows the oil drop until it is stationary. When the potential difference between the plates is 72.0 V, the oil drop stops moving. How many excess electrons are on the oil drop? **3**

(b) An experiment with a similar approach was used by Robert Millikan. What did he conclude from his investigation? **1**

Question 30 – (4 marks)

The diagram shows a representation of a hydrogen atom.



The atom absorbs a photon of electromagnetic radiation which causes an electron to transition from Level 2 to level 5 – the transition marked A.

(a) What is the frequency of the absorbed photon? **3**

(b) What would result from an electron transition marked F between level 4 and 1? (No calculation is required). **1**

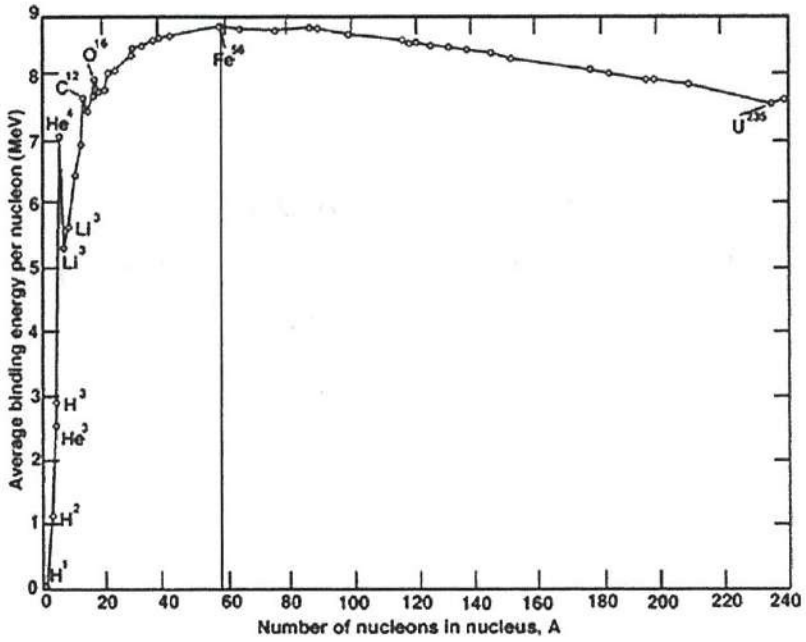
Question 31 (9 marks)

Our understanding of the atom changed significantly between 1904 and 1913 through the contributions of Thompson, Rutherford and Bohr

Outline the main features of each model and explain how each model improved upon the existing model.

Question 32 (6 marks)

The graph shows the average binding energy per nucleon for a range of elements.



(a) Elements to the left of Fe-56 on the graph are formed by nuclear fusion. Explain how this is related to binding energy. **3**

(b) A nucleus of U - 235 will break down into 2 smaller nuclei if it captures a neutron.

What is this process called? **1**

Question continued on next page

The reaction below shows that, as an example, U-235 can break into Ba-141 and Kr-92.

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

Energy is released in this process.

(c) Where does the energy come from and how could it be calculated? **2**

Question 33 (4 marks)

Muons are unstable subatomic particles that decay into electrons and neutrinos with a mean lifetime of 2.2 μs. They are produced when cosmic rays bombard the upper atmosphere about 11.4 km above the earth's surface, and they travel very close to the speed of light relative to the earth.

Explain how observations of these muons can be used as evidence to support Einstein's Special Theory of Relativity.

Question 34 (8 marks)

A group of students went on an excursion to the reactor at the Australia's Nuclear Science and Technology Organisation. During a walk around the facility, the tour guide stated that a radioactive substance, technetium-99m, which is produced in the reactor, has a decay constant of $3.2 \times 10^{-5}\ s^{-1}$.

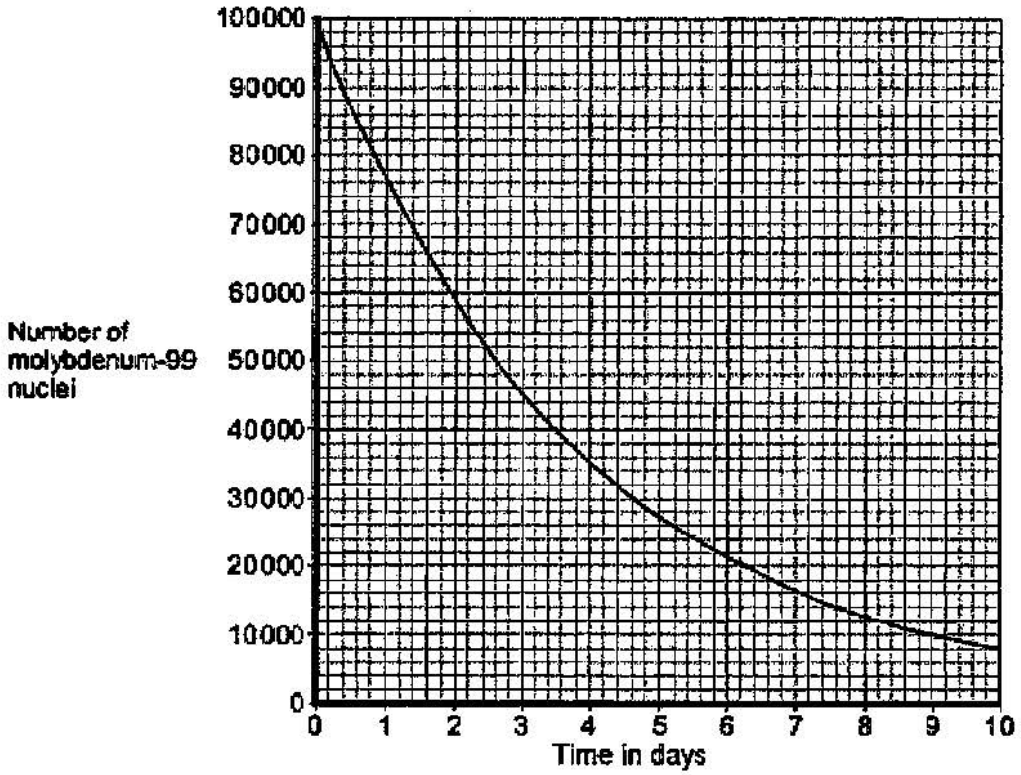
(a) What is the half-life of technetium-99m in hours? **2**

(b)Technetium-99m is a pure gamma emitter. The activity of two samples of technetium-99m was measured using a Geiger counter. The activity of one sample was found to be three times greater than the other. What does this tell you about the 2 samples? **2**

(c) Technetium-99m is formed from the breakdown of molybdenum-99. What type of particle would molybdenum-99 emit to form technetium-99m? **1**

Question continued on next page

The graph shows how the number of molybdenum-99 nuclei changes over time as the nuclei decay.



(d) What is the half-life, in days, of molybdenum-99? 1

(e) What percentage of the original molybdenum-99 is remaining after 8 days? 2

End of examination

Extra page – Question 28-34 – If you use this page CLEARLY indicate which question is being answered

Physics

Hornsby Girls High School
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HSC Task 3
Trial Examination

Student Number

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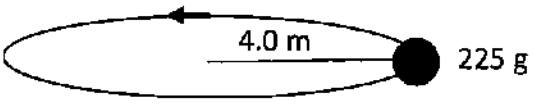

How would the angular velocity of this mass change if it continued to rotate with the same frequency, but the string was let out until it was 6.0 m long?

cont. frequency means constant angular change = D

(A) The angular velocity would be 1.5 times greater.

(B) The angular velocity would decrease by one third.

(C) The angular velocity would decrease by two thirds.

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4. Which identifies the characteristics of the motion of a projectile?

vertical motion accelerated by gravity horizontal is cont.

(A) The vertical velocity is greater than the horizontal velocity.

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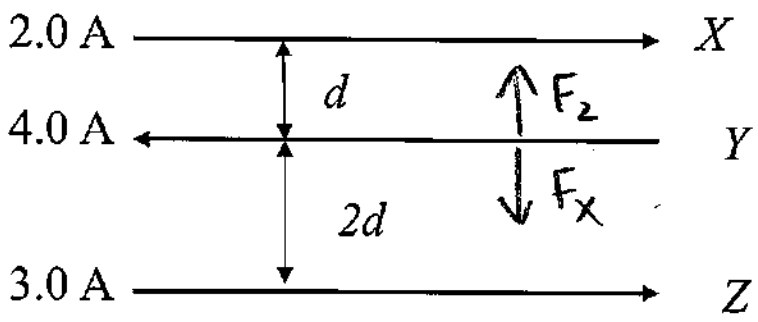
5. Three current-carrying wires are set up as shown. The force on wire Y due to the other two wires in this situation is F.

both opposite direction ∴ repel

$F_{net} = F_x + F_2$
double both
$= 2F_x + 2F_2$
$= 2(F_x + F_2)$
$= 2F_{net}$



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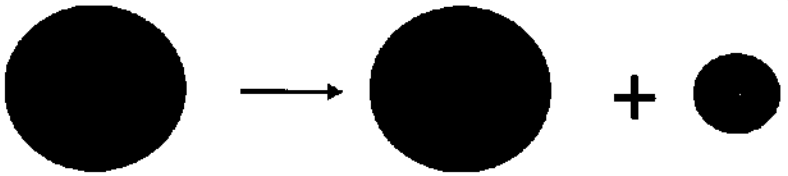
α = 2 proton 2 neutrons



∴ X loses 2 protons + 2 neutrons to become Y

How will the nucleus of Y be different from that of X?

(A) The nucleus of Y will have 2 protons more than the nucleus of X

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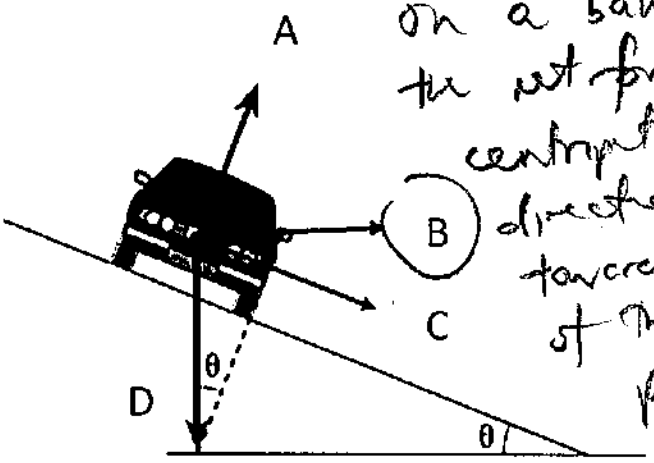

On a banked curve the net force is the centripetal force directed horizontally towards the centre of the circular path

Which arrow, A, B, C, D, represents the **direction** of the net force on the vehicle?

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If the transformer is ideal, what is the current in the primary coil?

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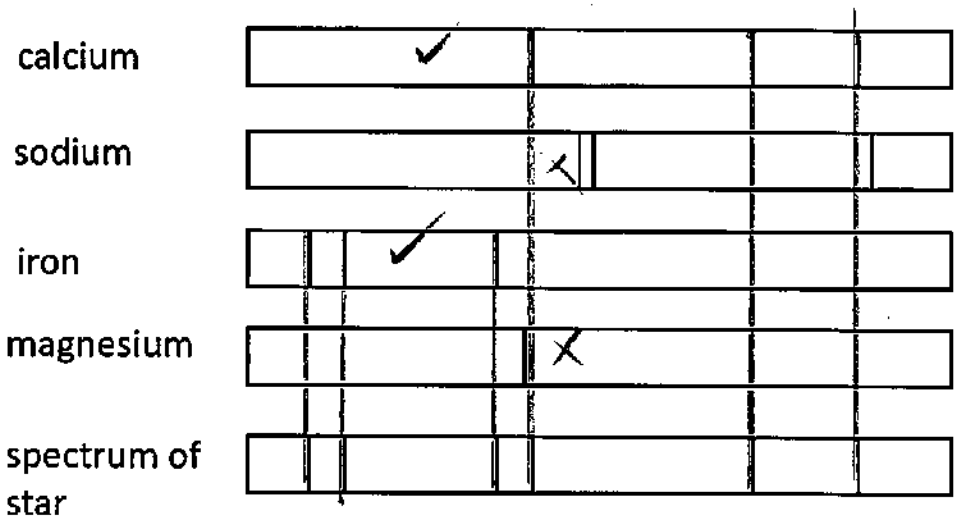
$\frac{V_p}{V_s} = \frac{I_s}{I_p}$ $\frac{1600}{800} = \frac{3.34}{I_p}$

$I_p = \frac{3.34}{2} = 1.67$

14. The absorption spectra of 4 metals and a star are shown below.



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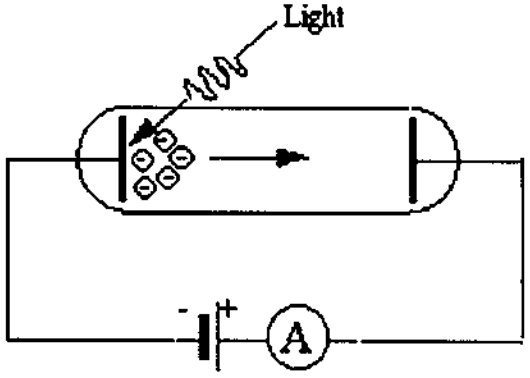

If the intensity of intensity of the light is increased, what other variable will also increase?

(A) maximum photon energy

(B) photon wavelength

(C) maximum electron kinetic energy

(D) photocurrent magnitude

each photon emits a single electron greater intensity = more photons = more current.

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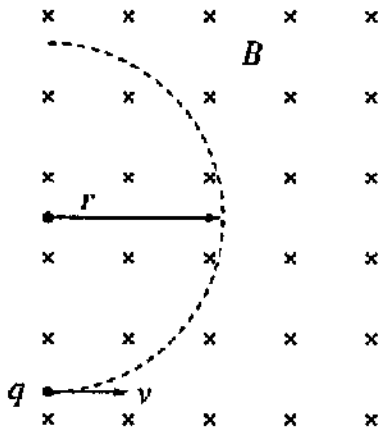

$qvB = \frac{mv^2}{r}$

$r = \frac{mv}{qB}$

$r \propto \frac{1}{B}$ $\frac{r}{2} \propto \frac{1}{2B}$

If the magnitude of the magnetic field was doubled and the other variables were kept constant, what would the new radius be?

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Hornsby Girls High School
HSC Physics Trial 2019

Student Number | | | | | | | | | |

Section I
Multiple Choice Answer Sheet

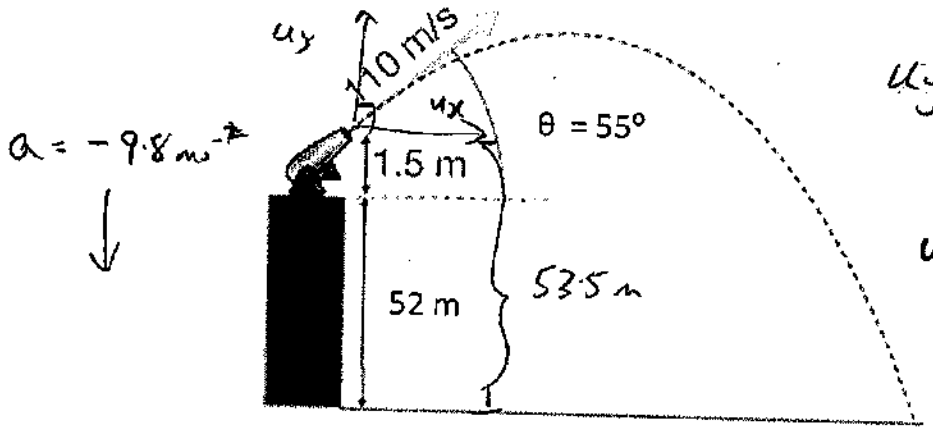
Shade in the oval. If you make a change, clearly indicate which the correct answer is.

1.	A ●	B ○	C ○	D ○
2.	A ●	B ○	C ○	D ○
3.	A ○	B ○	C ○	D ●
4.	A ○	B ○	C ●	D ○
5.	A ○	B ○	C ●	D ○
6.	A ●	B ○	C ○	D ○
7.	A ○	B ○	C ●	D ○
8.	A ○	B ○	C ○	D ●
9.	A ○	B ●	C ○	D ○
10.	A ○	B ●	C ○	D ○
11.	A ●	B ○	C ○	D ○
12.	A ○	B ○	C ○	D ●
13.	A ○	B ○	C ○	D ●
14.	A ○	B ○	C ●	D ○
15.	A ○	B ○	C ○	D ●
16.	A ○	B ○	C ●	D ○
17.	A ○	B ●	C ○	D ○
18.	A ○	B ●	C ○	D ○
19.	A ○	B ○	C ●	D ○
20.	A ○	B ●	C ○	D ○

Student Number

Question 21 (6 marks)

A cannon fired a projectile from a cliff, with an initial velocity of 110 ms^{-1} at an angle of 55° as shown.



$u_y = u\sin\theta$
$= 110\sin 55$
$= 90.1\ ms^{-1}\uparrow$

$u_x = u\cos\theta$
$= 110\cos 55$
$= 63.1\ ms^{-1}\rightarrow$

note: diagram not drawn to scale. Ignore the effect of air resistance in your calculations.

(a) What was the maximum height above ground level reached by the projectile? 3

using vertical component $v^2 = u^2 + 2as$ $v = 0$ at max height

$s = \frac{u^2}{2a} = \frac{90.1^2}{19.6} = 414$ m from cannon mouth

Height above ground $= 414 + 53.5 = 468$ m

$= 470$ m (2 sig figs)

(b) What was the velocity of the projectile at the position of maximum height? 1

$v_x = u_x = 63.1\ ms^{-1}$ $\therefore v = 63\ ms^{-1}$ horizontal $\rightarrow$

$v_y = 0$

(c) How far had the projectile travelled horizontally at the position of maximum height? 2

find t using vertical component $v = u + at$ $v = 0$

$t = \frac{u}{a} = \frac{90.1}{9.8} = 9.19$ s

use horizontal component $s = v_x t$

$= 63.1 \times 9.19 = 580.1$ m

$= 580$ m (2 sig fig)

Question 22 (8 marks)

The table displays data from the 8 planets in our solar system.

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
Mass (x 10^{24}kg)	0.33	4.87	5.97	0.642	1898	568	86.8	102
Diameter (km)	4879	12,104	12,756	6792	142,984	120,536	51,118	49,528
Density (kg/m3)	5427	5243	5514	3933	1326	687	1271	1638
Length of Day (hours)	4222.6	2802	24	24.7	9.9	10.7	17.2	16.1
Orbital Period (days)	88	224.7	365.2	687	4331	10,747	30,589	59,800
Average Distance from Sun (x10^6 km)	57.9	108.2	149.6	227.9	778.6	1433.5	2872.5	4495.1
Perihelion (x10^6 km)	46	107.5	147.1	206.6	740.5	1352.6	2741.3	4444.5
Aphelion (x 10^6 km)	69.8	108.9	152.1	249.2	816.6	1514.5	3003.6	4545.7

The mass of the Sun = 2.00×10^{30} kg.

(a) At what distance from the sun is Mercury travelling with its greatest orbital velocity? Which of Kepler's laws did you use to answer this? 2

At perihelion 46×10^6 km — Kepler's 2nd Law of Areas

(b) What is the average gravitational force between the Sun and Mars? 2

$F = \frac{GM_S M_M}{r^2}$ $M_S = 2.00 \times 10^{30}$ kg $M_M = 0.642 \times 10^{24}$ kg

$r = 227.9 \times 10^9$ m

$= \frac{6.67 \times 10^{-11} \times 2.00 \times 10^{30} \times 0.642 \times 10^{24}}{(227.9 \times 10^9)^2}$

$= 1.65 \times 10^{21}$ N

(c) What is the gravitational field strength on the surface of Saturn?

$g = \frac{GM}{r^2}$ $M = 568 \times 10^{24}$ kg $r = \frac{120536}{2} \times 10^3$ m

$= 60268 \times 10^3$ m

$g = \frac{6.67 \times 10^{-11} \times 568 \times 10^{24}}{(60268 \times 10^3)^2} = \frac{3.788 \times 10^{15}}{3.6 \times 10^{15}}$

$= 10.4$ ms^{-2}

Q22 continued

(d) What is the escape velocity from the surface of Saturn? 2

$\frac{1}{2}mv_2 = \frac{GMm}{r}$

$v = \sqrt{\frac{2GM}{r}} = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 5.68 \times 10^{26}}{60268 \times 10^3}}$

$= 3.55 \times 10^4 \text{ ms}^{-1}$

Question 23 (5 marks)

Students carried out an experiment to determine the relationship between the radius and velocity for a 42 g mass moving with a uniform circular motion. The centripetal force was kept constant for each variation in radius. The time for 10 complete cycles was measured. The results are shown in the table below.

Radius of turn (cm)	time for 10 cycles (s)
10	4.3
20	6.1
30	7.3
40	8.5
50	9.5
60	10.1

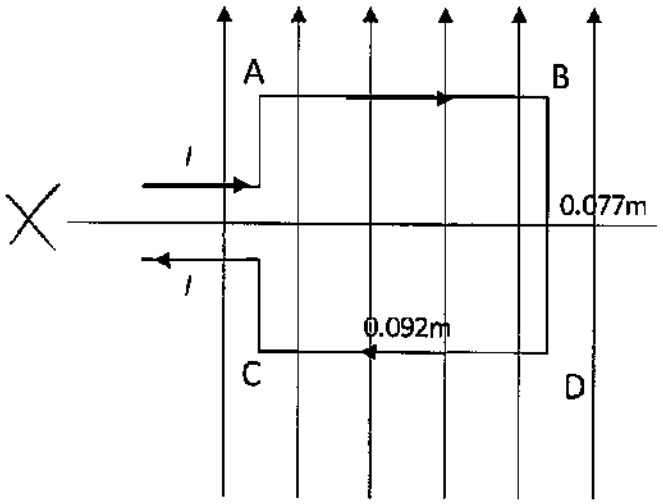
They were asked by their teacher to use all the results to determine the magnitude of the constant centripetal force.

List and explain the steps of the analysis required to calculate the centripetal force. (You are not required to calculate the force.)

1. convert radius into metres so force is in Newtons
2. Divide time by 10 to find time for one cycle.
3. Use centripetal force equation to find the force for each variation $F = \frac{mv^2}{r}$
4. Use $v = \frac{2\pi r}{T}$ to find velocity for F_c equation
5. Average the 6 values to get an average force

Question 24 (6 marks)

A motor uses a coil with 80 turns that has dimensions of 0.092 m by 0.077 m, as shown in the diagram. A current of 1.5 A flows through the coil in the direction shown. The coil is vertical and is in a magnetic field of 5.1×10^{-2} T directed upwards.



(a) What is the magnitude and direction of the magnetic force exerted on side AB? **3**

$F = nBIL$

$= 80 \times 5.1 \times 10^{-2} \times 1.5 \times 0.092$

$= 5.6 \times 10^{-1}$ N out of page

(b) What is the magnitude and direction of the torque experienced by the coil in this position? **2**

$\tau = nBIA \sin\theta \quad \theta = 90 \quad n = 80$

$= 80 \times 5.1 \times 10^{-2} \times 1.5 \times (0.092 \times 0.077) \sin 90$

$= 4.3 \times 10^{-2}$ Nm clockwise as viewed from X

(c) The coil rotates as a result of the applied torque. What would happen to the magnitude of the torque as the coil rotates through 90°? **1**

$\tau \propto \sin\theta$ ∴ torque reduces to zero as a $\sin\theta$ relationship

Question 25 (4 marks)

A rectangular loop of wire is moved at a constant velocity across a magnetic field as shown in the diagram. The plane of the coil is perpendicular to the field lines at all times.

A current flows in the direction shown in Fig 1. and the coil experiences a force in the opposite direction to the motion. However, when the coil is entirely inside the field, Fig. 2, there is no current and no opposing force.

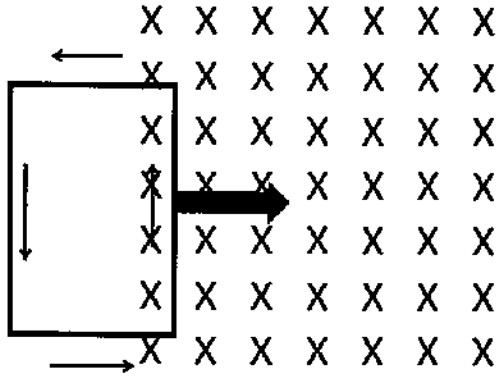


Fig. 1

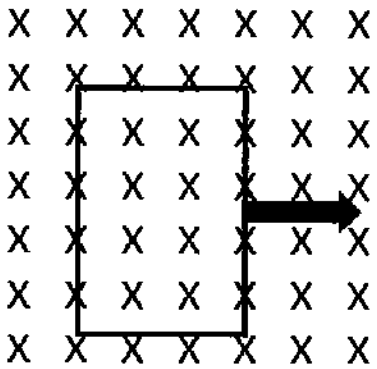


Fig. 2

Use your understanding of Faraday's law and Lenz's law to explain this scenario.

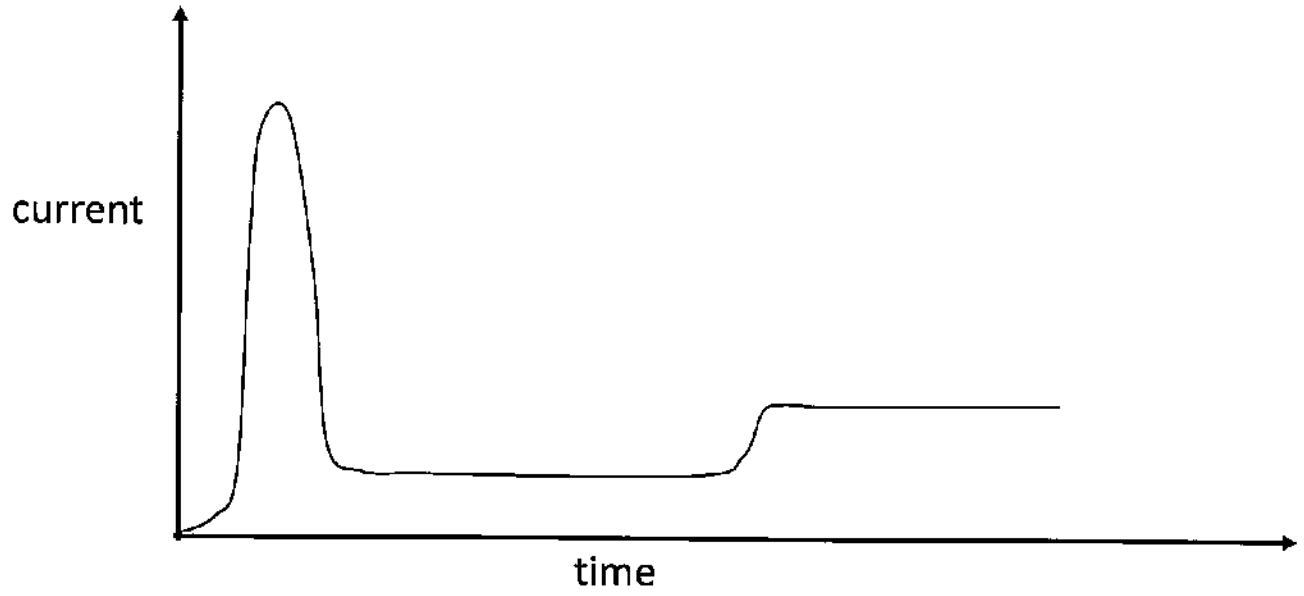
When a conductor experiences a change in flux over time an EMF will be induced (Faraday Law). If there is a closed circuit the EMF will induce a current that will flow in a direction that opposes the change. (Lenz) In figure 1 the loop is experiencing a change in flux and the induced current produces a magnetic field that opposes the motion. In fig 2 there is no change in flux therefore there is no induced current and therefore no opposing force.

Question 26 (5 marks)

A battery operated electric drill was connected to an ammeter to measure the current in the rotor.

When the drill was switched on, the current rapidly increased to 5.5 A and then reduced quickly to a steady value of 0.9 A.

The drill was then used to drill a hole, placing a load on the motor. The current went up to 2.1 A while it was drilling.



Explain why the current changed like this.

The current is due to the net voltage applied to the rotor coil $V_{net} = V_{supply} - V_{back}$ $I = V_{net}/R$
On start up, there is no back EMF so $V_{net} = V_{supply}$ which gives a large current because R is small.
The current causes the coil to rotate, so it experiences a change in flux and a back EMF is induced
V_{net} is reduced, therefore the current drops. The steady rotation produces a constant back emf so the current is constant. When a load is applied, the coil rotation slows. The back EMF is reduced so the net voltage increases which results in a higher current.

Question 27 (6 marks)

Throughout history, light has been a mystery that scientists have tried to explain. During the 1700s, the two prominent scientists Newton and Huygens proposed very different hypotheses on the nature of light.

(a) Compare Newton's and Huygens' models of light, including ONE similarity and ONE difference between them. 4

Newton's model said that light is made of rigid perfectly elastic particles called corpuscles. Huygens proposed that light was a longitudinal wave that propated through a medium called the aether. The is a difference between the two models. A similarity is that both models could be used to explain wave properties like reflection and refraction.

(b) Huygens' model was accepted over Newton's largely due to the experimental work of Thomas Young. What did Young's work show and how did it support Huygens over Newton? 2

Thomas Young's double slit experiment showed that light from two sources showed interference which is a property of waves not particles. Therefore they supported the wave model over the particle model.

Answers

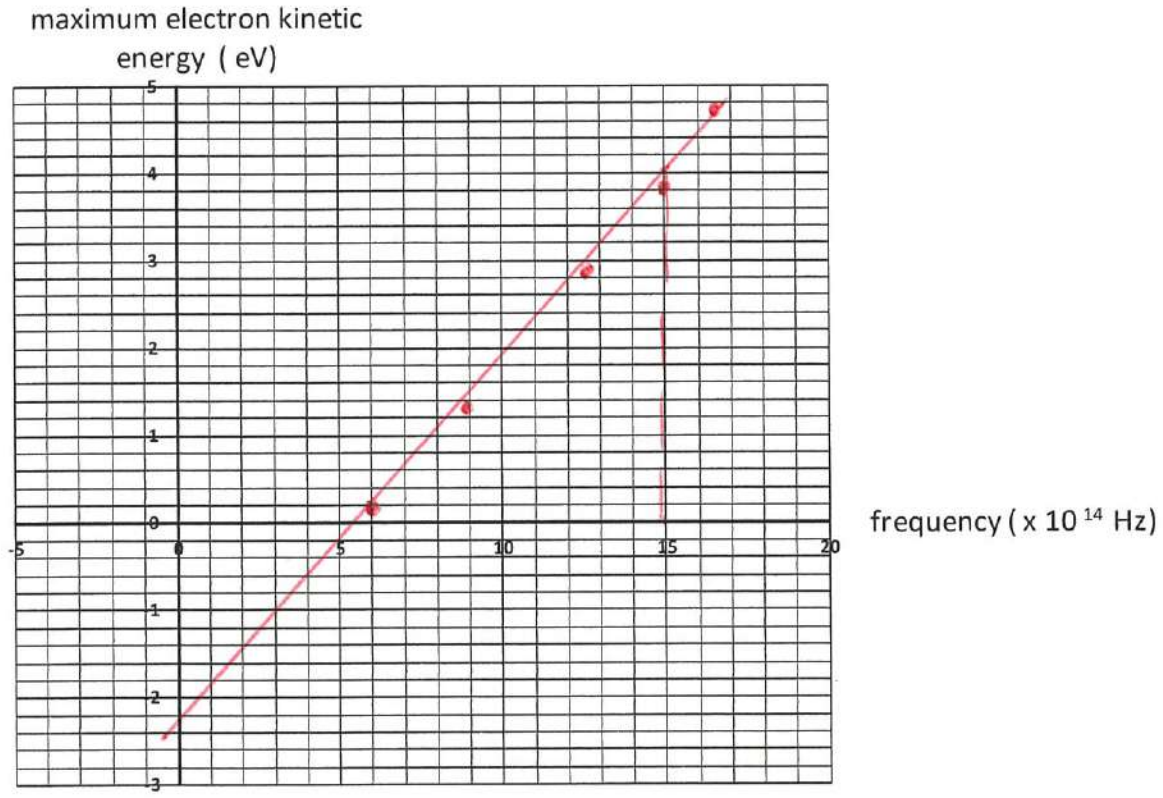
Student Number

Question 28 (5 marks)

Photoelectric effect data using sodium as a target metal is given below.

Light (photon) frequency (x 10^{14} Hz)	Electron kinetic energy (eV)
6.0	0.18
8.8	1.32
12.5	2.85
15.0	3.81
16.4	4.65

(a) Plot a graph of this data. Draw a line of best fit. **2**



(b) Use the graph to:

(i)derive a value for Planck's constant 'h' with unit eVs. Show working on the graph. **2**

gradient = $\frac{4.65-0}{(16.4-5.6)\times10^{14}} = \frac{4.0}{(15-5.6)\times10^{14}}$

$= 4.3\times10^{-15}$ eVs $= 3.77\times10^{-15}$ eVs

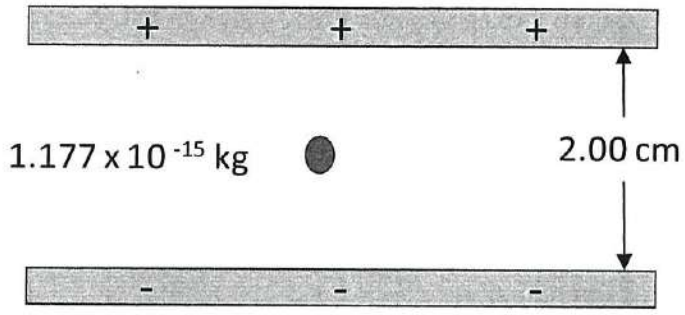
approximate range of values allowed

(b) find the work function for sodium metal. **1**

2.3 eV (±0.2) — from intercept or calculation

Question 29 (4 marks)

An oil drop of mass 1.177×10^{-15} kg falls vertically into the evacuated space between two parallel charged plates, which are 2.00 cm apart. The oil drop is negatively charged.



(a) The voltage is altered so that it slows the oil drop until it is stationary. When the potential difference between the plates is 72.0 V, the oil drop stops moving. How many excess electrons are on the oil drop? **3**

$F_e = F_w \therefore qE = mg$ ✓ 1

$\therefore q\frac{V}{d} = mg$

$q = \frac{mgd}{V} = \frac{1.177 \times 10^{-15} \times 9.8 \times 0.0200}{72}$ ✓ 1

$= 3.20 \times 10^{-18}$ C

No. of $e = \frac{3.20 \times 10^{-18}}{1.6 \times 10^{-19}} = 20$ electrons 1

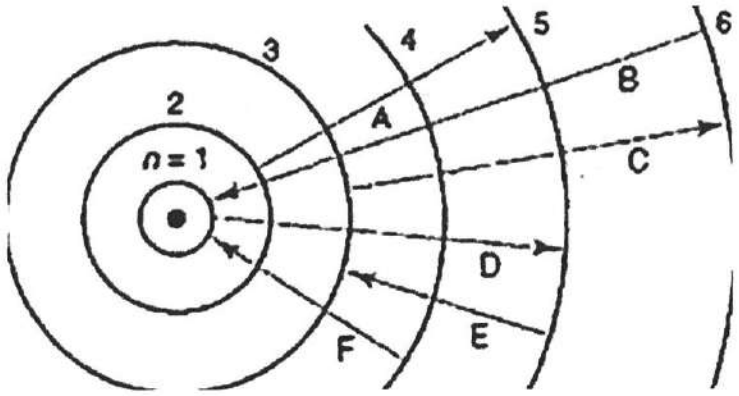
(b) An experiment with a similar approach was used by Robert Millikan. What did he conclude from his investigation? **1**

Charge on electron

(Oil drop charges were an integer multiple of this charge) 1

Question 30 – (4 marks)

The diagram shows a representation of a hydrogen atom.



The atom absorbs a photon of electromagnetic radiation which causes an electron to transition from Level 2 to level 5 – the transition marked A.

(a) What is the frequency of the absorbed photon? **3**

$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ $f = c \times \frac{1}{\lambda}$ ✓

$\therefore \frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{5^2} - \frac{1}{2^2}\right)$ ✓

$\therefore \lambda = 434\ nm$

$c = f\lambda \therefore f = c/\lambda = 6.91 \times 10^{14}\ Hz$ ✓

(b) What would result from an electron transition marked F between level 4 and 1? (No calculation is required). **1**

An emission of an ultraviolet photon ✓

Question 31 (9 marks)

Our understanding of the atom changed significantly between 1904 and 1913 through the contributions of Thompson, Rutherford and Bohr

Outline the main features of each model and explain how each model improved upon the existing model.

- ~~Bohr~~ Thomson - improved on earlier models (ie Dalton) - pioneering work on cathode rays ie. discovered electron in 1897 and determined its charge to mass ratio - very different to q/m for canal rays.

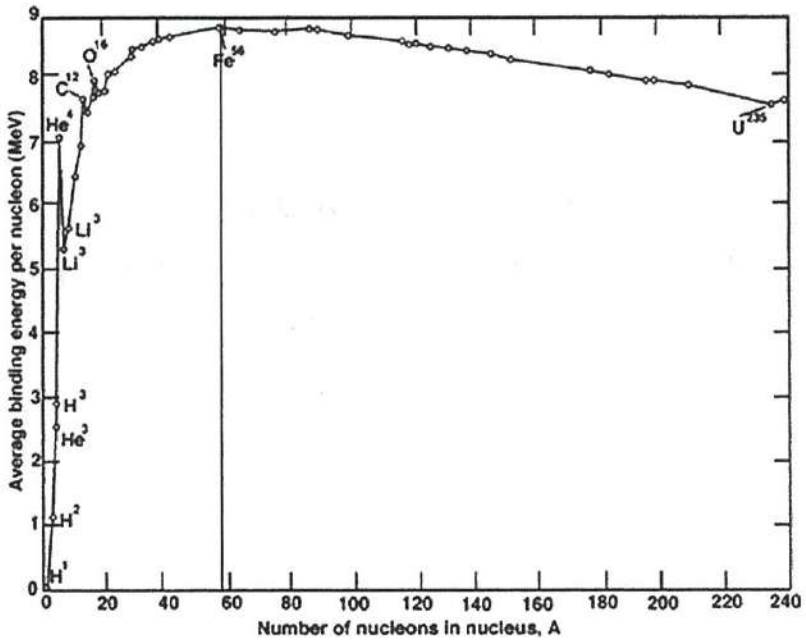
Subsequently Thomson devised his "plum-pudding" model with electrons embedded in a diffuse charge. 3

- Rutherford - Based on the Geiger/Marsden experiment, showed that atoms consist of a compact, dense +ve nucleus surrounded by electron orbits, analogous to planets orbiting the Sun. However, this configuration should collapse in a fraction of a second due to emission of electromagnetic radiation following Maxwell's laws. Also couldn't explain emission/absorption line spectra. 3

- Bohr - breakthrough idea in showing electrons were confined to shells with quantised energy levels. Lines were emitted/absorbed as electrons moved between energy levels. However, Bohr's model was an ad hoc mixture of quantum & classical physics and still couldn't explain why radiation was not lost as electrons orbited. Also, could not explain Zeeman splitting or fine structure. Superseded by Schrödinger model 3

Question 32 (6 marks)

The graph shows the average binding energy per nucleon for a range of elements.



(a) Elements to the left of Fe-56 on the graph are formed by nuclear fusion. Explain how this is related to binding energy. **3**

Binding energy refers to the work needed to dissociate nucleons from a nucleus. In terms of binding energy per nucleon, elements near iron (the iron peak) have the most stable nuclei. Fusion occurs when light elements produce heavier nuclei closer to the iron peak. This process releases energy

(b) A nucleus of U - 235 will break down into 2 smaller nuclei if it captures a neutron.

What is this process called? **1**

Nuclear fission

Question continued on next page

The reaction below shows that, as an example, U-235 can break into Ba-141 and Kr-92.

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

Energy is released in this process.

(c) Where does the energy come from and how could it be calculated? **2**

1 Mass defect — mass of products less than reactions — converted to energy via $E = mc^2$

Question 33 (4 marks)

Muons are unstable subatomic particles that decay into electrons and neutrinos with a mean lifetime of 2.2 μs. They are produced when cosmic rays bombard the upper atmosphere about 11.4 km above the earth's surface, and they travel very close to the speed of light relative to the earth.

Explain how observations of these muons can be used as evidence to support Einstein's Special Theory of Relativity.

Refer to muons generated in upper atmosphere from cosmic ray collisions. Due to their short mean lifetime, even travelling at c, should not be able to reach surface.

1 To the observer, muons experience time dilation.

1 In the muon frame, experiences length contraction due to relativistic speed.

1 Help Confirms Special relativity

Question 34 (8 marks)

A group of students went on an excursion to the reactor at the Australia's Nuclear Science and Technology Organisation. During a walk around the facility, the tour guide stated that a radioactive substance, technetium-99m, which is produced in the reactor, has a decay constant of $3.2 \times 10^{-5}\ s^{-1}$.

(a) What is the half-life of technetium-99m in hours? **2**

$\lambda = 3.2 \times 10^{-5}\ s^{-1}$

$\lambda = \ln 2 / T_{\frac{1}{2}} \quad \therefore T_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = 2.17 \times 10^{3}$ sec

$= 6.0$ hrs.

(b)Technetium-99m is a pure gamma emitter. The activity of two samples of technetium-99m was measured using a Geiger counter. The activity of one sample was found to be three times greater than the other. What does this tell you about the 2 samples? **2**

If activity is three times greater, mass of sample is 3 x greater.

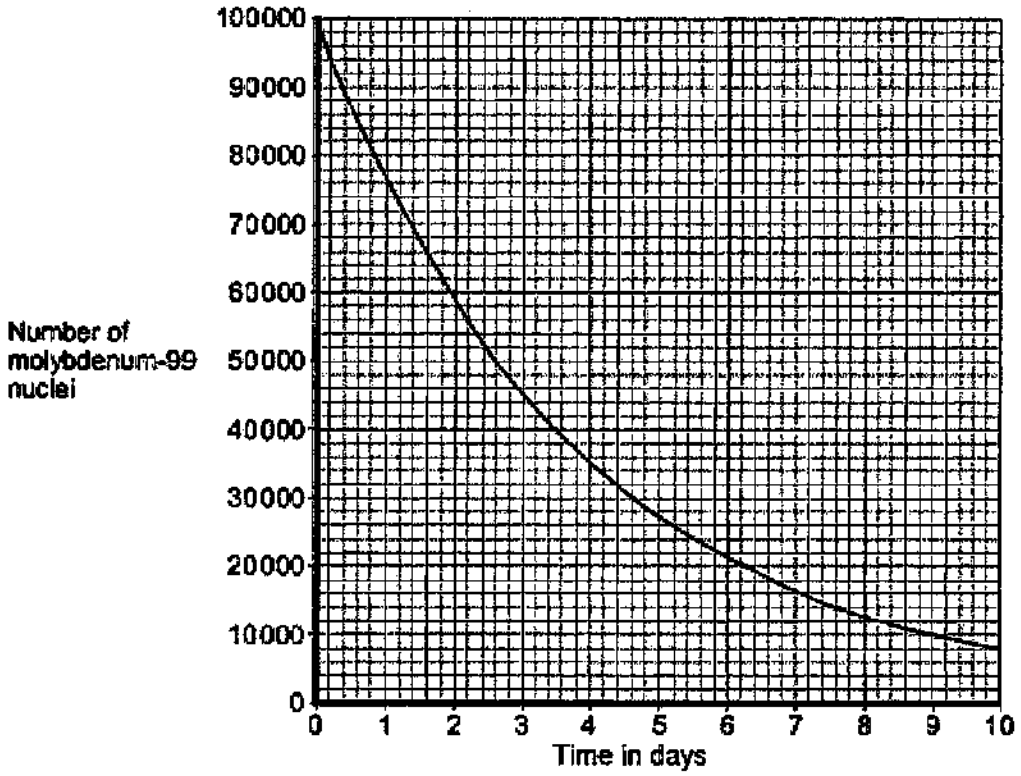
(c) Technetium-99m is formed from the breakdown of molybdenum-99. What type of particle would molybdenum-99 emit to form technetium-99m? **1**

electron

$^{99}_{42}Mo \rightarrow {}^{99m}_{43}Tc + {}^{0}_{-1}e$

Question continued on next page

The graph shows how the number of molybdenum-99 nuclei changes over time as the nuclei decay.



(d) What is the half-life, in days, of molybdenum-99? 1

From graph, $T_{\frac{1}{2}} = 2.6$ days ✓1

(e) What percentage of the original molybdenum-99 is remaining after 8 days? 2

Percentage = 12000/100000 × 100/1 ✓1

= 12% ✓1

(Also using formula)

End of examination