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

Hornsby Girls High School

Physics

Trial Examination 2020

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A data sheet, formulae sheet and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 20 marks

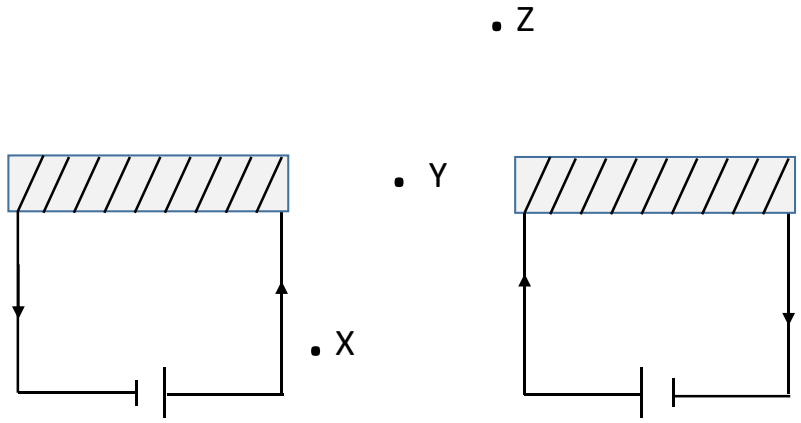
Attempt Questions 1–20
Allow about 35 minutes for this section
Answer on the multiple choice capture sheet

Section II – 80 marks
Attempt Questions 21–34
Allow about 2 hours and 25 minutes for this section

Section I

20 marks Attempt Questions 1–20 Allow about 35 minutes for this section.

1. The diagram below shows the view from above of two electromagnets. The direction the currents are shown by arrows. Points X, Y and Z are in the plane of the two electromagnets.



Which of the following is correct?

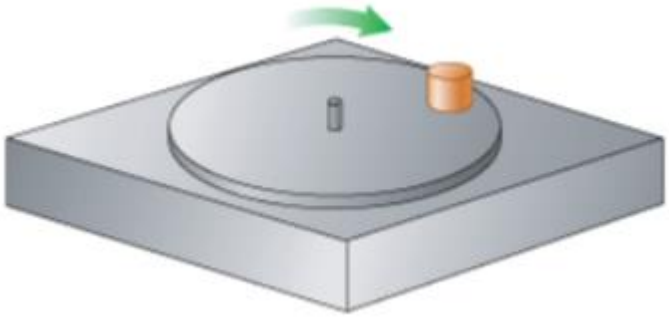
(A) A stationary electron at Z would experience a force to the right

(B) A stationary proton at Z would experience a force to the right

(C) An alpha particle moving to the right at Y would experience a force upwards out of the page

(D) An electron moving to the right at X would experience a force upwards out of the page

2. A block is placed on the edge of a horizontal turntable as shown. The turntable starts rotating from rest and speeds up. At some critical speed the block slides off the turntable.



Which statement is true about this scenario?

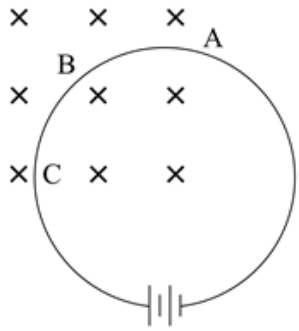
(A) The block slides when the centripetal force is less than friction

(B) The block slides when the centripetal force is greater than friction

(C) The critical speed is independent of the mass of the block

(D) The critical speed is independent of the distance of the block from the centre

3. A length of wire labelled ABC in a uniform magnetic field is connected to an external circuit as shown below



What is the direction of the force acting on the wire at point B?

(A)

(B)

(C)

(D)

4. Which nuclear equation accurately shows the alpha decay of Radium 223?

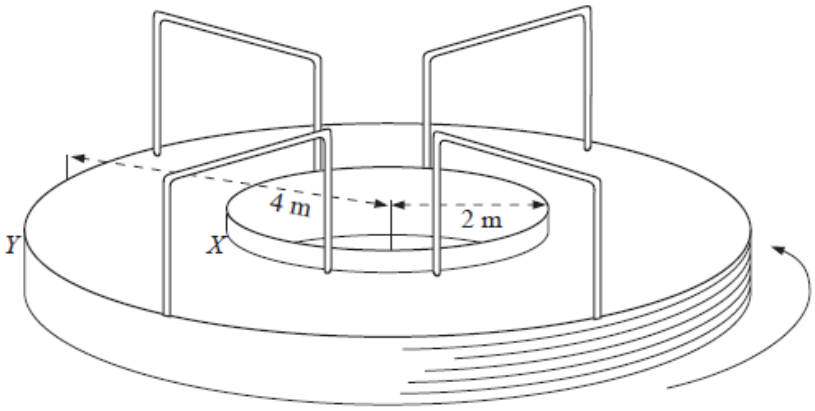
(A) $^{223}_{88}\text{Ra} \rightarrow {}^{219}_{86}\text{Rn} + {}^{4}_{2}\text{He}$

(B) $^{219}_{86}\text{Rn} \rightarrow {}^{223}_{80}\text{Ra} + {}^{4}_{2}\text{He}$

(C) $^{223}_{86}\text{Ra} \rightarrow {}^{219}_{87}\text{Fr} + {}^{0}_{-1}\text{e}$

(D) $^{223}_{88}\text{Ra} \rightarrow {}^{210}_{89}\text{Ac} + {}^{0}_{-1}\text{e}$

5. A merry go round is shown in the diagram. X is a point on the inner edge and Y is a point on the outer edge.



When the merry go round is spinning, which of the following ratios is correct?

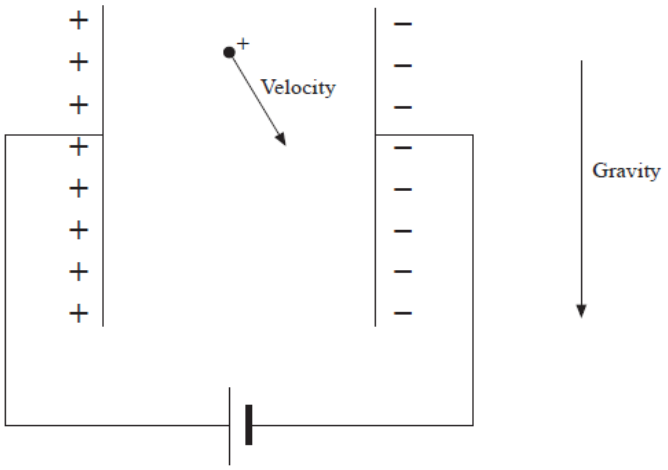
	$\frac{\text{Linear velocity of X}}{\text{Linear velocity of Y}}$	$\frac{\text{Angular velocity of X}}{\text{Angular velocity of Y}}$
(A)	1:1	1:1
(B)	1:2	1:1
(C)	1:2	1:2
(D)	1:1	1:2

6. A very long train is travelling close to the speed of light. An observer on a platform watches the train travel past.

Which of the following statements is true?

(A) Time will appear to be running faster in the train according to the observer on the platform.
(B) The platform will appear longer to the passenger on the train than the observer on the platform.
(C) A passenger on the train and the observer on the platform both measure time slowing in the other frame of reference.
(D) The observer on the platform will observe a longer train while the observer on the train see the platform shortened

7. A small positive sphere is projected into a region between two vertical charged plates as shown. This is performed in a vacuum so there is no air resistance.



While the sphere remains in the uniform field, which statement is correct about the vertical component of its acceleration?

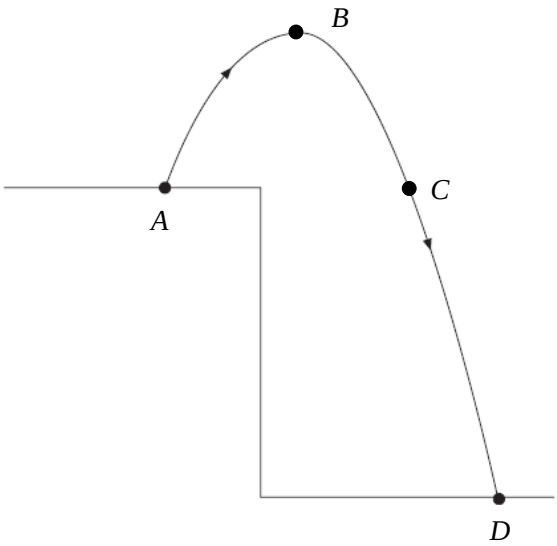
(A) greater than acceleration due to gravity

(B) less than acceleration due to gravity

(C) equal to the acceleration due to gravity

(D) dependent on the size of the field

8. A projectile is launched from the top of a cliff at Point A and lands below at Point D as shown.



Which of the following is correct about the motion of the projectile, if air resistance is ignored?

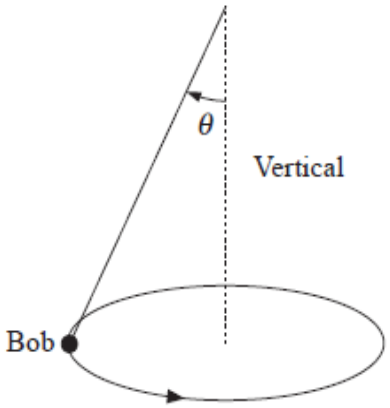
(A) The speed at A is the same as at C

(B) It takes longer to travel from A to B than is does from B to C

(C) The total time of flight is twice the time it takes to reach point B

(D) The horizontal displacement from A to D is independent of the launch velocity

9. The diagram shows a conical pendulum rotating with a constant speed.



Which diagram represents the forces applied to the bob?

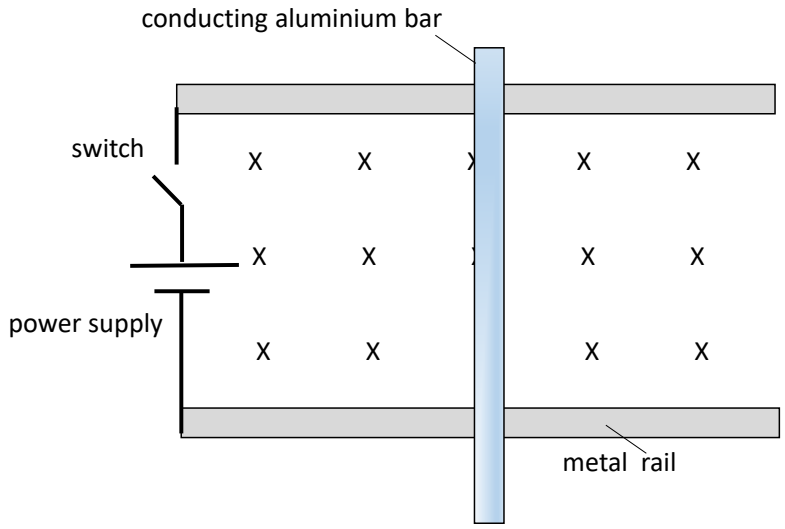
(A)

(B)

(C)

(D)

10. A light aluminium bar is placed on two horizontal metal rails that are connected to a power supply as shown in the top view below. The bar and rails are located in a uniform magnetic field as shown by the X. The bar is not connected to the bar so it is free to move.



What does the bar do when the switch is closed?

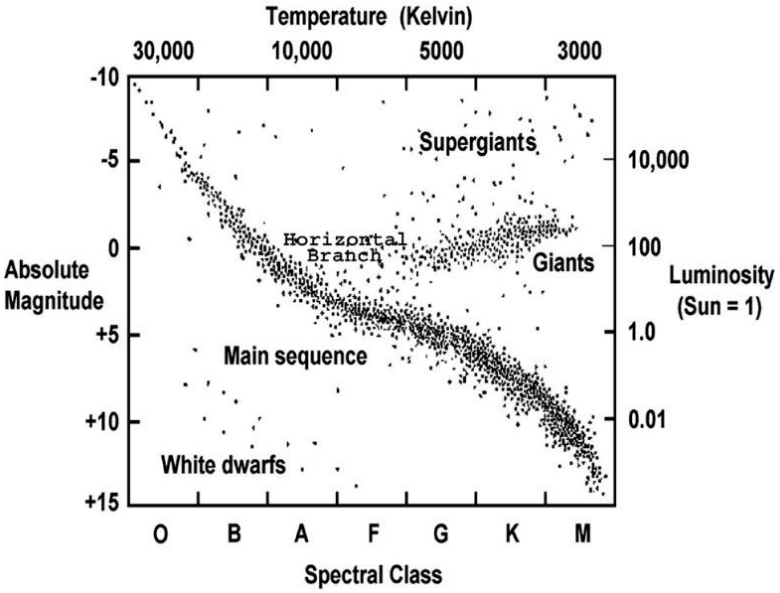
(A) It jumps directly upwards

(B) It moves to the left

(C) It moves to the right

(D) It rotates

11. Sirius A has an absolute magnitude of 1.4 and is a spectral type A star. Which wavelength best approximates the wavelength at which Sirius A is emitting?



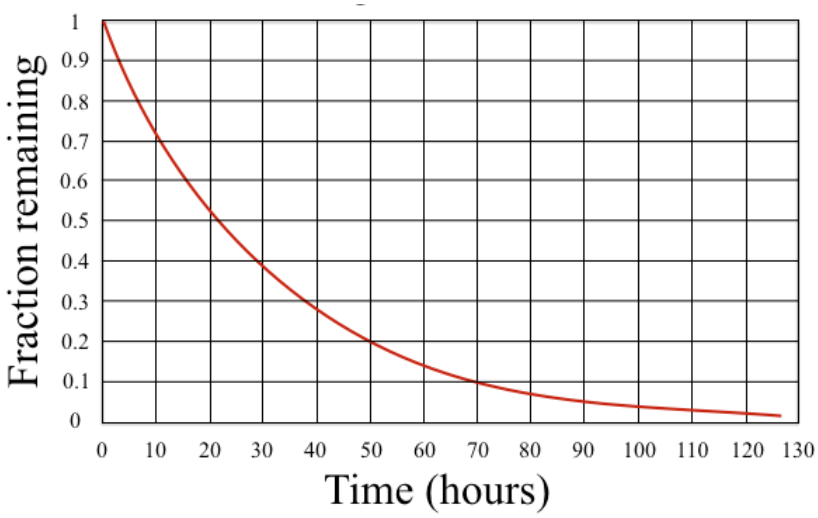
(A) 190 nm

(B) 290 nm

(C) 390 nm

(D) 490 nm

12. The rate of decay of a sample of magnesium-28 was measured over time and the results plotted on the axes shown.



Which of the values below is the radioactive decay constant of magnesium-28?

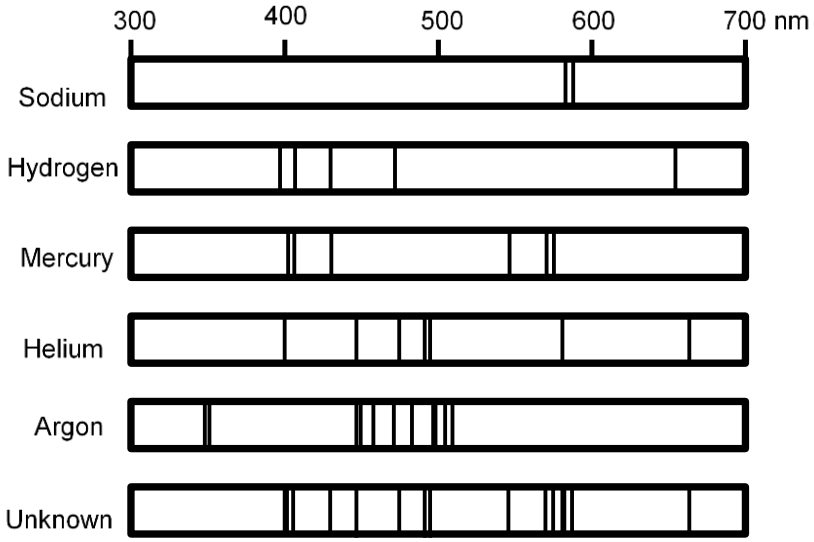
(A) 4.0×10^{1}

(B) 2.0×10^{1}

(C) 5.0×10^{-1}

(D) 3.5×10^{-2}

13. Below is the emission spectrum from an unknown light source.



What elements are present in the light source?

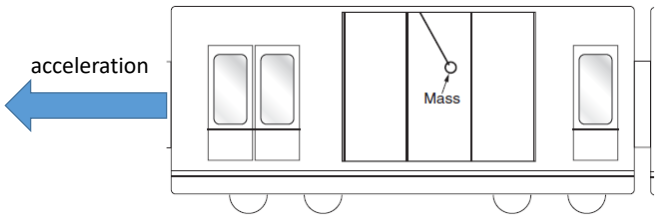
(A) Hydrogen, Mercury and Argon

(B) Mercury, Hydrogen and Helium

(C) Mercury, Helium and Sodium

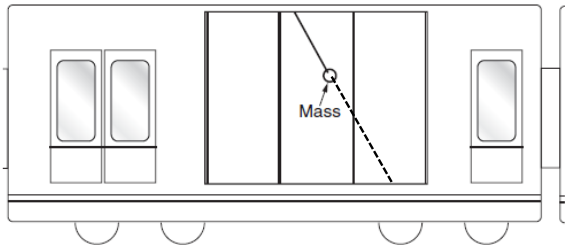
(D) Argon, Sodium and Hydrogen

14. A train is accelerating uniformly to the left. A mass on a string makes a constant angle to the vertical as shown.

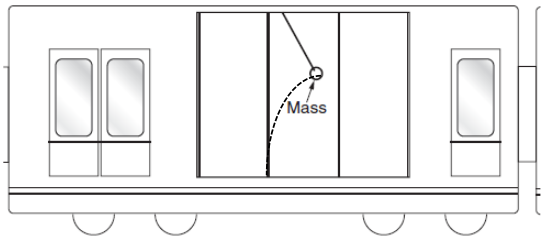


The string breaks and the mass falls. Which diagram show the trajectory of the mass as observed by a person sitting in the train?

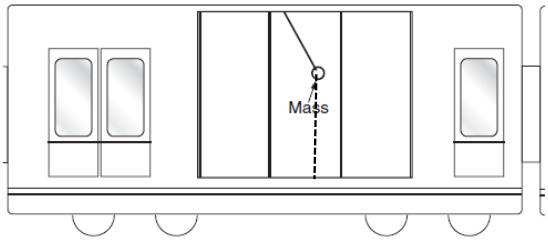
(A)



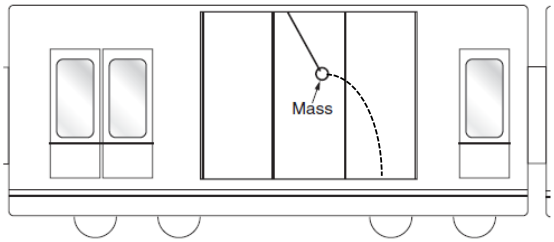
(B)



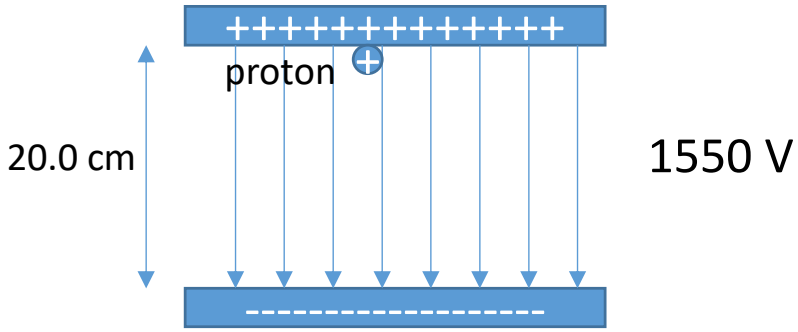
(C)



(D)



15. A proton is accelerated by an electric field between parallel plates with a potential difference of 1550V. The proton starts from the positive plate as shown.



What is the de Broglie wavelength of the proton when it reaches the bottom plate?

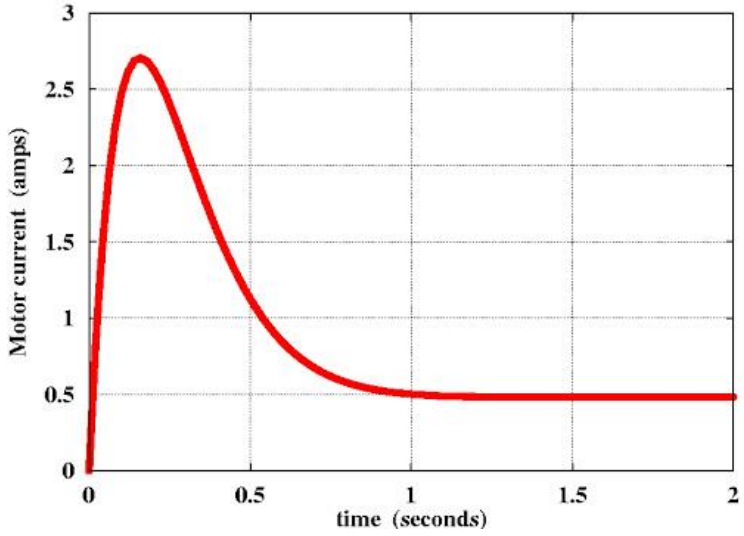
(A) 2.91×10^{-22} m

(B) 7.28×10^{-13} m

(C) 1.38×10^{12} m

(D) 3.41×10^{21} m

16. The graph shows how the current in a brushed motor varies after start up.



Which statement is true?

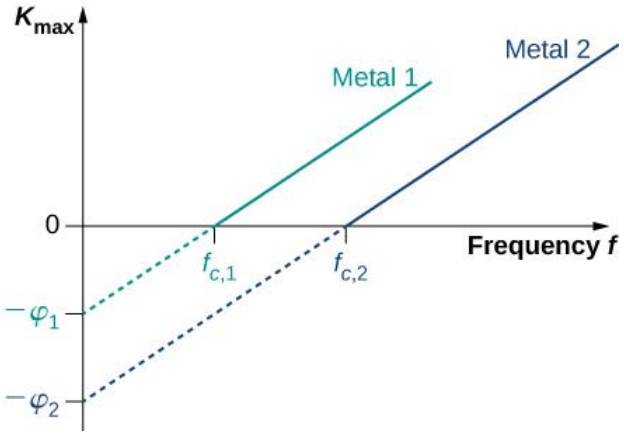
(A) As the motor gains speed the momentum increases reducing the input energy required

(B) As the speed of the motor increases the back emf increases which reduces the net emf

(C) The current changes because the input voltage is changing to keep the speed constant

(D) The resistance of the rotor increases as it heats up which reduces the current in the first 0.5 s

17. Light is shone onto two metals to investigate the photo electric effect.



Which statement is true about the two metals?

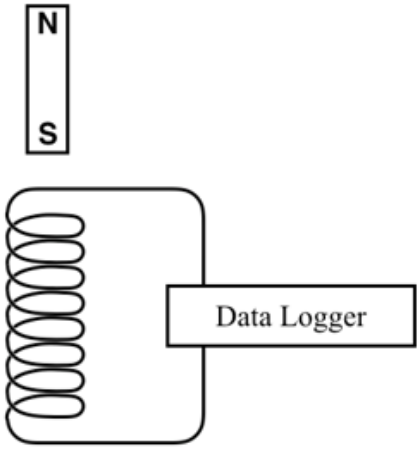
(A) Metal 1 has a greater work function than Metal 2

(B) Metal 2 has a lower threshold frequency than Metal 1

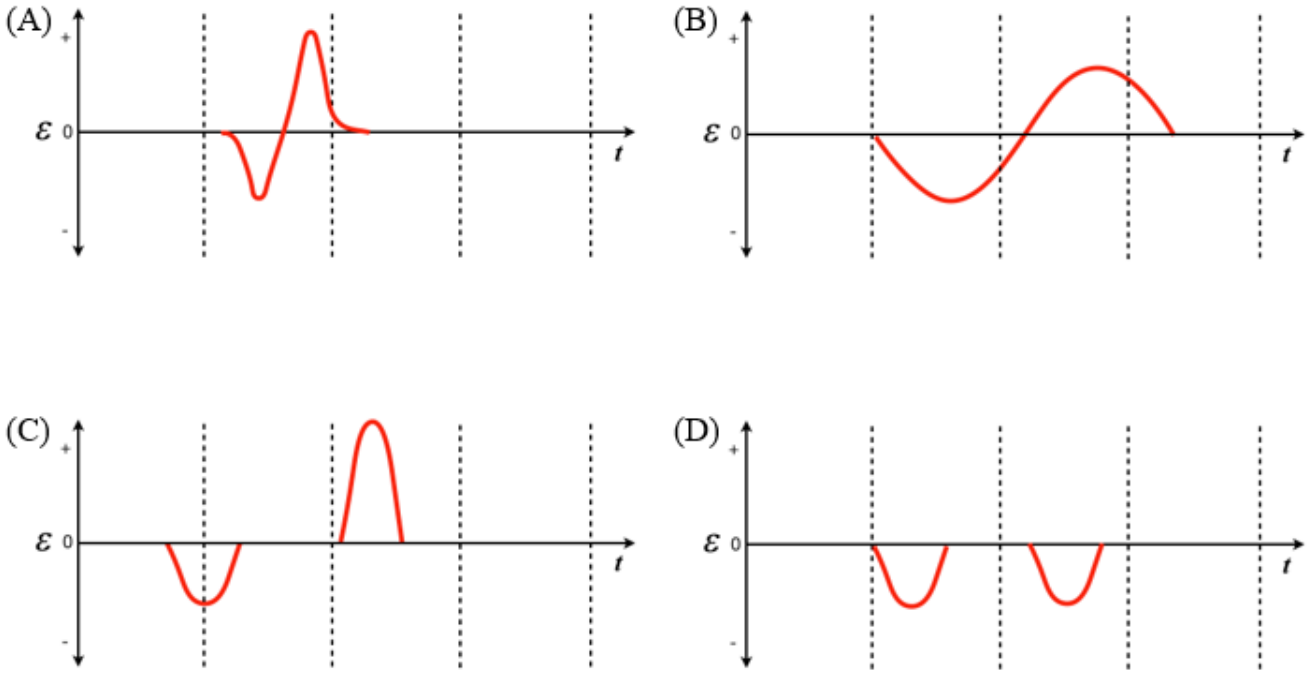
(C) For both metals a higher frequency will produce a greater current

(D) Metal 1 will emit electrons over a greater range of light frequencies

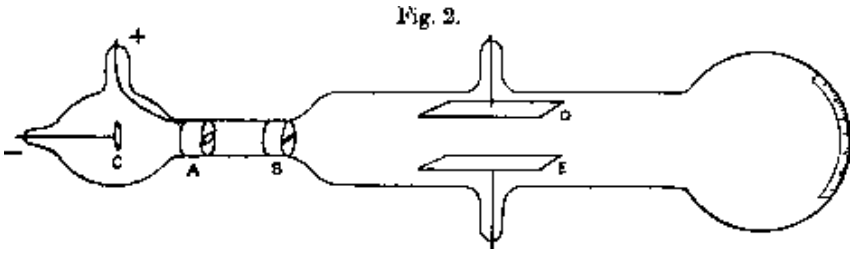
18. In an experiment a magnet was dropped through a solenoid and the emf generated was recorded by a data logger.



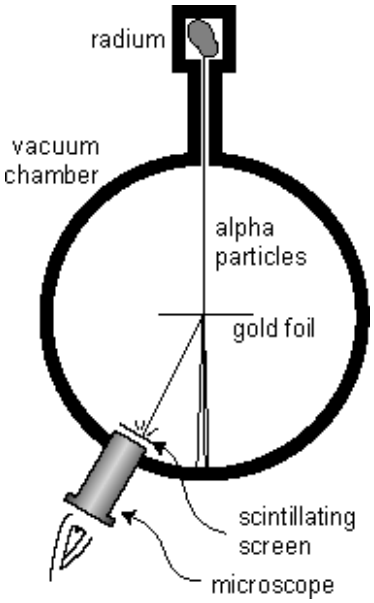
Which graph shows the result of this experiment?



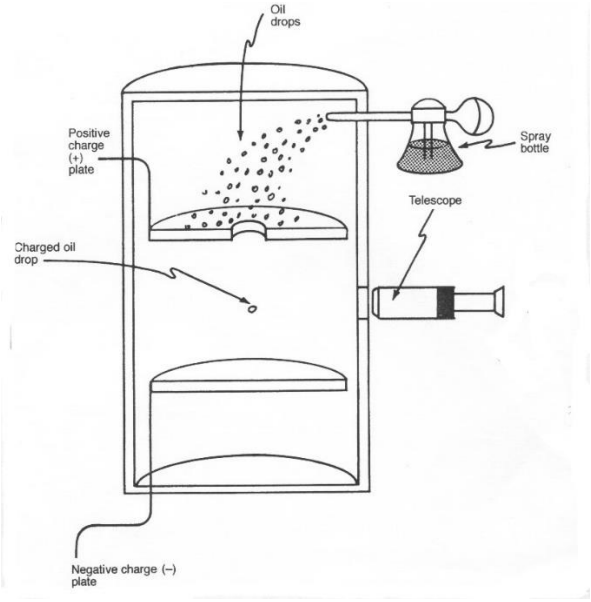
19. The diagrams show different apparatus that used to explore different aspects of the atom.



Appartus 1



Appartus 2

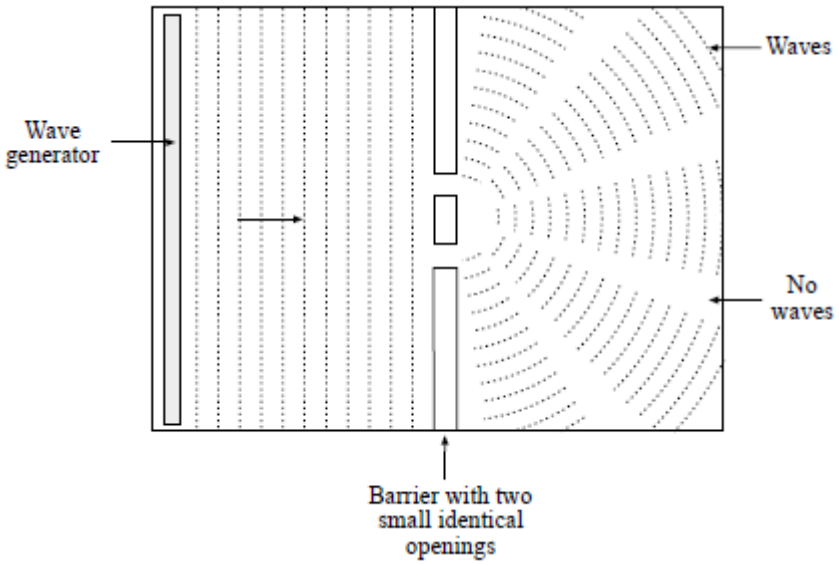


Appartus 3

Which option correctly links the scientist to the apparatus they used?

	Apparatus 1	***Apparatus 2***	***Apparatus 3***
(A)	Thomson	Rutherford	Milliken
(B)	Milliken	Chadwick	Thomson
(C)	Crookes	Geiger	Davisson
(D)	Crookes	Chadwick	Milliken

20. The diagram shows water waves passing through two openings in a barrier.



Which two aspects of wave behaviour best explain the pattern on the right hand side of the barrier?

(A) refraction and reflection

(B) refraction and diffraction

(C) diffraction and interference

(D) interference and polarisation

Section II

80 marks Attempt all questions in the spaces provided.

Questions 21–36 Allow about 2 hours and 25 minutes for this section

Question 21 (7 marks)

The table contains information about two planets, Neptune and Pluto, which were discovered after Kepler died.

Planet	Orbital period (earth years)	Average distance from the sun (km)	Diameter (km)	mass (kg)
Neptune	165	4.48×10^9	49200	1.02×10^{26}
Pluto	248	5.91×10^9	2380	1.31×10^{22}

a) Show that the information in the table is consistent with Kepler's 3rd law. 2

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b) Calculate the acceleration due to gravity on the surface of Neptune. 2

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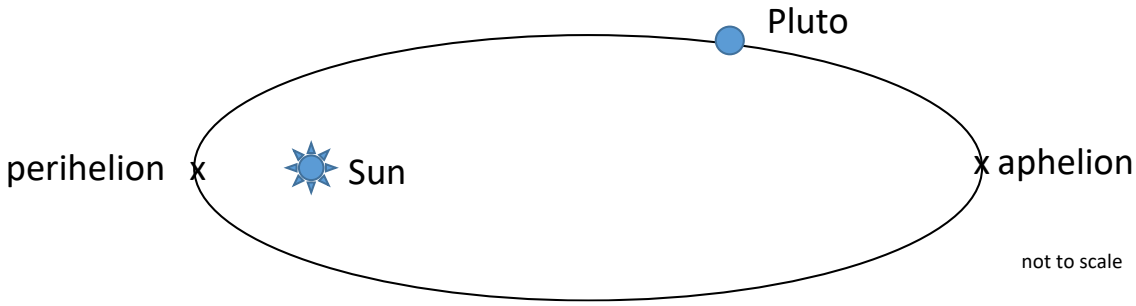
Question 21 continued on next page

c) Pluto has an elliptical orbit with an eccentricity of 0.244.



Compare the orbital velocity and gravitational potential energy of Pluto at the perihelion and at the aphelion. 3

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Question 22 (3 marks)

Derive the escape velocity equation, including specific reference the relevant physical principle.

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

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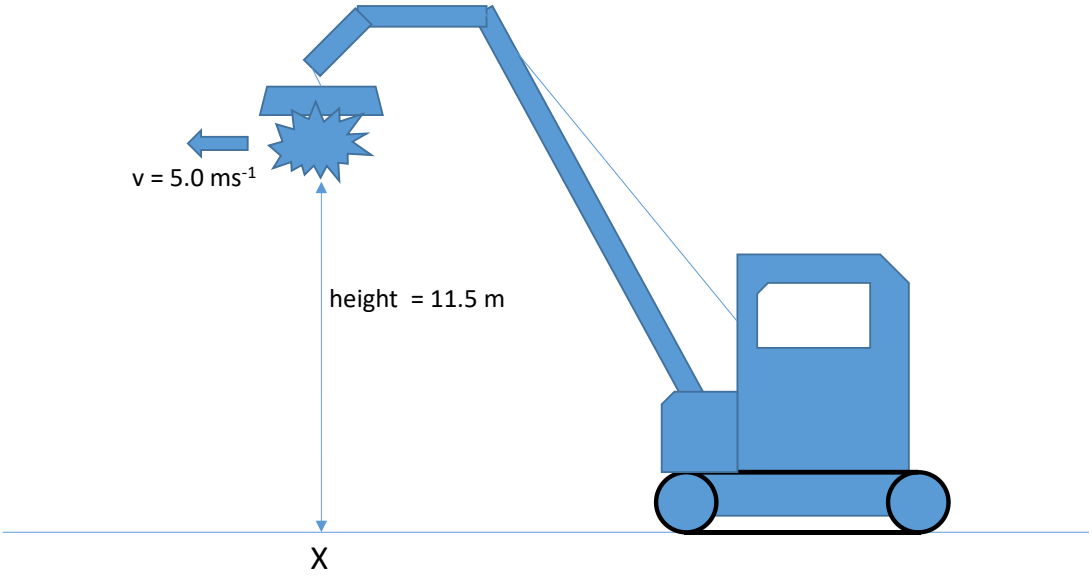
Question 23 (7 marks)

A crane uses an electromagnet to lift a 2000 kg crushed car to a height of 11.5 m and then moves it sides with a velocity of 5.0 ms^{-1}.

When the car is directly about point X, power is suddenly cut and the car falls to the ground.



a) How long does it the car take to reach the ground? 2

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b) How far from point X does the car hit the ground? 2

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Question 23 continued on next page

c) What is the velocity of the car upon impact? 3

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Question 24 (3 marks)

Explain why the presence of a bank on a curve allows a racing car to travel faster than on a horizontal curve with the same radius.

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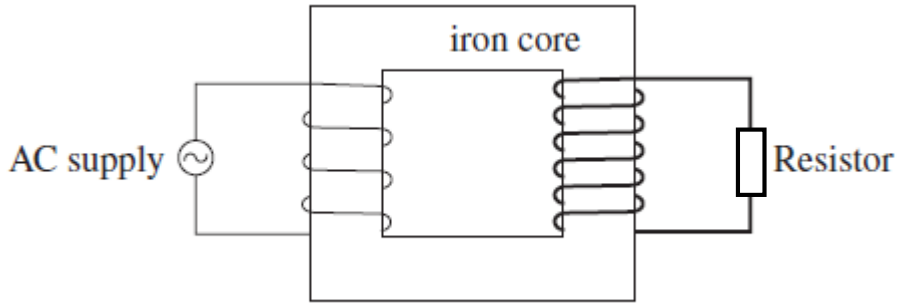
Question 25 (5 marks)

A step-up transformer is constructed using a laminated iron core. The coils are made using copper wires of different thicknesses as shown.



a) Explain why the supply is AC not DC. 2

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b) 20.0 Volts is applied to the primary coil. The input power is 15.0 W. The output current is 0.5 A and the 14.0 W is dissipated by the resistor.

Determine the voltage across the resistor and the efficiency of the transformer. 3

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Question 25 continued on next page

c) Given the ratio of turns is 2:3, the calculated value is different to the voltage predicted by this ratio. Explain why this is the case. 2

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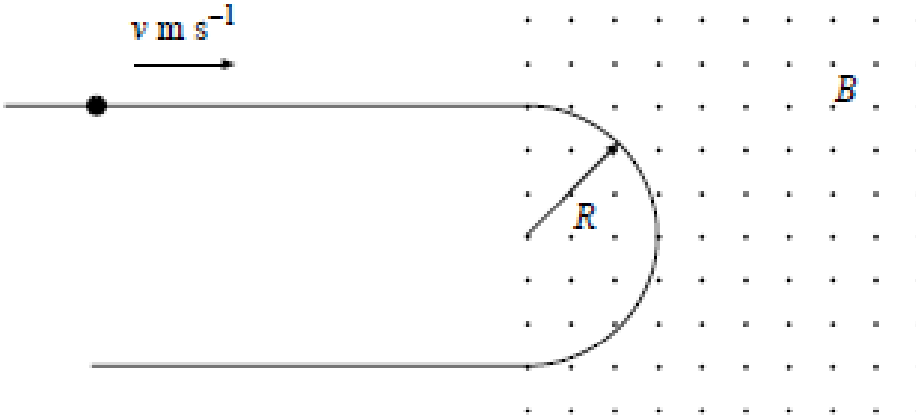
Question 26 (5 marks)

A proton is projected into a uniform magnetic field and follows a semicircular path as shown.



a) Explain the shape of the path. 3

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b) Another proton is projected along the same initial path at half the speed. Sketch the path of the second proton. 2

Question 27 (4 marks)

The proton- proton chain and CNO cycle are processes that release energy in stars.

a) What, besides energy, is the main product of both of these reactions? 1

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b) In what type of stars would these processes be occurring? 1

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c) Outline one fusion process other than the proton- proton chain and CNO cycle that occurs in stars. 2

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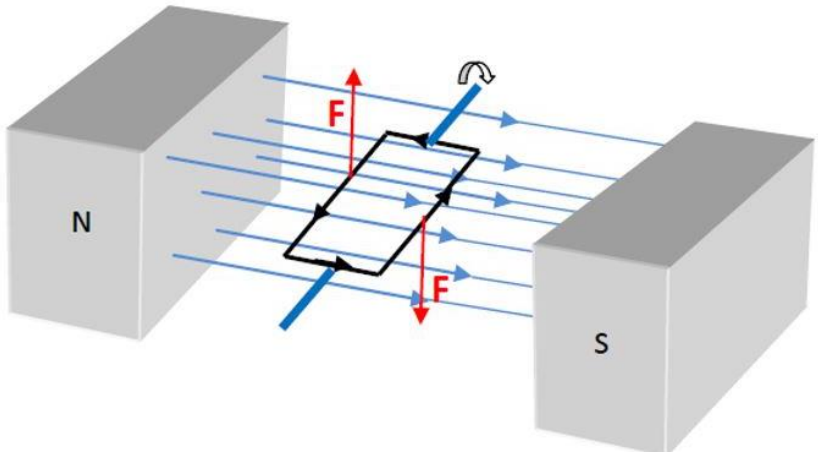
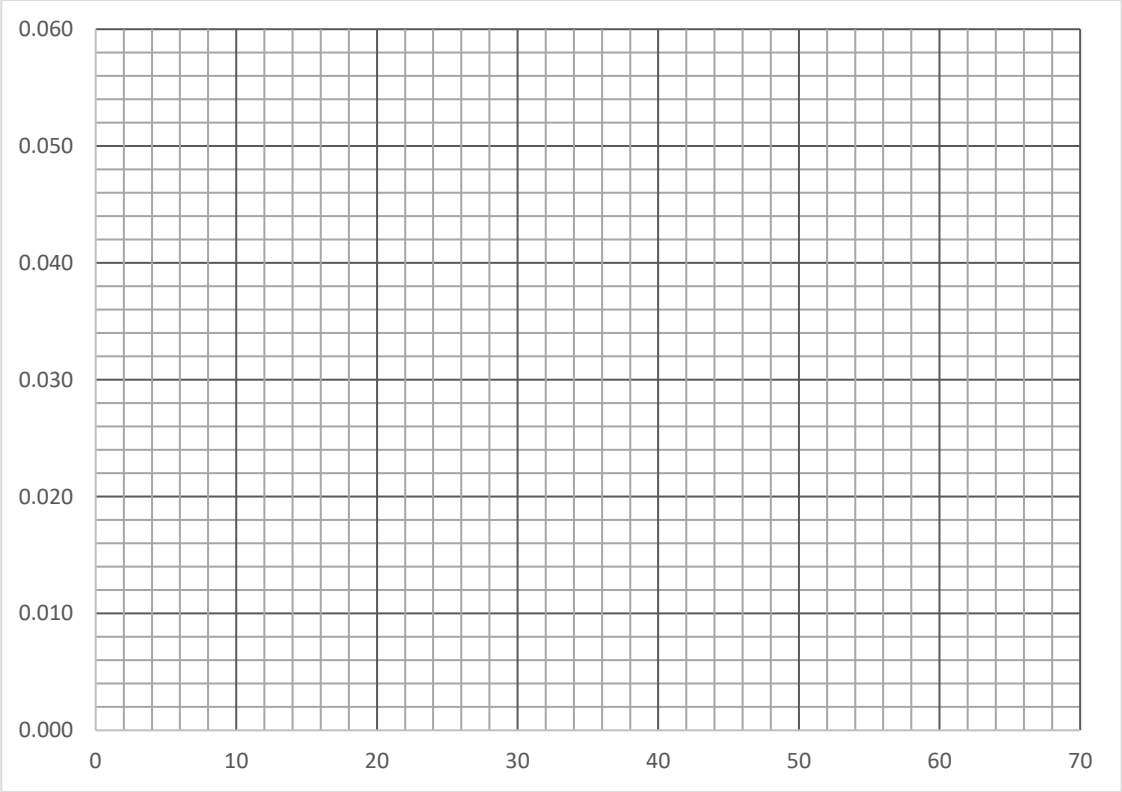
Question 28 (7 marks)

A single rectangular loop is able to rotate inside a uniform magnetic field as shown. The normal to plane of the coil is initially perpendicular to the field lines, making an angle of 90°. The coil is allowed do rotate and the torque is measured at the angles shown in the table.



Angle °	Torque (Nm)
25	0.025
35	0.034
45	0.042
55	0.049
65	0.054

a) On the grid provided, plot a graph of *torque vs angle.* 2



b) The trend line appears to show that τ is directly proportional to the angle Θ. Assess the validity of drawing a straight line for this data. 2

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Question 28 continued on next page

c) Predict the torque when the angle is 90º. 1

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c) In a real motor the torque output needs to be uniform. Outline how one design feature of a real motor produces a much more uniform torque. 2

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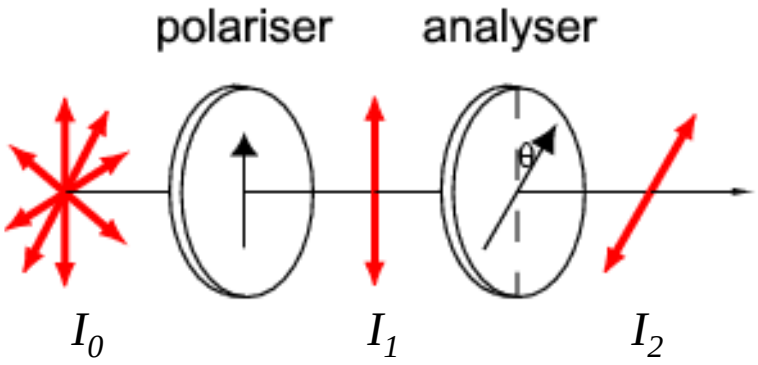
Question 29 (3 marks)

A beam of unpolarised light is passed through two polarising filters as shown. The plane of polarisation of the analyser is at an angle θ = 40º to the polariser.



The initial light, I_0, incident on the polariser is 3.47×10^{-2} W m^{-2}.

a) What is the intensity of the light, I_2 after it has passed through both filters? 2

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b) What characteristic of the wave model of light is supported by the fact it can be polarised? 1

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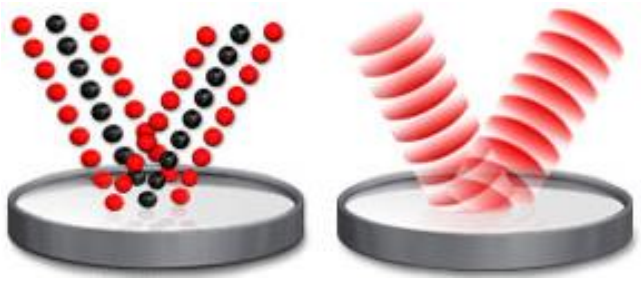
Question 30 (7 marks)

The diagram shows two different models of light that were around in the late 1600s



Particles Waves

a) Which of these models was proposed by Newton? 1

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b) With reference to general characteristics of scientific models, why was Newton's model rejected in favour of the model proposed by Huygens? 2

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c) In the currently accepted model of light, light has a dual wave particle nature. Why is this duality necessary? Provide examples to support your answer. 4

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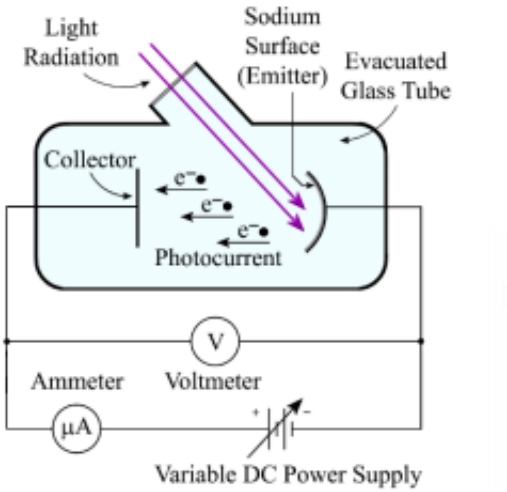
Question 31 (5 marks)

When visible light is incident on a clean sodium surface, photoemission can occur. The work function of sodium is 3.7×10^{-19} J.



a) Monochromatic light with a wavelength of 651 nm is directed onto the sodium surface. Does photoemission occur? Support your answer with relevant maths. 2

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b) The intensity of the light is doubled. Explain how this affects the emission of electrons from the sodium surface. 3

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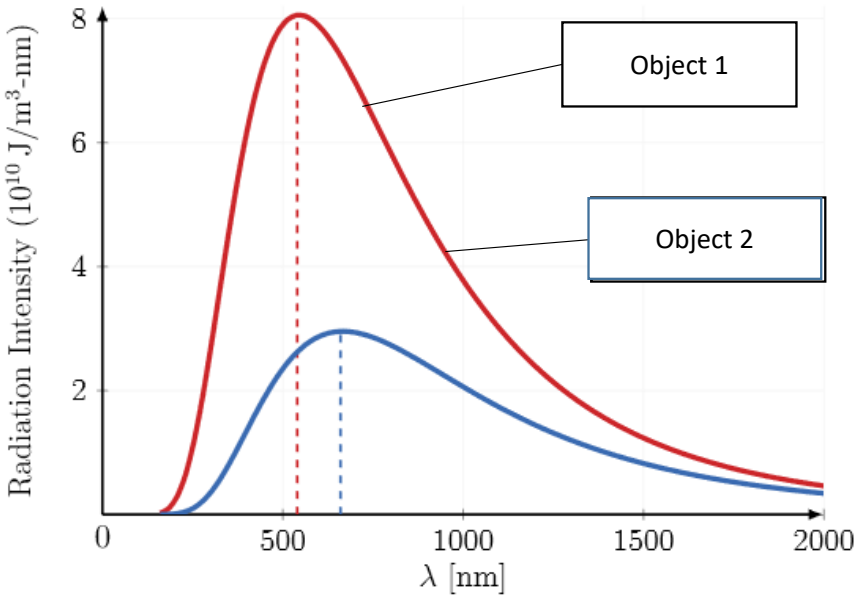
Question 32 (7 marks)

The graph shows the black body radiation curves for two objects.



a) Compare the temperatures of the two objects. 2

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b) Compare the power output of the two objects. 2

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Question 32 continued on next page

c) If these objects were stars in our galaxy and Object 1 was at twice the distance as Object 2 from Earth, compare how bright they would appear. 3

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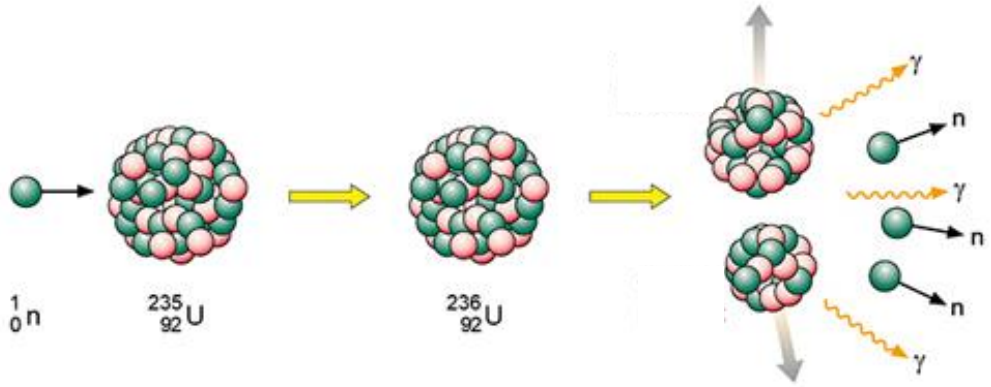
Question 33 (9 marks)

The diagram shows what can happen when a nucleus of uranium 235 captures a neutron.



Uranium 235 has been used as a fuel in both atomic weapons and in nuclear power stations. With reference to the diagram and relevant physical principles, explain how Uranium 235 can be used for both of these applications.

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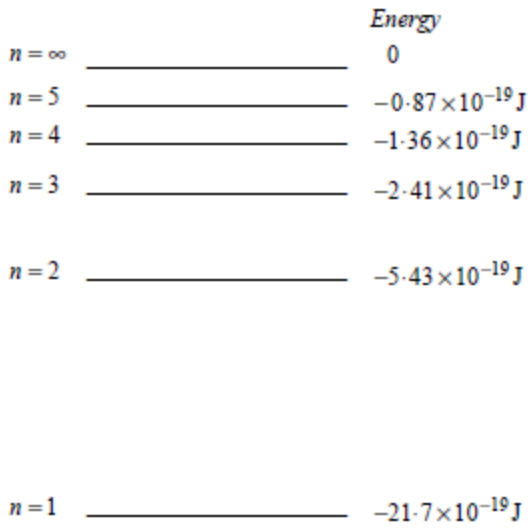
Question 34 (6 marks)

The diagram shows some of the energy levels for a hydrogen atom.



a) For an electron to move from n =2 to n = 5, what energy photon would it need to absorb? 2

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b) How would this appear in the spectrum produced by passing white light through hydrogen gas? 1

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c) How did de Broglie explain the presence of the different electron energy levels in a hydrogen atom? 3

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Extra writing page – if you use this page, clearly indicate which question you are answering as well as noting this in the question book – eg Q 19 continued on back page.

Extra writing page – if you use this page, clearly indicate which question you are answering as well as noting this in the question book – eg Q 19 continued on back page.

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

Hornsby Girls High School

Physics

Trial Examination 2020

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA may be used
- A data sheet, formulae sheet and Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 20 marks

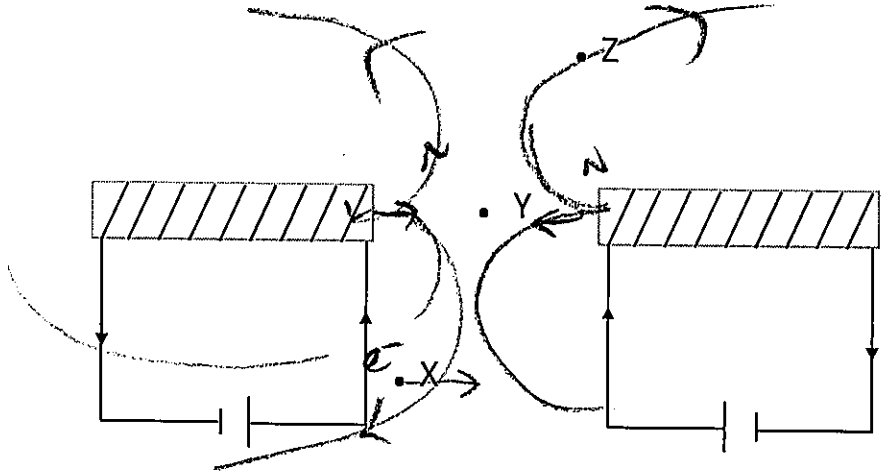
Attempt Questions 1–20
Allow about 35 minutes for this section
Answer on the multiple choice capture sheet

Section II – 80 marks
Attempt Questions 21–34
Allow about 2 hours and 25 minutes for this section

Section I

20 marks Attempt Questions 1–20 Allow about 35 minutes for this section.

1. The diagram below shows the view from above of two electromagnets. The direction the currents are shown by arrows. Points X, Y and Z are in the plane of the two electromagnets.



Which of the following is correct?

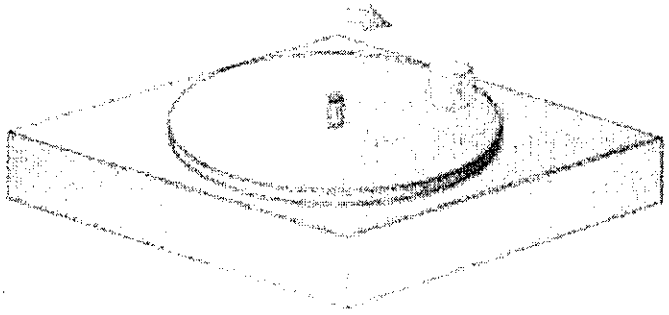
(A) A stationary electron at Z would experience a force to the right stationary No force

(B) A stationary proton at Z would experience a force to the right

(C) An alpha particle moving to the right at Y would experience a force upwards out of the page NO FIELD NO FORCE

(D) An electron moving to the right at X would experience a force upwards out of the page

2. A block is placed on the edge of a horizontal turntable as shown. The turntable starts rotating from rest and speeds up. At some critical speed the block slides off the turntable.



$F = \frac{mv^2}{r} = mr\omega^2 = F_f$

friction provides F_c

∴ if more friction is needed than is available block slides

Which statement is true about this scenario?

(A) The block slides when the centripetal force is less than friction

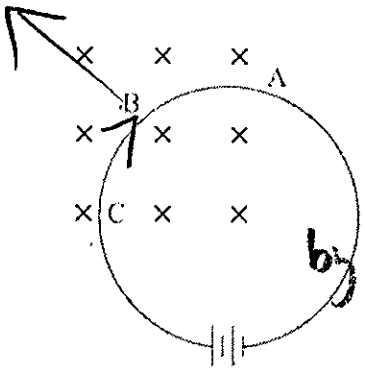
(B) The block slides when the centripetal force is greater than friction

(C) The critical speed is independent of the mass of the block – since F_f depends on mass

(D) The critical speed is independent of the distance of the block from the centre

from formula above

3. A length of wire labelled ABC in a uniform magnetic field is connected to an external circuit as shown below

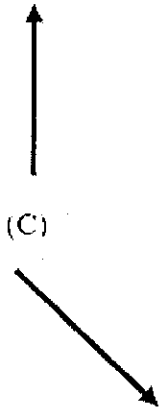


by RHR

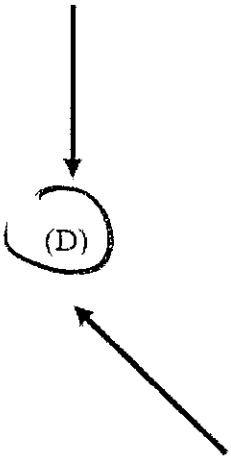
fingers into page
palm points in direction shown

What is the direction of the force acting on the wire at point B?

(A)



(B)



(C)

(D)

4. Which nuclear equation accurately shows the alpha decay of Radium 223?

(A) $^{223}_{88}Ra \rightarrow {}^{219}_{86}Rn + {}^{4}_{2}He$

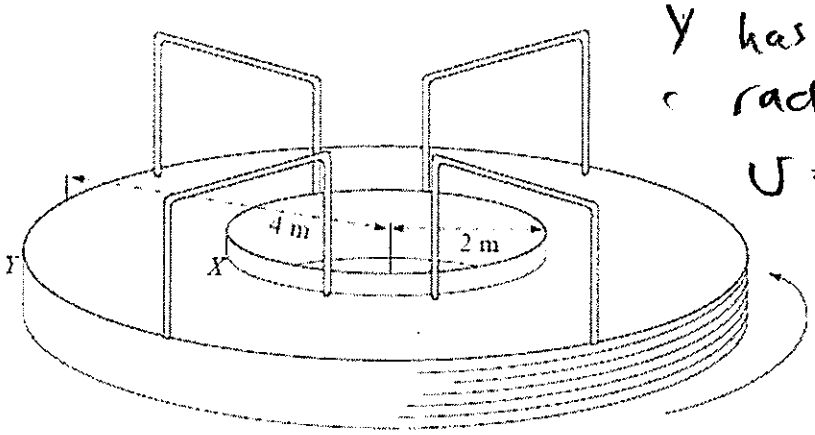
(B) $^{219}_{86}Rn \rightarrow {}^{223}_{80}Ra + {}^{4}_{2}He$

(C) $^{223}_{86}Ra \rightarrow {}^{219}_{87}Fr + {}^{0}_{-1}e$

(D) $^{223}_{88}Ra \rightarrow {}^{210}_{89}Ac + {}^{0}_{-1}e$

atomic mass down by 4
atomic number down by 2
4 He emitted

5. A merry go round is shown in the diagram. X is a point on the inner edge and Y is a point on the outer edge.



Y has twice the radius.
$v = \frac{2\pi r}{T}$
so twice v

When the merry go round is spinning, which of the following ratios is correct? rotating together / so same angular velocity

	$\frac{\text{Linear velocity of X}}{\text{Linear velocity of Y}}$	$\frac{\text{Angular velocity of X}}{\text{Angular velocity of Y}}$
(A)	1:1	1:1
(B)	1:2	1:1
(C)	1:2	1:2
(D)	1:1	1:2

6. A very long train is travelling close to the speed of light. An observer on a platform watches the train travel past.

Which of the following statements is true? slower

(A) Time will appear to be running faster in the train according to the observer on the platform.

(B) The platform will appear longer to the passenger on the train than the observer on the platform. shorter

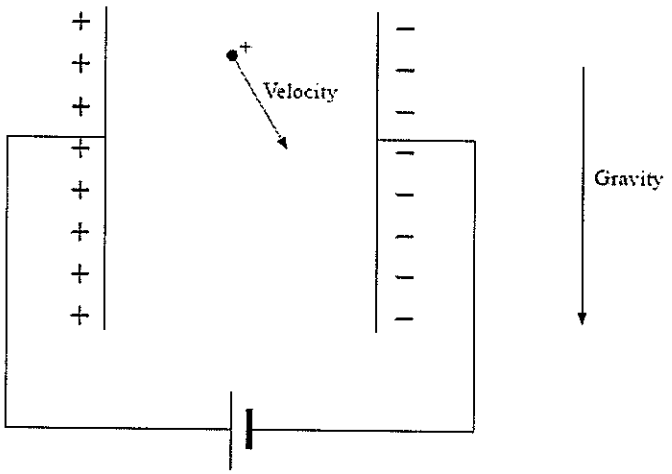
(C) A passenger on the train and the observer on the platform both measure time slowing in the other frame of reference.

(D) The observer on the platform will observe a longer train while the observer on the train see the platform shortened

moving length is contracted
Many clocks run slow

7. A small positive sphere is projected into a region between two vertical charged plates as shown. This is performed in a vacuum so there is no air resistance.

Independence of components



While the sphere remains in the uniform field, which statement is correct about the vertical component of its acceleration?

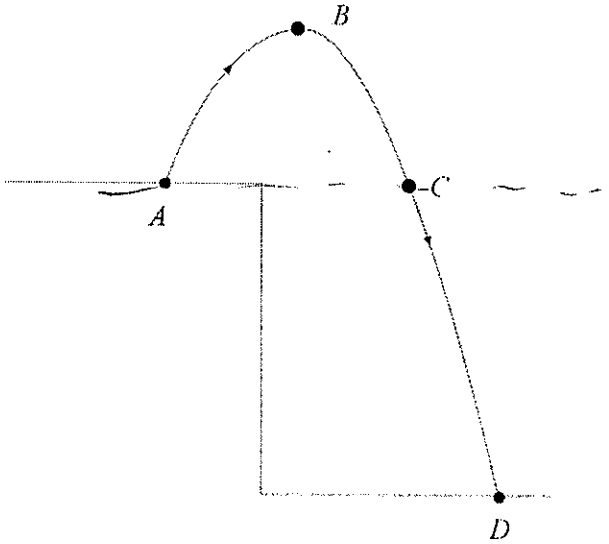
(A) greater than acceleration due to gravity

(B) less than acceleration due to gravity

(C) equal to the acceleration due to gravity — vertical component not affected by horizontal component

(D) dependent on the size of the field

8. A projectile is launched from the top of a cliff at Point A and lands below at Point D as shown.



Which of the following is correct about the motion of the projectile, if air resistance is ignored?

(A) The speed at A is the same as at C speed not velocity

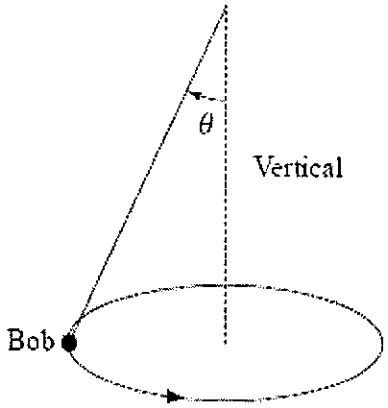
(B) It takes longer to travel from A to B than is does from B to C

(C) The total time of flight is twice the time it takes to reach point B since lands lower

(D) The horizontal displacement from A to D is independent of the launch velocity

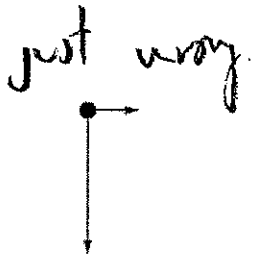
$\Delta x = v_x t$

9. The diagram shows a conical pendulum rotating with a constant speed.

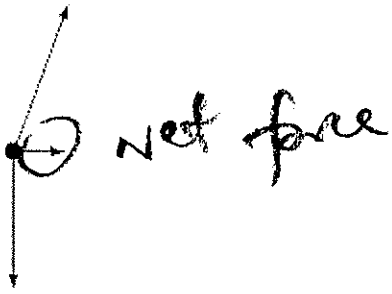


Which diagram represents the forces applied to the bob?

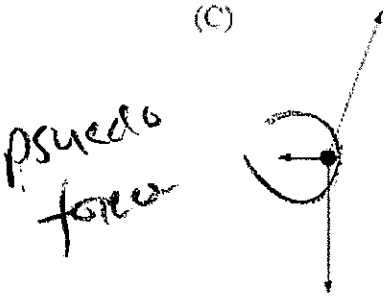
(A)



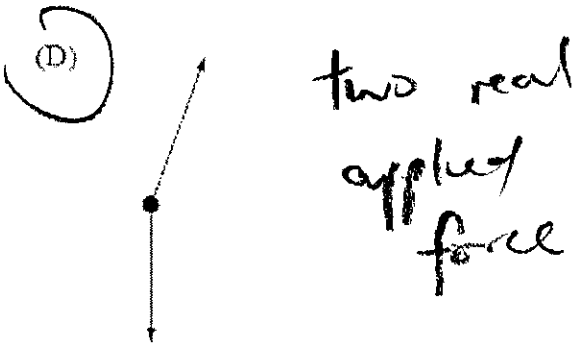
(B)



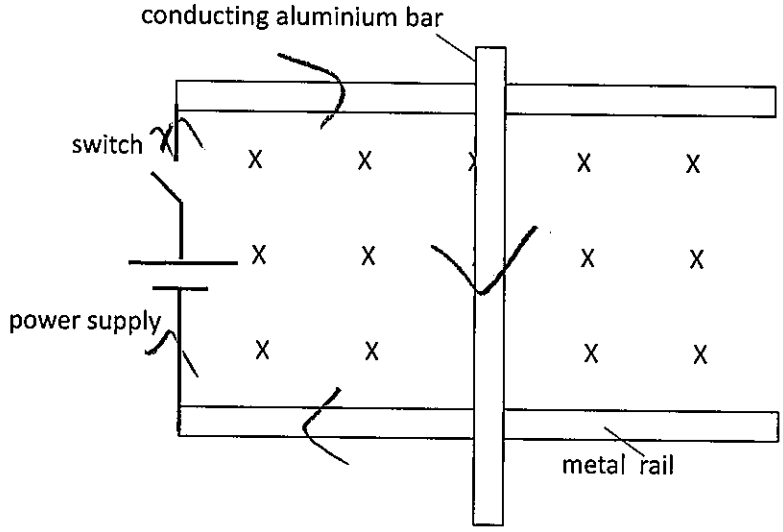
(C)



(D)



10. A light aluminium bar is placed on two horizontal metal rails that are connected to a power supply as shown in the top view below. The bar and rails are located in a uniform magnetic field as shown by the X. The bar is not connected to the bar so it is free to move.



by RHR
field into page

What does the bar do when the switch is closed?

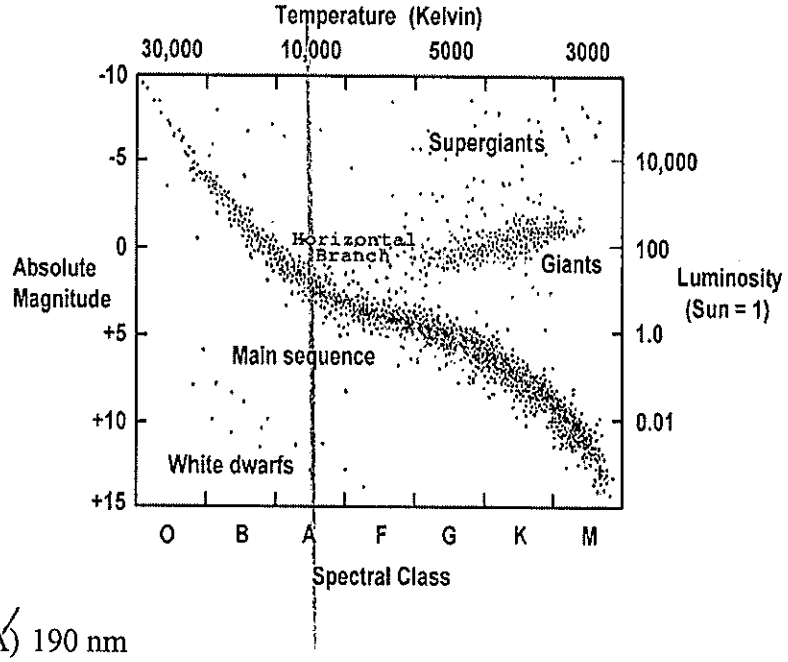
(A) It jumps directly upwards

(B) It moves to the left

(C) It moves to the right

(D) It rotates

11. Sirius A has an absolute magnitude of 1.4 and is a spectral type A star. Which wavelength best approximates the wavelength at which Sirius A is emitting?



$\lambda_{max} = \frac{b}{T}$

$= \frac{2.898 \times 10^{-3}}{10\,000}$

$= 2.898 \times 10^{-7}\ m$

$= 290\ nm$

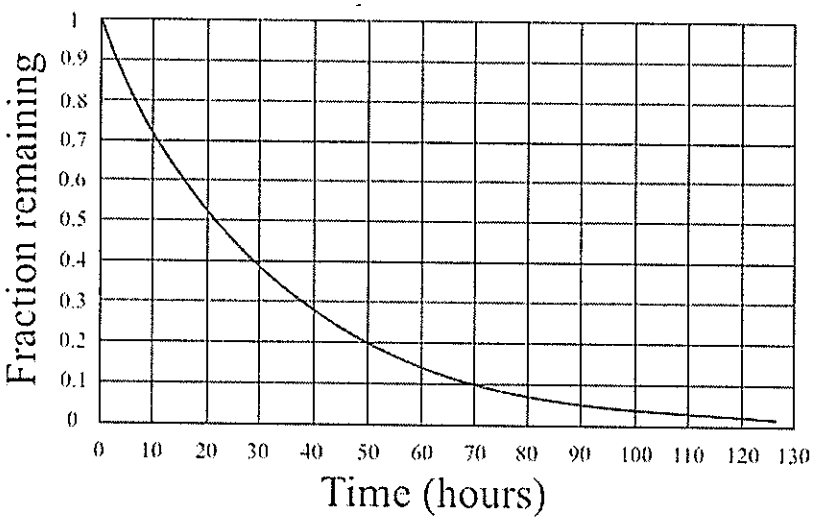
(A) 190 nm

(B) 290 nm

(C) 390 nm

(D) 490 nm

12. The rate of decay of a sample of magnesium-28 was measured over time and the results plotted on the axes shown.



$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

$= \frac{0.6}{20}$

$= 3.5 \times 10^{-2}$

Which of the values below is the radioactive decay constant of magnesium-28?

there are no units for λ ∴ no conversion to seconds for time

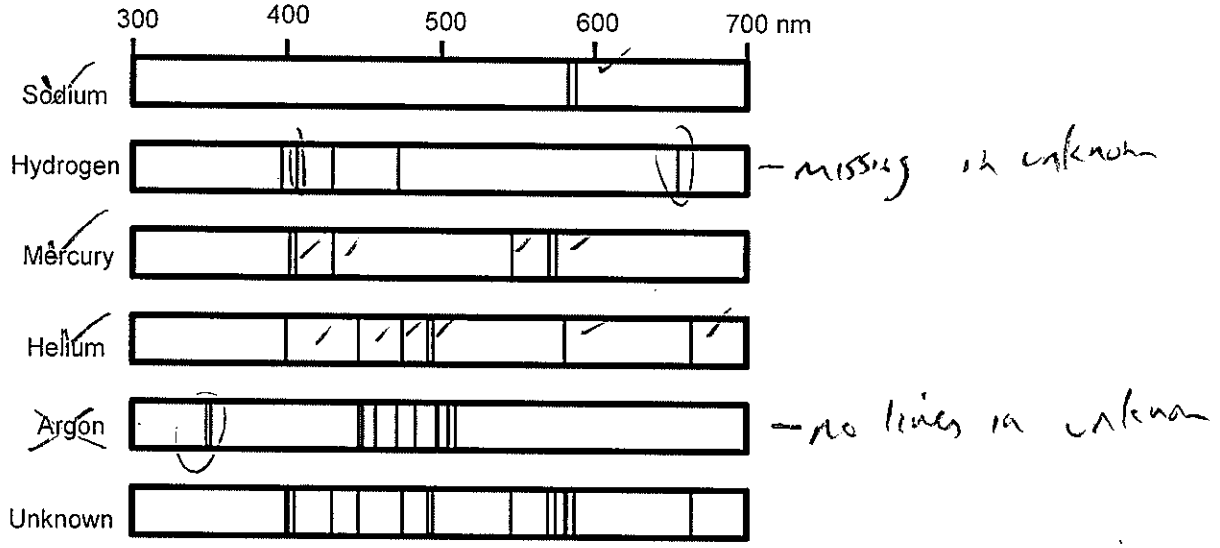
(A) 4.0×10^{1}

(B) 2.0×10^{1}

(C) 5.0×10^{-1}

(D) 3.5×10^{-2}

13. Below is the emission spectrum from an unknown light source.



– missing in unknown

– no lines in unknown

What elements are present in the light source?

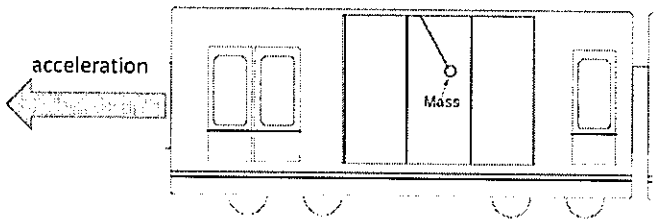
(A) Hydrogen, Mercury and Argon

(B) Mercury, Hydrogen and Helium

(C) Mercury, Helium and Sodium

(D) Argon, Sodium and Hydrogen

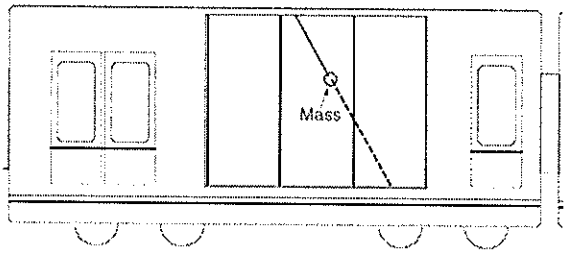
14. A train is accelerating uniformly to the left. A mass on a string makes a constant angle to the vertical as shown.

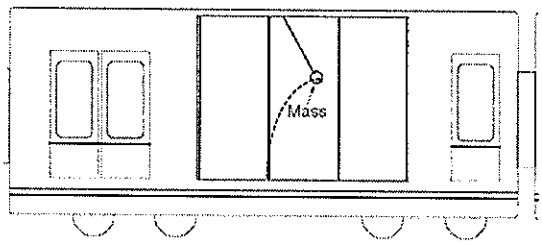


The string breaks and the mass falls. Which diagram show the trajectory of the mass as observed by a person sitting in the train?

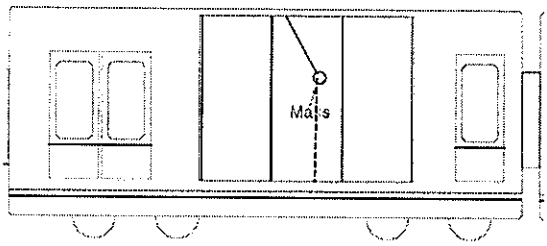
(A) accelerate vertically and horizontally to give straight line

(B)

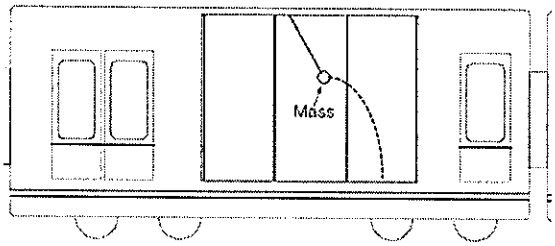




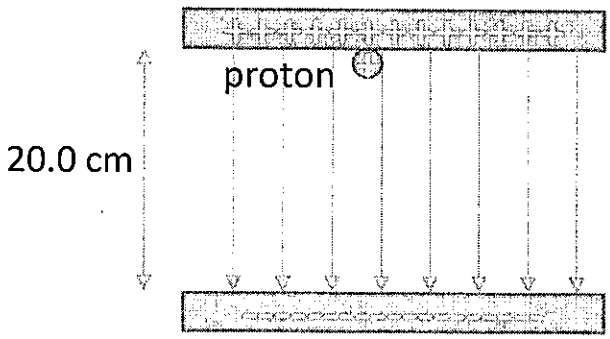
(C)



(D)



15. A proton is accelerated by an electric field between parallel plates with a potential difference of 1550V. The proton starts from the positive plate as shown.



$W = qV = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2qV}{m}} =$

$\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}}{1.673 \times 10^{-27} \times}$

What is the de Broglie wavelength of the proton when it reaches the bottom plate?

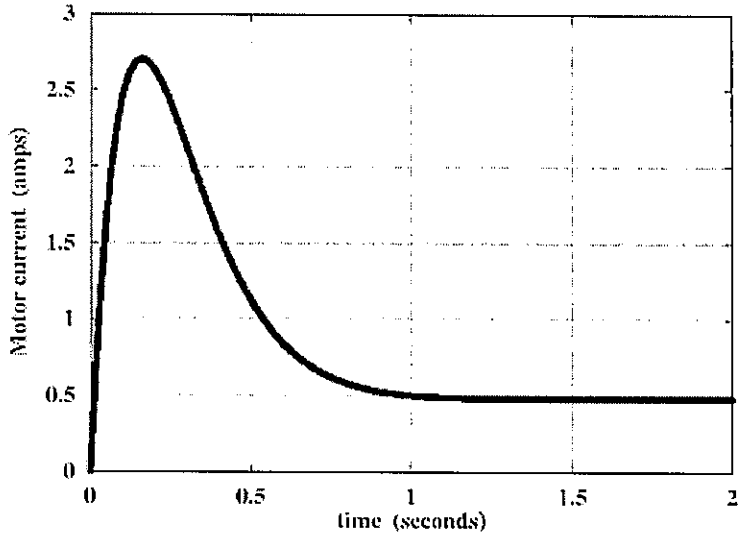
(A) 2.91×10^{-22} m

(B) 7.28×10^{-13} m

(C) 1.38×10^{12} m

(D) 3.41×10^{21} m

16. The graph shows how the current in a brushed motor varies after start up.



Which statement is true?

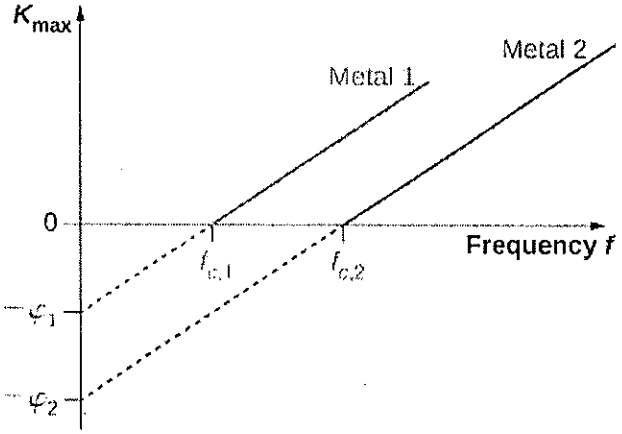
(A) As the motor gains speed the momentum increases reducing the input energy required

(B) As the speed of the motor increases the back emf increases which reduces the net emf

(C) The current changes because the input voltage is changing to keep the speed constant

(D) The resistance of the rotor increases as it heats up which reduces the current in the first 0.5 s

17. Light is shone onto two metals to investigate the photo electric effect.



work function ϕ

Which statement is true about the two metals?

(A) Metal 1 has a greater (lower) work function than Metal 2

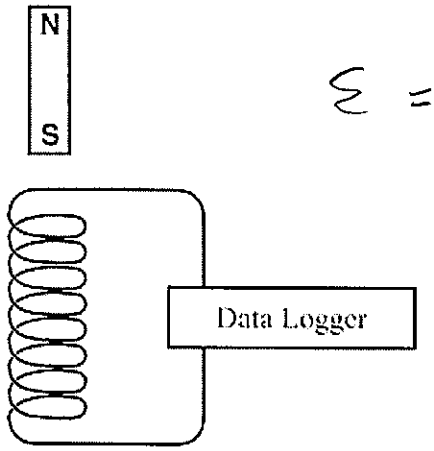
(B) Metal 2 has a lower (higher) threshold frequency than Metal 1

(C) For both metals a higher frequency will produce a greater current – more K_{max} ∴ more electrons

(D) Metal 1 will emit electrons over a greater range of light frequencies

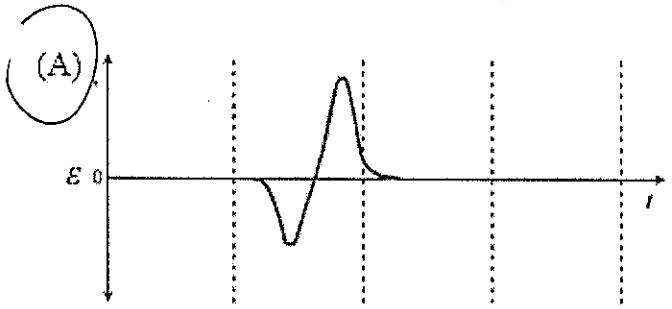
has a lower threshold frequency ∴ more frequencies will cause photo emission

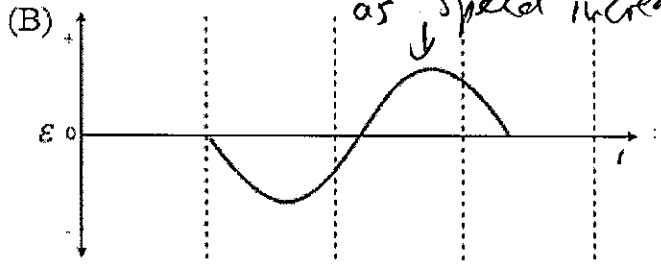
18. In an experiment a magnet was dropped through a solenoid and the emf generated was recorded by a data logger.

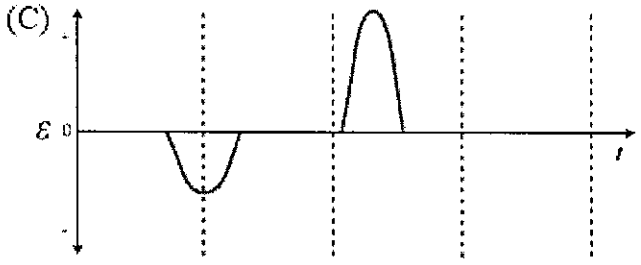


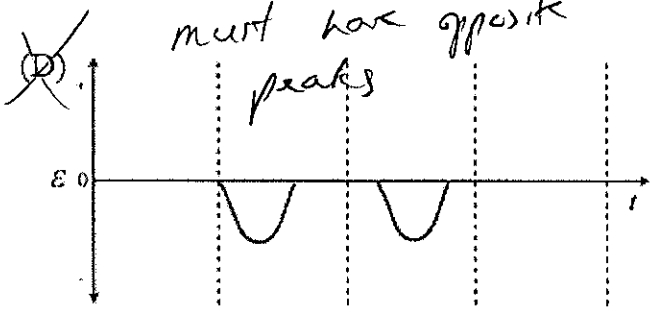
$\mathcal{E} = -\frac{\Delta\Phi}{\Delta t}$

Which graph shows the result of this experiment?





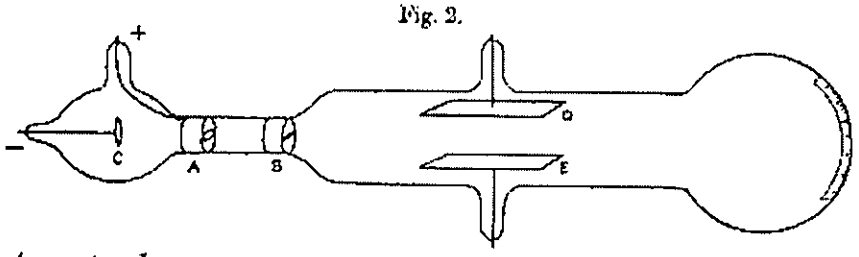




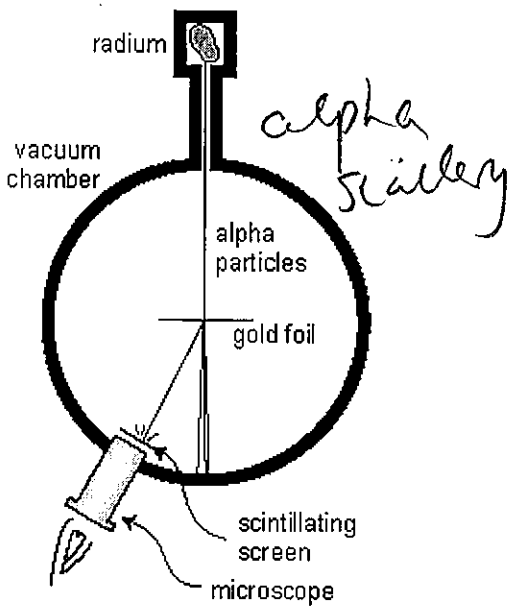
A is better than C

C shows long period of zero emf - given the magnet is not much shorter than the coil, thus period of zero change in flux caused by very short

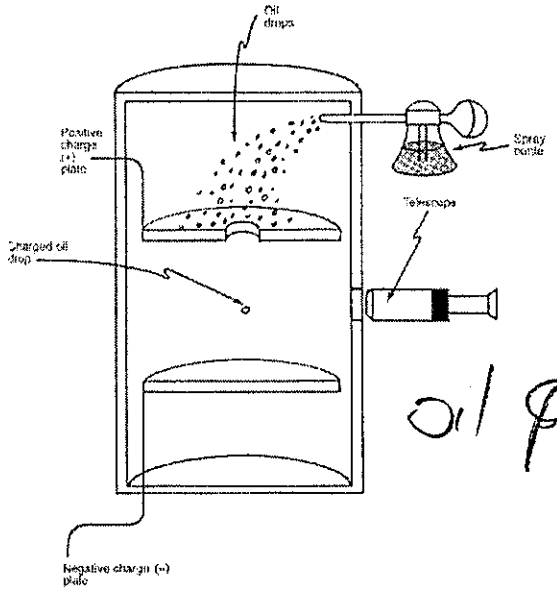
19. The diagrams show different apparatus that used to explore different aspects of the atom.



Appartus 1



Appartus 2

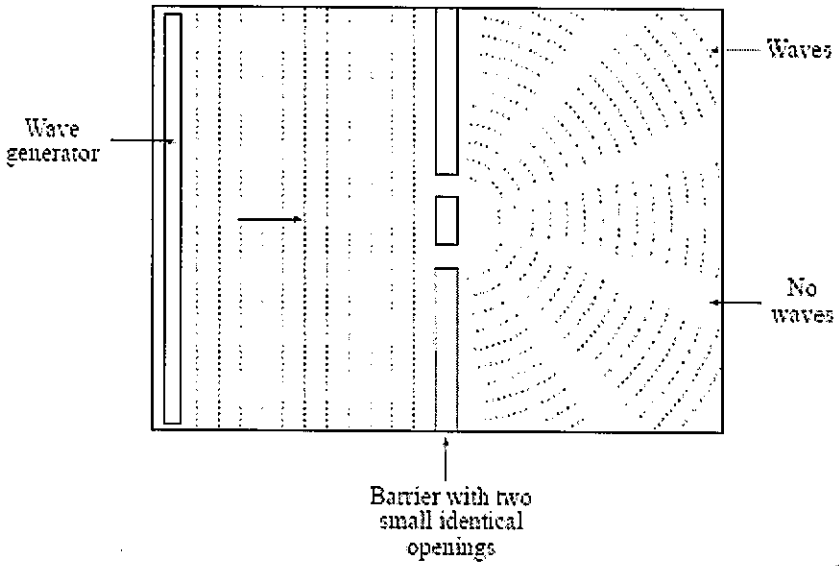


Appartus 3

Which option correctly links the scientist to the apparatus they used?

	Apparatus 1	*Apparatus 2*	*Apparatus 3*
(A)	Thomson	Rutherford	Milliken
(B)	Milliken	Chadwick	Thomson
(C)	Crookes	Geiger	Davisson
(D)	Crookes	Chadwick	Milliken

20. The diagram shows water waves passing through two openings in a barrier.



Which two aspects of wave behaviour best explain the pattern on the right hand side of the barrier?

(A) refraction and reflection

(B) refraction and diffraction

(C) diffraction and interference

(D) interference and polarisation

while refraction and diffraction occur, the pattern on the right hand side is caused by interference

Section II

80 marks Attempt all questions in the spaces provided.

Questions 21–36 Allow about 2 hours and 25 minutes for this section

Question 21 (7 marks)

The table contains information about two planets, Neptune and Pluto, which were discovered after Kepler died.

Planet	Orbital period (earth years)	Average distance from the sun (km)	Diameter (km)	mass (kg)
Neptune	165	4.48×10^9	49200	1.02×10^{26}
Pluto	*248*	5.91×10^9	2380	1.31×10^{22}

a) Show that the information in the table is consistent with Kepler's 3rd law. 2

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

Neptune $(4.48 \times 10^9)^3 / 165^2$ = 3.3×10^{24}

Pluto $(5.91 \times 10^9)^3 / 248^2$ = 3.4×10^{24}

They are the same, so consistent with Kepler's law

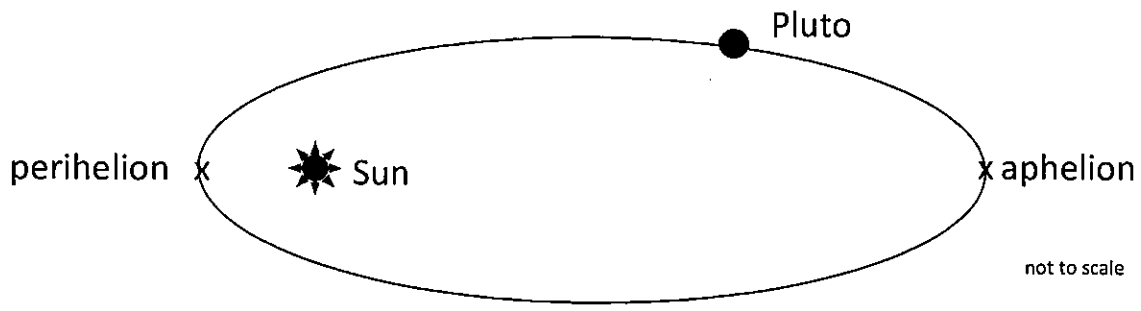
b) Calculate the acceleration due to gravity on the surface of Neptune. 2

$g = GM/r^2$

$= 6.67 \times 10^{-11} \times 1.02 \times 10^{26}/$

Question 21 continued on next page

c) Pluto has an elliptical orbit with an eccentricity of 0.244.



Compare the orbital velocity and gravitational potential energy of Pluto at the perihelion and at the aphelion. 3

Total mechanical energy is conserved at all points in the orbit i.e. kinetic energy + gravitational potential is the same.

At the aphelion, $U = -\frac{GMm}{r}$ r is at a maximum value so U is a maximum value, according to Kepler's 2nd law, the velocity will be a minimum therefore K will be a minimum. $K = \frac{1}{2}mv^2$

At the perihelion, r is at a minimum value so U is a minimum value, according and the velocity will be a maximum therefore K will be a maximum.

Question 22 (3 marks)

Derive the escape velocity equation, including specific reference the relevant physical principle.

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

This is based on the law of conservation of energy as kinetic energy is converted into gravitational potential energy

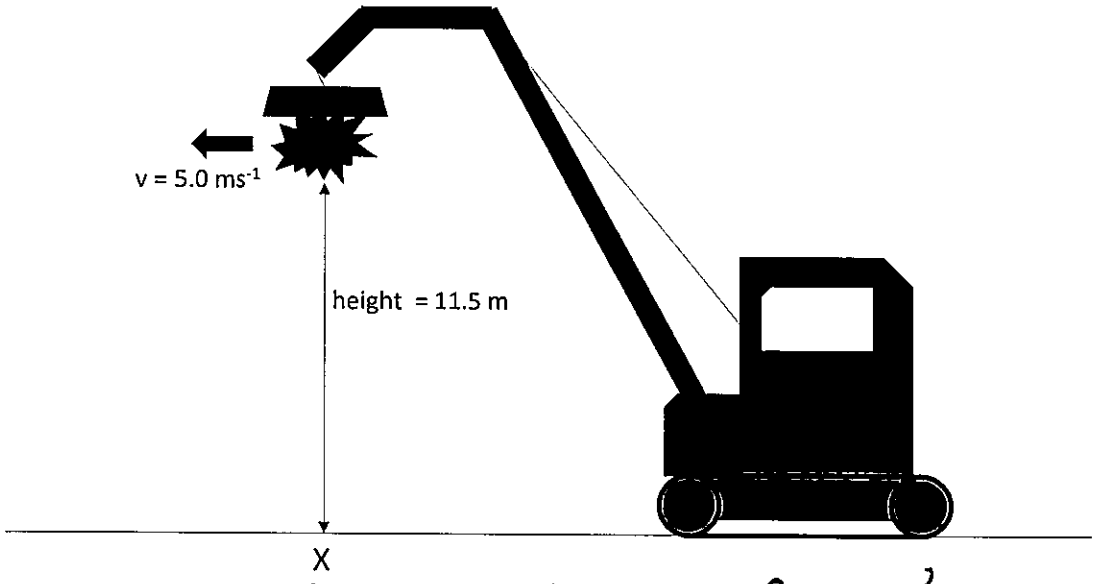
$$K = \frac{1}{2}mv^2$$

$$U = -\frac{GMm}{r}$$

Question 23 (7 marks)

A crane uses an electromagnet to lift a 2000 kg crushed car to a height of 11.5 m and then moves it sides with a velocity of 5.0 ms^{-1}.

When the car is directly about point X, power is suddenly cut and the car falls to the ground.



$u = 0 \quad s = 11.5\,m \quad a = 9.8\,ms^{-2}$

a) How long does it the car take to reach the ground? 2

$s = ut + \frac{1}{2}at^2$

$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \times 11.5}{9.8}}$

$= 1.53\,s \leq 1.5\,sec$

b) How far from point X does the car hit the ground? 2

$\Delta x = v_x t$

$= 5.0 \times 1.53$

$= 7.65$

$= 7.7\,m$

Question 23 continued on next page

c) What is the velocity of the car upon impact? 3

$\vec{v} = \vec{v}_y + \vec{v}_x$

$\vec{v}_y = u_y + at$

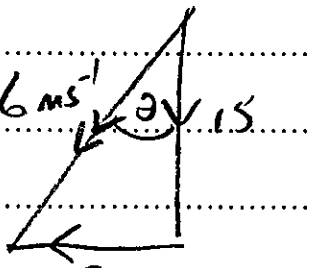
$= 0 + 9.8 \times 1.53$

$= 14.99 = 15\ ms^{-1}$

$v_x = 5.0\ ms^{-1}$

$v = \sqrt{5.0^2 + 15^2}$

$= 15.8\ ms^{-1} = 16\ ms^{-1}$



$\theta = \tan^{-1}\frac{5}{15}$

$= 18^\circ$

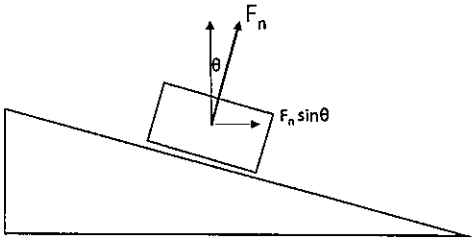
Question 24 (3 marks)

Explain why the presence of a bank on a curve allows a racing car to travel faster than on a horizontal curve with the same radius.

For a car on a horizontal curve, the centripetal force is produced entirely by friction between the tyres and the road. The friction has a maximum value which determines the maximum velocity for particular mass and radius.

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

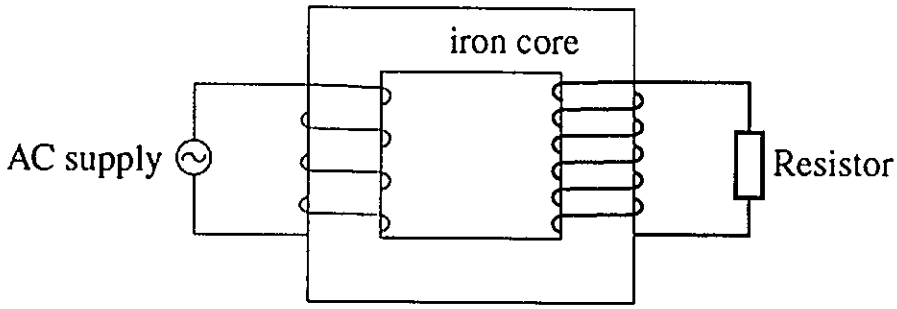
On a banked curve, the horizontal component of the normal force, provides an additional force to friction.



This additional force allows the car to travel at a greater velocity for the same mass and radius of curve

Question 25 (5 marks)

A step-up transformer is constructed using a laminated iron core. The coils are made using copper wires of different thicknesses as shown.



a) Explain why the supply is AC not DC. 2

AC is alternating, there the voltage in the primary coil is continually changing, whereas DC is constant.

The changing voltage in necessary because the changing voltage induces a voltage in the secondary coil.

b) 20.0 Volts is applied to the primary coil. The input power is 15.0 W. The output current is 0.5 A and the 14.0 W is dissipated by the resistor.

Determine the voltage across the resistor and the efficiency of the transformer. 3

$\text{Efficiency} = \frac{P_{out}}{P_{in}} \times 100 = \frac{14.0}{15.0} \times 100 = 93\%$

$P = IV \qquad I = 0.5\text{A} \qquad P = 14.0\text{W}$

$V = \frac{P}{I} = \frac{14.0}{0.5} = 28\text{V}$ across resistor

Question 25 continued on next page

c) Given the ratio of turns is 2:3, the calculated value is different to the voltage predicted by this ratio. Explain why this is the case. 2

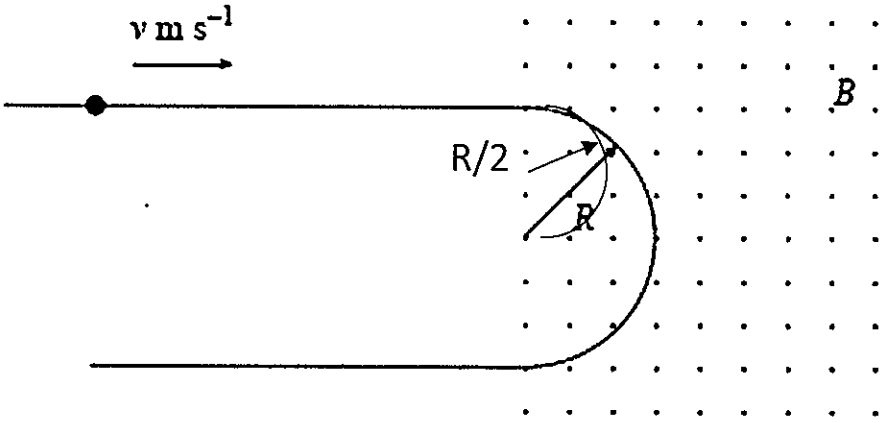
$n_p/n_s = V_p/V_s = 2/3 = 20/V_s$

The turns ratio of 2:3 would give a predicted voltage of 30 volts in the secondary coil.

As it is only 28 V there must be poor flux linkage between the coils.

Question 26 (5 marks)

A proton is projected into a uniform magnetic field and follows a semicircular path as shown.



a) Explain the shape of the path. 3

The proton experiences a force from the magnetic field which is always perpendicular to the velocity vector.

The direction is determined by the charge and the filed direction given by the right hand rule.

A force that is constant in magnitude and perpendicular to the velocity vector produces circular motion with a constant radius as shown on the diagram. $F_c = \frac{mv^2}{r}$

b) Another proton is projected along the same initial path at half the speed. Sketch the path of the second proton. 2

Question 27 (4 marks)

The proton- proton chain and CNO cycle are processes that release energy in stars.

a) What, besides energy, is the main product of both of these reactions? 1

Helium

b) In what type of stars would these processes be occurring? 1

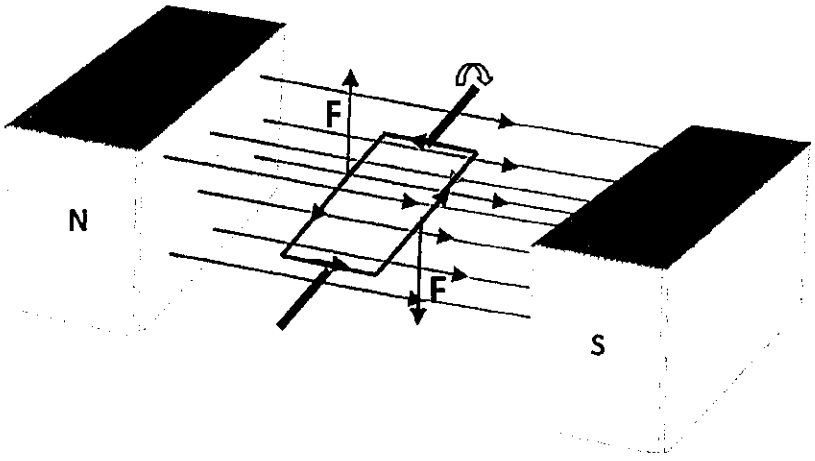
Main sequence

c) Outline one fusion process other than the proton- proton chain and CNO cycle that occurs in stars. 2

The triple alpha process converts He into Carbon 12. 2 He nuclei fuse to produce Be – 8. The Be* fuses with another He nucleus to produce C12

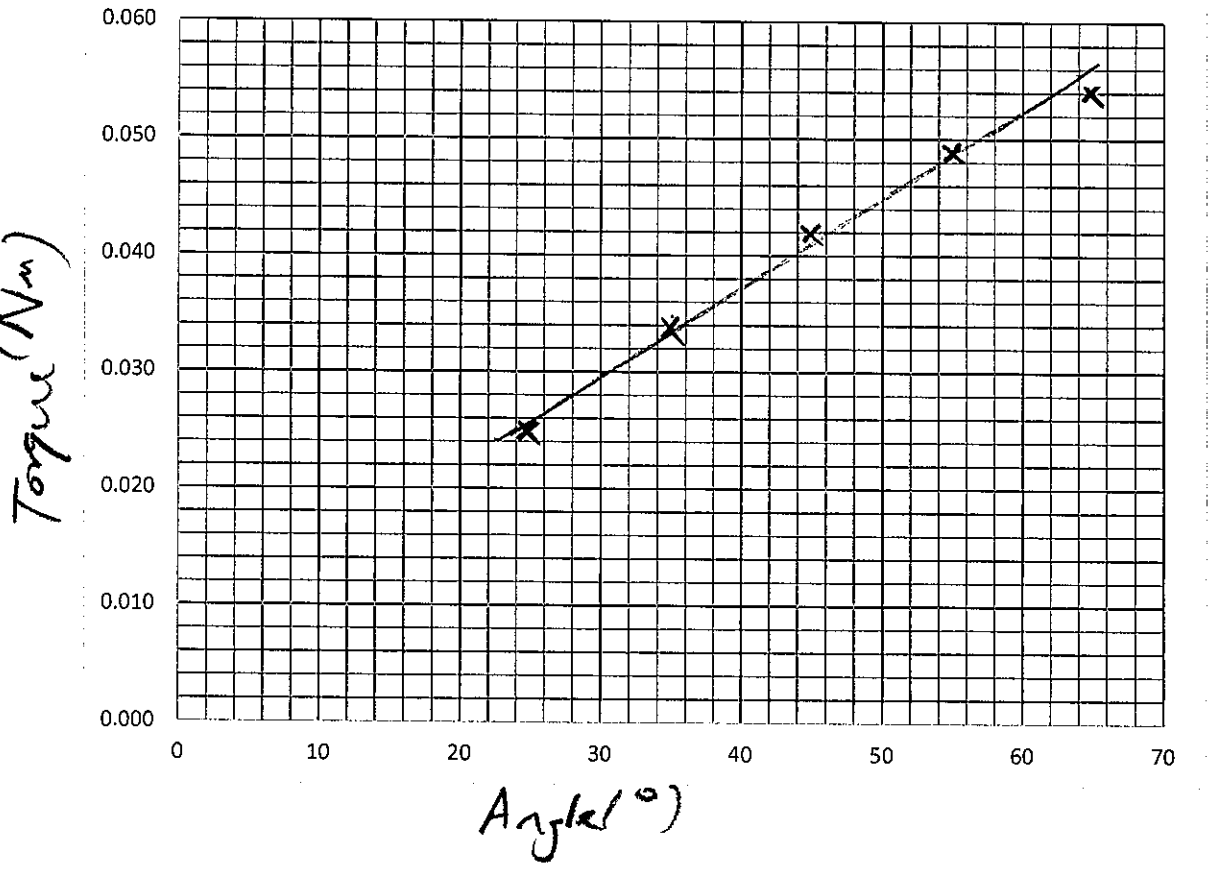
Question 28 (7 marks)

A single rectangular loop is able to rotate inside a uniform magnetic field as shown. The normal to plane of the coil is initially perpendicular to the field lines, making an angle of 90°. The coil is allowed do rotate and the torque is measured at the angles shown in the table.



Angle °	Torque (Nm)
25	0.025
35	0.034
45	0.042
55	0.049
65	0.054

a) On the grid provided, plot a graph of *torque vs angle.* 2



b) The trend line appears to show that τ is directly proportional to the angle Θ. Assess the validity of drawing a straight line for this data. 2

For the small range of data, the relationship is linear and therefore a straight-line would be valid to predict torque values within the data set.

OR

Torque on a coil is given by $\tau = nIA_{\perp}B = nIAB\sin\theta$ which is not a linear relationship. It would be more valid to draw a curve because of this relationship.

Question 28 continued on next page

c) Predict the torque when the angle is 90°.

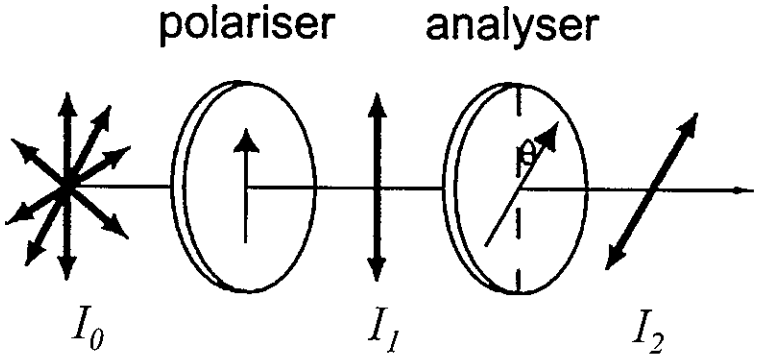
Using $\tau = nIA_{\perp}B = nIAB\sin\theta$ for any value in the table, maximum torque = 0.06 Nm

c) In a real motor the torque output needs to be uniform. Outline how one design feature of a real motor produces a much more uniform torque. 2

Curved magnetic pole pieces are used to provide a radial field so that the angle between the plane of the coil and the field is constant, which gives a constant torque.

Question 29 (3 marks)

A beam of unpolarised light is passed through two polarising filters as shown. The plane of polarisation of the analyser is at an angle $\theta = 40°$ to the polariser.



The initial light, I_0, incident on the polariser is 3.47×10^{-2} W m^{-2}.

a) What is the intensity of the light, I_2 after it has passed through both filters? 2

$I_1 = I_0/2 = 3.47 \times 10^{-2}/2 = 1.735 \times 10^{-2}$

$I_2 = I_1 \cos^2\theta$

$= 1.735 \times 10^{-2} \cos^2 40$

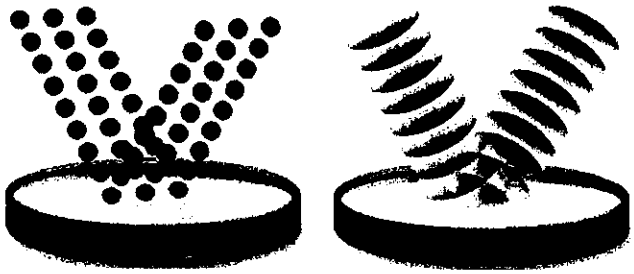
$= 1.019 = 1.0 \times 10^{-2}$ W m^{-2}

b) What characteristic of the wave model of light is supported by the fact it can be polarised? 1

it is a transverse wave

Question 30 (7 marks)

The diagram shows two different models of light that were around in the late 1600s



Particles Waves

a) Which of these models was proposed by Newton? 1

particle

b) With reference to general characteristics of scientific models, why was Newton's model rejected in favour of the model proposed by Huygens? 2

Scientific models are constructed to explain/describe phenomena and make predictions. The results of Young's double slit experiment could be explained using Huygen's wave model as being caused by interference. The results could not be explained by the particle model, hence it was rejected.

c) In the currently accepted model of light, light has a dual wave particle nature. Why is this duality necessary? Provide examples to support your answer. 4

The dual nature of light is that is has wave properties as well as particle properties.

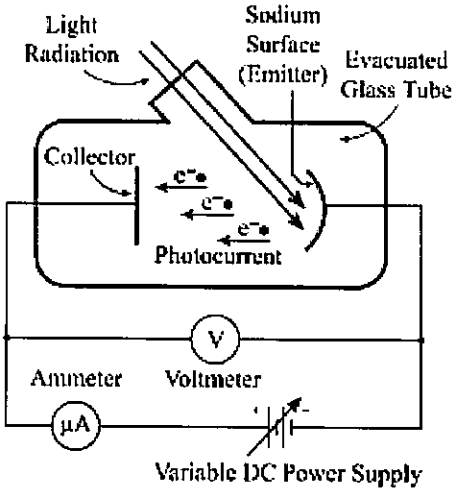
This was necessary because some observed phenomena can only be explained in terms of wave properties and some can only be explained if light acts like a particle.

Examples of wave properties include interference, polarization and diffraction.

Examples of light behaving as a particle include the photo electric effect and black body radiation.

Question 31 (5 marks)

When visible light is incident on a clean sodium surface, photoemission can occur. The work function of sodium is 3.7×10^{-19} J.



a) Monochromatic light with a wavelength of 651 nm is directed onto the sodium surface. Does photoemission occur? Support your answer with relevant maths. 2

Photon Energy $= hf = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \times 3.00 \times 10^{8}}{651 \times 10^{-9}} = 3.05 \times 10^{-19}$ J

Since photon energy is < work function, No photo emission occurs

b) The intensity of the light is doubled. Explain how this affects the emission of electrons from the sodium surface. 3

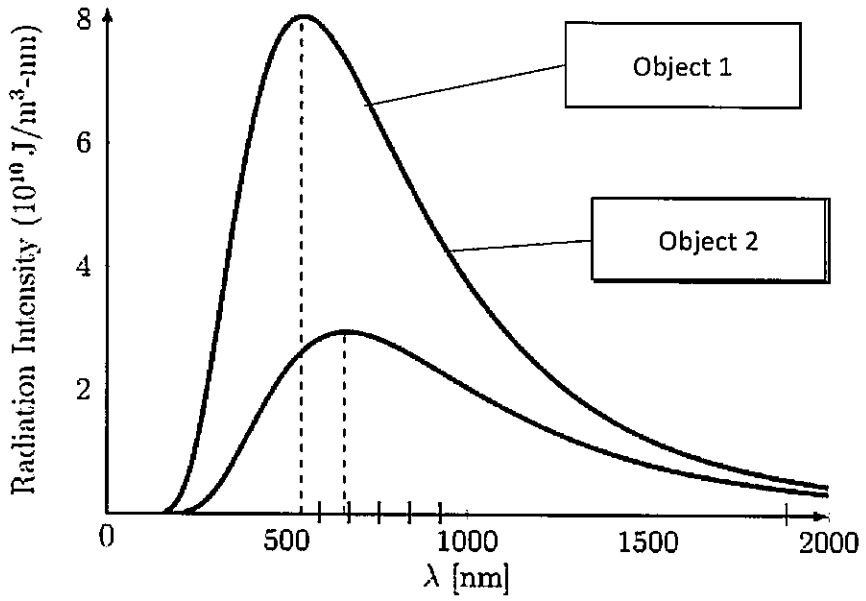
In the photoelectric effect, a photon is absorbed by an electron and gives up all its energy to the electron. The energy of the photon is given by E = hf. If this is below the work function no photoemission occurs.

The intensity of the light is a measure of the number of photons arriving on an area per unit time. Doubling the intensity will double the number of electrons incident on the metal.

Since the photons do not have enough energy to overcome the work function, doubling the intensity has no affect there is still no photoemission.

Question 32 (7 marks)

The graph shows the black body radiation curves for two objects.



a) Compare the temperatures of the two objects. 2

Object 1 is hotter than object 2 according to Wien's law $\lambda_{max} = \frac{b}{T}$ $T = b/\lambda_{max}$

Object 1 $\lambda_{max} = 550nm$ $T_1 = 2.898 \times 10^{-3} / 550 \times 10^{-9} = 5300$ K

Object 2 $\lambda_{max} = 680nm$ $T_2 = 2.898 \times 10^{-3} / 680 \times 10^{-9} = 4300$ K

b) Compare the power output of the two objects. 2

Assuming the objects are the same size, the power output is proportional to T^4 (shown by the area under the graph)

so Object 1 has a higher power output than Object 2 as it is hotter

Question 32 continued on next page

c) If these objects were stars in our galaxy and Object 1 was at twice the distance as Object 2 from Earth, compare how bright they would appear. 3

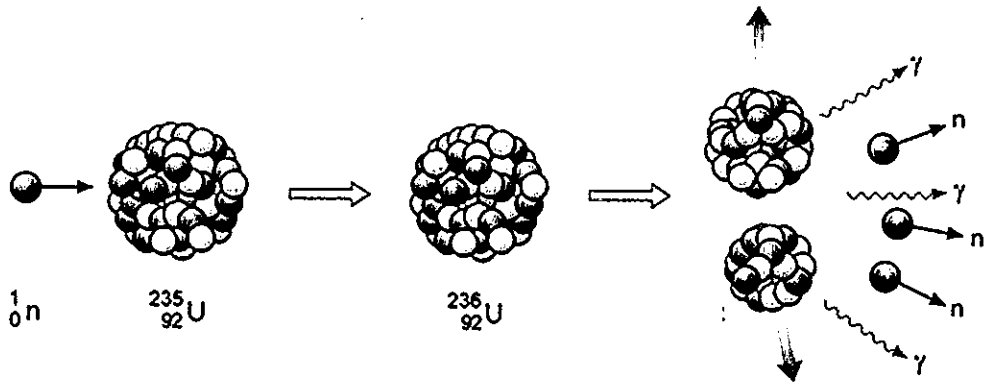
The brightness is a measure of intensity of light arriving from the object. The intensity is related to the distance by $I \propto I_0 / r^2$ or $b = L / r^2$ where L is the luminosity

$b_1 = L_1 / (2r)^2 = L_1 / 4r^2$ $b_2 = L_2 / r^2$

$b_1 : b_2 = L_1 / 4r^2 : L_2 / r^2 = L_2 / 4 : L_1$ so if the luminosity of bot objects is known the relative brightness can be determined.

Question 33 (9 marks)

The diagram shows what can happen when a nucleus of uranium 235 captures a neutron.



Uranium 235 has been used as a fuel in both atomic weapons and in nuclear power stations. With reference to the diagram and relevant physical principles, explain how Uranium 235 can be used for both of these applications.

As shown in the diagram, in nuclear fission, a large unstable nucleus such as U235 splits into two smaller nuclei that are more stable, releasing energy in the process. The fission products have less mass than the parent nucleus. This mass defect represents the amount of energy that is released as kinetic energy of the products and gamma photons, according to $E = \Delta mc^2$

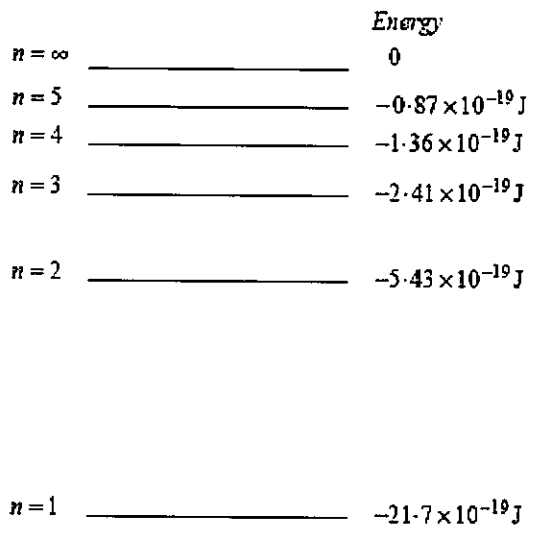
The fission process also releases further neutrons, which can then split additional fissionable nuclei, resulting in a chain reaction that releases more energy. For this chain reaction to be self-sustaining, a minimum amount of fissionable nuclei need to be present called the critical mass.

In a nuclear weapon the chain reaction is uncontrolled. This occurs because a nucleus releases more than one neutron which can be captured by other nuclei which will then decay and release further neutrons, which produces an exponential increase in the number of nuclei decaying. This occurs in a very short period of time, which releases a very large amount of energy rapidly which constitutes an explosion.

In a nuclear power station, the chain reaction is controlled such that only one neutron from each decay causes one further breakdown. This releases energy at a controlled rate, which can be used to heat water to steam that turns a turbine in a generator.

Question 34 (6 marks)

The diagram shows some of the energy levels for a hydrogen atom.



a) For an electron to move from n =2 to n = 5, what energy photon would it need to absorb? 2

$\Delta E = E_f - E_i$

$= -0.87 \times 10^{-19} - (-5.43 \times 10^{-19})$

$= \underline{4.56 \times 10^{-19}\ J}$

(or could use Rydberg equation, but is more complicated)

b) How would this appear in the spectrum produced by passing white light through hydrogen gas? 1

There would be a dark (absorption) line corresponding the wavelength of this photon.

c) How did de Broglie explain the presence of the different electron energy levels in a hydrogen atom? 3

Electrons have wave properties as well as mass where the wavelength $\lambda = h/mv$.

The electrons can occupy energy levels where the electron wavelength will produce a standing wave by constructively interfering with itself.

Each successive energy level is a standing wave containing one extra complete wavelength $2\pi r = n\lambda$