Girraween High School

2020 **HIGHER SCHOOL CERTIFICATE TRIAL EXAMINATION**

Physics

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, formula sheet and Periodic Table are provided
Total marks: 100	**Section I – 20 marks** (pages 1 – 9) • Attempt questions 1 – 20 • Allow about 35 minutes for this section **Section II – 80 marks** (pages 10 – 26) • Attempt questions 21 – 37 • 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

Use the Multiple Choice Answer Sheet on page 10 for Questions 1 – 20

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1 A ball rolls off the edge of a table and traces out the path shown below.

Which of the following correctly describes the motion of the ball (ignoring air resistance)?

(A) Initially, the velocity of the ball is zero.

(B) The horizontal acceleration of the ball is constant.

(C) The ball has the greatest velocity immediately before impact.

(D) The vertical acceleration increases as the ball approaches the ground.

2 The ratio of the radius of Mars orbit to that of Earth's orbit is 1.5:1.

How long is one Mars year?

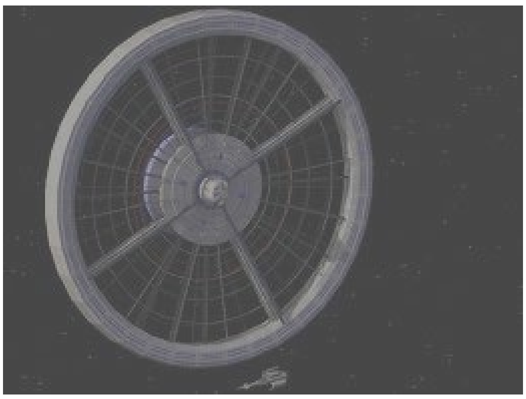
(A) 1.5 Earth years

(B) 1.8 Earth years

(C) 2.3 Earth years

(D) 3.4 Earth years

3 Gerard K O'Neill was a champion of space colonisation. He designed a rotating ring measuring 513 m in diameter that would have people living on the inside. The rotation would simulate Earth gravity of 9.8 Nkg^{-1} within the ring.



At what velocity must the ring be spinning to produce centripetal acceleration the same as Earth's gravity?

(A) 50 ms^{-1}

(B) 71 ms^{-1}

(C) 5.0×10^3 ms^{-1}

(D) 25×10^3 ms^{-1}

4 Calculate the energy released from an electron-positron annihilation.

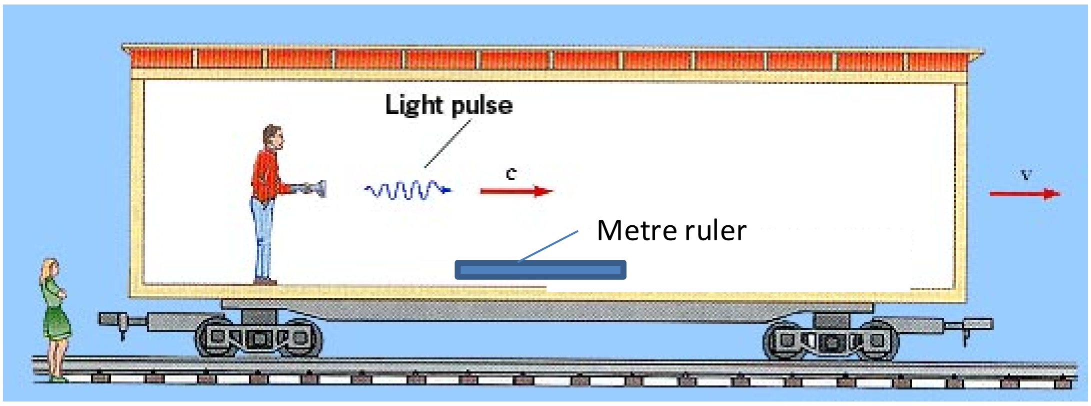
(A) 8.19×10^{-14} eV

(B) 1.638×10^{-13} eV

(C) 0.51 MeV

(D) 1.02 MeV

5 A man stands on a train moving at an extremely high velocity, *v*, pointing a torch in the direction of motion. A woman stands next to the track. A metre ruler lies on the floor of the train as shown.



Which of the following correctly describes an observation that could be made?

(A) Both observers would measure the speed of light and length of the rule to be the same.

(B) The woman observes the ruler to be less than one metre and the speed of light to be $(c + v)$

(C) The man observes the speed of light to be $(c - v)$ and the metre rule to be one metre long.

(D) Both observers measure the speed of light be *c*, but do not agree on the length of the ruler.

6 What is the energy of a photon of blue light with wavelength 475 nm?

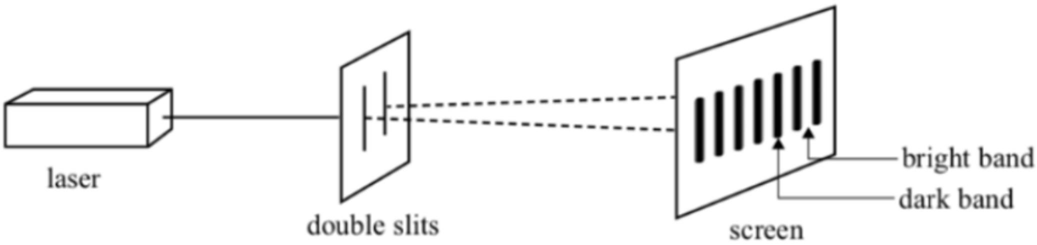
(A) 475 J

(B) 4.18×10^{-19} J

(C) 3.15×10^{-40} J

(D) 1.05×10^{-48} J

7 Light from a green laser passes through a double-slit arrangement, as seen below. An interference pattern is observed on the screen.



Which of the following actions would increase the spacing between the bands?

(A) Increasing the separation of the laser and the double slit.

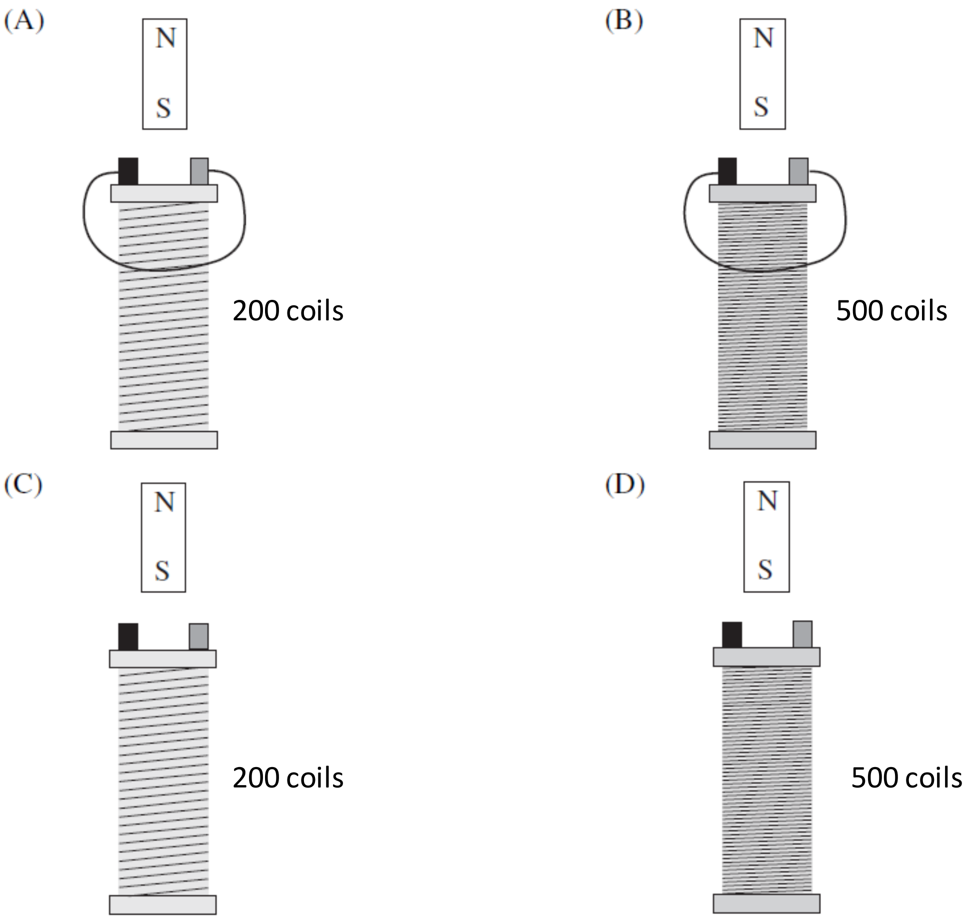
(B) Decreasing the distance between the double slits and the screen.

(C) Changing from a green laser to a blue laser.

(D) Changing from a green laser to a red laser.

8 A permanent bar magnet is dropped from rest through a number of hollow solenoids, as shown in the diagrams below. All solenoids have the same length. Two of the solenoids have a connecting wire between the ends of the solenoid.

In which case would the magnet experience the greatest resistive force as it passes into the solenoid?



9 A transformer is designed to operate with 415 V across the primary coil and to produce a voltage of 12 V across the secondary coil.

If the primary coil has 1000 windings (coils), what is the number of windings on the secondary coil?

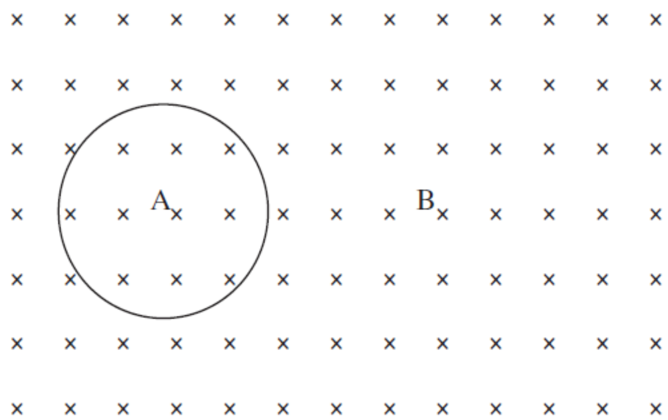
(A) 3

(B) 29

(C) 3 500

(D) 34 583

10 The diagram below shows a circular loop of conducting wire in a uniform magnetic field directed into the page.



The loop is moved from point A to point B in the plane perpendicular to the field lines. Which statement is true when the coil is moving?

(A) The flux through the coil remains unchanged.

(B) A clockwise current is induced.

(C) An anticlockwise current is induced.

(D) The coil experiences a change in flux.

11 In 1900 Max Planck developed a new understanding of thermal radiation. He developed an equation that features a physical constant that now bears his name: Planck's constant, h, which has a value of 6.626×10^{-34} J s.

Planck's constant is:

(A) The ratio between the speed of light in vacuum to the speed of light in a material.

(B) The constant of proportionality between masses interacting under gravity only.

(C) The ratio between the energy in joules and frequency of electromagnetic radiation.

(D) The ratio between the temperature of a molecule and its kinetic energy in joules.

12 An electron moving with a velocity of 3.0×10^3 ms^{-1} passes at 90° through a magnetic field of strength 2×10^{-2} T.

Identify which expression gives the magnitude of force on the electron due to the magnetic field.

(A) $F = 1.602 \times 10^{-19} \times 3000 \times 0.02 \times \sin 90°$

(B) $F = 1.602 \times 10^{-19} \times 3000 \times 200 \times \sin 90°$

(C) $F = 1 \times 3.0 \times 10^3 \times 2 \times 10^{-2} \times \cos 90°$

(D) $F/l = 1.602 \times 10^{-19} \times 3000 \times 200 \times \cos 90°$

13 What is the main advantage that follows from the use of transformers in power systems?

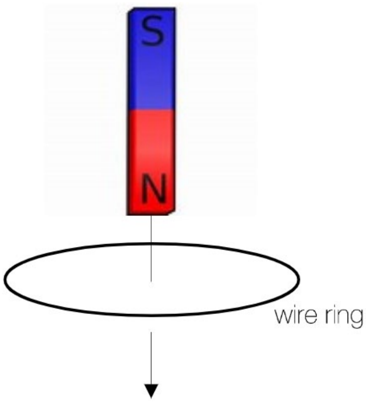
(A) Transformers allow the high voltages at which power is generated to be stepped down to usable levels.

(B) Transformers allow voltages to be stepped up so that larger currents can be generated and transmission efficiency can be improved.

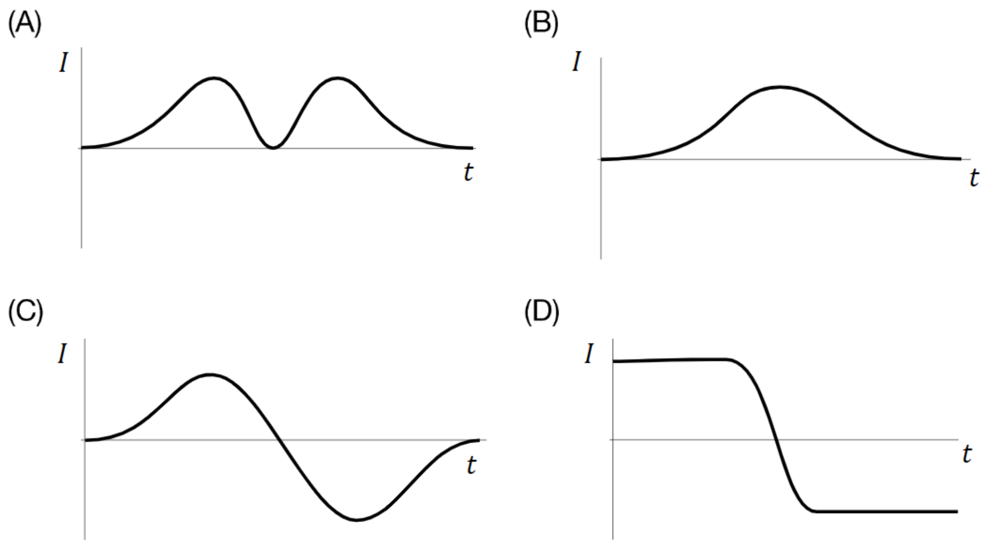
(C) Transformers allow the low voltages at which power is generated to be stepped up to usable levels.

(D) Transformers allow voltages to be stepped up for transmission with lower currents so that transmission efficiency can be improved.

14 A bar magnet is lowered at constant speed through a wire ring, as shown in the diagram.



Which of the following graphs best represents the variation of the current induced in the ring, I, with time, t?



15 A powerful light is shone onto a metallic surface in a vacuum but initially no electrons are observed emitted from the surface.

Which of the following circumstances is most likely to follow?

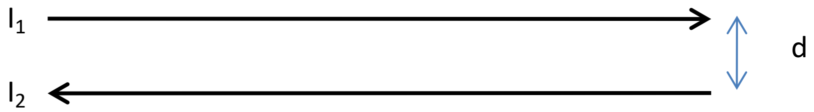
(A) Electrons are emitted after sufficient time has passed for them to accumulate enough energy from the light.

(B) Electrons are emitted after increasing the power of the light.

(C) Electrons are emitted after decreasing the frequency of the light.

(D) Electrons are emitted after decreasing the wavelength of the light.

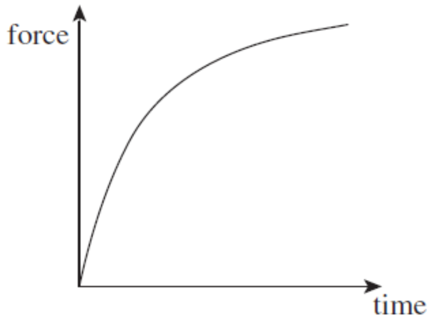
16 Two long conductors are suspended parallel as shown in the diagram below. The current in both wires is equal, but opposite in direction.



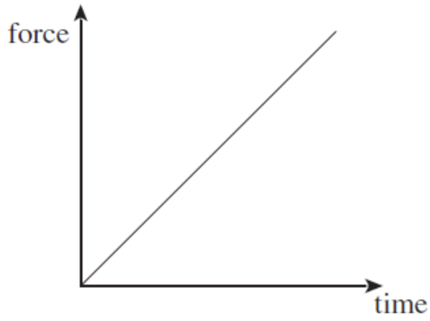
The distance, d, between the two wires is decreased at a steady rate.

Which graph below shows how the force between the wires will change over time?

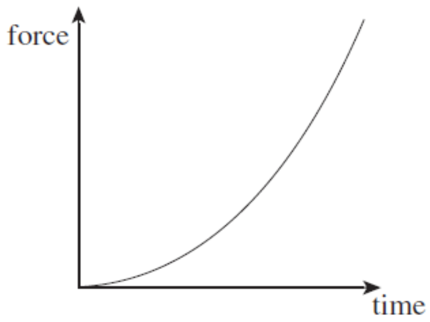
(A)



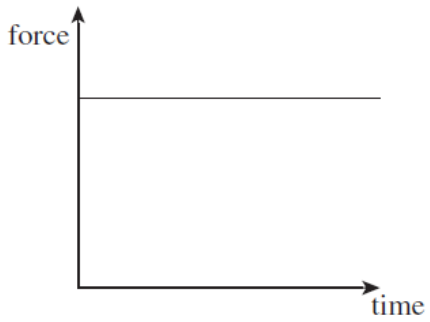
(B)



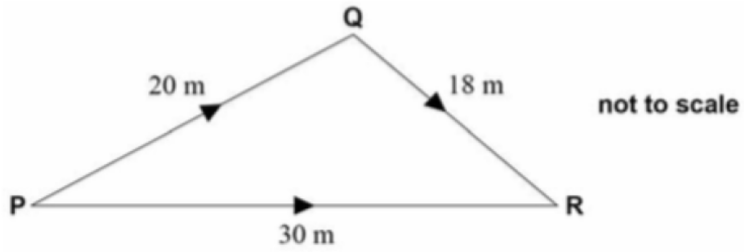
(C)



(D)



17 In the diagram below, P is a source of radio waves of frequency 75 MHz. The waves travel to R by two paths, P → Q → R and P→ R.



What is the path difference between the two waves at R in terms of the wavelength λ of the waves?

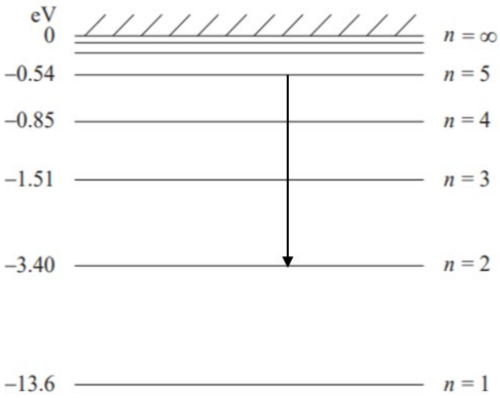
(A) λ

(B) 2λ

(C) 4λ

(D) 8λ

18 A hydrogen atom that has been raised to a $n = 5$ excited state quickly returns to a lower state, $n = 2$.



[*This diagram is not drawn to scale.*]

The arrow on the diagram on the right represents one transition between energy levels.

What is the wavelength of the photon that would be emitted when a hydrogen atom undergoes the transition from $n = 5$ to $n = 2$ as on the diagram?

(A) 31.5 nm

(B) 43.4 nm

(C) 315 nm

(D) 434 nm

19 A proton is circulating inside the ring of a synchrotron. The proton has an orbital radius of 82 m and a velocity of 1.25×10^8 m s^{-1}.

What is the magnitude of the magnetic field required to keep the proton in this radial distance?

(A) 0.0175 T

(B) 0.0185 T

(C) 0.0188 T

(D) 0.0196 T

20 Plane-polarised light is incident normally on a polariser which is able to rotate in the plane perpendicular to the light as shown below.

Diagram 1

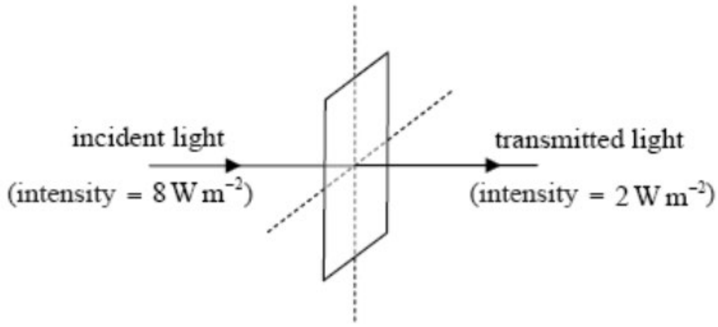
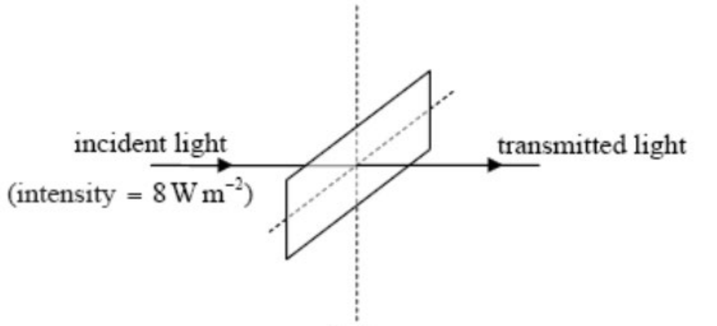


Diagram 2



In diagram 1, the intensity of the incident light is 8 W m^{-2} and the transmitted intensity of light is 2 W m^{-2}. Diagram 2 shows the polariser rotated 90º from the orientation in diagram 1.

What is the new transmitted intensity?

(A) 0 W m^{-2}

(B) 2 W m^{-2}

(C) 6 W m^{-2}

(D) 8 W m^{-2}

Student Number								

Physics
Section I – Multiple Choice Answer Sheet

Instructions for answering questions in Section I

- Complete your answers in either blue or black pen
- Multiple choice

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample 1: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ **B** ○ **C** ● **D** ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ○ **B** ○ **C** ⊗ **D** ●

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word ***correct*** and drawing an arrow as follows.

A ○ **B** ○ **C** ⊗ ← correct **D** ⊗

1. A ○ B ○ C ○ D ○
2. A ○ B ○ C ○ D ○
3. A ○ B ○ C ○ D ○
4. A ○ B ○ C ○ D ○
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6. A ○ B ○ C ○ D ○
7. A ○ B ○ C ○ D ○
8. A ○ B ○ C ○ D ○
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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								
Section I /20								
Section II /80								
Total /100								

Physics
Section II

80 marks
Attempt Questions 21 – 37
Allow about 2 hours 25 minutes for this section

Instructions

- Write your student number at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of the response.
- Show all relevant working in questions involving calculations
- Extra writing paper is available, please raise your hand to request more paper. If you use extra paper, clearly indicate your student number and which question you are answering.

Please turn over

Question 21 (5 marks)

A GPS satellite with a mass of 11 000 kg orbits the Earth at an altitude of 20 000 km.

a) Calculate the magnitude of its gravitational potential energy. **2**

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b) Calculate its orbital velocity. **3**

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Question 22 (5 marks)

A catapult releases its projectile 4.0 m above the ground with an initial velocity of 50 ms-1 at 40° to the horizontal, as shown in the diagram below.

a) Determine the maximum height reached above the ground by the projectile. **2**

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Question 22 continues on page 12.

Question 22 (continued)

b) What is the range of the projectile? **3**

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Question 23 (3 marks)

Solar activity generates streams of very fast charged particles that travel outwards into space.

a) A relativistic electron is generated by such activity and travels towards the Earth at 0.9 times the speed of light. If the Earth–Sun distance is 150 000 000 km, calculate how long it takes the electron to get here as measured on the Earth. **1**

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b) How much time would have passed in the reference frame of the electron? **2**

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End of Question 23

Please turn over

Question 24 (3 marks)

Titan is a moon of Saturn with a radius of 2 575 km and a mass of 1.35×10^{23} kg.

a) Calculate the acceleration due to gravity on the surface of Titan. **1**

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b) Titan has no atmosphere. What is the minimum speed required by a gas particle to completely escape the gravitational field of Titan? **2**

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Question 25 (3 marks)

Einstein used thought experiments to help explain some of the counterintuitive aspects of special relativity. **3**

Outline the difference between a thought experiment and a real experiment and explain why Einstein used thought experiments to explain relativity. Include an example in your response.

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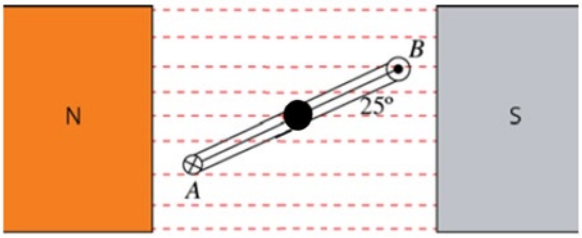
End of Question 25

Please turn over

Question 26 (6 marks)

The diagram below shows the end-on view of a simple DC motor, consisting of a square coil of 20 turns, within a uniform magnetic field of 2.5×10^{-2} T provided by permanent magnets.



The square coil of side length 5 cm and it is situated at an angle of 25° to the field. The current in the coil is 0.45 A and is directed away from the observer on side A.

a) Determine the force acting on side B, including its direction. **2**

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b) Calculate the torque acting on the coil in the position shown. **2**

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c) What will be the effect of adding extra coils at regular angles on the operation of the motor? **2**

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End of Question 26

Please turn over

Question 27 (3 marks)

Assuming a transformer is close to 100 per cent energy efficient, explain how energy is conserved if the transformer is used to step voltage down. **3**

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Question 28 (4 marks)

Outline the requirements necessary for a satellite to orbit the Earth in a geostationary orbit. Include any relevant calculations in your answer. **4**

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End of Question 28

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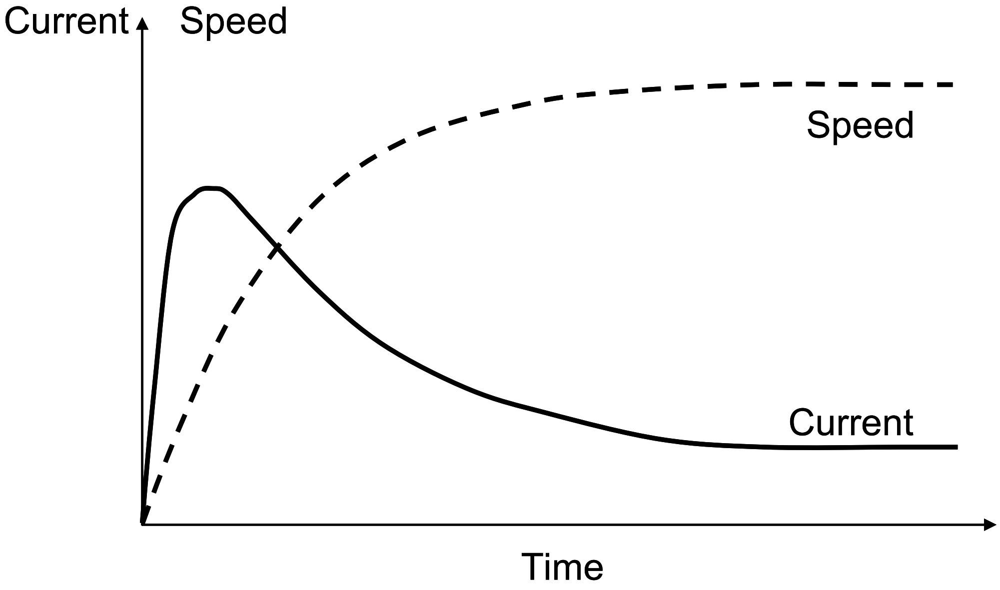
Question 29 (3 marks)

DC traction motors are used in electric cars because they can combine high starting torques with the ability to provide regenerative braking. When a traction motor is connected to a voltage source, the current in the armature increases rapidly and then falls as the speed of the motor reaches a steady value as shown in the graph below.



Describe and explain the trend of the current curve shown in the graph above against the speed of the motor. **3**

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End of Question 29

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Question 30 (4 marks)

One of the cathode ray tubes you studied contains a metal cross as shown in the picture below.

a) Describe the observations a student would be able to make when observing this tube in operation. **2**

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b) Identify two inferences that can be made from the observations made from the cathode ray tube. **2**

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End of Question 30

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Question 31 (4 marks)

The CERN physics program uses powerful accelerators such as the Large Hadron Collider (LHC) and detectors to study fundamental particles. Some huge amounts of electrical energy are consumed when the LHC is in operation and accelerating protons.

Each proton in the LHC is typically accelerated to reach 0.999c before it collides into another proton travelling in the opposite direction at the same speed.

a) Determine the relativistic momentum of a colliding proton in the LHC. **2**

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b) The LHC seeks, among other things, to give clarity to aspects of the Standard Model of matter. Part of that model includes quarks and the composite particles known as hadrons. With reference to the Standard Model, describe the composition of a proton. **2**

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End of Question 31

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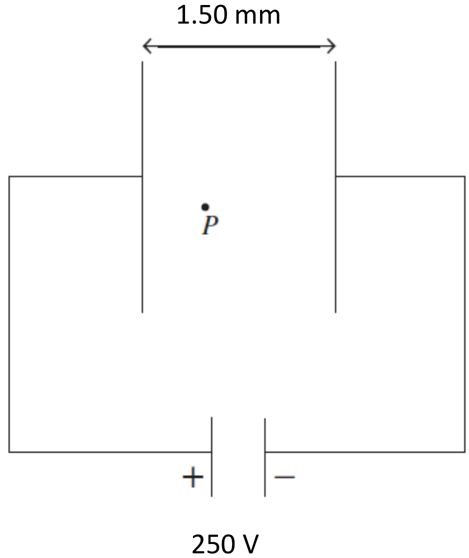
Question 32 (4 marks)

The diagram below shows two parallel plates 1.50 mm apart. They are connected to a power supply which produces a potential difference of 250 V. The region between the plates is a vacuum.



a) Calculate the electric field that exists between the plates. **1**

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b) An alpha particle (consisting of two protons and two neutrons) is placed in the field at point *P*. Calculate the force on the alpha particle due to the electric field. **1**

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c) Describe **quantitatively** the effect of the field on the alpha particle. **2**

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End of Question 32

Please turn over

Question 33 (4 marks)

In an experiment in 1971, four caesium atomic clocks were flown twice around the world in commercial airliners. The times on the clocks were synchronised before departure with four identical clocks at the US Naval Observatory. The clocks from the planes were compared with clocks left at the Observatory when the planes landed after their journeys.

a) What was the experiment trying to measure? **1**

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b) Why were four clocks used on both the planes and at the Observatory? **1**

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c) Identify one other example of experimental evidence supporting the prediction of Special Relativity and indicate which prediction is supported. **2**

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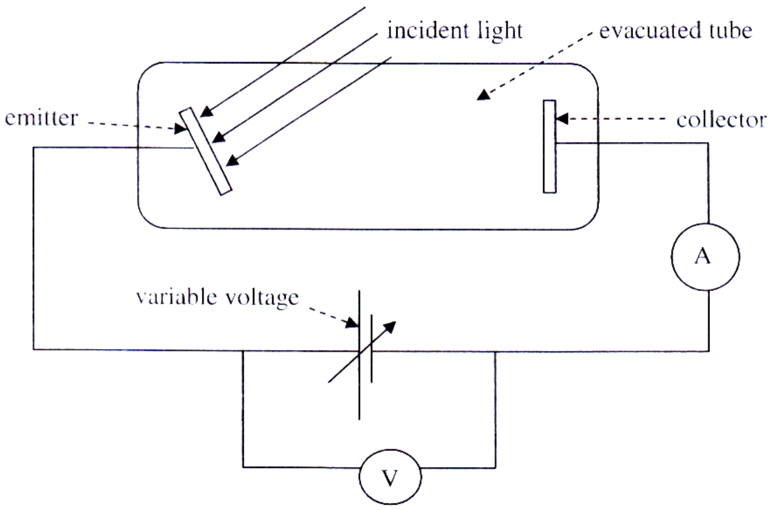
End of Question 33

Please turn over

Question 34 (8 marks)

An investigation was carried out to study the behaviour of caesium metal when ultraviolet light of a range of frequencies was shone onto it.

The diagram below shows the setup of the investigation. The work function of the metal is determined by adjusting the variable voltage to stop the emitted electrons from reaching the collector.



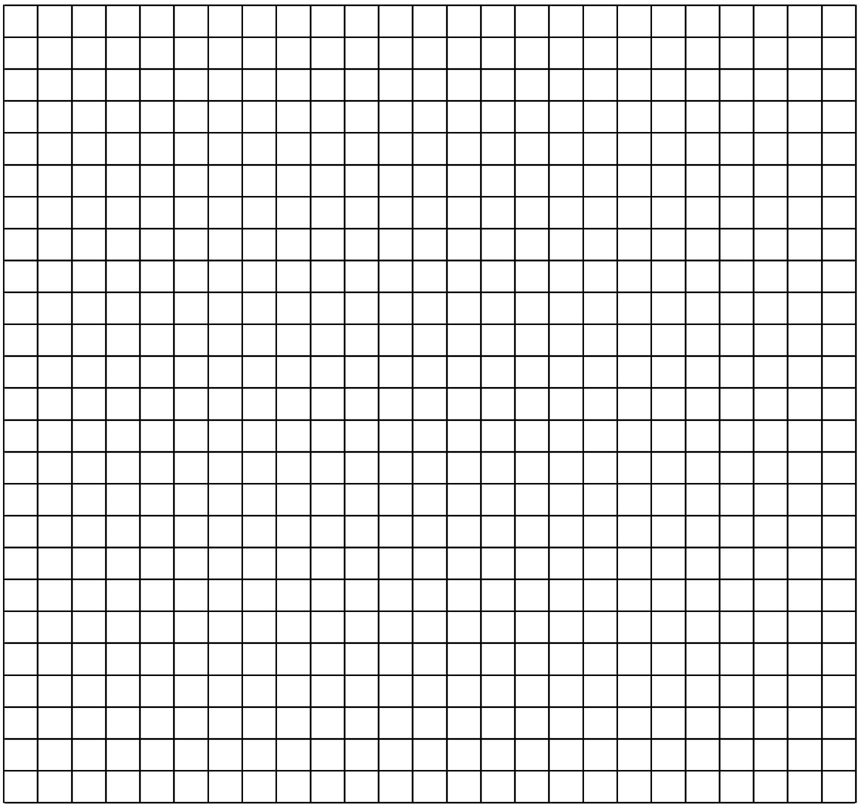
A partial table of results of stopping voltage versus frequency is given below.

Frequency ($\times 10^{14}$ Hz)	Stopping Voltage (V)
6.3	0.50
7.5	1.00
8.7	1.50
10.5	2.25

Question 34 continues on page 22

Question 34 (continued)

a) Choose appropriate scales and plot the results on the graph below with stopping voltage on the vertical axis. **3**



b) Determine the work function of caesium in eV. **1**

c) From your graph, determine the threshold freqeuncy for caesium. **1**

d) The experiment is repeated after the caesium metal plate has been replaced by a different metal. On your graph in part (a), draw another line to show the results of the repeated experiment (values are not required). **1**

Question 34 continues on page 23

Question 34 (continued)

e) Why is the concept of a quantum of electromagnetic radiation necessary to explain this graph? **2**

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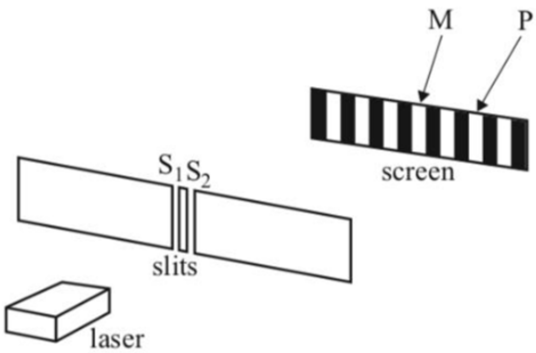
Question 35 (7 marks)

A barrier with two narrow slits S_1 and S_2 which are 0.2 mm apart is placed as shown in the path of a laser light with a wavelength of 532 nm. An interference pattern is observed. The point M on the screen is at the centre of the interference pattern. There is a bright band at point P on the screen. It is the second bright band to the right of M, as shown.



a) Outline the meaning of the term diffraction and explain why it is essential for the interference pattern in this experiment **2**

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b) Explain why there will be a bright fringe on the screen at point M. **2**

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Question 35 continues on page 24

Question 35 (continued)

c) Calculate the angle of the band at point P from the central axis. **3**

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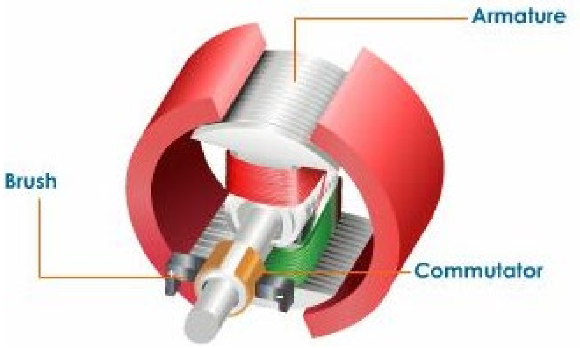
Question 36 (6 marks)

The diagram below shows the main components of a brushed DC motor.



a) Outline the role of the commutor and thebrushes. **3**

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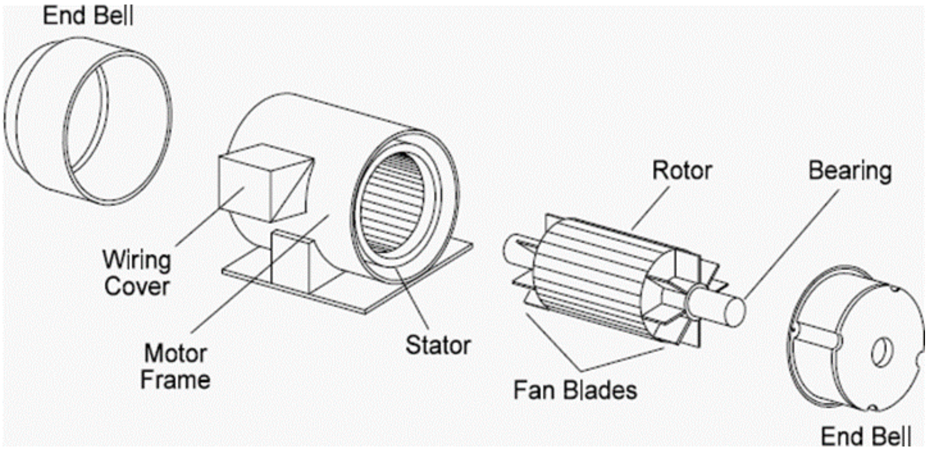
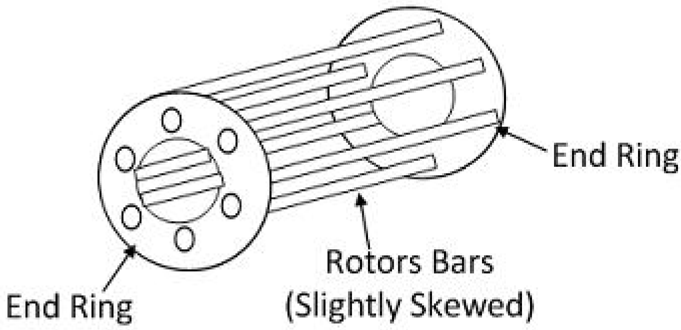
Question 36 continues on page 25

Question 36 (continued)

b) The diagram below shows the parts that make up an AC induction motor.



Below is a diagram showing the rotor component from the diagram above.



Unlike the brushed DC motor there is no electrical contact between the conductors in the rotor and an external power supply.

Explain how electric currents are produced in the bars of the rotor when the AC motor is operating. **3**

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End of Question 36

Please turn over

Question 37 (8 marks)

"Scientific progress typically builds on the successes and limitations of previous ideas". **8**

Discuss this statement with reference to the work of Rutherford, Bohr and de Broglie in furthering our understanding of atomic structure.

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End of Examination

Girraween High School

2020 **HIGHER SCHOOL CERTIFICATE TRIAL EXAMINATION**

Physics

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, formula sheet and Periodic Table are provided
Total marks: 100	**Section I – 20 marks** (pages 1 – 10) • Attempt questions 1 – 20 • Allow 35 minutes for this section **Section II – 80 marks** (pages 11 – 25) • Attempt questions 21 – 37 • Allow 2 hours and 25 minutes for this section

Section I
20 Marks

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

Use the Multiple Choice answer sheet for Questions 1 – 20

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1 A ball rolls off the edge of a table and traces out the path shown below.

Which of the following correctly describes the motion of the ball (ignoring air resistance)?

(A) Initially, the velocity of the ball is zero.

(B) The horizontal acceleration of the ball is constant.

(C) The ball has the greatest velocity immediately before impact.

(D) The vertical acceleration increases as the ball approaches the ground.

2 The ratio of the radius of Mars orbit to that of Earth's orbit is 1.5:1

How long is one Mars year?

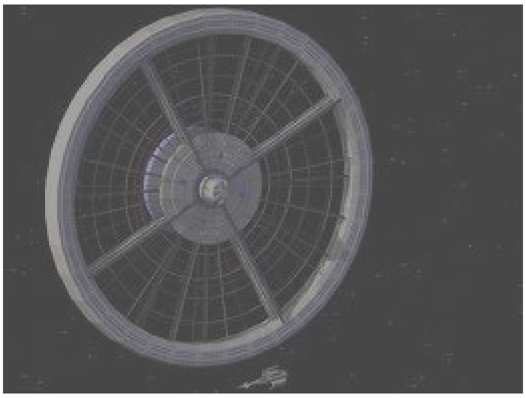
(A) 1.5 Earth years

(B) 1.8 Earth years

(C) 2.3 Earth years

(D) 3.4 Earth years

3 Gerard K O'Neill was a champion of space colonisation. He designed a rotating ring measuring 513 meters in diameter that would have people living on the inside. The rotation would simulate Earth gravity of 9.8 Nkg^{-1} within the ring.



At what velocity must the ring be spinning to produce centripetal acceleration the same as Earth's gravity?

(A) 50 ms^{-1}

(B) 71 ms^{-1}

(C) 5.0×10^3 ms^{-1}

(D) 25×10^3 ms^{-1}

4 Calculate the energy released from an electron-positron annihilation.

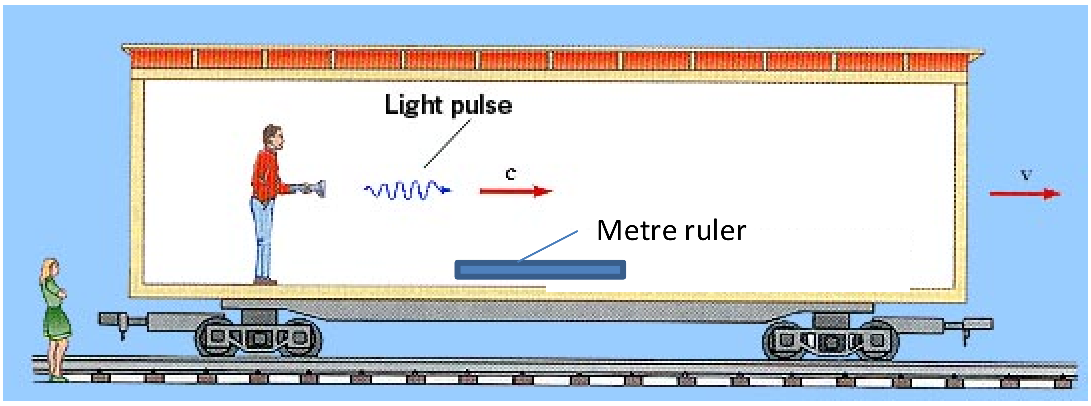
(A) 8.19×10^{-14} eV

(B) 1.638×10^{-13} eV

(C) 0.51 MeV

(D) 1.02 MeV

5 A man stands on a train moving at an extremely high velocity, *v*, pointing a torch in the direction of motion. A woman stands next to the track. A metre ruler lies on the floor of the train as shown.



Which of the following correctly describes an observation that could be made?

(A) Both observers would measure the speed of light and length of the rule to be the same.

(B) The woman observes the rule to be less than one metre and the speed of light to be $(c + v)$.

(C) The man observes the speed of light to be $(c – v)$ and the metre rule to be one metre long.

(D) Both observers measure the speed of light be c, but do not agree on the length of the ruler.

6 What is the energy of a photon of blue light with wavelength 475 nm?

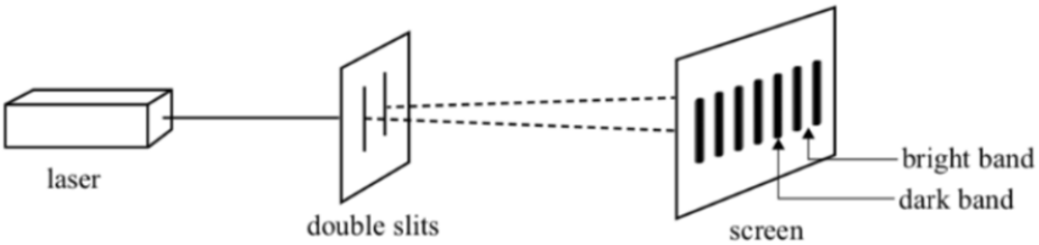
(A) 475 J

(B) 4.18×10^{-19} J

(C) 3.15×10^{-40} J

(D) 1.05×10^{-48} J

7 Light from a green laser passes through a double-slit arrangement, as seen below. An interference pattern is observed on the screen.



Which of the following actions would increase the spacing between the bands?

(A) Increasing the separation of the laser and the double slit.

(B) Decreasing the distance between the double slits and the screen.

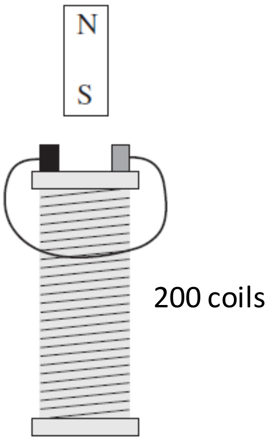
(C) Changing from a green laser to a blue laser.

(D) Changing from a green laser to a red laser.

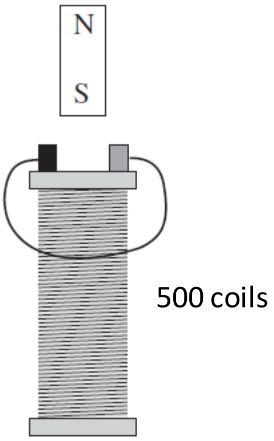
8 A permanent bar magnet is dropped from rest through a number of hollow solenoids, as shown in the diagrams below. All solenoids have the same length. Two of the solenoids have a connecting wire between the ends of the solenoid.

In which case would the magnet experience the greatest resistive force as it passes into the solenoid? B

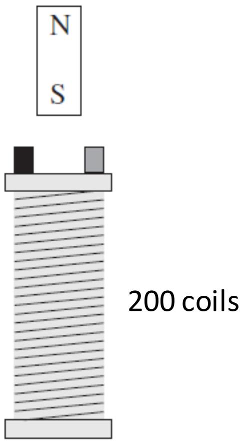
(A)



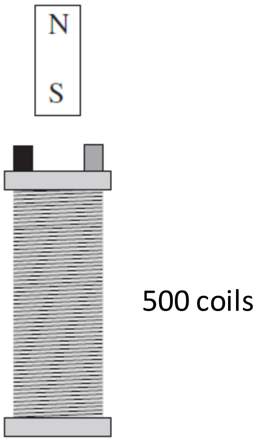
(B)



(C)



(D)



9 A transformer is designed to operate with 415 V across the primary coil and to produce a voltage of 12 V across the secondary coil.

If the primary coil has 1000 windings (coils), what is the number of windings on the secondary coil?

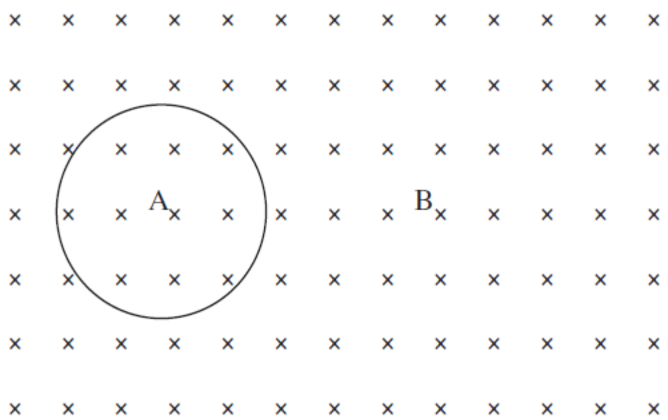
(A) 3

(B) 29

(C) 3 500

(D) 34 583

10 The diagram below shows a circular loop of conducting wire in a uniform magnetic field directed into the page.



The loop is moved from point A to point B in the plane perpendicular to the field lines. Which statement is true when the coil is moving?

(A) The flux through coil remains unchanged.

(B) A clockwise current is induced.

(C) An anticlockwise current is induced.

(D) The coil experiences a change in flux.

11 In 1900 Max Planck developed a new understanding of thermal radiation. He developed an equation that features a physical constant that now bears his name: Planck's constant, h, which has a value of 6.626×10^{-34} J s.

Planck's constant is:

(A) The ratio between the speed of light in vacuum to the speed of light in a material.

(B) The constant of proportionality between masses interacting under gravity only.

(C) The ratio between the energy in joules and frequency of electromagnetic radiation.

(D) The ratio between the temperature of a molecule and its kinetic energy in joules.

12 An electron moving with a velocity of 3.0×10^3 ms^{-1} passes at 90° through a magnetic field of strength 2×10^{-2} T

Identify which expression gives the magnitude of force on the electron due to the magnetic field.

(A) $F = 1.602 \times 10^{-19} \times 3000 \times 0.02 \times \sin 90°$

(B) $F = 1.602 \times 10^{-19} \times 3000 \times 200 \times \sin 90°$

(C) $F = 1 \times 3.0 \times 10^3 \times 2 \times 10^{-2} \times \cos 90°$

(D) $F/l = 1.602 \times 10^{-19} \times 3000 \times 200 \times \cos 90°$

13 What is the main advantage that follows from the use of transformers in power systems?

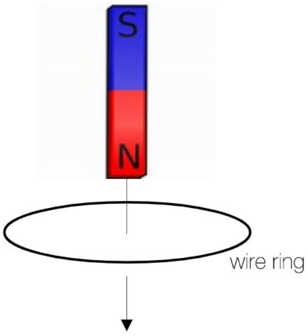
(A) Transformers allow the high voltages at which power is generated to be stepped down to usable levels.

(B) Transformers allow voltages to be stepped up so that larger currents can be generated and transmission efficiency can be improved.

(C) Transformers allow the low voltages at which power is generated to be stepped up to usable levels.

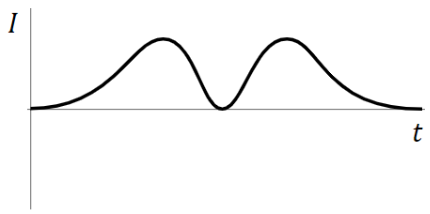
(D) Transformers allow voltages to be stepped up for transmission with lower currents so that transmission efficiency can be improved.

14 A bar magnet is lowered at constant speed through a wire ring, as shown in the diagram.

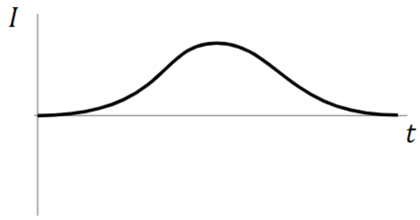


Which of the following graphs best represents the variation of the current induced in the ring, I, with time, t? C

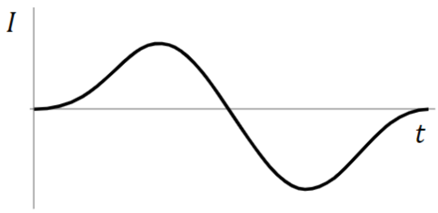
(A)



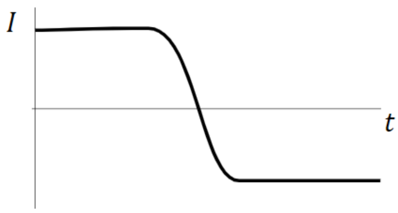
(B)



(C)



(D)



15 A powerful light is shone onto a metallic surface in a vacuum but initially no electrons are observed emitted from the surface.

Which of the following circumstances is most likely to follow?

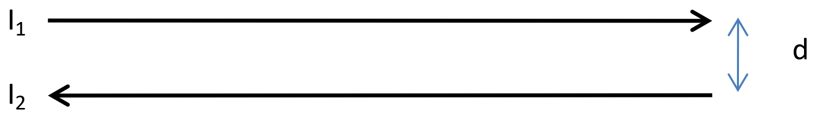
(A) Electrons are emitted after sufficient time has passed for them to accumulate enough energy from the light.

(B) Electrons are emitted after increasing the power of the light.

(C) Electrons are emitted after decreasing the frequency of the light.

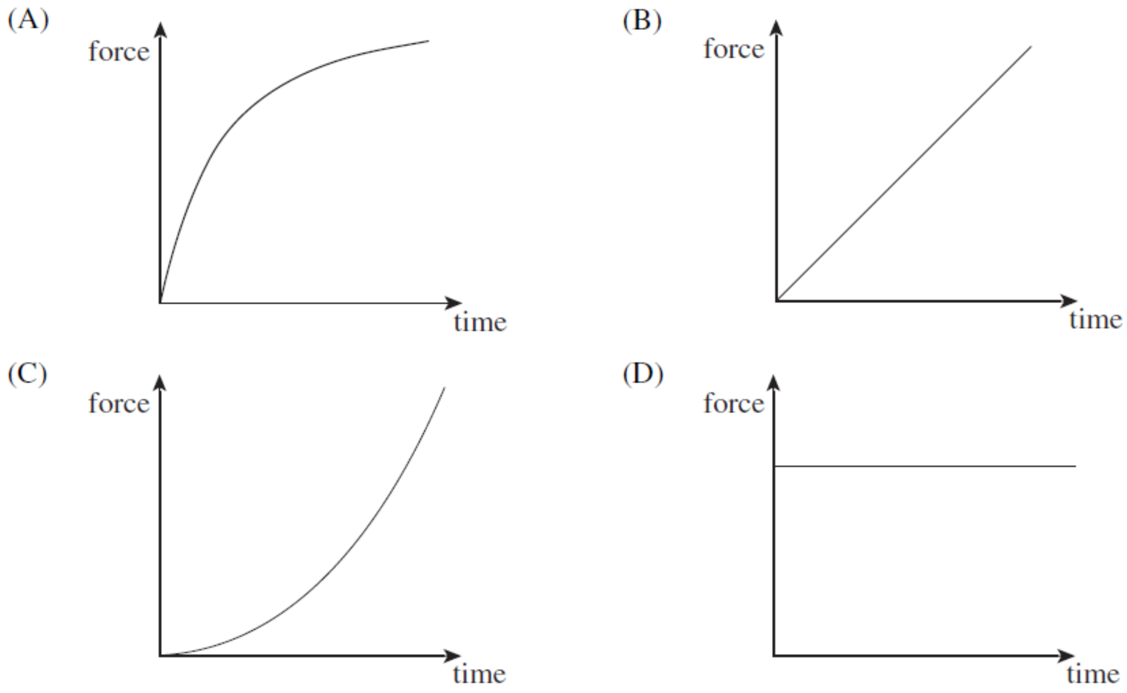
(D) Electrons are emitted after decreasing the wavelength of the light.

16 Two long conductors are suspended parallel as shown in the diagram below. The current in **both** wires is equal, but opposite in direction.

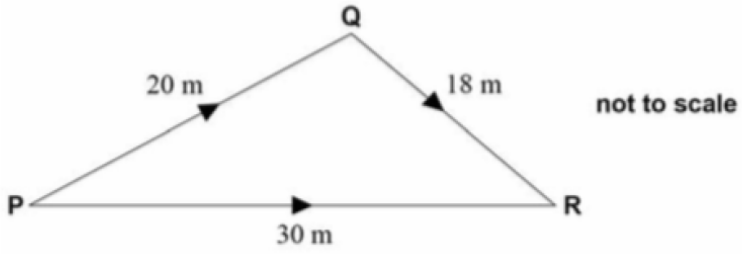


The distance, d, between the two wires is decreased at a steady rate.

Which graph below shows how the force between the wires will change over time? **C**



17 In the diagram below, P is a source of radio waves of frequency 75 MHz. The waves travel to R by two paths, P → Q → R and P→ R.



What is the path difference between the two waves at R in terms of the wavelength λ of the waves?

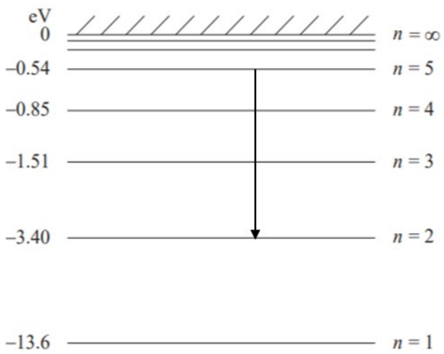
(A) λ

(B) 2λ

(C) 4λ

(D) 8λ

18 A hydrogen atom that has been raised to n = 5 excited state quickly returns to a lower state, n = 2. The arrow on the diagram on the right represents one transition between energy levels.



[This diagram is not drawn to scale.]

What is the wavelength of the photon that would be emitted when a hydrogen atom undergoes the transition from n = 5 to n = 2 as on the diagram?

(A) 31.5 nm

(B) 43.4 nm

(C) 315 nm

(D) 434 nm

19 A proton is circulating inside the ring of a synchrotron. The proton has an orbital radius of 82 m and a velocity of 1.25×10^8 m s^{-1}.

What is the magnitude of the magnetic field required to keep the proton in this radial distance?

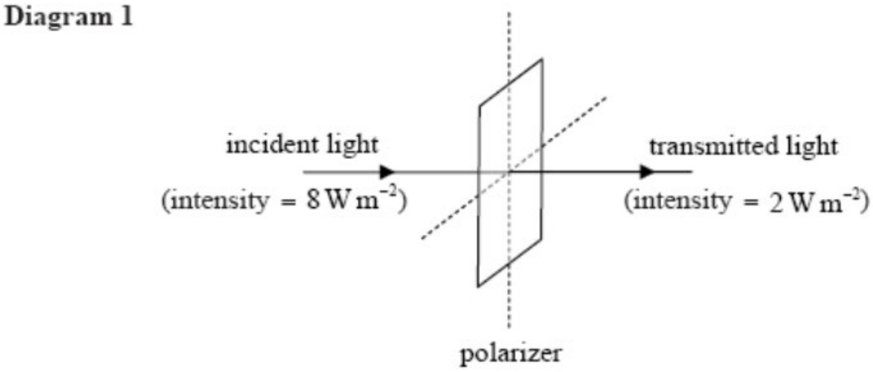
(A) 0.0175 T

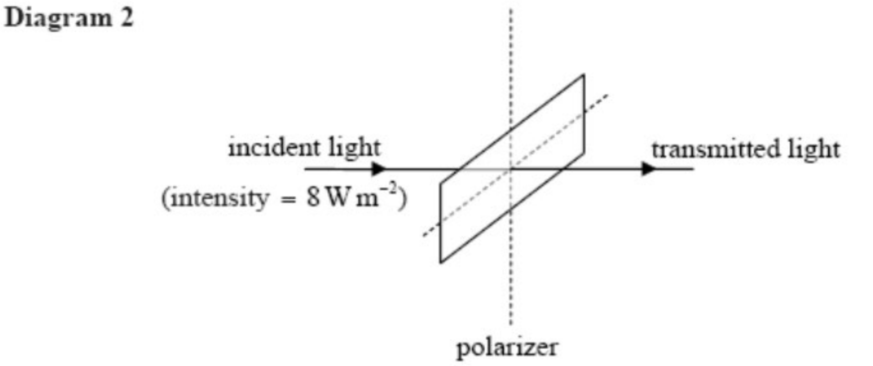
(B) 0.0185 T

(C) 0.0188 T

(D) 0.0196 T

20 Plane-polarised light is incident normally on a polariser which is able to rotate in the plane perpendicular to the light as shown below.





In diagram 1, the intensity of the incident light is 8 W m^{-2} and the transmitted intensity of light is 2 W m^{-2}. Diagram 2 shows the polariser rotated 90º from the orientation in diagram 1.

What is the new transmitted intensity?

(A) 0 W m^{-2}

(B) 2 W m^{-2}

(C) 6 W m^{-2}

(D) 8 W m^{-2}

Student Number								

Instructions for answering questions in Section I

- Complete your answers in either blue or black pen
- Multiple choice

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample 1: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9
A ○ **B** ○ **C** ● **D** ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ○ **B** ○ **C** ✗ **D** ●

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word ***correct*** and drawing an arrow as follows.

A ○ **B** ○ **C** ✗ ← correct **D** ✗

Section I – Multiple Choice Answer Sheet

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								
Section I /20								
Section II /80								
Total /100								

Physics
Section II

80 marks
Attempt Questions 21 – 38
Allow about 2 hours 25 minutes for this section

Instructions

- Write your student number at the top of this page.
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of the response.
- Show all relevant working in questions involving calculations
- Extra writing paper is available, please raise your hand to request more paper. If you use extra paper, clearly indicate your student number and which question you are answering.

Please turn over

Question 21 (5 marks)

A GPS satellite with a mass of 11,000 kg orbits the Earth at an altitude of 20 000 km.

(a) Calculate the magnitude of its gravitational potential energy. **2**

$Ep = GmM_E / r$

$= 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 1.1 \times 10^{4} / (2.64 \times 10^{7})$

$= 1.67 \times 10^{11}$ J

Criteria	Marks
• Correct calculation of GPE with units	2
• Substitues into a relevant formula for calculating energy	1

(b) Calculate its orbital velocity. **3**

$mv_o^2/r = GmM_E/r^2$

So $v = \sqrt{(GM_E/r)}$

$= \sqrt{(6.67 \times 10^{-11} \times 6.0 \times 10^{24}/2.64 \times 10^{7})}$

$= 3{,}895\ ms^{-1}$

Criteria	Marks
• Equates centripetal force with gravitational force • Rearranges and eliminates the mass of the satellite • Correct calculation of orbital velocity with units	3
• Incorrect calculation but with correct units • Correct answer but missing units	2
• Substitues into a relevant formula	1

Question 22 (5 marks)

A catapult releases its projectile 4.0 m above the ground with an initial velocity of 50 ms^{-1} at 40° to the horizontal.

(a) Determine the maximum height reached above the ground by the projectile. **2**

Max height is when $v_y = 0$ *ie* $0 = u_y^2 - 2g\Delta y$

So $\Delta y = u_y^2/2g$ *and max height* $= 4+\Delta y$

$= 4 + 50^2 sin^2 40° / (2 \times 9.8) = 56.7$ m

Criteria	Marks
• Calculates the correct height with units	2
• Calculates a height without including the initial 4m with or without correct units	1

(b) What is the range of the projectile? **3**

Time of flight given by $\Delta y = u_y t - gt^2/2$

$gt^2/2 - u_y t + \Delta y = 0$

So $t = (u_y \pm \sqrt{(u_y^2 - 2*g\,\Delta y)})/g$

$= (50 sin 40° \pm \sqrt{(50^2 sin^2 40° - 2 * 9.8 * 4)})/9.8$

$= 6.7$ *s*

So range $= u_x t = 50 cos 40° m/s \times 6.7 s = 256$ m

Criteria	Marks
• Uses equations in y direction to calculate time of flight AND • Uses time of flight to find the range in the x direction OR • Correct calculation of range by any method with units	3
• Incorrect calculation of time of flight used to calculate the range with correct units • Correct answer by any method but missing units	2
• Substitues into a relevant formula to find the time of flight OR • Substitues into a relevant formula to find the range	1

Question 23 (3 marks)

Solar activity generates streams of very fast charged particles that travel outwards into space.

(a) A relativistic electron is generated by such activity and travels towards the Earth at 0.9 times the speed of light. If the Earth–Sun distance is 150,000,000 km, calculate how long it takes the electron to get here as measured on the Earth. **1**

$t = d/v$

$= 1.5 \times 10^{11}$ m / $0.9 \times 3 \times 10^8$ m/s

$= 556$ s $= 9.3$ minutes

Criteria	Marks
• Correct calculation of time with appropriate units	1

(b) How much time would have passed in the reference frame of the electron? **2**

$\gamma = \sqrt{(1 - 0.9^2)} = 0.44$

$t_e = t_0\gamma = 556$ s x 0.44 = 242s

Criteria	Marks
• Uses relativity equation correctly • Correct calculation of time with correct units	2
• Substitues into a relevant formula but mixes up the times (t and t_o)	1

Question 24 (3 marks)

Titan is a moon of Saturn with a radius of 2 575 km and a mass of 1.35 x 10^{23} kg. It has no atmosphere.

(a) Calculate the acceleration due to gravity on the surface of Titan. **1**

$g_{Titan} = Gm_{Titan}/R_{Titan}^2 = 6.67 \times 10^{-11} \times 1.35 \times 10^{23} / (2.575 \times 10^6)^2$

$= 1.36$ ms^{-2}

Criteria	Marks
• Correct calculation of acceleration with appropriate units	1

(b) Titan has no atmosphere. What is the minimum speed required by a gas particle to completely escape the gravitational field of Titan? **2**

$v_e = \sqrt{(2Gm_{Titan}/r_{Titan})}$

$= \sqrt{(2 \times 6.67 \times 10^{-11} \times 1.35 \times 10^{23} / 2.575 \times 10^6)}$

$= 2.64 \times 10^3$ m/s

Criteria	Marks
• Equates kinetic energy with gravitational potential energy • Rearranges and eliminates mass • Correct calculation of escape velocity with units	2
• Equates kinetic energy with gravitational potential energy but errors in substitution and calculation	1

Question 25 (3 marks)

Einstein used thought experiments to help explain some of the counter-intuitive aspects of special relativity.

Outline the difference between a thought experiment and a real experiment and explain why Einstein used thought experiments to explain relativity. Include an example in your response. **3**

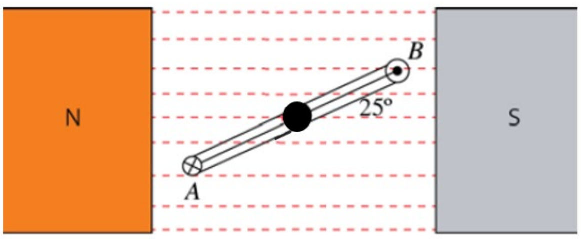
- thought experiments are not actually carried out

- Einstein used thought experiments to consider what would happen in circumstances that could not actually be created

- such as travelling at speeds close to the speed of light

Criteria	Marks
• States that thought experiments can not actually be carried out but real experiments can be done • Uses thought experiments to postulate what might happen (get results) if they could be carried out • Uses thought experiments to explain or model aspects of "Relativity" such as when objects approach the speed of light	3
• States that thought experiments can not actually be carried out but real experiments can be done • Discusses the difficulties of experimenting and getting results at the "limits of relativity"	2
• States that thought experiments can not actually be carried out but real experiments can be done OR • Discusses the difficulties of experimenting at the "limits of relativity"	1

Question 26 (6 marks)



The diagram on the right shows the end-on view of simple DC motor, consisting of a square coil of 20 turns, within a uniform magnetic field of 2.5×10^{-2} T provided by permanent magnets.

The square coil of side length 5 cm and it is situated at an angle of 25° to the field. The current in the coil is 0.45 A and is directed away from the observer on side A.

(a) Determine the force acting on side *B* including its direction. **2**

$F_B = nBIl\sin\theta$

$= 20 \times 2.5 \times 10^{-2} \times 0.45 \times 0.05 \times \sin 90^{o}$

$= 1.125 \times 10^{-2}$ N upwards

Criteria	Marks
• Uses correct equation to calculate force • Correct calculation of force with correct direction and unit	2
• Correct calculation of force without correct direction	1

(b) Calculate the torque acting on the coil in the position shown. **2**

$\tau = n\,B\,I\,A\,\sin\theta$

$= 20 \times 2.5 \times 10^{-2} \times 0.45 \times 0.05 \times 0.05 \times \sin 65 = 5.10 \times 10^{-4}$ N.m

Criteria	Marks
• Uses correct equation to calculate torque • Uses correct angle with correct units	2
• Uses correct equation but uses incorrect angle or substitution errors	1

(c) What will be the effect of adding extra coils at regular angles on the operation of the motor? **2**

Explains that the resultant torque which results from adding the torque of each coil which undergoes sinusoidal variation will be more steady than a single coil rotating alone in the motor. *Hence the operation of the motor will be more smooth or steady.*	*2*
One of the two above.	*1*

Sample:

As can be seen from the torque equation, the torque varies as the sin of the angle the coil makes with the magnetic field. This means it will vary throughout a rotation. By adding extra coils at regular angles the torque of the motor will be smoothed or it will make the motor to rotate more steadily.

Question 27 (3 marks)

Assuming a transformer is close to 100 per cent energy efficient, explain how energy is conserved if the transformer is used o step voltage down. **3**

- Energy conservation implies that Power in = Power out

Energy = Power x time (time is the same for both in and out)

- where Power = VI

- So if V decreased then I must be increased (inversely proportional) so that the Power remains constant.

Criteria	Marks
• States that energy if given by power x time • States or implies that time is not a fator (same) • States that V is inversely proportional to I in order that the power is the same for both input and output	3
• States that energy if given by power x time • States that V is inversely proportional to I in order that the power is the same for both input and output	2
• States that V is inversely proportional to I in order that the power is the same for both input and output	1

Question 28 (4 marks)

Outline the requirements necessary for a satellite to orbit the Earth in a geostationary orbit.

Include any relevant calculations in your answer.

Criteria	Marks
• Includes 3 correct calculations of radius, altitude and velocity • Includes a relevent concept from the list below	4
• Includes 2 correct calculations of radius, altitude or velocity • Includes a relevent concept from the list below	3
• Includes any correct calculations of radius, altitude or velocity • Includes a relevent concept from the list below	2
• Attempts any relevent calculation OR states any relevent concept from; T is 24 hrs, orbit is circular, the satellite appears stationary above the earth's surface, the orbit is equatorial	1

Sample answer

$$r = \sqrt[3]{\frac{GM}{4\pi^2}T^2} = 4.24 \times 10^4\ km$$

Altitude = satellite radius – radius of the earth

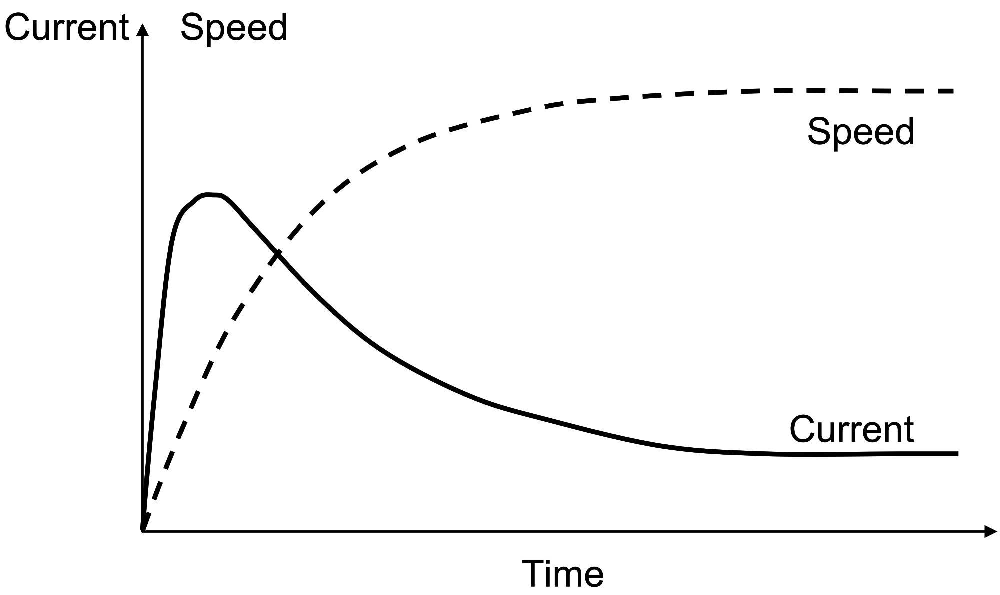
= 4.24 x 10⁷ m – 0.6371 x 10⁷m

= 3.60 x 10⁷ m (36,000 km)

$$v = \sqrt{\frac{GM}{r}} = 3086.8\ ms^{-1}$$

Question 29 (3 marks)

DC traction motors are used in electric cars because they can combine high starting torques with the ability to provide regenerative braking. When a traction motor is connected to a voltage source the armature current increases rapidly and then falls as the speed of the vehicle reaches a steady value as shown in the graph below.



Explain why the current initially rises to a peak value and then falls to a steady value as the motor picks up speed. **3**

Current rises to a peak determined by resistance of armature

As motor gains speed back emf increases

As back emf causes current to fall

Criteria	Marks
• States that the initial current is determined by the resisstance of the armature	3

• States that the back e.m.f. increases as the motor speeds up (Lenz's Law) • States that as the back e.m.f. increases the current through the armature will decrease	
• States that the back e.m.f. increases as the motor speeds up (Lenz's Law) • States that as the back e.m.f. increases the current through the armature will decrease	2
• States that the current trends are due to back e.m.f.	1

Question 30 (4)

One of the cathode-ray tubes you studied contains a metal cross as shown in the picture below.

(a) Describe the observations a student would be able to make when observing this tube in operation. **2**

- Cathode rays are emitted from the negative electrode and can be seen

to produce an image of the cross on the end and a yellow glow on the glass

- except where they are intercepted by the metal cross.

Criteria	Marks
• Describes 2 features that can be observed when the tube is operated	2
• Describes a feature that can be observed when the tube is operated	1

(b) Identify two inferences that can be made from the observations made from the cathode ray tube. **2**

- cathode rays travel in straight lines

- cathode rays do not pass through metal

Criteria	Marks
• States 2 properties that can be infered from the observed features	2
• States any property that can be infered from one of the observed features	1

Question 31 (4 marks)

The CERN physics program uses powerful accelerators such as the Large Hadron Collider (LHC) and detectors to study fundamental particles. Some huge amounts of electrical energy is consumed when the LHC is in operation of accelerating protons.

Each proton in the LHC is typically accelerated to reach 0.999c before it collides into another proton travelling in the opposite direction at the same speed.

Determine the momentum of a colliding proton in the LHC. 2

Criteria	*Marks*
A correct determination of the momentum of the colliding proton using the correct equation of $p_v = \frac{m_0 v}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$	*2*
One error in calcuation but used the correct equation	*1*

Sample answer:

$$p_v = \frac{m_0 v}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

$$= \frac{(1.673 \times 10^{-27})(0.999 \times 3 \times 10^8)}{\sqrt{\left(1 - \frac{(0.999c)^2}{c^2}\right)}}$$

$$= 1.12 \times 10^{-17}\ kgms^{-1}$$

The LHC seeks among other things, to give clarity to aspects of the Standard Model of matter. Part of that model includes quarks and the composite particles known as hadrons. With reference to the Standard Model, describe the composition of a proton. 2

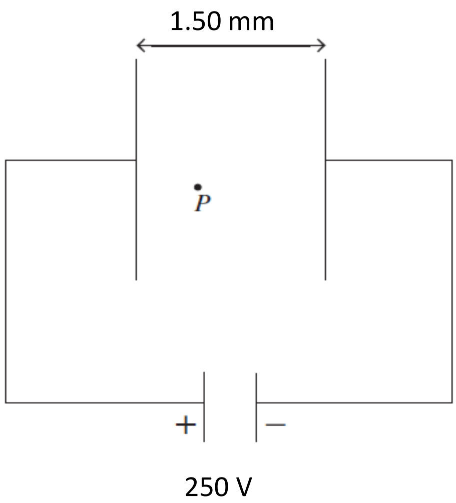
Criteria	*Marks*
A description of how a proton is composed of three quarks, two up and one down quarks AND *A description of the nature of those quarks leading to a hadron with a charge of +1.* *OR* *A detailed description of how a proton is composed of three quarks and describes the nature of forces between them using gluon.*	*2*
A general description of a proton being composed of quarks	*1*

Sample answer:

A proton is a quark composition hadron composed of three quarks. It is hence a baryon. A proton is composed of two up quarks each with electric charge of $+\frac{2}{3}$, for a total of $+\frac{4}{3}$ together combine with one down quark with electric charge of $-\frac{1}{3}$. Adding these charges together yields the proton with a charge of +1.

Question 32 (4 marks)

The diagram below shows two parallel plates 1.50 mm apart. They are connected to a power supply which produces a potential difference of 250 V. The region between the plates is a vacuum.



Calculate the electric field that exists between the plates. **1**

$E = V/d = 250\ V / 1.5 \times 10^{-3}\ m = 1.67 \times 10^{5}\ V/m$

Criteria	**Marks**
Correct calculation of the electric field with appropriate units	**1**

An alpha particle (consisting of two protons and two neutrons) is placed in the field at point P.

Calculate the force on the alpha particle due to the electric field. **1**

$F = Eq = 1.67 \times 10^5$ V/m x 2 x 1.6×10^{-19} C = 5.3×10^{-14} N

Criteria	Marks
Correct calculation of the force with appropriate units	1

Describe **quantitatively** the effect of the field on the alpha particle.

2

The field (towards the right) will accelerate the alpha particle to the right (negative plate)

at a rate given by $a = F/m = 5.3 \times 10^{-14}$ N / (4 x m_p) = 7.9×10^{12} ms^{-2}

Criteria	Marks
Identifies that the alpha particles will accelerate towards the negative plate (towards the right) Calculates the acceleration with units	2
Identifies that the alpha particles will be accelerated towards the negative plate (towards the right) OR Calculates the acceleration with units	1

Question 33 (4 marks)

In an experiment in 1971, four caesium atomic clocks were flown twice around the world in commercial airliners. The times on the clocks were synchronised before departure with four identical clocks at the US Naval Observatory. The clocks from the planes were compared with clocks left at the Observatory when the planes landed after their journeys.

(a) What was the experiment trying to measure?

1

The time dilation effect predicted by Einstein.

Criteria	Marks
States that it was about the effect of time dialation	1

Why were four clocks used on both the planes and at the Observatory?

1

To assess the reliability of the measurements

Criteria	Marks
States that the use of more clocks would improve the reliability of the data	1

Identify one other example of experimental evidence supporting the prediction of Special Relativity and indicate which prediction is supported. **2**

Criteria	Marks

Identifies a correct example Connects the example to the correct prediction	**2**
Correct example only OR One valid, relevant statement	**1**

Sample answer:

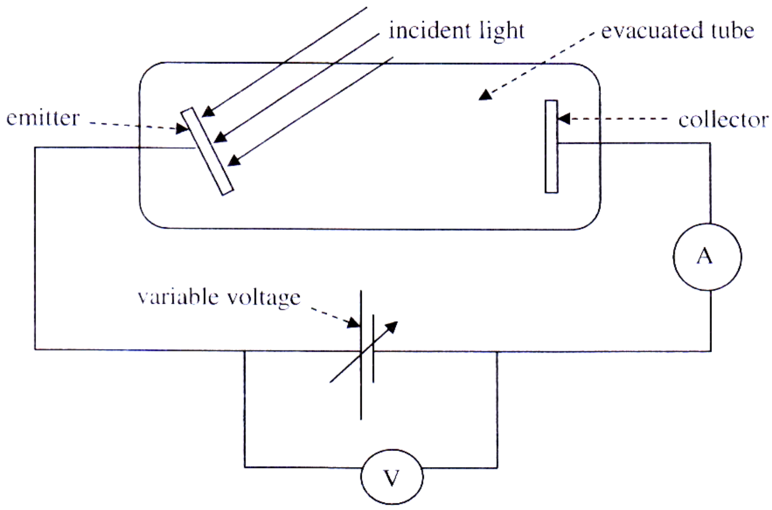
Particle Accelerators – Mass dilation is observed in the collision products of particle collisions in particle accelerators such as the LHC in Switzerland, where the mass of the results of the collision is greater than the sum of the rest masses of the colliding particles.

Detection of muon near Earth's surface – due to time dilation of their life span

Question 34 (8 marks)

An investigation was carried out to study the behaviour of caesium metal when ultraviolet light of a range of frequencies was shone onto it.

The diagram below shows the setup of the investigation. The work function of the metal is determined by adjusting the variable voltage to stop the emitted electrons from reaching the collector.

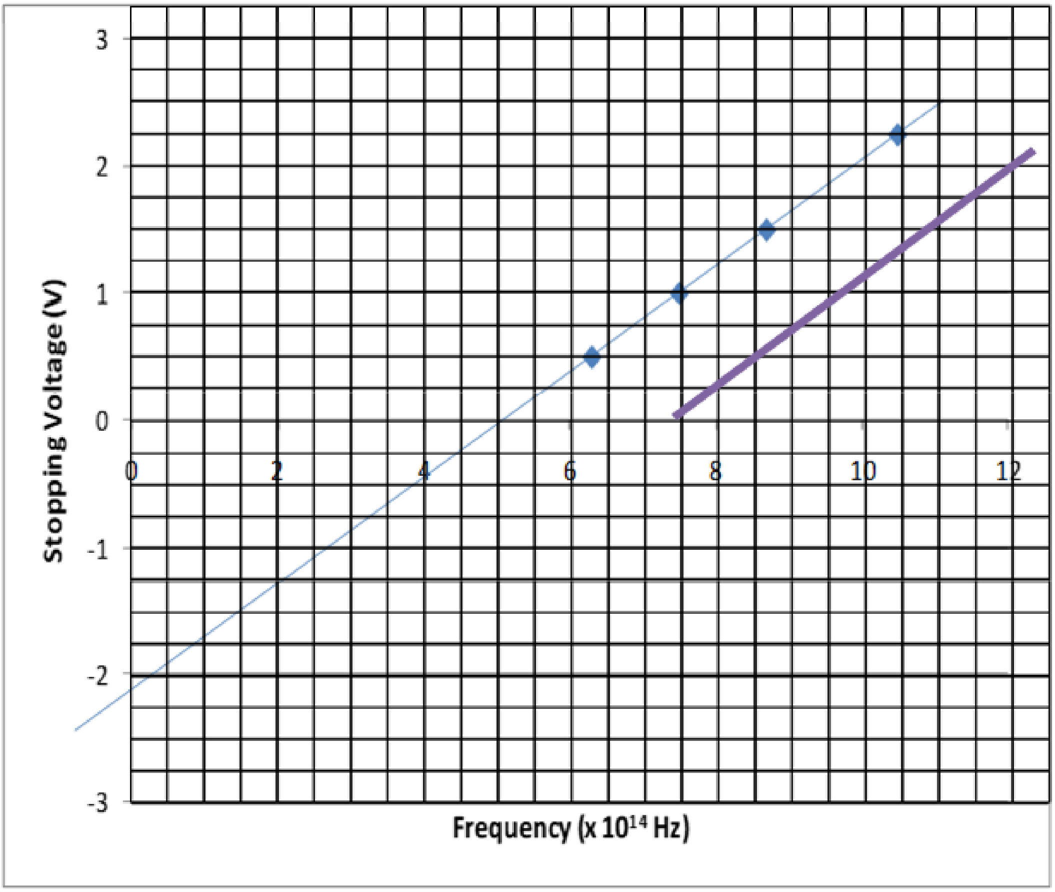


A partial table of results of stopping voltage versus frequency is given below.

Frequency ($x10^{14}$ Hz)	**Stopping Voltage (V)**
6.3	0.50

7.5	1.00
8.7	1.50
10.5	2.25

Choose appropriate scales and plot the results on the graph below with stopping voltage on the vertical axis. **3**



Criteria	Marks
Suitable linear scales Axes correctly labelled with units in brackets Data points clearly and accurately plotted AND a line of best fit is drawn.	3
Suitable linear scales Axes correctly labelled but without units Data points clearly plotted but may have an accuracy error	2
Attempts to plot a graph of the data	1

Determine the work function of caesium in eV. **1**

Work function = 2.1 eV by extrapolation of the graph

OR Equation: $eV = hf - W$ so putting $V = 0$ then $W/e = hf_0/e$ where f_0 is 5×10^{14} Hz.

So $W/e = 6.626 \times10^{-34} \times 5\times10^{14}/1.6\times10^{-19} = 2.07$ eV

Criteria	Marks
Uses the graph OR by use of equation – finds the work function	**1**

From your graph, determine the threshold frequency for caesium. **1**

Threshold frequency $f_0 = 5\times10^{14}$ Hz

Criteria	Marks
Uses the graph OR by use of equation – finds the threshhold frequency	**1**

The experiment is repeated after the caesium metal plate has been replaced by a different metal. On your graph in part (a), draw another line to show the results of the repeated experiment (values are not required). **1**

Criteria	Marks
Draws a line on the graph parallel to the line for caesium	**1**

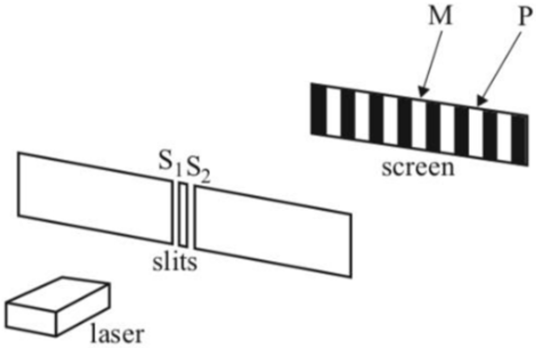
Why is the concept of a 'quantum' of electromagnetic radiation necessary to explain this graph? **2**

The quantum concept, that electromagnetic radiation is transmitted as discrete quanta of energy called photons, explains why no electrons are ejected below a threshold frequency (f_0) and that the kinetic energy of ejected electrons is proportional to the frequency.

Criteria	Marks
• Links that the concept of a 'quantum' of electromagnetic radiation to that it is transmitted as or it consists of discrete packets of energy *or* quanta *or* photons. (**C**) • Explains that no electrons are ejected below a threshold frequency as the energy of photons depends on the frequency (i.e. $E = hf$) of light. (**f**) ADDITIONAL but not necessary: the kinetic energy of ejected electrons is proportional to the frequency.	**2**
• One of the two above	**1**

Question 35 (7 marks)

A barrier with two narrow slits S_1 and S_2 which are 0.2 mm apart is placed as shown in the path of laser light of wavelength 532 nm. AN interference pattern is observed. The point M on the screen is at the centre of the interference pattern. There is a bright band at point P on the screen. It is the second bright band to the right of M, as shown.



(a) Outline the meaning of the term diffraction and explain why it is essential for the interference pattern in this experiment. **2**

Criteria	*Marks*
Outlines diffraction as spreading of light after passing through slits OR as the fact that each slit acts as point source. (M) *Explains that diffraction is necessary to get pattern that is not in line with slits. OR (P)* *So that diffracted waves from each slit can combine (as if from 2 point sources). OR So that waves from the slits can interact with each other as they coincide on screen. (P)*	*2*
One of the above	*1*

Sample answer:

Diffraction is the spreading out of a wave when it passes through an aperture. It is necessary to produce parts of the interference pattern that are not in direct line with the slits.

(b) Explain why there will be a bright fringe on the screen at point M. **2**

Criteria	*Marks*
States that point M is equal distance from each slit. (ED) *Links equal path length to constructive interference. (CI)*	*2*
One of the above	*1*

Sample answer:

Point M is a equal distance from each slit. Laser light in phase at the two slits will also be in phase at M, so will produce constructive interference resulting in a bright patch.

(c) Calculate the angle of the band at point P from the central axis.

3

Criteria	*Marks*
Correct substitution into double slit equation, correct answer.	*3*
As above but unit conversion error or wrong fringe number. *OR* *One incorrect substitution*	*2*
Correct equation with two incorrect substitutions	*1*

Sample answer:

m = 2 (i.e. the second bright fringe from centre)

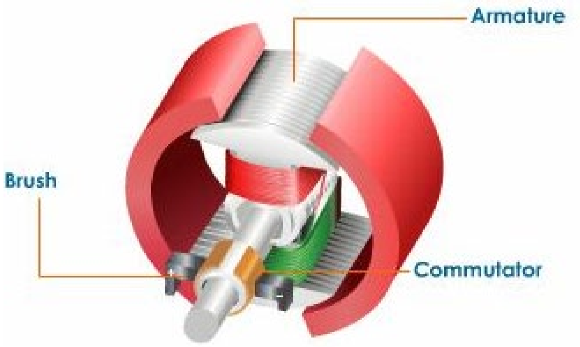
$$m\lambda = d\sin\theta$$

$$2 \times 532 \times 10^{-9} = 0.2 \times 10^{-3} \times \sin\theta$$

$$\theta = \sin^{-1}\left(\frac{2 \times 532 \times 10^{-9}}{0.2 \times 10^{-3}}\right) = \sin^{-1}(0.00532) = 0.30°$$

Question 36 (6 marks)

The diagram shows the main parts of a brushed DC motor.



(a) Outline the role of the commutator and brushes.

3

the brushes provide a contact to the power supply

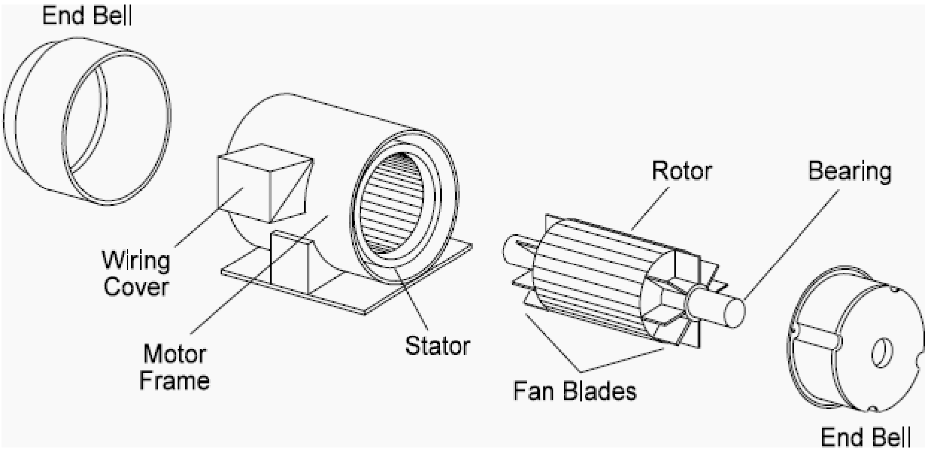
the commutator reverses the current direction in the armature/rotor every half a rotation

this current reversal maintains a constant torque direction for the armature

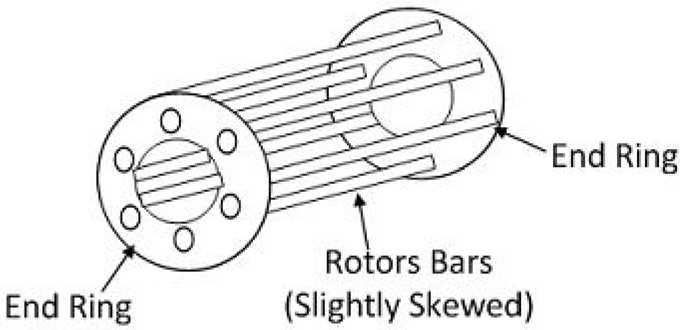
Criteria	Marks
• States that the "brushes" allow electrical contact between the *moving* armature and the *fixed* external source of power (**b**) • States that the commutator is *split* to allow the direction of the direct current to be reversed every half a cycle (**c**) • States that the above configuration allows the armature to keep moving (spinning) in the same direction (**r**)	3
• States that the "brushes" allow electrical contact between the *moving* armature and the *fixed* external source of power	2

• States that the commutator is *split* to allow the direction of the direct current to be reversed every half a cycle OR • States that the above configuration allows the armature to keep moving (spinning) in the same direction	
• States any function of the brushes or the commutator that facillitates the working of the DC motor	1

The diagram shows the parts that make up an AC induction motor.



Below is a diagram showing the squirrel cage rotor component from the diagram above.



Unlike the brushed DC motor there is no electrical contact between the conductors in the rotor and an external power supply.

Explain how electric currents are produced in the bars (rods between the end rings) of the rotor when the AC motor is operating. **3**

A rotating magnetic field is set up by AC current supplied to electromagnetic coils located on the stator the conducting bars of the rotor experience a change in flux as they are inside this rotating magnetic field and this induces a voltage the conducting bars are connected at either end therefore a current is produced from the induced voltage (which creates a magnetic field that can interact with the field from the stator coils and cause it to rotate).

Criteria	Marks
• States that AC is applied to the *fixed* stator coils and this creates a rotating magnetic field (**AC**) • States that the bars in the *moveable* rotor experience a changing magnetic flux because of above. (**MF**) • States that the flux in the bars causes a voltage and thus current in the bars (which will create it's own magnetic field to interact with the field in the stator coils and thus cause the rotor to spin). (**VC**)	**3**
• States that AC is applied to the *fixed* stator coils and this creates a rotating magnetic field AND • States that the bars in the *moveable* rotor thus experience a changing magnetic flux OR • States that the flux in the bars causes a voltage and thus current in the bars (which will create it's own magnetic field to interact with the field in the stator coils and thus cause the rotor to spin (rotate))	**2**
Describes any correct aspect of the operation of an AC motor	**1**

Question 37 (8 marks)

"Scientific progress typically builds on the successes and limitations of previous ideas".

Discuss this statement with reference to the work of Rutherford, Bohr and de Broglie in furthering our understanding of atomic structure. 8

Criteria	*Marks*
Covers the key successes and limitations of Rutherford in depth. (RSD and RL) *Covers the key successes and limitation of Bohr in depth. (BSD and BL)* *Covers the developments made by de Broglie. (dBD)* *For 8 marks to be awarded, answer must show depth, be logically sequenced and conatin no errors of fact.*	*7-8*
Describes strengths and weaknesses of the work of BOTH Rutherford and Bohr and the work of de Broglie also covered. *However, the response is not coherent, and lacks depth and possibly has ambiguous or significant factually wrong statements. (RS and RL) (BS and BL) (dB)* *OR*	*5-6*

The work of de Broglie covered, along with relevant information about Bohr and Rutherford. However, overall response lacks depth.	
Describes strengths and weaknesses of the work of BOTH Rutherford and Bohr *OR* *The work of de Broglie covered in some depth, along with relevant information about either Bohr or Rutherford.*	*3-4*
Describes work of TWO of the scientists. *OR* *Describes strengths and weaknesses of the work of either Rutherford or Bohr*	*2*
Makes correct statement about the work of one of the scientists.	*1*

Sample answer:

Rutherford's alpha scattering experiments led him to propose that the mass of the atom was concentrated in a central small, dense an positively charged nucleus. Most of the rest of the atom was empty space, with negative electrons orbiting the nucleus in circular orbits. Rutherford's model successfully explained the alpha scattering data, and was thus an improvement of J J Thompson's 'Plum Pudding' model, which lacked a central nucleus.

However it did not explain the hydrogen emission spectral lines, nor did it explain why the electrons did not spiral into the nucleus, emitting EMR as they did so, thus leading to the collapse of the atom.

Bohr built on Rutherford's ideas, by keeping the concept of a positive nucleus surrounded by orbiting electrons. He said electrons existed in stationary states where they were able to orbit the nucleus without emitting EMR. He also explained the hydrogen spectral lines were due to electrons dropping from a higher stationary state to a lower one. However it lacked a mechanism for explaining why the stationary states existed.

De Broglie was able to explain why Bohr's stationary states existed. To do this, he had to start considering the electron as a wave (and his equation of $\lambda = \frac{h}{mv}$ *assigned electrons a tiny yet measurable wavelength), and not just as a particle. This led to the wave-particle model for matter. In de Broglie's model, the electrons formed standing waves in their orbits, and as standing waves, they did not radiate energy, thus remaining stable. Direct experimental evidence for de Broglie's ideas came from Davisson and Germer who observed electron diffraction (diffraction being a defining property of waves).*

End of examination.