Student Number…….

NORTH SYDNEY GIRLS HIGH SCHOOL

2021

HSC

Practice Task

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, formulae sheet and Periodic Table are provided on separate sheets
- **Write your student number at the top of this booklet**

Total marks 100

Section I
20 marks (pages 2–12)
Attempt Questions 1–20
Allow about 35 minutes for this section

Section II
80 marks (pages 13–32)
Attempt Questions 21–32
Allow about 2 hour and 25 minutes

There are 32 questions to answer.

Attempt **Section I** in the multiple-choice answer sheet and **Section II** in the spaces provided. These spaces provide guidance for the expected length of each response.

Section I

20 marks
Attempt Question 1-20
Allow about 35 minutes for this section

Use the multiple-choice answer sheet for Questions 1-20

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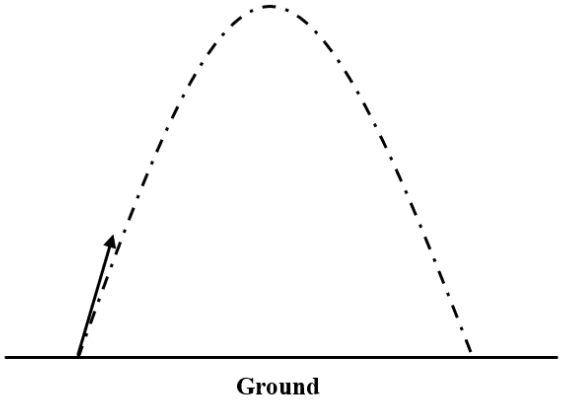
1. Which of the following is constant for the entire flight of a projectile?



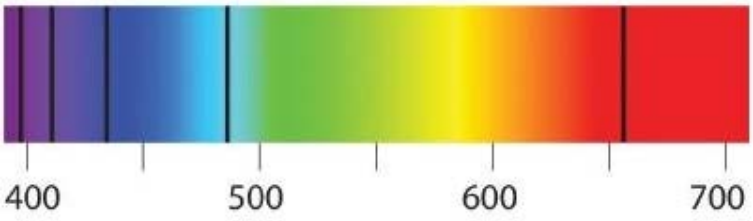
A. Distance from the ground

B. Speed

C. Velocity

D. Acceleration

2. The following spectrum was observed during an experiment.



Which type of spectrum is this?

A. Continuous spectrum

B. Emission spectrum

C. Absorption spectrum

D. Electromagnetic spectrum

3. A proton travels at a velocity of $0.5\ \mathrm{ms}^{-1}$ from right to left perpendicular to a magnetic field, B, of strength 2.0×10^{-5} mT. The magnetic field is running vertically downwards. What is the size of the force that the particle will experience?

A. 1.6×10^{-24} N into the page

B. 1.6×10^{-24} N out of the page

C. 1.6×10^{-27} N down the page

D. 1.6×10^{-27} N out of the page

4. Neptune has a mass of 1.024×10^{26} kg and radius of 2.46×10^{7}m. What is the gravitational field strength on the surface of Neptune?

A. $2.8\ \mathrm{N\ kg}^{-1}$

B. $9.8\ \mathrm{N\ kg}^{-1}$

C. $11.3\ \mathrm{N\ kg}^{-1}$

D. $22.6\ \mathrm{N\ kg}^{-1}$

5. A group of scientists on Earth are observing a nearby star, Barnard's Star. They noticed that the peak wavelength of Barnard's Star's radiation is 925 nm. What is the surface temperature of Barnard's Star?

A. 3133 K

B. 13870 K

C. 21632 K

D. 9.399×10^{11} K

6. Which of the following statements correctly describes the change in force between two parallel current carrying conductors, when one current decreases by a factor of four, and the separation distance halves?

A. The force will increase by a factor of eight.

B. The force will halve.

C. The force will remain the same.

D. The force will increase by a factor of two.

7. A satellite S_1 is in a stable low-Earth orbit (LEO) and another satellite S_2 is in a stable geostationary orbit (GEO). Both satellites have the same mass. Which of the following is correct about the two satellites in orbit?

	Great orbital speed	**Greater gravitational potential energy**
A.	S_1	S_1
B.	S_1	S_2
C.	S_2	S_1
D.	S_2	S_2

8. Which of the following best describes the problem with using classical physics to predict the spectrum of light emitted by a heated body?

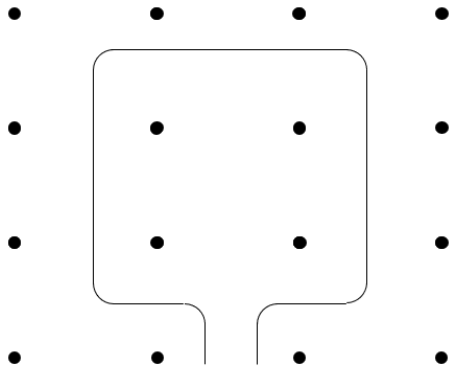
A. Predictions of classical physics did not agree with experimental data for short wavelengths.

B. Prediction of classical physics did not agree with experimental data for long wavelengths.

C. Predictions of classical physics did not agree with experimental data due to poor experimentation.

D. Predictions of classical physics did not agree with experimental data as the predicted spectrum is continuous rather than discrete.

9. A rectangular coil of area 40.0 cm^2 and resistance 2.0 Ω is located in a uniform magnetic field $B = 8.0 \times 10^{-4}$ T which is directed out of the page. The plane of the coil is perpendicular to the field as shown in the diagram below.



What is the magnitude of the emf induced in the coil when the strength of the magnetic field is doubled in a time of 1.0 ms?

A. 3.2×10^{-2} V

B. 3.2×10^{-3} V

C. 1.6×10^{-3} V

D. 1.6×10^{-2} V

10. Five square wire loops of side length 15 cm are free to rotate within a magnetic field strength of 2.50×10^{-4} T. A current of 3.00 A is flowing through the coil. What is the torque on the coil when the plane of the coil is at an angle of 30° to the magnetic field?

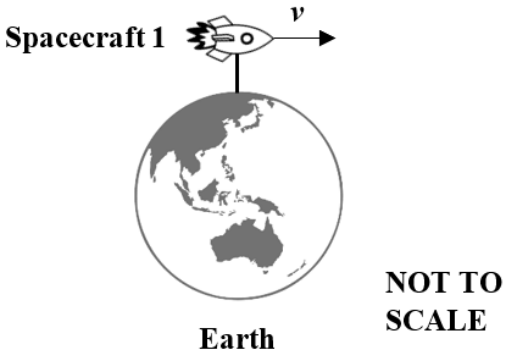
A. 7.3×10^{-5} Nm

B. 4.2×10^{-5} Nm

C. 1.4×10^{-5} Nm

D. 4.2×10^{-4} Nm

11. Spacecraft 1 is launched with an initial speed v and eventually enters a circular orbit near the Earth's surface. An identical spacecraft, Spacecraft 2, is launched from the same position with a launch speed of $2v$. Which of the following best describes the motion of Spacecraft 2? Ignore air resistance.



A. It will enter a circular orbit around the Earth with a shorter period than spacecraft 1.

B. It will enter a circular orbit around the Earth with a longer period than spacecraft 1.

C. It will travel in a parabolic path and return to the surface of the Earth.

D. It will leave the Earth and travel to outer space.

12. Which of the following statements about the energy of a photon is correct?

A. The energy of a photon is always the same.

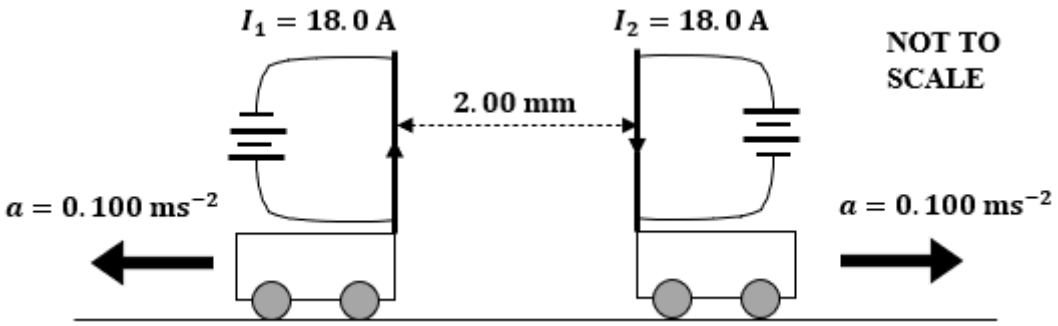
B. The energy of a photon is proportional to its wavelength.

C. The energy of a photon is proportional to its frequency.

D. The energy of a photon is proportional to its period.

13. Two parallel wires, both 4.00 m long, are placed vertically on two identical frictionless trolleys on a horizontal surface.

When the power supply is switched on, both wires have a current of 18.0 A and the trolleys move away in opposite directions from each other with initial accelerations of $0.100\ \text{ms}^{-2}$.



What is the mass of each trolley?

A. 1.30 kg

B. 2.60 kg

C. 5.20 kg

D. 10.4 kg

14. Which of the following statements best describes the speed of light in various media, including a vacuum?

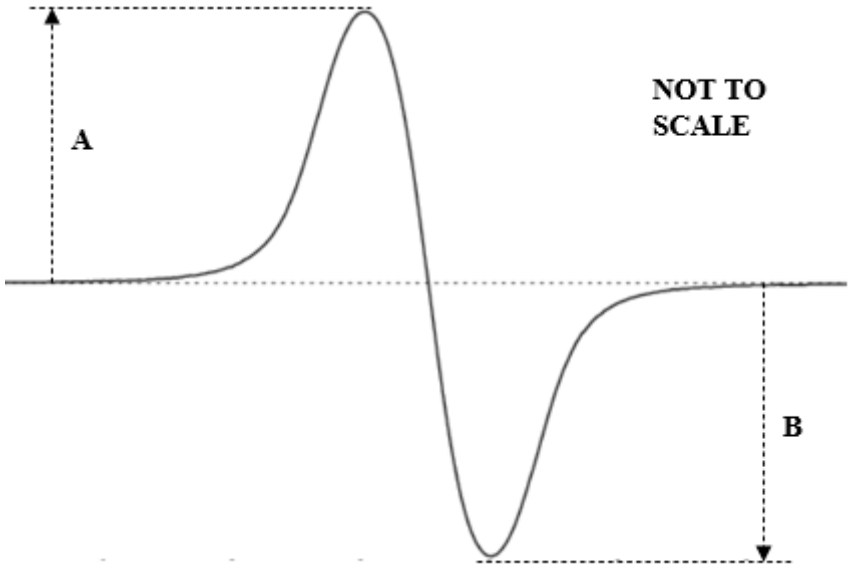
A. The speed of light in a medium depends only on the relative motion between the medium and the light source.

B. The speed of light in a medium depends only on the mass density of the material.

C. The speed of light in a medium depends only on the temperature of the material.

D. The speed of light in a medium depends only on the magnetic and electrical properties of the medium.

15. When a magnet is dropped through a coil, a voltage sensor will detect an induced voltage as shown below.



Which of the following is correct?

	Comparison between the peak and the trough	Explanation
A.	$A = B$	The strength of the magnet is the same.
B.	$A = B$	The area of the coil is the same.
C.	$A < B$	The magnet speeds up as it falls through the coil.
D.	$A > B$	The coil heats up as the magnet falls.

16. If the frequency of the electrical supply to an AC induction motor is increased, what happens to the speed of the rotor?

A. It is decreased.

B. It remains constant.

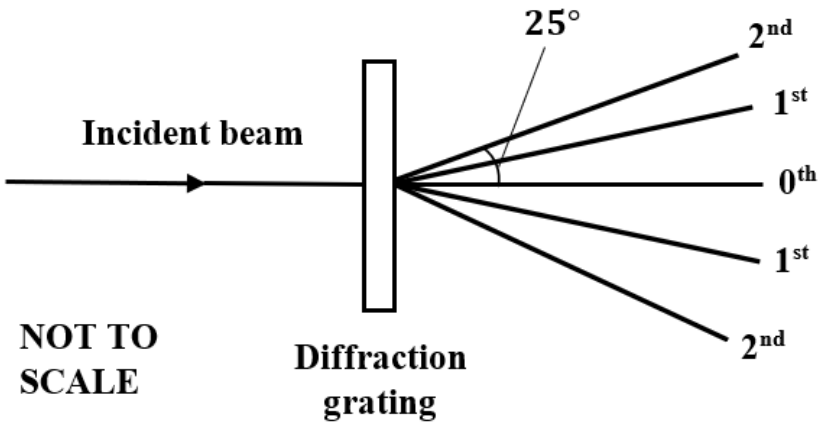
C. It is increased.

D. It is increased in the opposite direction.

17. A famous chef is using an electrical beater to make cake batter. As the batter thickens it creates friction causing the beaters to slow down. Which choice below best describes what happens to the current and the back emf in the beaters' coils and the back emf in these coils as the beaters slow down?

	Current in coils	**Back emf**
A.	Increases	Increases
B.	Increases	Decreases
C.	Decreases	Increases
D.	Decreases	Decreases

18. A beam of monochromatic light is shone on a diffraction grating. The second-order bright fringes are found at 25° to the incident beam as shown in the diagram below.



What is the highest order of bright fringe that can be observed?

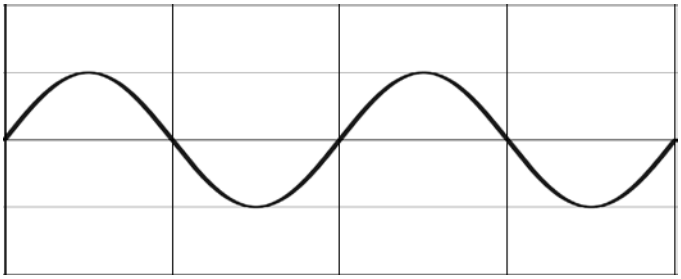
A. 2nd order

B. 3rd order

C. 4th order

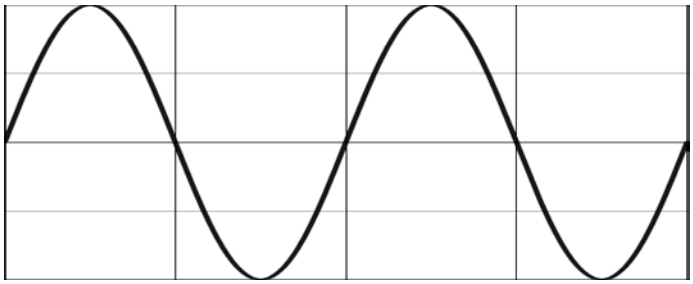
D. 5th order

19. A simple generator consists of a coil with N = 100 turns and an area of 100 cm^2 in a uniform magnetic field of B = 0.5 T. Originally it has a frequency of 50.0 Hz and produces the following voltage output as a function of time.



Another experiment was carried out by changing some of the variables and the result is shown in diagram A below.

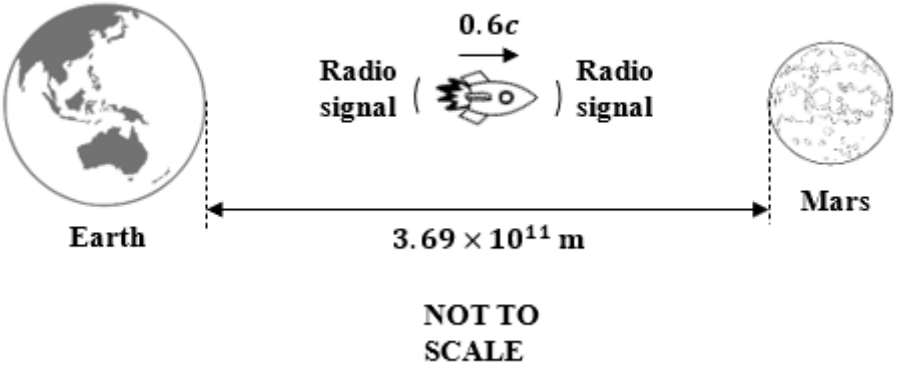
Diagram A



Given that the scale of both diagrams are the same, which of the specifications in the table below could produce the voltage output described by diagram A?

	f (Hz)	B (T)	N (turns)	A (cm^2)
A.	50	0.50	200	100
B.	100	0.50	200	100
C.	100	1.00	50	100
D.	50	0.50	400	100

20. Kirsten is travelling in a spacecraft towards Mars at $0.6c$ relative to Earth and Mars. When the spacecraft is halfway between Earth and Mars, Kirsten sends a radio signal towards Earth and Mars as shown in the diagram below.



NOT TO SCALE

Given that the distance between the surface of Earth and Mars is 3.69×10^{11}m (measured from Earth), how long would it take until the radio signal reaches the surface of Earth and Mars respectively (in Earth and Mars' frame of reference)?

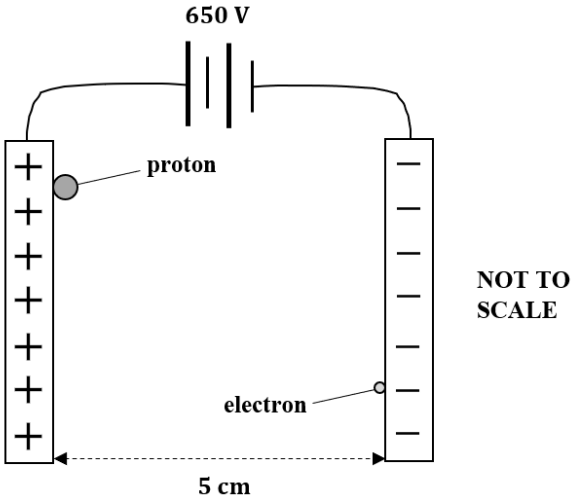
	Time to reach the surface of Earth (s)	Time to reach the surface of Mars (s)
A.	984	984
B.	1538	384
C.	1230	1230
D.	615	615

Section II

80 marks
Attempt Question 21-32
Allow about 2 hour and 25 minutes for this section

Question 21 (5 marks)

A proton and an electron are accelerated from one charged parallel plate to the opposite plate. The plates have a potential difference of 650 V and are separated by a distance of 5 cm. The initial positions of the proton and electron are shown below.



(a) Find the final kinetic energy of both the electron and proton given that they were both initially at rest. **2**

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(b) Quantitatively compare the accelerations of both particles as they move between the two charged plates. **3**

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Question 22 (4 marks)

(a) State Einstein's two postulates for his theory of special relativity. **2**

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(b) Outline experimental evidence that validated the prediction of length contraction. **2**

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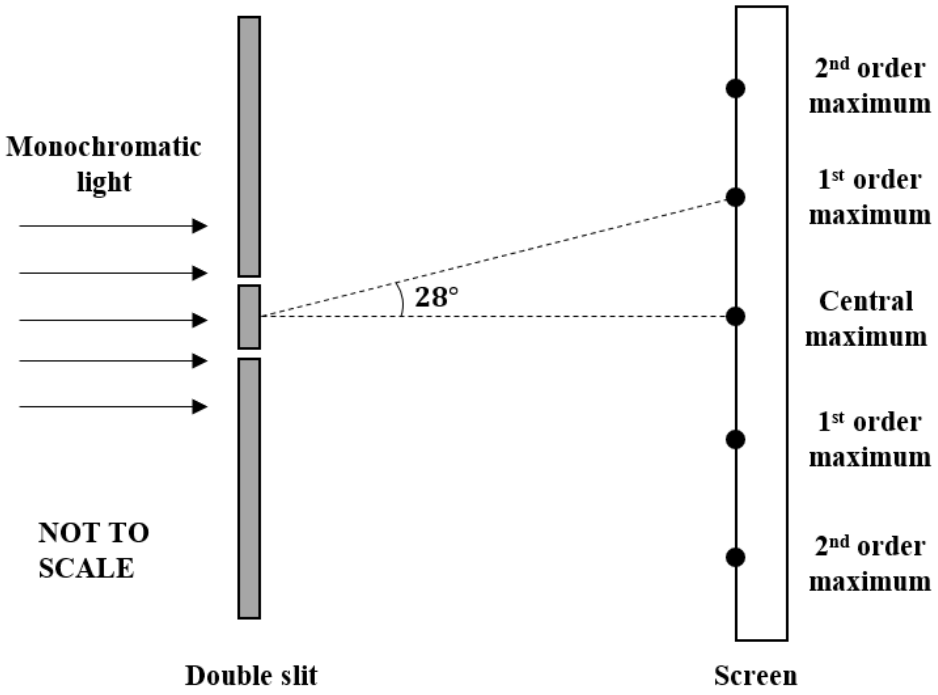
Question 23 (5 marks)

Monochromatic light passes through a double slit 1.25 μm apart. The 1st order maximum is observed to be 28° from the central maximum as shown in the diagram below.



(a) Determine the wavelength of the monochromatic light used. **2**

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(b) Explain the formation of the interference pattern on the screen. **3**

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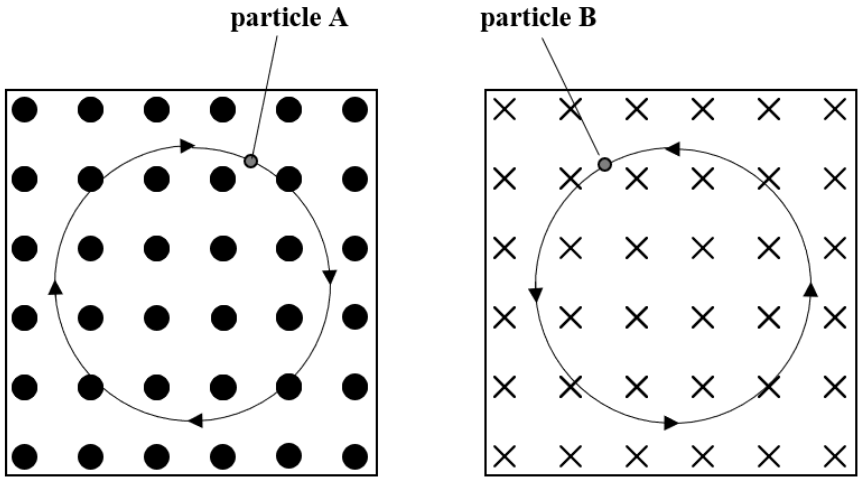
Question 24 (4 marks)

Charged particles A and B move into a magnetic field and move along different circular paths as shown.



NOT TO SCALE

(a) A student observes the diagrams and states that A and B are both negatively charged. Evaluate this statement. **2**

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(b) Particle A is more massive than particle B. Explain how it is possible for the radii of their paths in the fields to be identical. **2**

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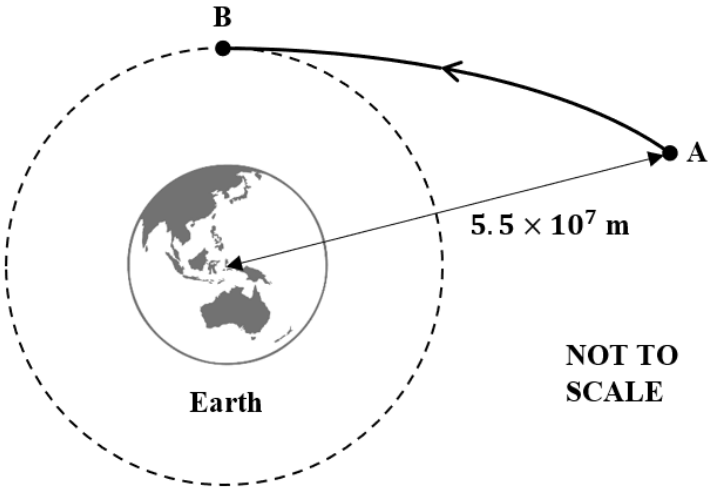
Question 25 (9 marks)

A 975 kg spacecraft is returning to Earth from a space mission. It will be placed into a geostationary orbit around the Earth before landing on the surface. The diagram below shows a possible path of the spacecraft as it approaches the Earth. Assume no air resistance for the entire journey of the spacecraft.



(a) Calculate the orbital speed of the spacecraft when it is in the geostationary orbit at point B. **3**

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(b) Calculate the change in gravitational potential energy of the spacecraft as it moves from point A to point B. **2**

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Question 25 continues on page 18

Question 25 (continued)

(c) Explain what happens to the total energy of the spacecraft as it moves from point A to point B. **2**

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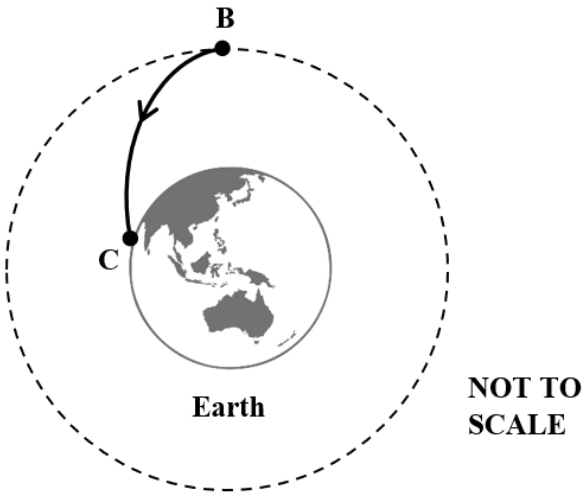
After a while in the geostationary orbit, the spacecraft turns on its thrusters momentarily to reduce its speed to 2.5×10^3 ms^{-1}. It then begins its descent to the surface as shown in the diagram below.



(d) Calculate the speed of the spacecraft just before it hits the surface at point C. **2**

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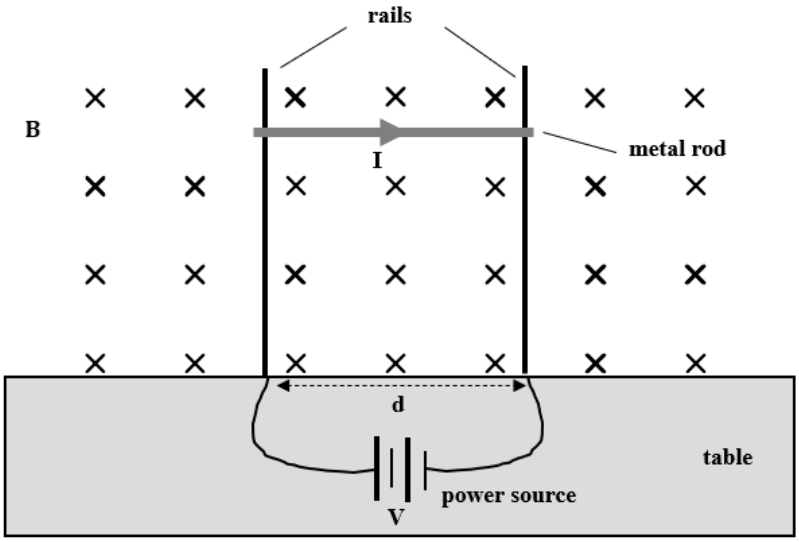
End of Question 25

Question 26 (5 marks)

A straight metal rod sits on two parallel metal rails spaced d m apart. The rails sit perpendicular to the table and the spacing between the rails (d) can be adjusted. The rails can be fixed into place once it is adjusted. The apparatus sits within a magnetic field directed into the page with adjustable strength (B). The power source supplies an adjustable voltage (V) and a current of magnitude I runs through the metal rod as shown below.



(a) The metal rod was observed to be stationary. What force(s) are acting on the metal rod? **2**

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(b) A group of students wanted to find the mass of the metal rod. Explain how the variable(s) could be changed and measured to allow them to calculate the mass. Friction can be ignored. **3**

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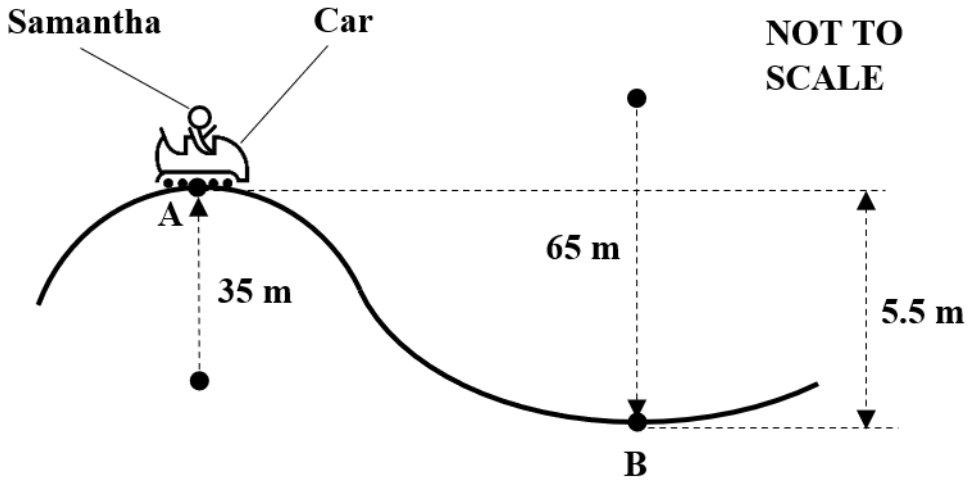
Question 27 (8 marks)

Samantha is riding in a car on a roller-coaster. Their combined mass equals 245 kg. As shown by the diagram below, it can be assumed that the track is circular near the points A and B with a radius 35 m and 65 m respectively.



(a) Consider Samantha and the car as a single object. On the diagram above, draw and label all the forces acting on the single object using a solid line. Use a dotted line to show the resultant force acting on the single object. **2**

Due to safety reasons, the rollercoaster was designed such that the passengers would NOT feel 'weightless' at point A.

(b) Calculate the maximum speed at which Samantha could be moving at point A. **2**

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Question 27 continues on page 21

(c) Assume that the car is travelling at the speed calculated in (b) and there is no friction and no driving force on the car after point A. Calculate the speed of the car when it reaches point B, 5.5 m below point A. **2**

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(d) Calculate the normal force acting on Samantha and the car at point B. **2**

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End of Question 27

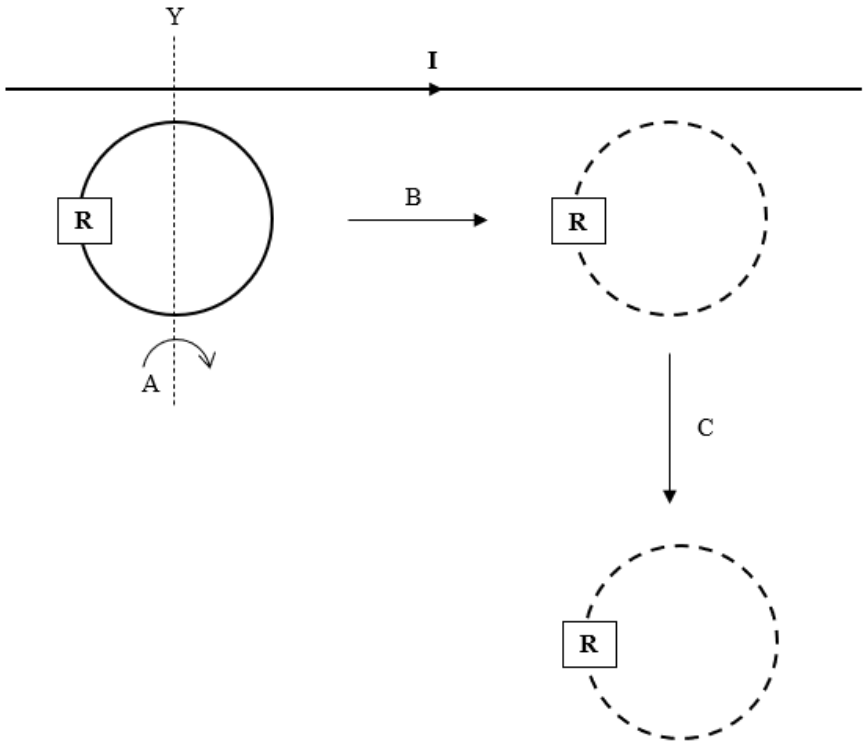
Question 28 (6 marks)

A circular wire loop is placed near a long straight wire carrying a constant current in the direction shown below. The loop moves three times:

A - it rotates once, uniformly about the Y-axis with the resistor R moving out of the page initially

B – it moves parallel to the straight wire with constant speed

C – it moves away perpendicularly from the straight wire with constant speed.



Question 28 continues on page 23

Question 28 (continued)

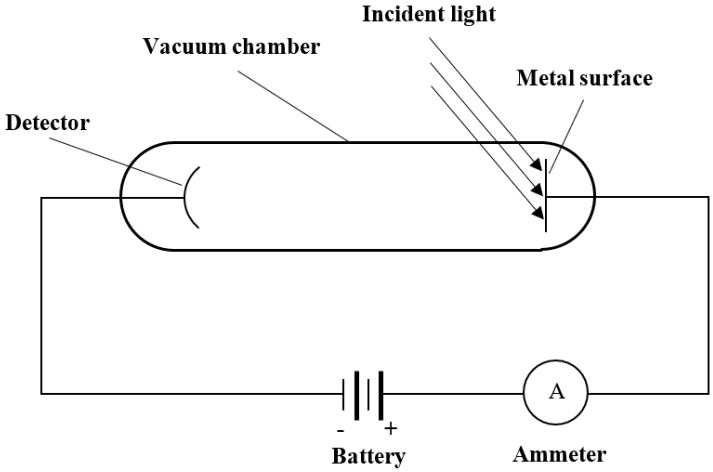
Complete the table in terms of the Motions of A, B and C by sketching the emf induced in the loop and state whether the direction of the emf is clockwise, anticlockwise or not relevant. **6**

Motion	Possible induced emf in the circular loop with respect to time	The direction of emf (clockwise/anticlockwise/ not relevant)
A		
B		
C		

End of Question 28

Question 29 (7 marks)

A group of students set up the experiment as shown in the diagram below to study the photoelectric effect.



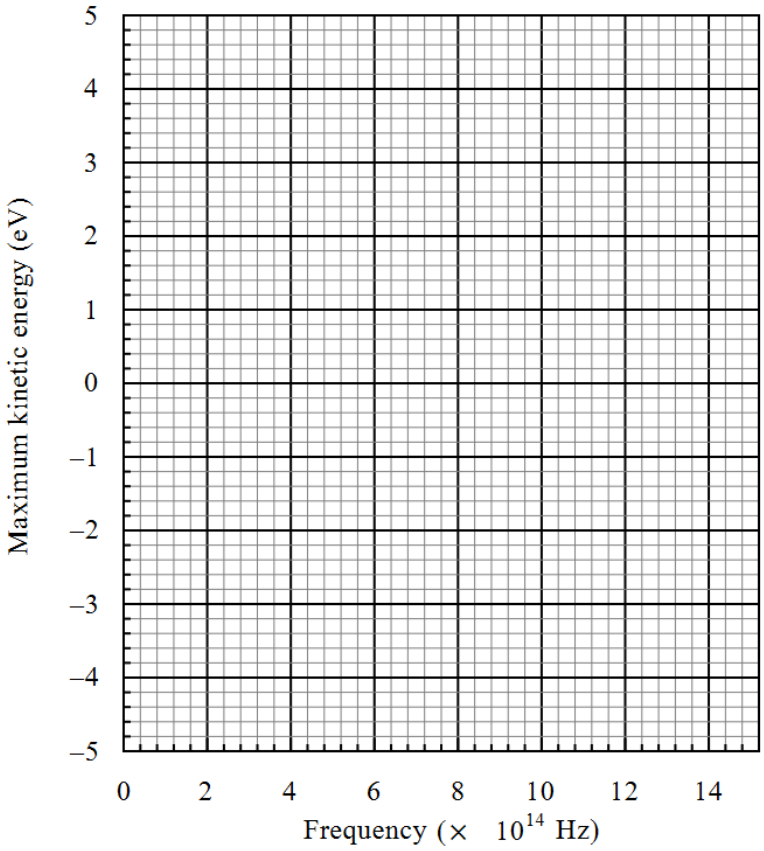
They shone light of varying wavelengths onto different metal surfaces and measured the stopping voltage. Using the stopping voltage, they were able to measure the work function for each metal surface they tested. The results are presented in the table below.

Metal Surface	**Work function (eV)**
Caesium	2.1
Barium	2.5
Calcium	2.9
Magnesium	3.7
Beryllium	5.0

Question 29 continues on page 25

Question 29 (continued)

(a) Using data from the table, draw a graph on the grid below of the maximum kinetic energy of an ejected electron against frequency of the incident light for **Calcium**. **2**



(b) If monochromatic light of wavelength 400 nm is incident on each of the metal surfaces, how many of them would exhibit photoelectric effect? Show all working. **2**

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Question 29 continues on page 26

(c) The students noticed that when light of a certain wavelength was shone on a metal surface, no electrons are emitted. They then increased the intensity of this light and still did not detect any electrons. Explain the students' observations and state whether this supports light being a wave or particle. **3**

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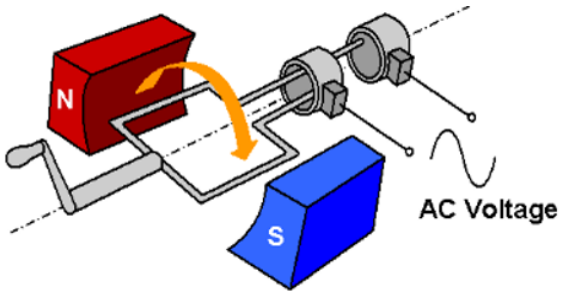
End of Question 29

Question 30 (7 marks)

A group of physics students made a simple AC generator in class. It had 150 turns of wire in a 6.00 cm wide square coil that was placed in a magnetic field of strength 1.85×10^2 mT. They connected the handle to a motor which rotated with a frequency of 4.00 Hz and used the electricity produced to power a light globe.



(a) Give that $\varepsilon = 2\pi nBAf$, calculate the emf produced by the generator. **2**

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(b) The students removed the motor and turned the handle themselves, maintaining a constant speed of rotation. They noticed the force required to turn the handle varied as the coil rotated. They also noticed that the light bulb glowed brightest when the force required was greatest and went out when the force required was virtually zero. Explain these observations using Lenz's Law and the Law of Conservation of Energy. **5**

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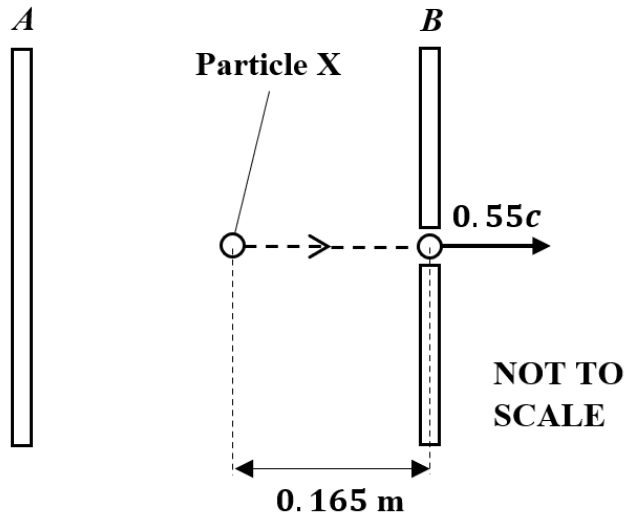
Question 31 (12 marks)

A group of scientists have created an unknown particle, particle X. They designed an experiment to identify this particle. Particle X was placed stationary between oppositely charged plates *A* and *B* as shown in the diagram below. The plates were charged such that particle X would exits with a speed of $0.55\,c$.



(a) Calculate the acceleration experienced by particle X if it took 2 ns to reach plate *B*. **2**

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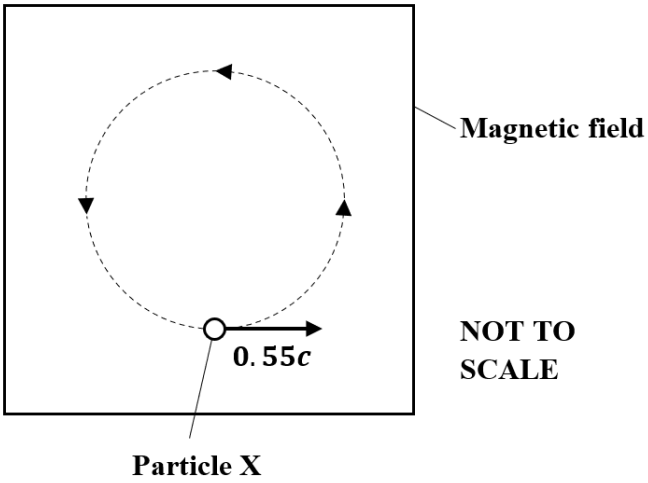
Question 31 continues on page 39

Question 31 (continued)

Particle X then travelled at a constant speed of $0.55\ c$ into a magnetic field as shown in the diagram below.



(b) When particle X is at rest, it has a mean lifetime of 2.6×10^{-8} s. Find the mean lifetime of particle X measured by the scientists as the particle travelled in circular motion inside the magnetic field. **2**

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(c) Show that the radius of the circular motion is given by $r = \frac{mv}{qB}$. **2**

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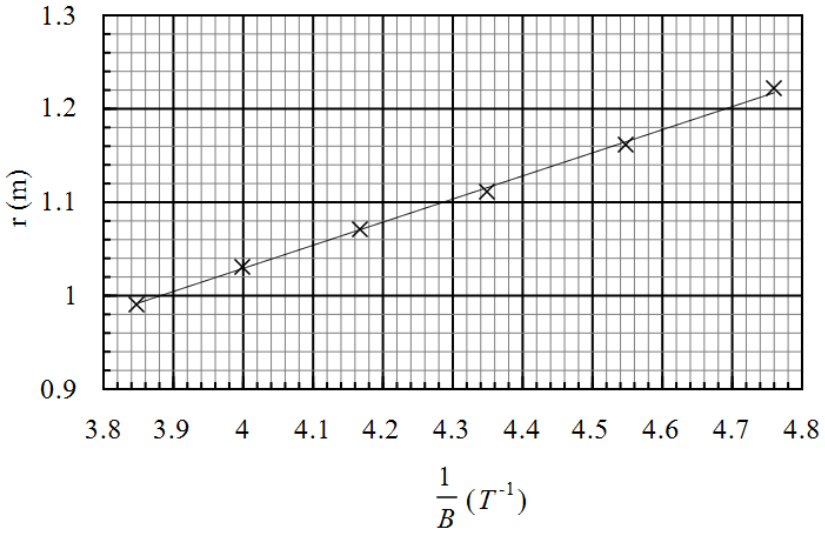
Question 31 continues on page 30

Question 31 (continued)

The scientists changed the magnetic field strength (B) and measured the radius of particle X's motion (r) in ***their frame of reference***. They then presented the results as a graph of r vs $\frac{1}{B}$ as shown below.



(d) Use the graph to determine the distance travelled by particle X in one cycle of the circular motion in the ***particle's frame of reference*** when the magnetic field strength is 0.238 T. **3**

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Question 31 continues on page 31

The scientists suspect that particle X is one of the particles listed in the table below.

Particle	**Charge (C)**	**Mass (kg)**
Pion	$+1.602 \times 10^{-19}$	2.49×10^{-28}
Kaon	-1.602×10^{-19}	8.79×10^{-28}
D	$+1.602 \times 10^{-19}$	3.33×10^{-27}

(e) Use the gradient of the graph to find the charge to mass ratio and predict what particle X might be. **3**

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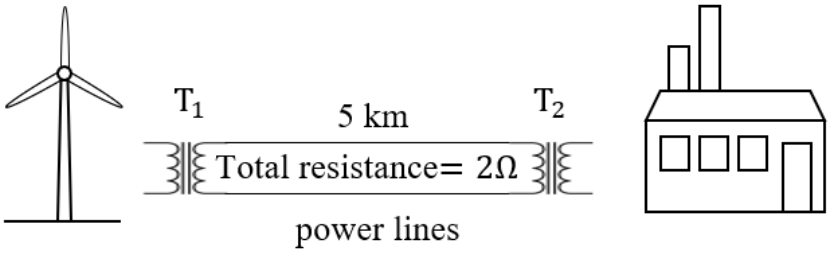
End of Question 31

Question 32 (8 marks)

A wind turbine runs a 150 kW generator with an output voltage of 1000 V. The voltage is increased by a transformer T_1, with a ratio of primary turns to secondary turns of 1:10, and transmitted to a town 5 km away through power lines with a total resistance of 2Ω. Another transformer T_2, with a ratio of primary turns to secondary turns of 40:1, reduces the voltage before it is delivered for commercial use.



Analyse the electrical data of the transformers and power lines and explain how the efficiency of this transmission process can be increased. Your analysis should include both qualitative and quantitative information. **8**

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Section II extra writing space

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Student Number…….

NORTH SYDNEY GIRLS HIGH SCHOOL

2021

HSC

Practice Task

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, formulae sheet and Periodic Table are provided on separate sheets
- **Write your student number at the top of this booklet**

Total marks 100

Section I
20 marks (pages 2–12)
Attempt Questions 1–20
Allow about 35 minutes for this section

Section II
80 marks (pages 13–32)
Attempt Questions 21–32
Allow about 2 hour and 25 minutes

There are 32 questions to answer.

Attempt **Section I** in the multiple-choice answer sheet and **Section II** in the spaces provided. These spaces provide guidance for the expected length of each response.

Section I

20 marks
Attempt Question 1-20
Allow about 35 minutes for this section

Use the multiple-choice answer sheet for Questions 1-20

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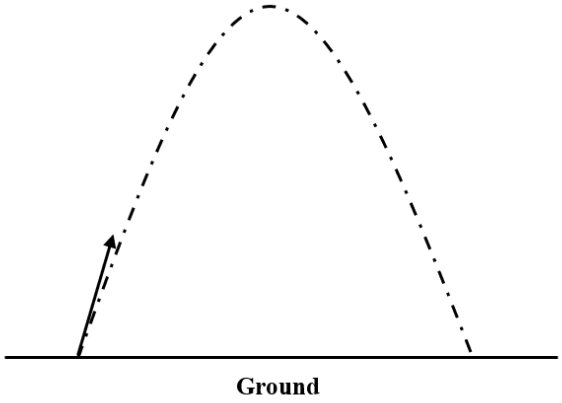
1. Which of the following is constant for the entire flight of a projectile?



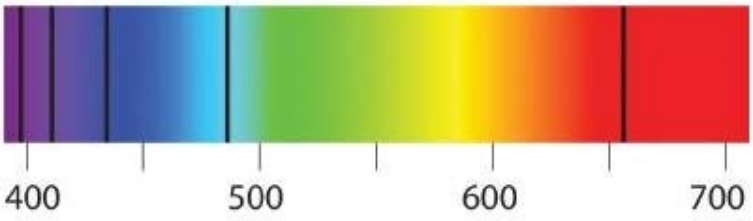
A. Distance from the ground

B. Speed

C. Velocity

D. Acceleration

2. The following spectrum was observed during an experiment.



Which type of spectrum is this?

A. Continuous spectrum

B. Emission spectrum

C. Absorption spectrum

D. Electromagnetic spectrum

3. A proton travels at a velocity of $0.5\ \text{ms}^{-1}$ from right to left perpendicular to a magnetic field, B, of strength 2.0×10^{-5} mT. The magnetic field is running vertically downwards. What is the size of the force that the particle will experience?

A. 1.6×10^{-24} N into the page

B. 1.6×10^{-24} N out of the page

C. 1.6×10^{-27} N down the page

D. 1.6×10^{-27} N out of the page

4. Neptune has a mass of 1.024×10^{26} kg and radius of 2.46×10^{7}m. What is the gravitational field strength on the surface of Neptune?

A. $2.8\ \text{N kg}^{-1}$

B. $9.8\ \text{N kg}^{-1}$

C. $11.3\ \text{N kg}^{-1}$

D. $22.6\ \text{N kg}^{-1}$

5. A group of scientists on Earth are observing a nearby star, Barnard's Star. They noticed that the peak wavelength of Barnard's Star's radiation is 925 nm. What is the surface temperature of Barnard's Star?

A. 3133 K

B. 13870 K

C. 21632 K

D. 9.399×10^{11} K

6. Which of the following statements correctly describes the change in force between two parallel current carrying conductors, when one current decreases by a factor of four, and the separation distance halves?

A. The force will increase by a factor of eight.

B. The force will halve.

C. The force will remain the same.

D. The force will increase by a factor of two.

7. A satellite S_1 is in a stable low-Earth orbit (LEO) and another satellite S_2 is in a stable geostationary orbit (GEO). Both satellites have the same mass. Which of the following is correct about the two satellites in orbit?

	Great orbital speed	**Greater gravitational potential energy**
A.	S_1	S_1
B.	S_1	S_2
C.	S_2	S_1
D.	S_2	S_2

8. Which of the following best describes the problem with using classical physics to predict the spectrum of light emitted by a heated body?

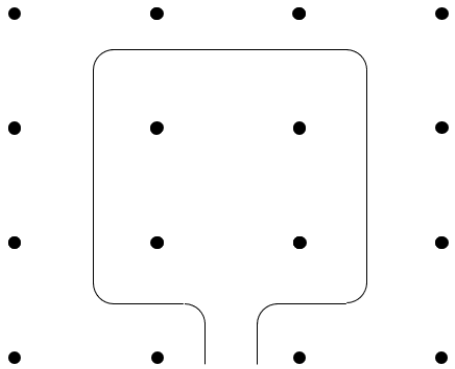
A. Predictions of classical physics did not agree with experimental data for short wavelengths.

B. Prediction of classical physics did not agree with experimental data for long wavelengths.

C. Predictions of classical physics did not agree with experimental data due to poor experimentation.

D. Predictions of classical physics did not agree with experimental data as the predicted spectrum is continuous rather than discrete.

9. A rectangular coil of area 40.0 cm^2 and resistance 2.0 Ω is located in a uniform magnetic field $B = 8.0 \times 10^{-4}$ T which is directed out of the page. The plane of the coil is perpendicular to the field as shown in the diagram below.



What is the magnitude of the emf induced in the coil when the strength of the magnetic field is doubled in a time of 1.0 ms?

A. 3.2×10^{-2} V

B. 3.2×10^{-3} V

C. 1.6×10^{-3} V

D. 1.6×10^{-2} V

10. Five square wire loops of side length 15 cm are free to rotate within a magnetic field strength of 2.50×10^{-4} T. A current of 3.00 A is flowing through the coil. What is the torque on the coil when the plane of the coil is at an angle of 30° to the magnetic field?

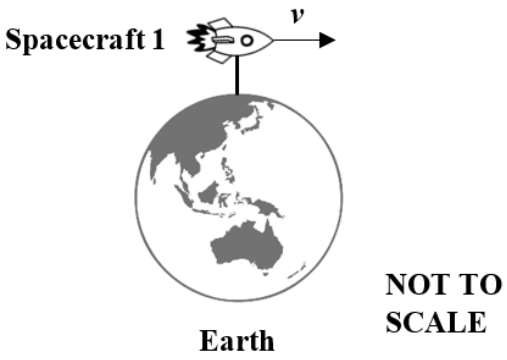
A. 7.3×10^{-5} Nm

B. 4.2×10^{-5} Nm

C. 1.4×10^{-5} Nm

D. 4.2×10^{-4} Nm

11. Spacecraft 1 is launched with an initial speed v and eventually enters a circular orbit near the Earth's surface. An identical spacecraft, Spacecraft 2, is launched from the same position with a launch speed of $2v$. Which of the following best describes the motion of Spacecraft 2? Ignore air resistance.



A. It will enter a circular orbit around the Earth with a shorter period than spacecraft 1.

B. It will enter a circular orbit around the Earth with a longer period than spacecraft 1.

C. It will travel in a parabolic path and return to the surface of the Earth.

D. It will leave the Earth and travel to outer space.

12. Which of the following statements about the energy of a photon is correct?

A. The energy of a photon is always the same.

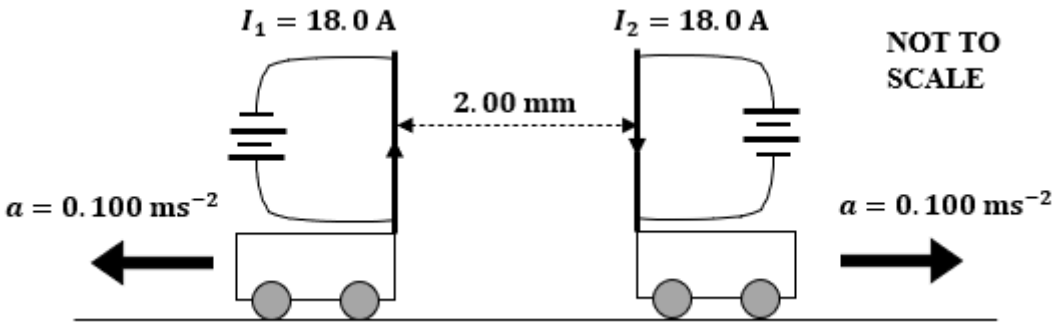
B. The energy of a photon is proportional to its wavelength.

C. The energy of a photon is proportional to its frequency.

D. The energy of a photon is proportional to its period.

13. Two parallel wires, both 4.00 m long, are placed vertically on two identical frictionless trolleys on a horizontal surface.

When the power supply is switched on, both wires have a current of 18.0 A and the trolleys move away in opposite directions from each other with initial accelerations of $0.100\ \text{ms}^{-2}$.



What is the mass of each trolley?

A. 1.30 kg

B. 2.60 kg

C. 5.20 kg

D. 10.4 kg

14. Which of the following statements best describes the speed of light in various media, including a vacuum?

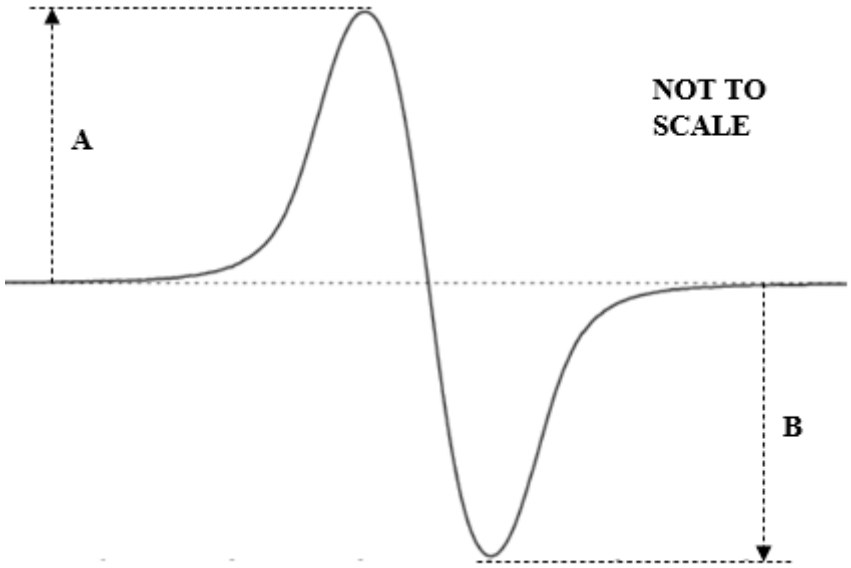
A. The speed of light in a medium depends only on the relative motion between the medium and the light source.

B. The speed of light in a medium depends only on the mass density of the material.

C. The speed of light in a medium depends only on the temperature of the material.

D. The speed of light in a medium depends only on the magnetic and electrical properties of the medium.

15. When a magnet is dropped through a coil, a voltage sensor will detect an induced voltage as shown below.



Which of the following is correct?

	Comparison between the peak and the trough	Explanation
A.	A = B	The strength of the magnet is the same.
B.	A = B	The area of the coil is the same.
C.	A < B	The magnet speeds up as it falls through the coil.
D.	A > B	The coil heats up as the magnet falls.

16. If the frequency of the electrical supply to an AC induction motor is increased, what happens to the speed of the rotor?

A. It is decreased.

B. It remains constant.

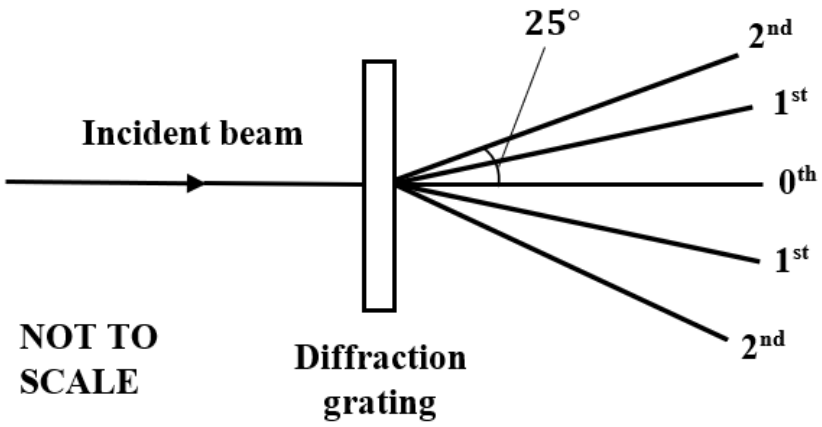
C. It is increased.

D. It is increased in the opposite direction.

17. A famous chef is using an electrical beater to make cake batter. As the batter thickens it creates friction causing the beaters to slow down. Which choice below best describes what happens to the current and the back emf in the beaters' coils and the back emf in these coils as the beaters slow down?

	Current in coils	**Back emf**
A.	Increases	Increases
B.	Increases	Decreases
C.	Decreases	Increases
D.	Decreases	Decreases

18. A beam of monochromatic light is shone on a diffraction grating. The second-order bright fringes are found at 25° to the incident beam as shown in the diagram below.



What is the highest order of bright fringe that can be observed?

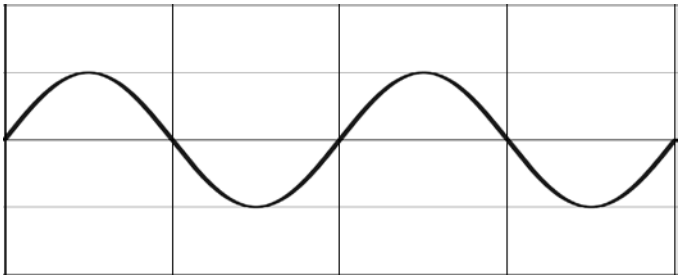
A. 2nd order

B. 3rd order

C. 4th order

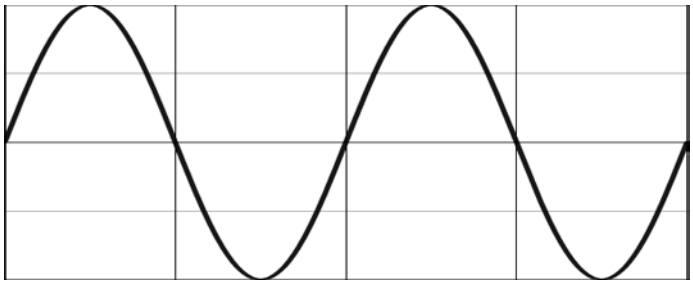
D. 5th order

19. A simple generator consists of a coil with N = 100 turns and an area of 100 cm^2 in a uniform magnetic field of B = 0.5 T. Originally it has a frequency of 50.0 Hz and produces the following voltage output as a function of time.



Another experiment was carried out by changing some of the variables and the result is shown in diagram A below.

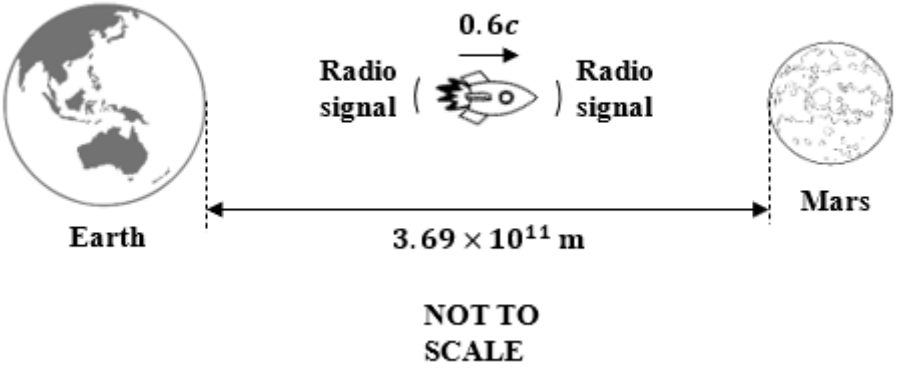
Diagram A



Given that the scale of both diagrams are the same, which of the specifications in the table below could produce the voltage output described by diagram A?

	f (Hz)	B (T)	N (turns)	A (cm^2)
A.	50	0.50	200	100
B.	100	0.50	200	100
C.	100	1.00	50	100
D.	50	0.50	400	100

20. Kirsten is travelling in a spacecraft towards Mars at $0.6c$ relative to Earth and Mars. When the spacecraft is halfway between Earth and Mars, Kirsten sends a radio signal towards Earth and Mars as shown in the diagram below.



NOT TO SCALE

Given that the distance between the surface of Earth and Mars is 3.69×10^{11}m (measured from Earth), how long would it take until the radio signal reaches the surface of Earth and Mars respectively (in Earth and Mars' frame of reference)?

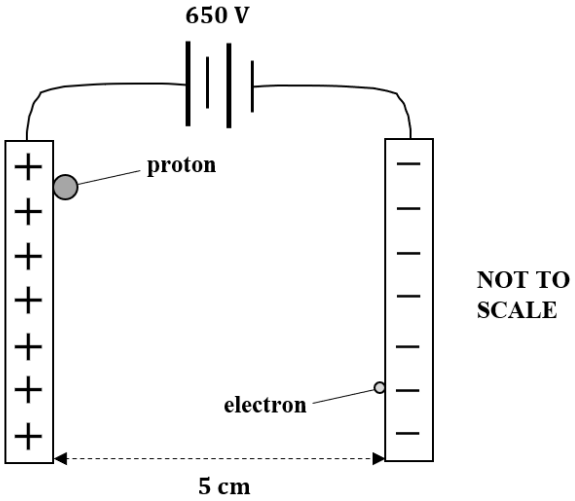
	Time to reach the surface of Earth (s)	Time to reach the surface of Mars (s)
A.	984	984
B.	1538	384
C.	1230	1230
D.	615	615

Section II

80 marks
Attempt Question 21-32
Allow about 2 hour and 25 minutes for this section

Question 21 (5 marks)

A proton and an electron are accelerated from one charged parallel plate to the opposite plate. The plates have a potential difference of 650 V and are separated by a distance of 5 cm. The initial positions of the proton and electron are shown below.



(a) Find the final kinetic energy of both the electron and proton given that they were both initially at rest. **2**

1 mark for recognising that the change in kinetic energy of the electron and proton is equal to qV.

$$\Delta K = W = qV$$

1 mark for calculating the final kinetic energy of the electron and proton

$$K_f - K_i = qV$$

$$K_f - 0 = (1.602 \times 10^{-19})(650)$$

$$K_f = 1.04 \times 10^{-16}\ \text{J}$$

(b) Quantitatively compare the accelerations of both particles as they move between the two charged plates. **3**

1 mark for calculating the electric field strength: $E = \frac{V}{d} = \frac{650}{0.05} = 13000\ \text{Vm}^{-1}$

1 mark for calculating the accelerating of the proton and electron:

For both the proton and electron, the force acting on each of the particle can be calculated by:

$$F = qE$$

$$ma = qE$$

$$a = \frac{qE}{m}$$

For the proton:

$$a = \frac{(1.602 \times 10^{-19})(13000)}{1.673 \times 10^{-27}} = 1.25 \times 10^{12}\ \text{ms}^{-2}$$

For the electron:

$$a = \frac{(-1.602 \times 10^{-19})(13000)}{9.109 \times 10^{-31}} = -2.29 \times 10^{15}\ \text{ms}^{-2}$$

1 mark for comparing the acceleration of both particles:

Therefore, the proton will experience a smaller magnitude of acceleration than the electron as the proton has more mass. The proton will be accelerated to the right whilst the electron will be accelerated to the left.

Question 22 (4 marks)

(a) State Einstein's two postulates for his theory of special relativity. **2**

1 mark for stating that the laws of physics are the same in all inertial frames of reference.

1 mark for stating that the speed of light is constant in all inertial frame of reference.

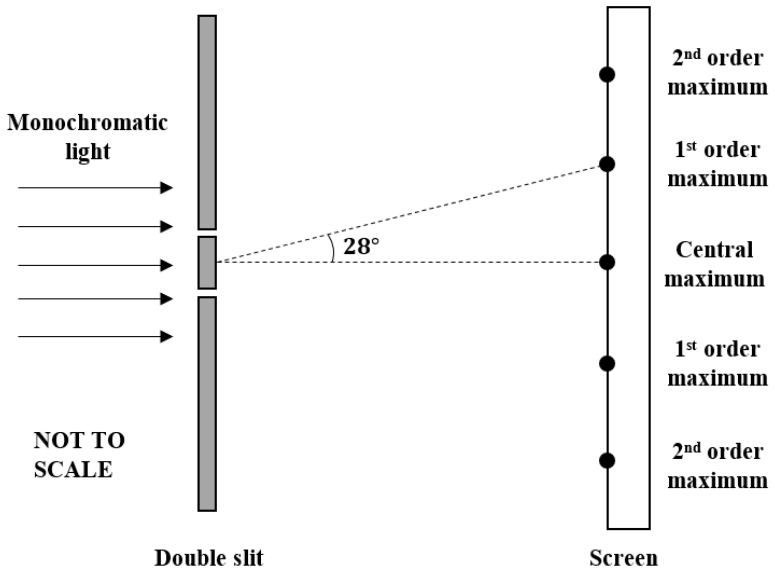
(b) Outline experimental evidence that validated the prediction of length contraction. **2**

2 marks – Correctly outlined an experimental evidence that validated the prediction of length contraction e.g. decay of muons in terms of the distance travelled by the muons.

1 mark – partially outlined an experimental evidence that validated the prediction of length contraction.

Question 23 (5 marks)

Monochromatic light passes through a double slit 1.25 μm apart. The 1st order maximum is observed to be 28° from the central maximum as shown in the diagram below.



(a) Determine the wavelength of the monochromatic light used. **2**

1 mark for correct substitution

1 mark for correct answer

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

$$(1.25 \times 10^{-6}) \sin 28° = (1)\lambda$$

$$\lambda = 5.87 \times 10^{-7} \text{ m}$$

(b) Explain the formation of the interference pattern on the screen. **3**

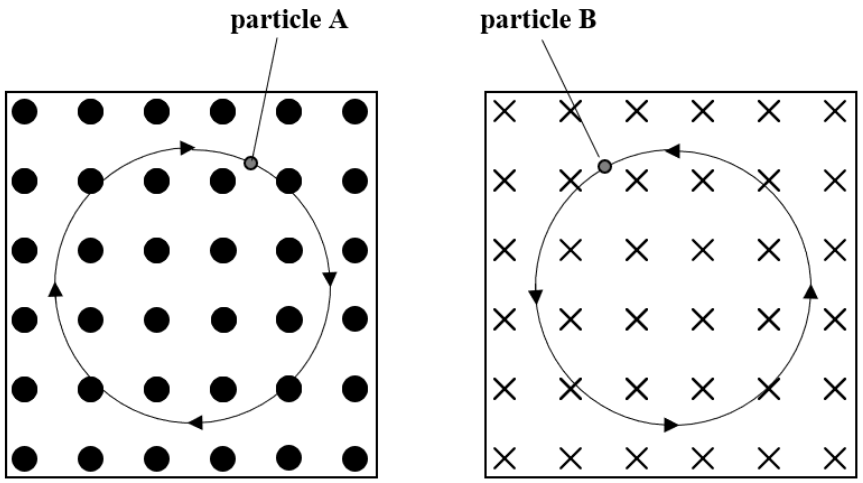
1 mark - explaining that the formation of the interference pattern is due to the superposition of waves travelling out of the two slits.

2 marks – explaining either the formation of the bright or dark fringe of the interference pattern e.g. the bright fringes are formed when the waves travelling out of the two slits constructively interfere at the screen. This occurs when the two waves have a path difference of $m\lambda$ where m is an integer.

3 marks – explaining both the formation of the bright and dark fringe of the interference pattern.

Question 24 (4 marks)

Charged particles A and B move into a magnetic field and move along different circular paths as shown.



NOT TO SCALE

(a) A student observes the diagrams and states that A and B are both negatively charged. Evaluate this statement. **2**

1 mark – mentioning that the students' statement is false

2 marks – mentioning that the students' statement is false AND stating that by using the right-hand rule (or equivalent), particle A and B must be both positively charged instead.

(b) Particle A is more massive than particle B. Explain how it is possible for the radii of their paths in the fields to be identical. **2**

1 mark for derive a relationship for the radius of motion.

The radius of the circular path is given by:

$$F_B = F_c$$

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

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

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

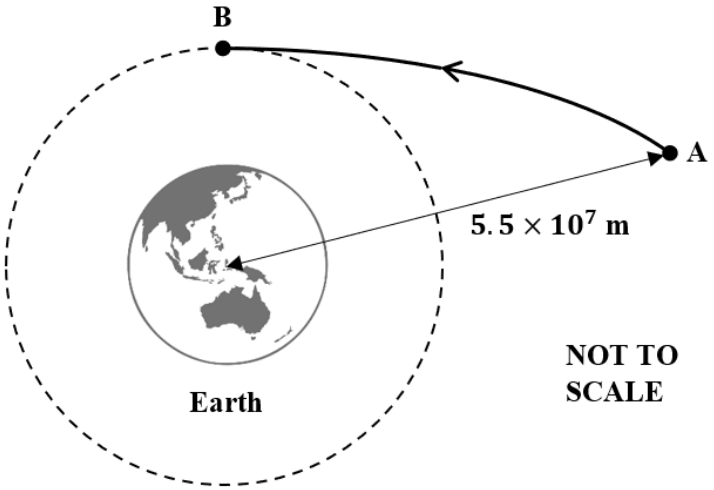
1 mark for explaining how it is possible for the radii of their paths to be identical by referring to one of the following:

Although particle A is more massive than particle B, the radii of their paths in the fields can still be identical if:

- the magnetic field for particle A is stronger
- the magnitude of charge for particle A is larger
- the speed at which particle A moves is lower

Question 25 (9 marks)

A 975 kg spacecraft is returning to Earth from a space mission. It will be placed into a geostationary orbit around the Earth before landing on the surface. The diagram below shows a possible path of the spacecraft as it approaches the Earth. Assume no air resistance for the entire journey of the spacecraft.



(a) Calculate the orbital speed of the spacecraft when it is in the geostationary orbit at point B. **3**

1 mark for recognising that when it is in the geostationary orbit, its period of orbit should be 24 hours.

1 mark for using Kepler's third law to find the radius of orbit

Using Kepler's third law:

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

$$\frac{r^3}{(24 \times 60 \times 60)^2} = \frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})}{4\pi^2}$$

$$r = 4.229\ldots \times 10^7 \text{ m}$$

1 mark for calculating the orbital speed using the radius

Orbital speed:

$$v = \frac{2\pi r}{T} = \frac{2\pi(4.229\ldots \times 10^7)}{(24 \times 60 \times 60)} = 3.08 \times 10^3 \text{ ms}^{-1}$$

(b) Calculate the change in gravitational potential energy of the spacecraft as it moves from point A to point B. **2**

1 mark for correct substitution

1 mark for correct answer (sig fig question)

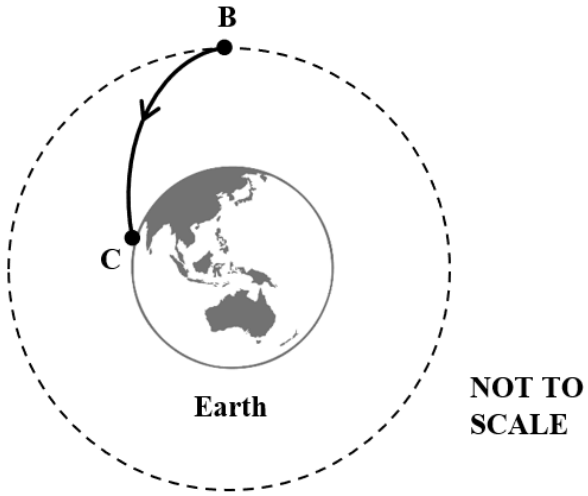
$$\begin{aligned}\Delta U &= U_f - U_i \\ &= -\frac{GMm}{r_f} - \left(-\frac{GMm}{r_i}\right) \\ &= -GMm\left(\frac{1}{r_f} - \frac{1}{r_i}\right) \\ &= -(6.67 \times 10^{-11})(6.0 \times 10^{24})(975)\left(\frac{1}{4.229\ldots \times 10^{7}} - \frac{1}{5.5 \times 10^{7}}\right) \\ &= -2.1 \times 10^{9}\ \text{J}\end{aligned}$$

(c) Explain what happens to the total energy of the spacecraft as it moves from point A to point B. **2**

1 mark for stating that the total energy of the spacecraft remains constant by the law of conservation of energy

1 mark for stating that the total energy of the spacecraft remains constant because the gravitational potential energy dropped by 2.1×10^{9} J whilst the kinetic energy increases by the same amount.

After a while in the geostationary orbit, the spacecraft turns on its thrusters momentarily to reduce its speed to 2.5×10^3 ms^{-1}. It then begins its descent to the surface as shown in the diagram below.



(d) Calculate the speed of the spacecraft just before it hits the surface at point C. **2**

1 mark for using the conservation of energy correctly and correct substitution

1 mark for calculating the speed of the spacecraft just before it hits the surface

Using the conservation of energy:

$$E_f = E_i$$

$$U_f + K_f = U_i + K_i$$

$$-\frac{GMm}{r} + \frac{1}{2}mv_f^2 = -\frac{GMm}{r} + \frac{1}{2}mv_i^2$$

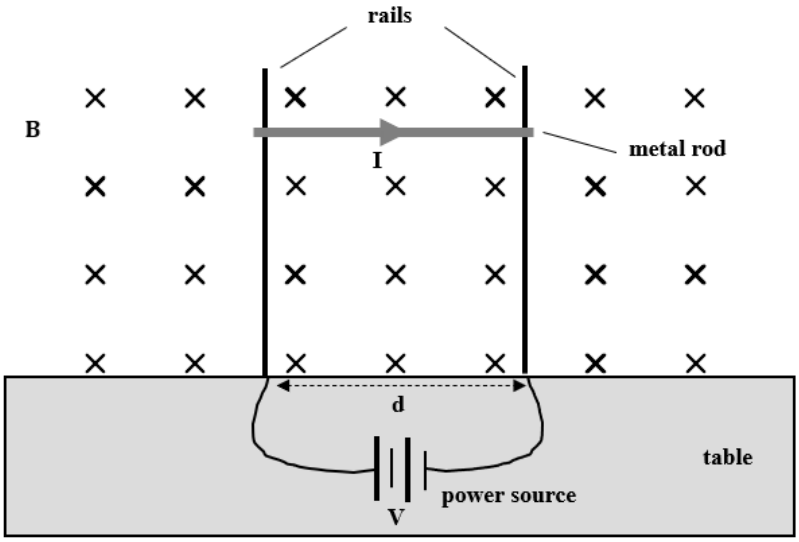
$$-\frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})(975)}{6.371 \times 10^6} + \frac{1}{2}(975)v_f^2 = -\frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})(975)}{4.229\ldots \times 10^7} + \frac{1}{2}(975)(2.5 \times 10^3)^2$$

$$v_f = 1.1 \times 10^4 \text{ ms}^{-1}$$

End of Question 25

Question 26 (5 marks)

A straight metal rod sits on two parallel metal rails spaced d m apart. The rails sit perpendicular to the table and the spacing between the rails (d) can be adjusted. The rails can be fixed into place once it is adjusted. The apparatus sits within a magnetic field directed into the page with adjustable strength (B). The power source supplies an adjustable voltage (V) and a current of magnitude I runs through the metal rod as shown below.



(a) The metal rod was observed to be stationary. What force(s) are acting on the metal rod? **2**

1 mark for stating that force due to gravity acts downwards

1 mark for stating that the force on the metal rod due to the magnetic field acts upwards.

(b) A group of students wanted to find the mass of the metal rod. Explain how the variable(s) could be changed and measured to allow them to calculate the mass. Friction can be ignored. **3**

1 mark for relating the relevant variables to the mass of the metal rod.

$$F_B = F_g$$

$$BIl = mg$$

$$BId = mg$$

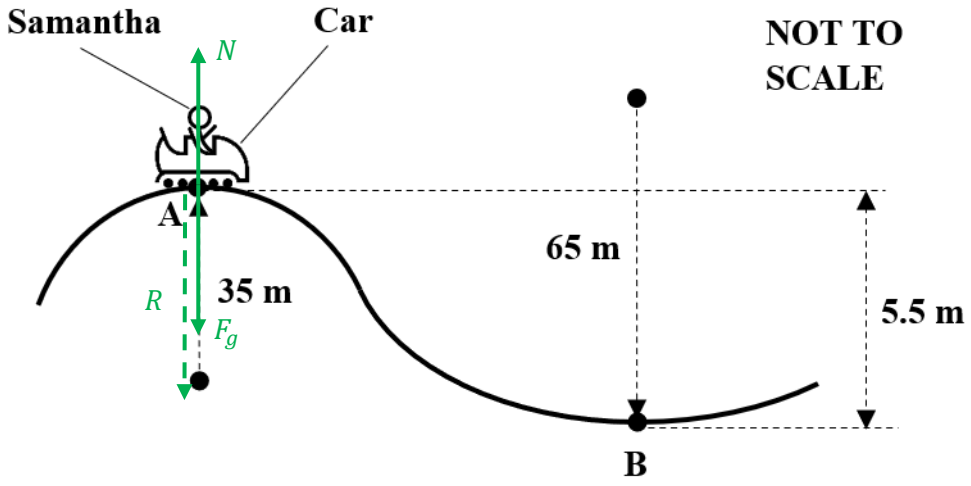
$$B = \frac{mg}{d}\left(\frac{1}{I}\right)$$

1 mark for identifying the correct variables that can be changed and measured e.g. changing the current (by changing the voltage supply) and measuring the magnetic field strength required to keep the metal rod stationary.

1 mark for explaining a suitable method to calculate the mass e.g. plot B vs $\frac{1}{I}$ and find the gradient. The gradient will give $\frac{mg}{d}$ which can then be used to find the mass of the metal rod.

Question 27 (8 marks)

Samantha is riding in a car on a roller-coaster. Their combined mass equals 245 kg. As shown by the diagram below, it can be assumed that the track is circular near the points A and B with a radius 35 m and 65 m respectively.



(a) Consider Samantha and the car as a single object. On the diagram above, draw and label all the forces acting on the single object using a solid line. Use a dotted line to show the resultant force acting on the single object. **2**

1 mark for correctly labelling that normal force and the for due to gravity

1 mark for correctly labelling the resultant force

Due to safety reasons, the rollercoaster was designed such that the passengers would NOT feel 'weightless' at point A.

(b) Calculate the maximum speed at which Samantha could be moving at point A. **2**

1 mark for correctly relating the centripetal force, force due to gravity and normal force at A.

For the passengers to feel 'weightless', the normal force must be zero.

$$F_c = F_g - N$$
$$F_c = F_g$$

1 mark for correctly calculating the maximum speed at which Samantha could be moving

$$\frac{mv^2}{r} = mg$$
$$v = \sqrt{rg}$$
$$v = \sqrt{35 \times 9.8}$$
$$v = 18.5\ldots$$
$$v = 19\ \text{ms}^{-1}$$

Samantha must be moving at under $19\ \text{ms}^{-1}$ to feel 'weightless'.

(c) Assume that the car is travelling at the speed calculated in (b) and there is no friction and no driving force on the car after point A. Calculate the speed of the car when it reaches point B, 5.5 m below point A. **2**

1 mark for correctly using the conservation of energy

1 mark for calculating the velocity at point B

$$E_i = E_f$$
$$U_i + K_i = U_f + K_f$$
$$K_f = K_i - \Delta U$$
$$\frac{1}{2}(245)v_f^2 = \frac{1}{2}(245)(18.5\ldots)^2 - (245)(9.8)(-5.5)$$
$$v_f = 21.23\ldots$$
$$v_f = 21\ \text{ms}^{-1}$$

(d) Calculate the normal force acting on Samantha and the car at point B. **2**

1 mark for correctly relating the centripetal force, force due to gravity and normal force at B.

1 mark for correctly calculating the normal force

$$F_c = N - F_g$$
$$N = F_c + F_g$$
$$N = \frac{mv^2}{r} + mg$$
$$N = \frac{(245)(21.23\ldots)^2}{65} + (245)(9.8)$$
$$N = 4100.1\ldots$$
$$N = 4100\ \text{N}$$

End of Question 27

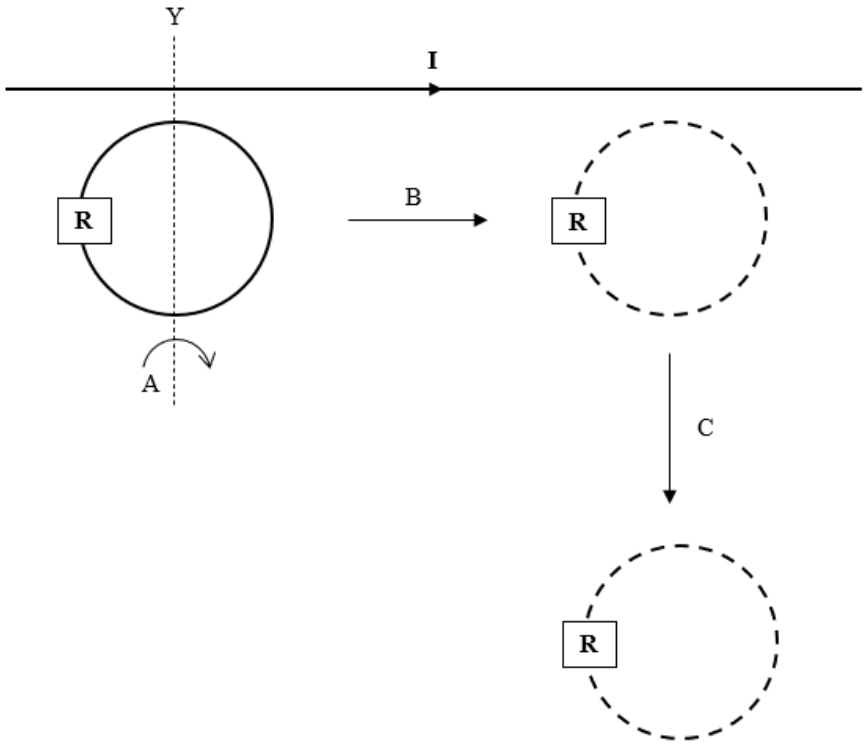
Question 28 (6 marks)

A circular wire loop is placed near a long straight wire carrying a constant current in the direction shown below. The loop moves three times:

A - it rotates once, uniformly about the Y-axis with the resistor R moving out of the page initially

B – it moves parallel to the straight wire with constant speed

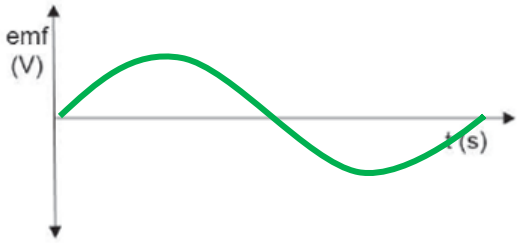
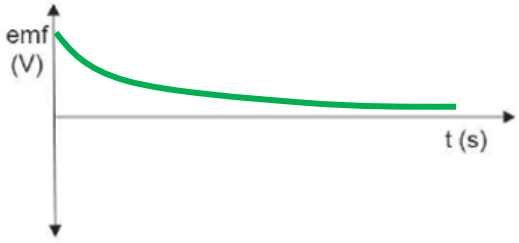
C – it moves away perpendicularly from the straight wire with constant speed.



Question 28 continues on page 23

Question 28 (continued)

Complete the table in terms of the Motions of A, B and C by sketching the emf induced in the loop and state whether the direction of the emf is clockwise, anticlockwise or not relevant. **6**

Motion	Possible induced emf in the circular loop with respect to time	The direction of emf (clockwise/anticlockwise/ not relevant)
A		clockwise
B		not relevant
C		clockwise

For each motion:

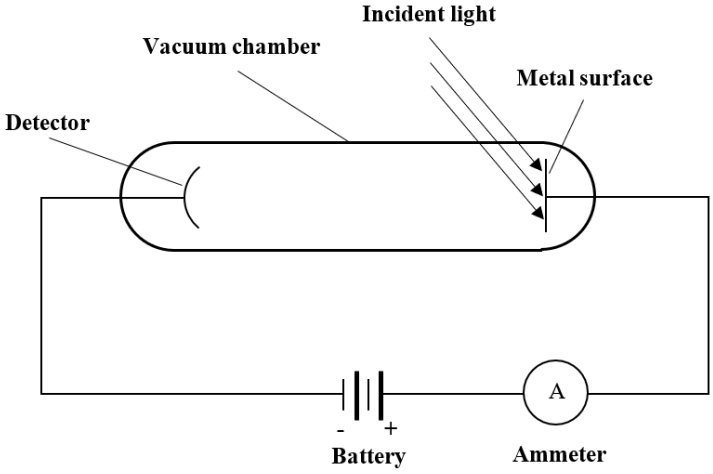
1 mark for correct shape of the emf vs time graph

1 mark for correct direction of emf (matches with the graph)

End of Question 28

Question 29 (7 marks)

A group of students set up the experiment as shown in the diagram below to study the photoelectric effect.



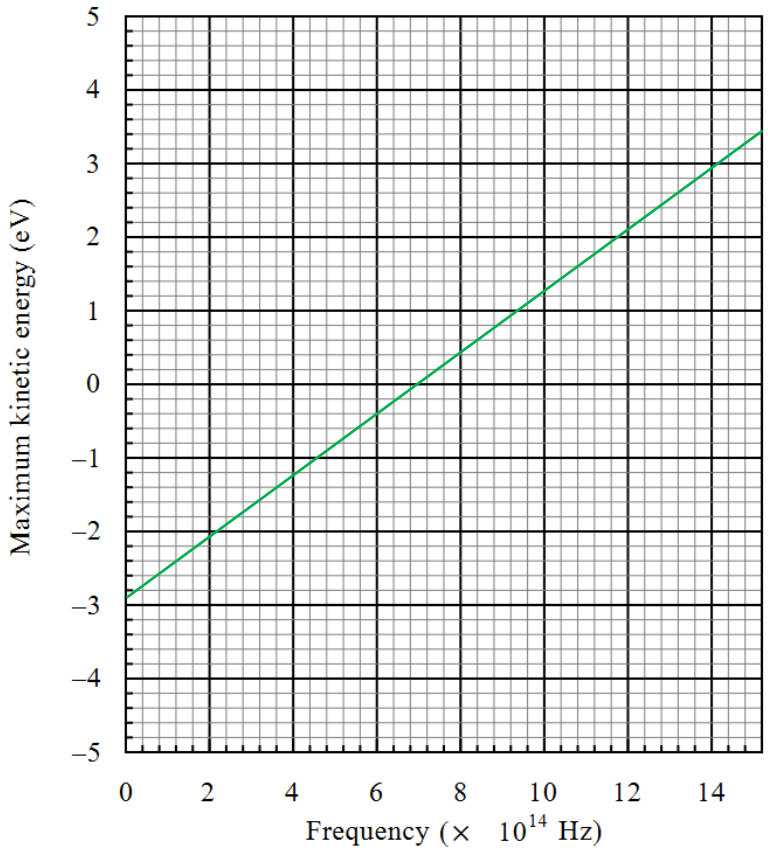
They shone light of varying wavelengths onto different metal surfaces and measured the stopping voltage. Using the stopping voltage, they were able to measure the work function for each metal surface they tested. The results are presented in the table below.

Metal Surface	**Work function (eV)**
Caesium	2.1
Barium	2.5
Calcium	2.9
Magnesium	3.7
Beryllium	5.0

Question 29 continues on page 25

Question 29 (continued)

(a) Using data from the table, draw a graph on the grid below of the maximum kinetic energy of an ejected electron against frequency of the incident light for **Calcium**. **2**



1 mark for drawing a linear graph with positive gradient with the correct y intercept (work function)

1 mark for correct gradient (Planck constant) or x intercept (threshold frequency)

(b) If monochromatic light of wavelength 400 nm is incident on each of the metal surfaces, how many of them would exhibit photoelectric effect? Show all working. **2**

1 mark for relevant calculations e.g. work function or threshold frequency of the metal.

1 mark for correctly identifying all metal surfaces that would exhibit photoelectric effect

We can determine maximum work function of the metal in which photoelectric effect could be observed.

$$K_{max} = hf - \phi$$

$$0 = (6.626 \times 10^{-34})\left(\frac{3.00 \times 10^{8}}{400 \times 10^{-9}}\right) - \phi$$

$$\phi = 4.9695 \times 10^{-19}\ \text{J}$$

$$\phi = \frac{4.965 \times 10^{-19}}{1.602 \times 10^{-19}}\ \text{eV}$$

$$\phi = 3.10\ \text{eV}$$

This means that the monochromatic light can cause the photoelectric effect on metal surfaces with a work function of less than 3.10 eV. So caesium, barium and calcium would exhibit photoelectric effect.

Question 29 continues on page 26

(c) The students noticed that when light of a certain wavelength was shone on a metal surface, no electrons are emitted. They then increased the intensity of this light and still did not detect any electrons. Explain the students' observations and state whether this supports light being a wave or particle. **3**

1 mark for mentioning that the photoelectric effect will only occur if the frequency of the light is above the metal's threshold frequency regardless of the intensity of the light

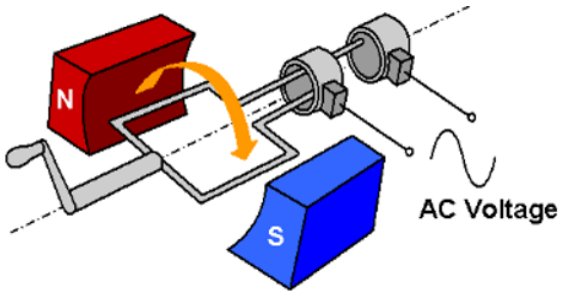
1 mark for stating that this observation supports the particle nature of light

1 mark for explaining that the energy of a photon is given by $E = hf$ and that a photon with frequency above the threshold frequency will have enough energy to cause an electron to be ejected from the metal surface (photoelectric effect). On the other hand, the wave model predicts that the photoelectric effect should occur at any frequency given that the intensity is high enough.

End of Question 29

Question 30 (7 marks)

A group of physics students made a simple AC generator in class. It had 150 turns of wire in a 6.00 cm wide square coil that was placed in a magnetic field of strength 1.85×10^2 mT. They connected the handle to a motor which rotated with a frequency of 4.00 Hz and used the electricity produced to power a light globe.



(a) Give that $\varepsilon = 2\pi nBAf$, calculate the emf produced by the generator. **2**

1 mark for correct substitution

1 mark for correct answer

$$\varepsilon = 2\pi(150)(1.85 \times 10^2 \times 10^{-3})(6.00 \times 10^{-2})^2 \times 4 = 2.51\text{V}$$

(b) The students removed the motor and turned the handle themselves, maintaining a constant speed of rotation. They noticed the force required to turn the handle varied as the coil rotated. They also noticed that the light bulb glowed brightest when the force required was greatest and went out when the force required was virtually zero. Explain these observations using Lenz's Law and the Law of Conservation of Energy. **5**

1 mark for stating that according to Lenz's law, the induced emf would be greatest when the rate of change of flux is the greatest

1 mark for stating that the light bulb glowed brightest when the induced emf was greatest as the induced current through the light bulb would be the greatest

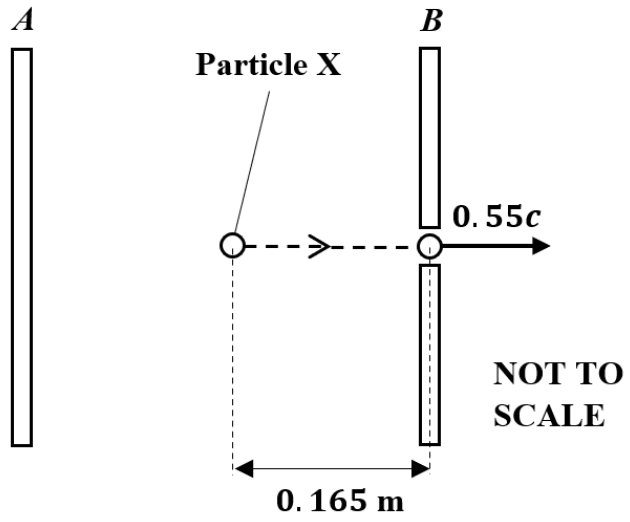
1 mark for stating that the rate of change of flux is zero when the plane of the coil is parallel to the magnetic field, and it is greatest when the plane of the coil is perpendicular to the magnetic field

1 mark for explaining that according to the law of conservation of energy, kinetic energy (force required to turn the handle) is converted into electrical energy (induced emf). When the induced emf is greatest, the kinetic energy required would also be the greatest.

1 mark for a cohesive response which links all the above into a logical response

Question 31 (12 marks)

A group of scientists have created an unknown particle, particle X. They designed an experiment to identify this particle. Particle X was placed stationary between oppositely charged plates *A* and *B* as shown in the diagram below. The plates were charged such that particle X would exits with a speed of $0.55\ c$.



(a) Calculate the acceleration experienced by particle X if it took 2 ns to reach plate *B*. **2**

1 mark for correct substitution

1 mark for correct answer

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

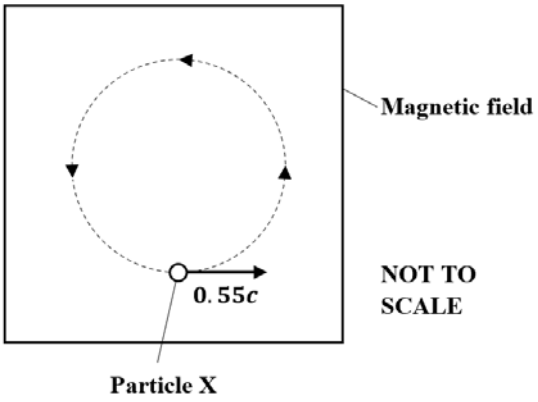
$$0.165 = 0 + \frac{1}{2}a(2 \times 10^{-9})^2$$

$$a = 8.25 \times 10^{16}\ \text{ms}^{-2}$$

Question 31 continues on page 39

Question 31 (continued)

Particle X then travelled at a constant speed of $0.55\ c$ into a magnetic field as shown in the diagram below.



(b) When particle X is at rest, it has a mean lifetime of 2.6×10^{-8} s. Find the mean lifetime of particle X measured by the scientists as the particle travelled in circular motion inside the magnetic field. **2**

1 mark for correct substitution

1 mark for correct answer

$$t_0 = 2.6 \times 10^{-8}$$

$$t_v = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$t_v = \frac{(2.6 \times 10^{-8})}{\sqrt{1 - \frac{(0.55c)^2}{c^2}}}$$

$$t_v = 3.1 \times 10^{-8}\ \text{s}$$

(c) Show that the radius of the circular motion is given by $r = \frac{mv}{qB}$. **2**

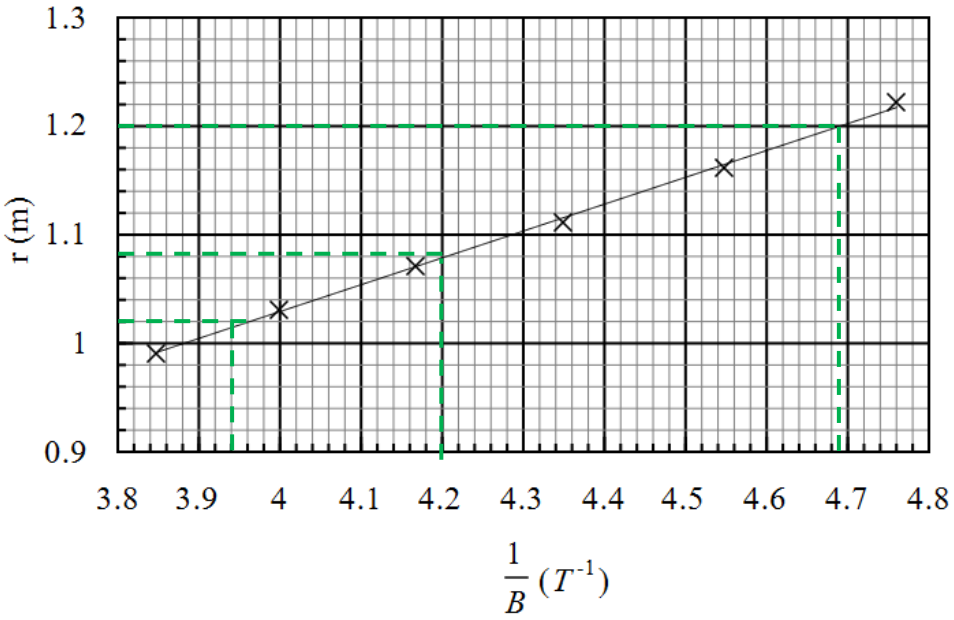
1 mark for equating the magnetic force to centripetal force

1 mark for correctly rearranging the equation to obtain the given relationship

$$F_B = F_c$$
$$qvB = \frac{mv^2}{r}$$
$$qB = \frac{mv}{r}$$
$$r = \frac{mv}{qB}$$

Question 31 (continued)

The scientists changed the magnetic field strength (B) and measured the radius of particle X's motion (r) in ***their frame of reference***. They then presented the results as a graph of r vs $\frac{1}{B}$ as shown below.



(d) Use the graph to determine the distance travelled by particle X in one cycle of the circular motion in the ***particle's frame of reference*** when the magnetic field strength is 0.238 T. **3**

1 mark for reading the correct radius from the graph

1 mark for calculating the radius in the particle's frame of reference

1 mark for calculating the distance travelled by the particle

When $B = 0.238, \frac{1}{B} = 4.2\ \text{T}^{-1}$

From the graph, the radius observed by the scientists would be 1.08 m.

Therefore, $l_0 = 1.08$ (rest length measured by the scientists)

$$l_v = l_0\sqrt{1 - \frac{v^2}{c^2}}$$

$$l_v = 1.08\sqrt{1 - \frac{(0.55c)^2}{c^2}}$$

$$l_0 = 0.90\ldots\ \text{m}$$

Therefore, in the particle's frame of reference, the particle would've travelled in a circle of radius $0.90\ldots$ m. So the total distance travelled by the particle would be

$$d = 2\pi r = 2\pi(0.90\ldots) = 5.7\ \text{m}$$

Question 31 (continued)

The scientists suspect that particle X is one of the particles listed in the table below.

Particle	Charge (C)	Mass (kg)
Pion	$+1.602 \times 10^{-19}$	2.49×10^{-28}
Kaon	-1.602×10^{-19}	8.79×10^{-28}
D	$+1.602 \times 10^{-19}$	3.33×10^{-27}

(e) Use the gradient of the graph to find the charge to mass ratio and predict what particle X might be. **3**

1 mark for calculating the gradient of the graph

1 mark for using the gradient of the graph to determine the charge to mass ratio of particle X

1 mark for comparing the charge to mass ratio of particle X to the particles in the table to predict what particle X might be.

$$m = \frac{1.2 - 1.02}{4.69 - 3.94} = 0.24$$

From c) we know that $r = \frac{mv}{qB} = \frac{mv}{q}\left(\frac{1}{B}\right)$, so the gradient of the graph represents $\frac{mv}{q}$. We also know that $v = 0.55c$.

$$0.24 = \frac{m(0.55c)}{q}$$

$$\frac{q}{m} = 6.875 \times 10^{8}\ \text{C kg}^{-1}$$

We can use the table to calculate the charge to mass ratio of each of the particles:

$$\text{Pion: } \frac{1.602\times10^{-19}}{2.49\times10^{-28}} = 6.4 \times 10^{8}\ \text{C kg}^{-1}$$

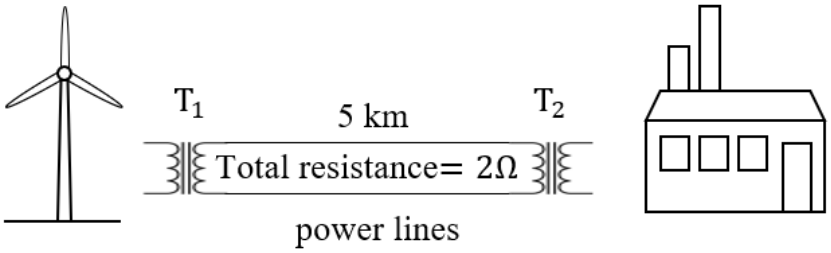
$$\text{Kaon: } \frac{1.602\times10^{-19}}{8.79\times10^{-28}} = 1.8 \times 10^{8}\ \text{C kg}^{-1}$$

$$\text{D: } \frac{1.602\times10^{-19}}{3.33\times10^{-27}} = 4.9 \times 10^{7}\ \text{C kg}^{-1}$$

The charge to mass ratio of particle X is closest to Pion, so it is likely that particle X is pion.

Question 32 (8 marks)

A wind turbine runs a 150 kW generator with an output voltage of 1000 V. The voltage is increased by a transformer T_1, with a ratio of primary turns to secondary turns of 1:10, and transmitted to a town 5 km away through power lines with a total resistance of 2Ω. Another transformer T_2, with a ratio of primary turns to secondary turns of 40:1, reduces the voltage before it is delivered for commercial use.



Analyse the electrical data of the transformers and power lines and explain how the efficiency of this transmission process can be increased. Your analysis should include both qualitative and quantitative information. **8**

To make power transmission more efficient transformers are used to step-up and step-down the voltage as it is transmitted over long distance.

Transformer, T1, increases the voltage for transmission. Since P=VI, by increasing the voltage we reduce the size of the current which reduces power loss (less electrical resistance) during transmission.

By using a ratio of Np:Ns = 1:10 we can calculate the voltage across the transmission wires and hence calculate the current and the power loss.

$\frac{V_P}{V_S} = \frac{N_P}{N_S}$ $\quad \frac{1000}{V_S} = \frac{1}{10}$ $\quad \therefore V_S = 10\,000\ V$

The transmission current is calculated using the power equation: P = VI,

So, 150 x 10^3 = 10 000 I $\quad \therefore I = 15\ A$

So the power lost during transmission = (current)^2 x resistance

$$P = I^2R$$
$$= (15)^2(2)$$
$$= 450\ \text{W}$$

Therefore, the percentage efficiency = $\frac{150 \times 10^3 - 450}{150 \times 10^3} = 99.7\%$

[An alternative approach to calculating efficiency would be to do calculations involving the loss of voltage due to resistance in the wires.

Since the resistance in the wires = 2Ω, the voltage loss = IR = 15(2) = 30V.

Therefore, even though there is a conversion to 10 000 V, there is a loss of 30 V lost in transmission. i.e. V = 10 000 -30 = 9970 V

Therefore, the percentage efficiency = $\frac{10\,000-30}{10\,000} = 99.7\%$]

This is a very efficient way to transmit electrical energy but it could be made even more efficient by increasing the number of turns on the secondary coil e.g. changing the ratio from 1: 10 to 1:20. After calculating this would make the voltage across the transmission lines = 20 000 V and the current in the wires = 7.5A

$\frac{V_P}{V_S} = \frac{N_P}{N_S}$ $\frac{1000}{V_S} = \frac{1}{20}$ $\therefore V_S = 20\,000\ V$ and 150 x 10^3 = 20 000 I $\therefore I = 7.5\ A$

So the power lost during transmission = (current)^2 x resistance

$$P = I^2R$$
$$= (7.5)^2(2)$$
$$= 112.5 \text{ W}$$

Therefore, the percentage efficiency = $\frac{150 \times 10^3 - 112.5}{150 \times 10^3} = 99.99\%$

At T2 the voltage now needs to be stepped down so that there is a small voltage (for safety) and a large current (for domestic and industrial use).

Using the new voltage of 20 000 V, then if we leave the original number of turns on T2 at a ratio of 40:1 then the size of the voltage in the secondary coil is only stepped down to 500 V which is too large and the supply current is 300 A which is too small for domestic use so we would need to change the ratio to 80:1 so the voltage is smaller and the current is larger.

$\frac{V_P}{V_S} = \frac{N_P}{N_S}$ $\frac{20000}{V_S} = \frac{80}{1}$ $\therefore V_S = 250\ V$ and 150 x 10^3 = 250 I $\therefore I = 600\ A$

Continued on next page.

Other factors that could increase efficiency would be to make the distance between the wind turbine and the town shorter, the width of the wires larger and change the type of metal in the conductor to one that has a lower resistivity. As given by the equation:

$$R = \rho \frac{l}{A}$$

Students can also talk about improving the efficiency of the transformers by using laminations, fins, heat sink etc.

End of paper