SYDNEY GRAMMAR SCHOOL

2022
TRIAL EXAMINATION

PHYSICS

Form VI

STRUCTURE OF PAPER

SECTION I

Multiple Choice 20 marks

Allow about 30 minutes for this section.

SECTION II

Parts A-D 80 marks

Allow about 2 hours and 30 minutes for this section.

EXAMINATION

DATE:	Wed 17th August 8.40 AM
DURATION:	3 hours (+5min reading)
MARKS:	100

CHECKLIST

Each boy should have the following:

- Examination Paper (including)
  - Examination sections
  - Extra Writing sheets
  - Data/Formula sheets
  - Multiple-Choice Answer Sheet

EXAM INSTRUCTIONS

- Remove the centre staple and hand in all parts of the examination in a neat bundle in its original order. Do not insert parts into other parts.
- WRITE YOUR **CANDIDATE NUMBER** IN THE SPACE PROVIDED AT THE TOP OF EACH SEPARATED PART OF THE PAPER.
- Responses requiring more writing space than provided should clearly be marked **CONTINUED**. When the response is continued on extra writing paper it should clearly indicate the question number.
  - Each detachable part A-D of Section II has additional writing space to use for that part.
  - Further additional writing paper can be given on request.
- There is a Data/Formula sheet included at the end of the paper.

Authors: DGB, SRW, AAH, PCK Master in charge: PCK

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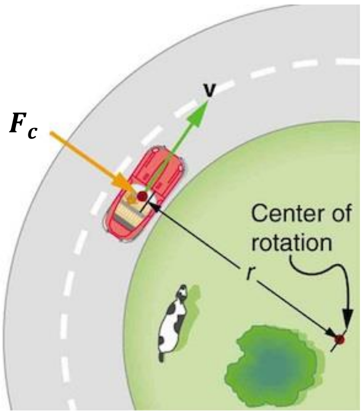
SECTION I: MULTIPLE CHOICE (20 marks)

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

1 A car of mass 1000 kg is following a circular road of radius r at velocity v and its centripetal force is F_c.



A truck of 3000 kg goes around the same corner. In order for the centripetal force to be the same for both the truck and the car then:

(A) The trucks speed must be $\frac{v}{\sqrt{3}}$.

(B) The trucks speed must be $\frac{v}{3}$.

(C) The trucks speed must be $\sqrt{3}v$.

(D) The trucks speed must be the same as the car.

2 A ball is thrown horizontally from the top of a cliff, and it hits the ground with a range, R, from the base of the cliff. A second ball is thrown horizontally from the top of the same cliff at three times the speed. What is the range of the second ball?

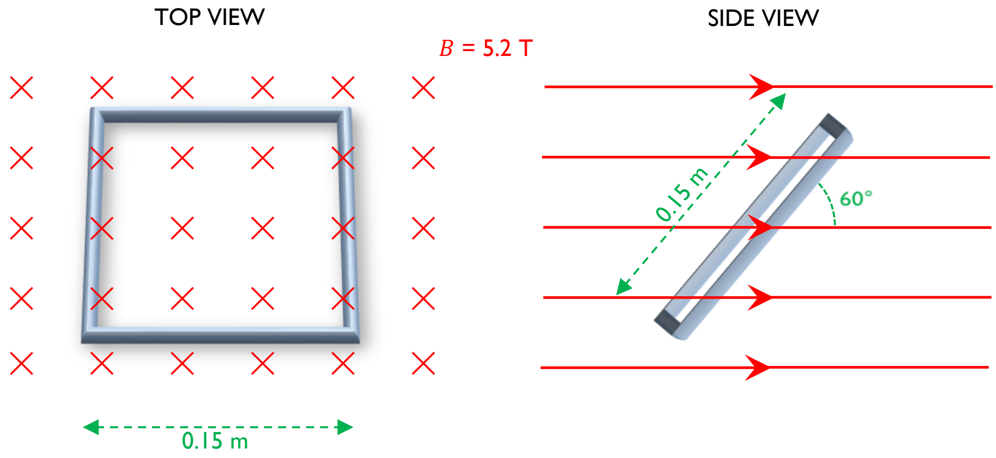
(A) R

(B) $2R$

(C) $3R$

(D) $4R$

3 A square loop of wire of side length 0.15 m is placed in a magnetic field of 5.2 T as shown below.



Calculate the magnetic flux, Φ, through the loop.

(A) 0.059 Wb

(B) 0.101 Wb

(C) 0.117 Wb

(D) 0.78 Wb

4 A boy throws a ball upwards from the roof of a moving car and then catches it when the car has travelled 100 m down the road. He throws the ball up again and it goes vertically four times higher than before.

How far has the car travelled this time when he catches it again?

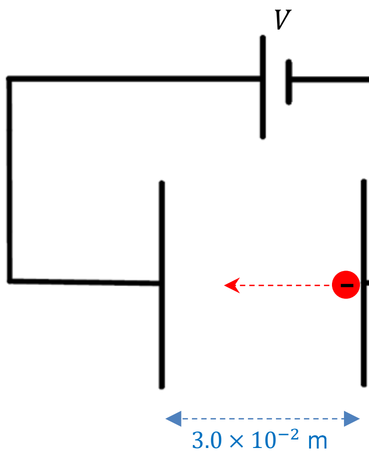
(A) 100 m

(B) 200 m

(C) 300 m

(D) 400 m

5 In the diagram below, an electron released from rest from the negative plate strikes the positive plate at a speed of 5.50×10^{6} m s^{-1}. The separation of the plates is 3.0×10^{-2} m.



Calculate the potential difference, V, between the two plates.

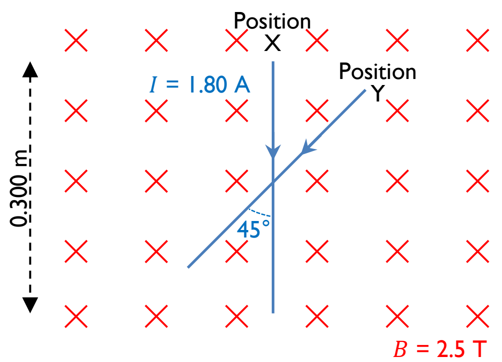
(A) 1.56×10^{-5} V

(B) 8.60×10^{1} V

(C) 1.72×10^{2} V

(D) 1.65×10^{5} V

6 In the diagram below, a wire of length 0.300 m sits in a 2.50 T magnetic field in Position X, as shown. The wire carries a current of 1.80 A. The wire is then rotated 45.0° to Position Y.



Calculate the *change* in the magnitude of the force acting on the wire after it rotates from X to Y.

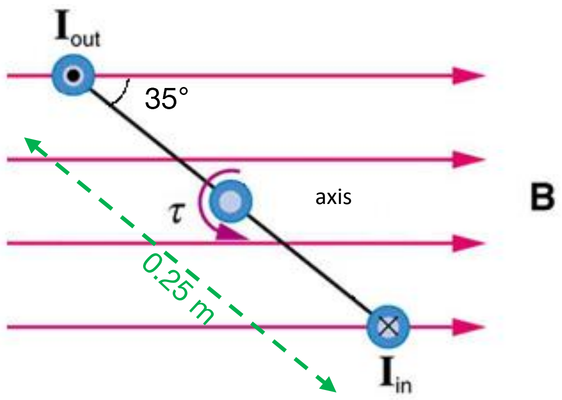
(A) 0 N

(B) 0.395 N

(C) 0.955 N

(D) 1.35 N

7 The diagram below shows a square coil rotating in a magnetic field at one instant in its rotation.



The square coil consists of 15 turns of wire, and has dimensions 0.25 x 0.25 m. A current of I = 3.25 A flows through it. The external magnetic field is B = 1.20 T.

Calculate the magnitude of the torque, τ, on the coil at the angle shown.

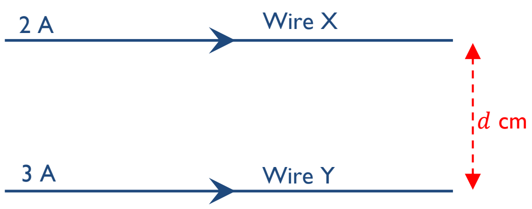
(A) 0.20 N m

(B) 2.01 N m

(C) 3.00 N m

(D) 4.73 N m

8 Two very long parallel long wires, X and Y, separated by a distance, d, have a force per unit length between them of 5.5×10^{-5} N m^{-1}. Wire X carries a current of 2 A, and Wire Y carries a current of 3 A as shown in the diagram below.



What is the separation, d, between the two wires?

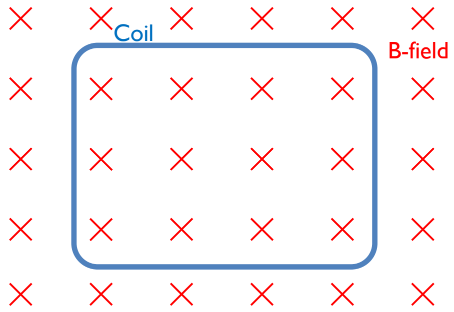
(A) 1 cm

(B) 2 cm

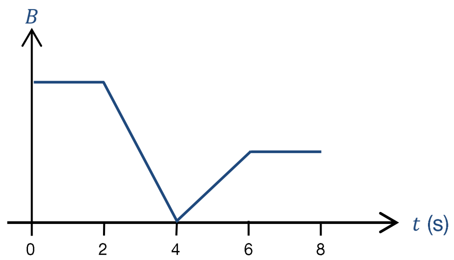
(C) 14 cm

(D) 15 cm

9 In the diagram below, a coil of wire is placed in a magnetic field so that the plane of the coil is perpendicular to the direction of the magnetic field.

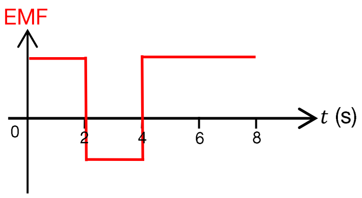


The strength of the magnetic field is then varied, as shown in the following graph.

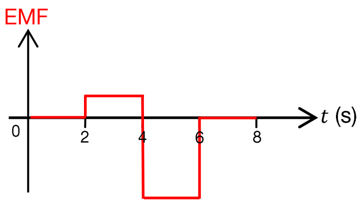


Which of the following graphs correctly shows the EMF induced across the coil?

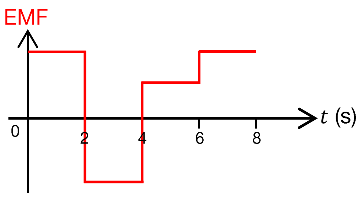
(A)



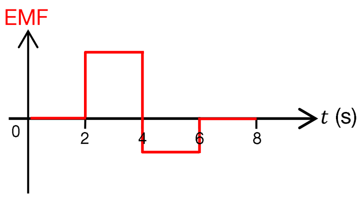
(B)



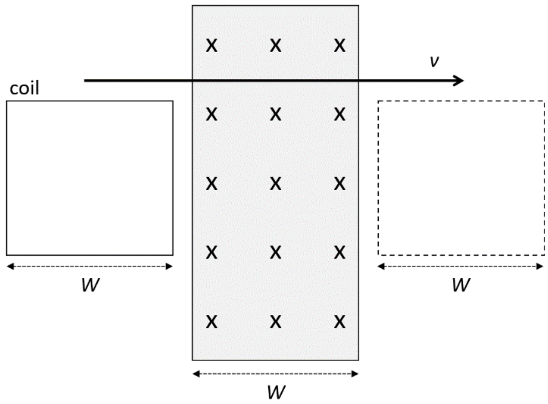
(C)



(D)



10 A square coil of conducting wire with sides of length W is moved at constant speed v left to right, through a uniform magnetic field which is directed into the page and has width W, as show below.



From the point where the coil enters the magnetic field until the point where it leaves it, which description best describes the direction of the current induced in the coil?

(A) Clockwise.

(B) Anti-clockwise.

(C) Clockwise then anti-clockwise.

(D) Anti-clockwise then clockwise.

11 A satellite of mass m is travelling in a circular orbit of radius r around a planet of mass M. If the satellite is moved to a new circular orbit where its kinetic energy is now 25% larger, then the radius of the new circular orbit will be:

(A) $\frac{\sqrt{5}r}{2}$

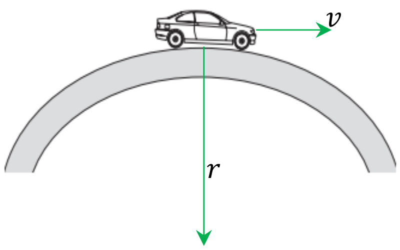
(B) $\frac{4r}{5}$

(C) $\frac{2r}{\sqrt{5}}$

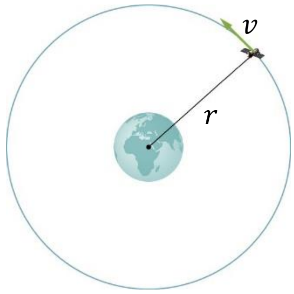
(D) $\frac{5r}{4}$

12 The net force on a car at the top of a bridge is compared to the net force on a satellite in a circular orbit.

A car of mass m drives over a circular hump-back bridge of radius r with a constant speed v.



A satellite of mass m orbits with an orbital radius of r and orbital velocity v around Earth with a mass M.



Which of the following correctly represents the net force in both situations?

	Net force on car at top of bridge	Net force on Satellite in circular orbit
(A)	$\frac{mv^2}{r}$	$\frac{mv^2}{r}$
(B)	mg	$\frac{GMm}{r^2}$
(C)	$mg - \frac{mv^2}{r}$	$\frac{mv^2}{r}$
(D)	$\frac{mv^2}{r} + mg$	$\frac{mv^2}{r} - \frac{GMm}{r^2}$

13 A red (wavelength 610 nm) laser pointer emits 0.5 mW of light.

How many photons per second are being emitted by the laser pointer?

(A) 1.5×10^{15}

(B) 1.5×10^{24}

(C) 1.2×10^{27}

(D) 4.6×10^{32}

14 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

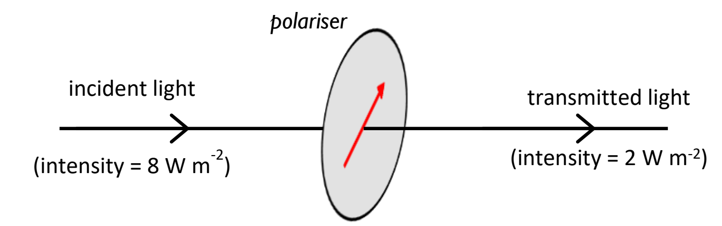
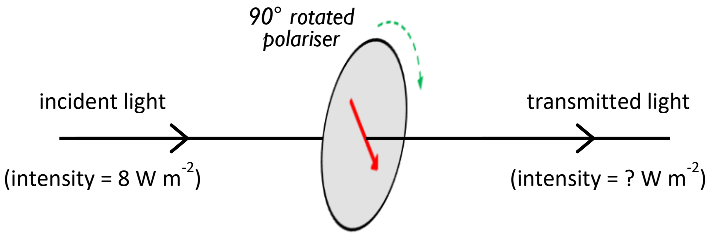


Diagram 2



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 90° from the orientation in Diagram 1.

In Diagram 2, 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}

15 An observer notes that the second-hand on a stopwatch is four times slower on a passing spacecraft.

What is the velocity of the spacecraft?

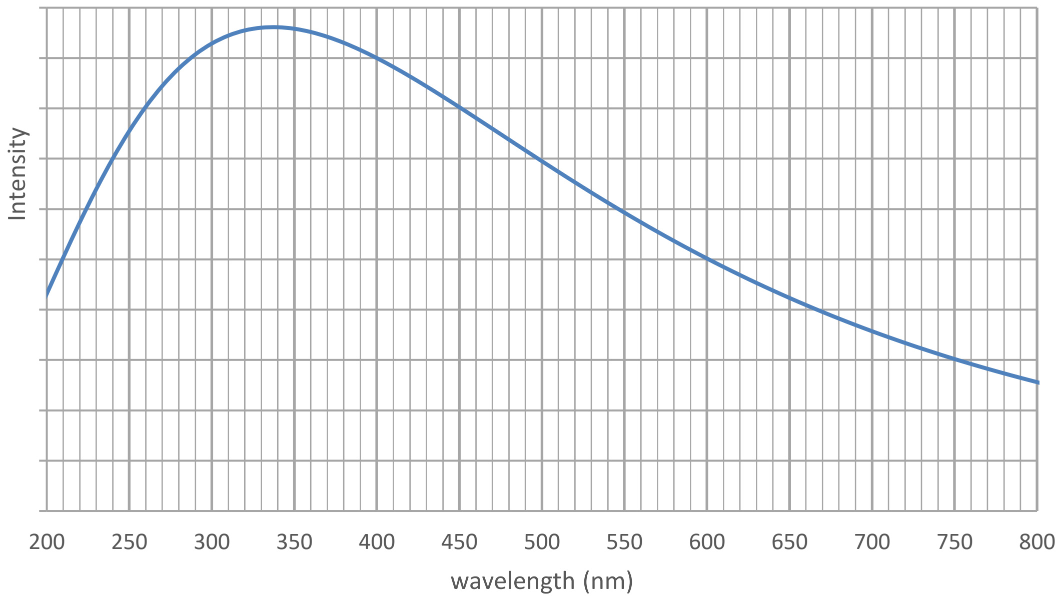
(A) $v = 0.25c$

(B) $v = 0.87c$

(C) $v = 0.94c$

(D) $v = 0.97c$

16 The spectrum of an object was measured and graphed below.



Which of the following best represents the temperature of this object?

(A) 8,280 K

(B) 8,524 K

(C) 9,348 K

(D) 14,490 K

17 What is the magnitude of the relativistic momentum of a proton travelling at half the speed of light?

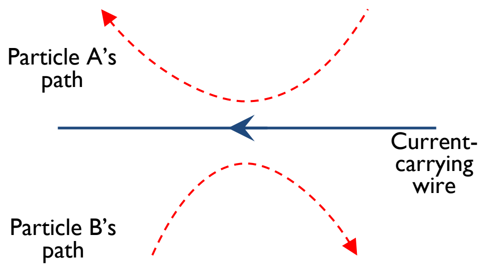
(A) $9.7 \times 10^{-28}\ \text{kg m s}^{-1}$

(B) $1.9 \times 10^{-27}\ \text{kg m s}^{-1}$

(C) $2.9 \times 10^{-19}\ \text{kg m s}^{-1}$

(D) $3.5 \times 10^{-19}\ \text{kg m s}^{-1}$

18 At two separate times, two charged particles approach a current-carrying wire and follow the trajectories depicted in the diagram below.



Determine the charge of each particle.

	Particle A	Particle B
(A)	Positively charged	Positively charged
(B)	Positively charged	Negatively charged
(C)	Negatively charged	Positively charged
(D)	Negatively charged	Negatively charged

19 The range of a projectile on horizontal surface is given by $R = \frac{u^2 \sin(2\theta)}{g}$, where R is the range, g is the acceleration due to gravity, u is the initial speed and θ is the angle of the projectile to the horizontal.

Which of the following changes would increase the range of the projectile to $2R$?

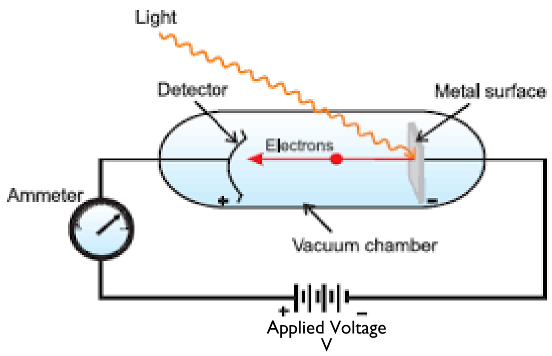
(A) u is doubled.

(B) g is doubled.

(C) θ is changed from 30° to 45°.

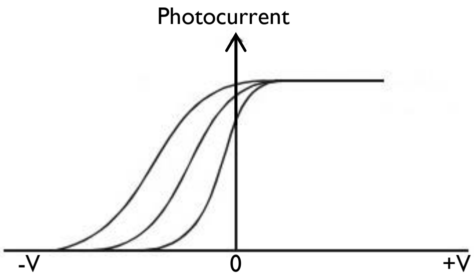
(D) u is multiplied by $\sqrt{2}$.

20 Two experiments are conducted using a photoelectric cell where the applied voltage is varied, and the resultant photocurrent is measured by the ammeter.

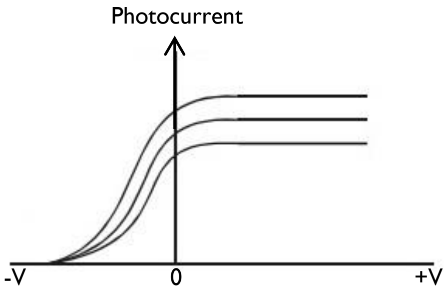


The results of both experiments are shown in the following graphs.

EXPERIMENT A



EXPERIMENT B



Which would be the correct interpretation of these experiments?

(A)	Experiment A is where three different frequencies of light were used.	Experiment B is where three different intensities of the same frequency of light were used.
(B)	Experiment A is where three different intensities of the same frequency of light were used.	Experiment B is where three different frequencies of light were used.
(C)	Experiment A is where three different intensities of the same frequency of light were used.	Experiment B is where three different metals were used.
(D)	Experiment A is where three different frequencies of light were used.	Experiment B is where three different metals were used.

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SECTION II: Part A (17 Marks)

CANDIDATE NUMBER							

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 21 (3 marks) **Marks**

Muons are particles created in the upper atmosphere by cosmic ray collisions and travel towards the ground at 0.98c. Of all the muons detected at an altitude of 10 km, only 1 in 45,000 were predicted to reach ground level with the rest decaying due to their short lifetime of 2.2 μs. However, it was measured that 1 in 8 were able to be detected at ground level.

Explain how this provides evidence to support Einstein's Special Theory of relativity. (*Calculations are not required.*)

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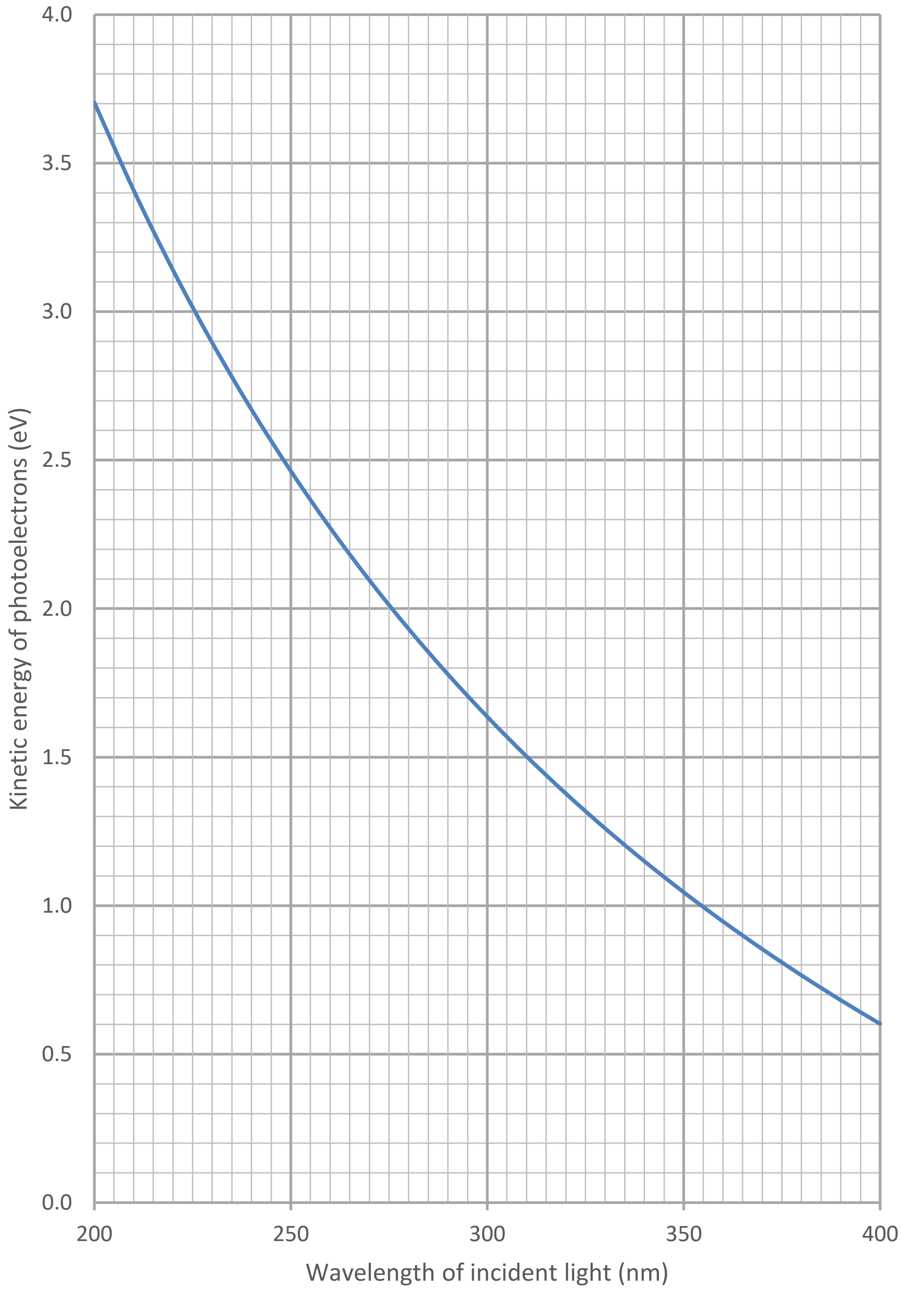
Question 22 (6 marks) **Marks**

When light is incident on Europium metal, photoelectrons are emitted. The graph below shows how the measured kinetic energy of the photoelectrons changes when different wavelengths of light are incident on the metal.



Question 22 continued on next page.

Question 22 continued **Marks**

(a) Using the graph, determine the work function of Europium.

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(b) For any metal there is a maximum wavelength of light after which no photoelectrons are emitted.

Use Einstein's explanation of the photoelectric effect to explain why no electrons are emitted if the wavelength is greater than this maximum.

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Question 23 (3 marks) **Marks**

Explain why, from an observer's point of view, an object with mass would not be able to accelerate to the speed of light, c, in a vacuum.

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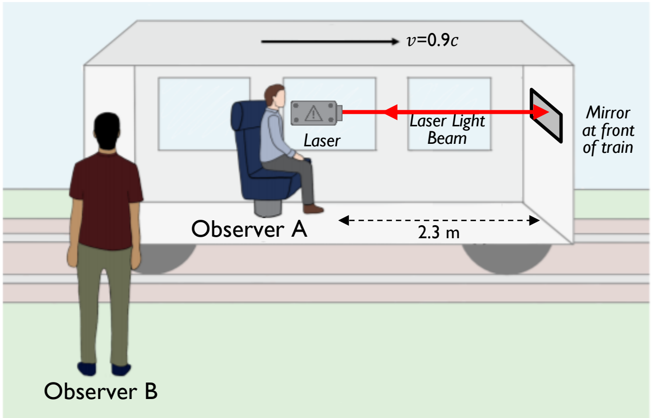
Question 24 (5 marks) **Marks**

As a thought experiment, Observer A is on a train travelling at a velocity of $v = 0.9c$ compared to Observer B.

Observer A shines a laser beam towards a mirror at the front of the train, a distance of 2.3 m. The light beam reflects off the mirror and returns to a timing device on the laser.



(a) According to observer A, how long would it take for the light beam to complete this journey?

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(b) According to observer B:

i. how long would it take for the light beam to complete this journey?

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ii. what is the distance he would measure between the laser and the mirror?

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Part A extra writing space

If you use this space, clearly indicate which question you are answering.

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SECTION II: Part B (17 Marks)

CANDIDATE NUMBER							

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

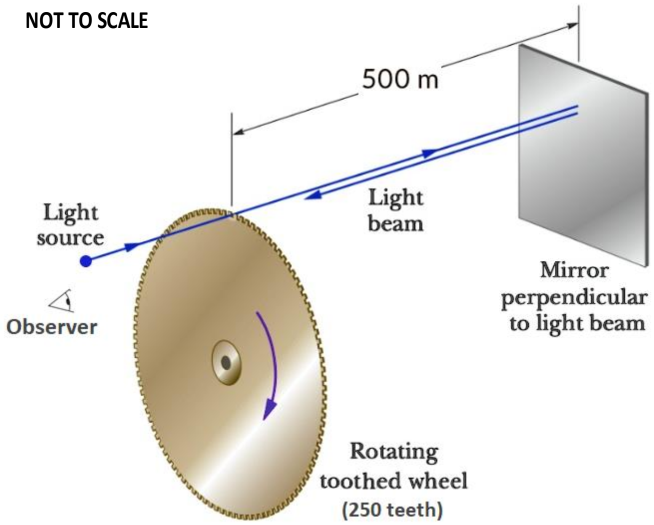
Question 25 (5 marks) — Marks

In the 1840s, French physicist Hippolyte Fizeau performed an experiment to measure the speed of light using a rotating toothed cogwheel.

He shone an intense light source at a mirror and broke up the light beam with a rotating toothed cogwheel. He adjusted the speed of rotation of the wheel until the reflected light beam could no longer be seen returning through the gaps in the cogwheel.

The diagram below shows a similar experiment:

- The rotating toothed cogwheel has 250 teeth and 250 gaps of the same width.
- The distance between the rotating toothed cogwheel and the mirror is 500 m.



(a) Determine the minimum rotation speed of the cogwheel that would completely block the returning light. **2**

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Question 25 continued on next page.

Question 25 continued **Marks**

(b) The same experiment is performed again but this time a 500 m long rectangular tank of pure water is added between the cogwheel and the mirror. The new minimum rotation speed of the toothed cogwheel that would completely block the returning light is 2830 rad/s, which is lower than the one measured in air.

i. What conclusion about the speed of light in water can be made from this observation?

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ii. This experiment provides evidence for Huygens model of light. Describe one other observation or experimental evidence that supports Huygens model.

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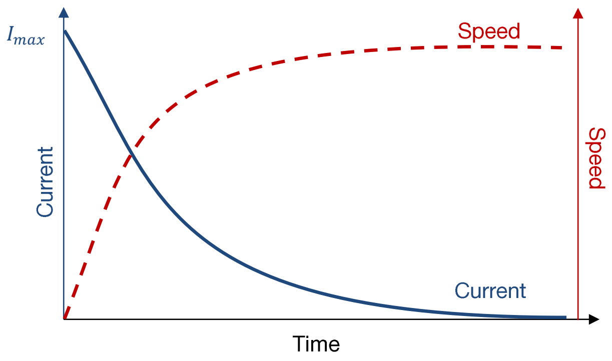
Question 26 (3 marks) **Marks**

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



Explain why the current starts at a specific maximum value I_{max} then falls to zero as the motor increases its speed.

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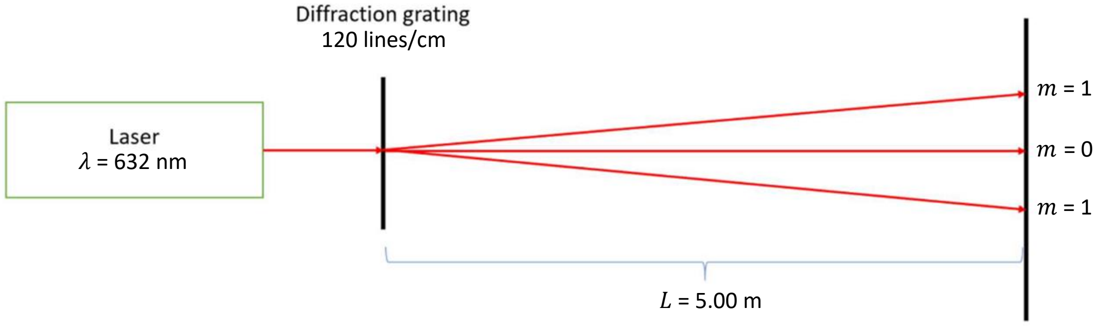
Question 27 (4 marks) **Marks**

A helium neon laser, which emits light of wavelength λ = 632 nm, is shone through a diffraction grating with 120 lines/cm. It is placed L = 5.00 m away from a screen. *(Only the 1st order maximum m = 1 is included in the diagram).*



(a) Determine the separation between the slits in the grating.

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(b) For the 3rd order maximum to occur, what is the additional distance or "path difference" that the light must have travelled from one slit on the grating to the screen compared to the adjacent slit?

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(c) What is the distance on the screen between the central maximum and the 3rd order maximum?

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Question 28 (5 marks) **Marks**

Explain how the stator in an AC induction motor generates torque in the rotor.

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Part B extra writing space

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SECTION II: Part C (18 Marks)

CANDIDATE NUMBER

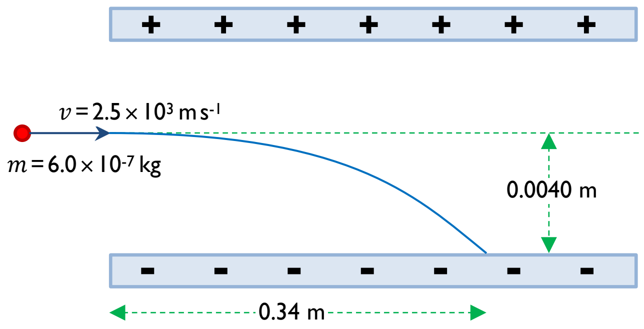
Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 29 (4 marks)

Marks

A charged particle of mass 6.0×10^{-7} kg is travelling at an initial velocity of 2.5×10^{3} m s^{-1}.

The particle enters a perpendicular electric field of 7.5×10^{4} NC^{-1}, and follows the trajectory shown below.



Calculate the magnitude of the charge on the particle.

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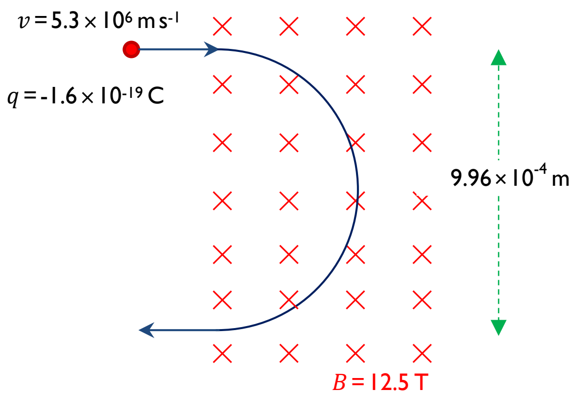
Question 30 (3 marks) **Marks**

A subatomic particle with a charge of -1.6×10^{-19} C travels at a speed of 5.3×10^{6} m s^{-1} into a perpendicular magnetic field of strength 12.5 T. It follows the path shown in the diagram below.



Calculate the mass of the particle.

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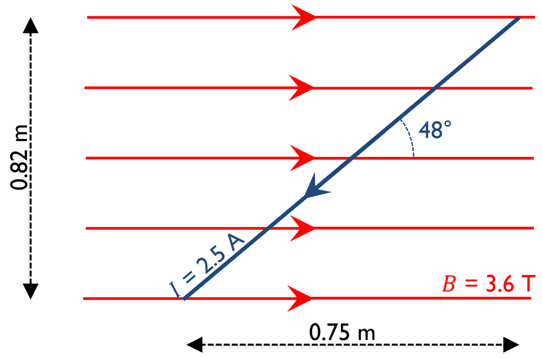
Question 31 (2 marks) **Marks**

The diagram below shows a current carrying wire in a uniform magnetic field.



Calculate the magnitude and direction of the magnetic force acting on the wire in the position shown.

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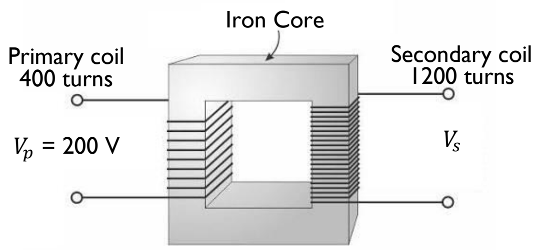
Question 32 (4 marks)

Marks

The diagram below shows a transformer. The transformer operates from an A.C. primary voltage of 200 V. The primary coil of the transformer has 400 turns, and the secondary coil has 1200 turns.



(a) Calculate the voltage across the secondary coil of the transformer.

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(b) Identify if this is a step-up or step-down transformer.

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(c) Explain one method of increasing the efficiency of this transformer.

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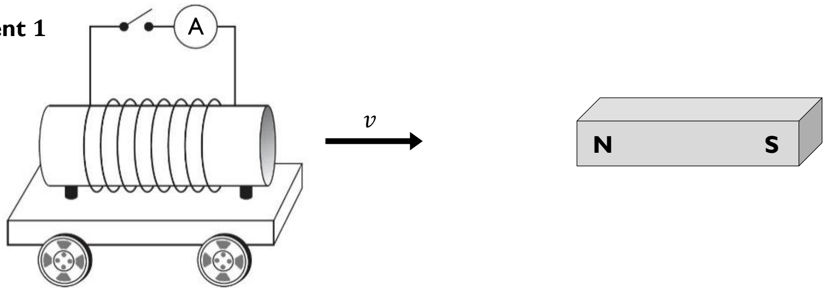
Question 33 (5 marks) **Marks**

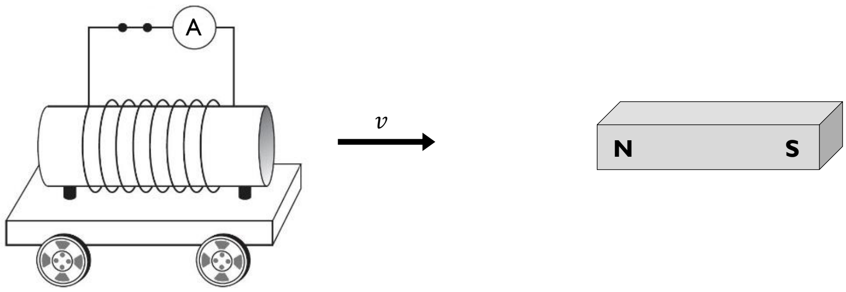
A pupil performs the experiments shown below. He puts a solenoid (a coil of wire) on the back of a motion trolley connected to an ammeter and a switch and pushes it towards a powerful **fixed** magnet at an initial speed v.

In Experiment 1 the switch is open. In Experiment 2 the conditions are exactly the same as Experiment 1 but now the switch is closed.

Experiment 1



Experiment 2



Describe and explain, in terms of the relevant Laws of Physics, the observations that he makes of the two experiments. (Ignore the effect of friction on the trolleys).

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Part C extra writing space

If you use this space, clearly indicate which question you are answering.

Do NOT write in this area.

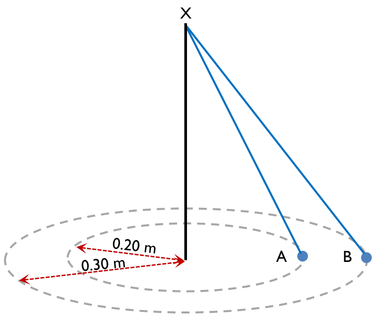
SECTION II: Part D (28 Marks)

CANDIDATE NUMBER							

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 34 (4 marks) **Marks**

Two spheres A and B are attached to the ends of light inextensible strings XA and XB as shown below.



They are swung in horizontal circles so that their periods are the same.

(a) Determine the ratio $\frac{v_B}{v_A}$ of the speed of sphere B (v_B) to the speed of sphere A (v_A).

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(b) Determine the ratio $\frac{a_B}{a_A}$ of the centripetal acceleration of sphere B (a_B) to the centripetal acceleration of sphere A (a_A).

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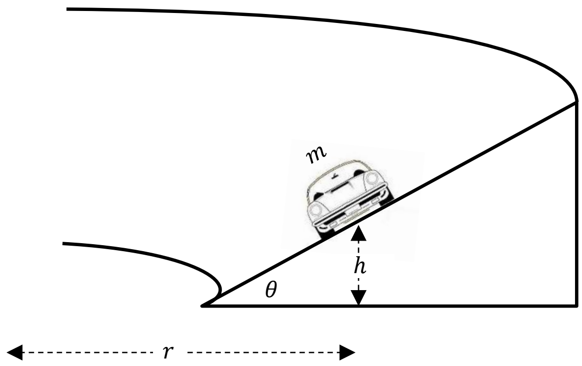
Question 35 (6 marks) **Marks**

A car of mass m = 1000 kg is travelling around a frictionless banked track (there is no friction between the wheel and the track) at an angle of θ = 30° to the horizontal and radius of r = 60 m.



(a) For the car:

i. determine the magnitude of the force of the track on the car (i.e., the Normal force).

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ii. determine the speed of the car required to maintain a constant radius of 60 m.

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Question 35 continued on next page.

Question 35 continued **Marks**

(b) If the speed of the car is doubled, explain why the car would have to move higher up the incline (i.e., h becomes larger) to still go around the circular track without any sideways friction from the track.

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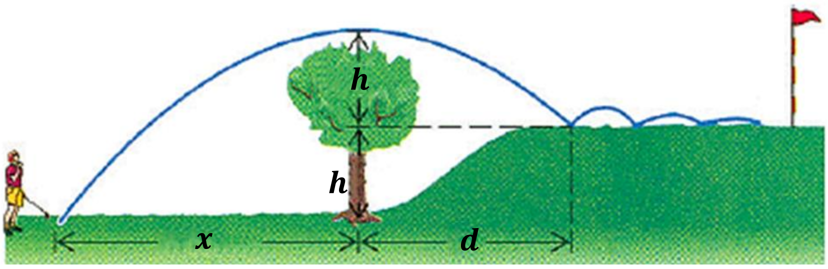
Question 36 (8 marks) **Marks**

A golfer must hit a shot over a tree and onto an elevated green as shown in the diagram below.



The distance to the tree is $x = 8.6$ m. The height of the green the ball lands on is $h = 3.0$ m and the maximum height his shot reaches is $2h$.

(a) What is the initial vertical velocity of the ball?

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(b) How long will it take the ball to reach its maximum height?

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Question 36 continued on next page.

Question 36 continued **Marks**

(c) What is the initial launch angle of the ball above the horizontal?

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(d) What is the distance d?

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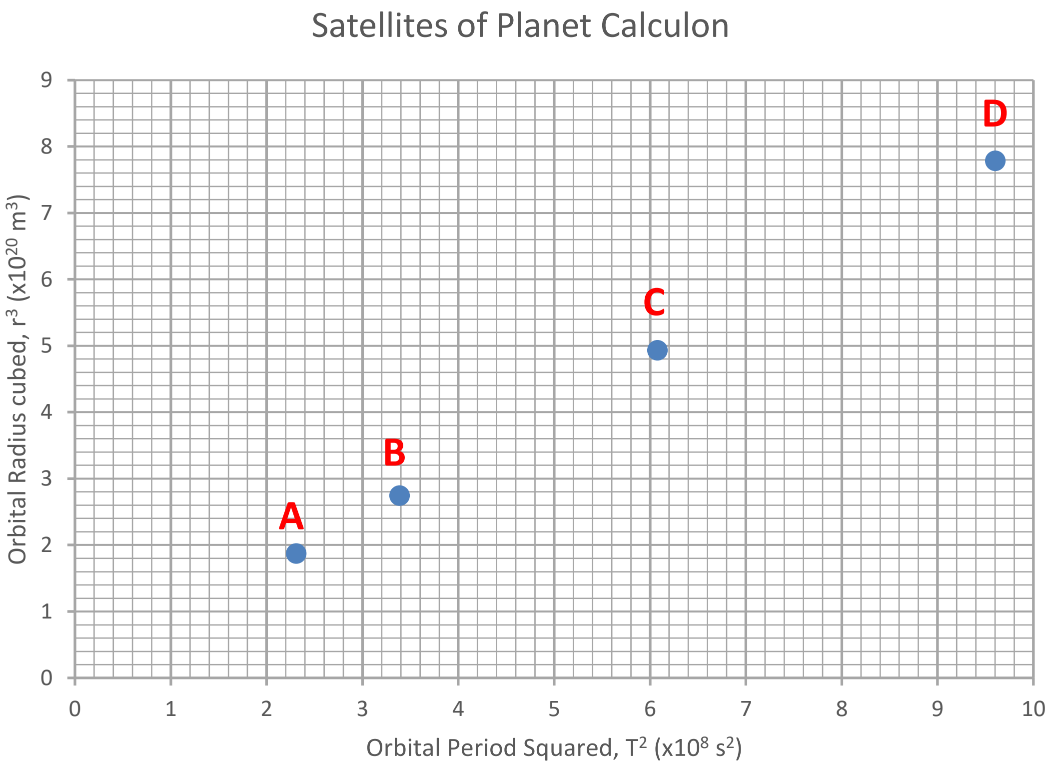
Question 37 (6 marks) **Marks**

Four satellites labelled A, B, C and D are orbiting a distant planet called Calculon. Their orbital properties are plotted below.



(a) Determine the mass of the planet Calculon.

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Question 37 continued on next page.

Question 37 continued **Marks**

(b) Determine the orbital velocity of satellite B.

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(c) If Satellite C is in a geostationary orbit around the planet Calculon then how long is a day on the planet (i.e., the time it takes for the planet to rotate once on its axis)?

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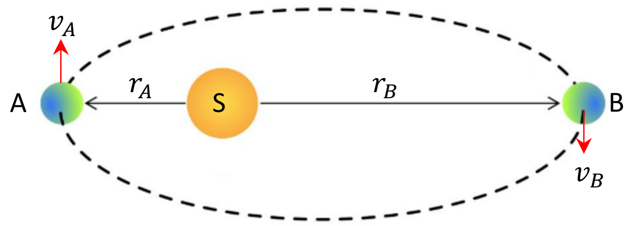
Question 38 (4 marks) **Marks**

A planet of mass m is orbiting a Star, S, of mass M in an elliptical orbit as shown below. The planet is shown at two points in its orbit. At position A it is at its closest to S and at position B, it is at its furthest. The distance from S to A is r_A whereas the distance S to B is r_B.



For an elliptical orbit the total energy is given by

$$E = -\frac{GMm}{r_A + r_B}$$

Use the total energy to determine the ratio of the kinetic energy $\left(\frac{K_A}{K_B}\right)$ of the planet at position A (K_A) compared to position B (K_B) if the distance r_B is three times larger than r_A. (i.e., $r_A = r$ and $r_B = 3r$ and $\frac{r_B}{r_A} = 3$).

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END OF EXAMINATION

Do NOT write in this area.

Part D extra writing space

If you use this space, clearly indicate which question you are answering.

Part D extra writing space

If you use this space, clearly indicate which question you are answering.

Do NOT write in this area.

SYDNEY GRAMMAR SCHOOL

CANDIDATE NUMBER

2022
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Physics

Section I - Multiple Choice

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

Sample: 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.

correct

A ~~●~~ B ~~●~~ C ○ D ○

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

SYDNEY GRAMMAR SCHOOL

2022
TRIAL EXAMINATION

PHYSICS

Form VI

CRIB

STRUCTURE OF PAPER	
SECTION I	
Multiple Choice	20 marks
Allow about 30 minutes for this section.	
SECTION II	
Parts A-D	80 marks
Allow about 2 hours and 30 minutes for this section.	

EXAMINATION	
DATE:	Wed 17th August 8.40 AM
DURATION:	3 hours (+5min reading)
MARKS:	100

CHECKLIST

Each boy should have the following:

Examination Paper (including)

- Examination sections
- Extra Writing sheets
- Data/Formula sheets
- Multiple-Choice Answer Sheet

EXAM INSTRUCTIONS

- Remove the centre staple and hand in all parts of the examination in a neat bundle in its original order. Do not insert parts into other parts.
- WRITE YOUR **CANDIDATE NUMBER** IN THE SPACE PROVIDED AT THE TOP OF EACH SEPARATED PART OF THE PAPER.
- Responses requiring more writing space than provided should clearly be marked **CONTINUED**. When the response is continued on extra writing paper it should clearly indicate the question number.
  Each detachable part A-D of Section II has additional writing space to use for that part.
  Further additional writing paper can be given on request.
- There is a Data/Formula sheet included at the end of the paper.

Authors: DGB, SRW, AAH, PCK Master in charge: PCK

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

SECTION I: MULTIPLE CHOICE (20 marks)

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

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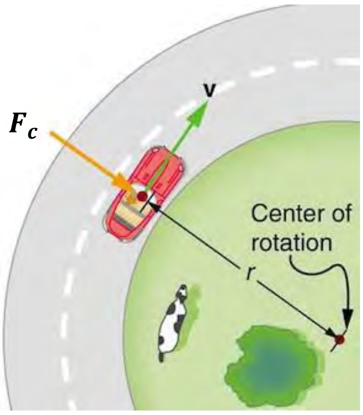
1 A car of mass 1000 kg is following a circular road of radius r at velocity v and its centripetal force is F_c.



$F = \frac{mv^2}{r} = \frac{(3m)\left(\frac{v}{\sqrt{3}}\right)^2}{r}$

A truck of 3000 kg goes around the same corner. In order for the centripetal force to be the same for both the truck and the car then:

(A) The trucks speed must be $\frac{v}{\sqrt{3}}$.

(B) The trucks speed must be $\frac{v}{3}$.

(C) The trucks speed must be $\sqrt{3}v$.

(D) The trucks speed must be the same as the car.

2 A ball is thrown horizontally from the top of a cliff, and it hits the ground with a range, R, from the base of the cliff. A second ball is thrown horizontally from the top of the same cliff at three times the speed. What is the range of the second ball?

(A) R

(B) $2R$

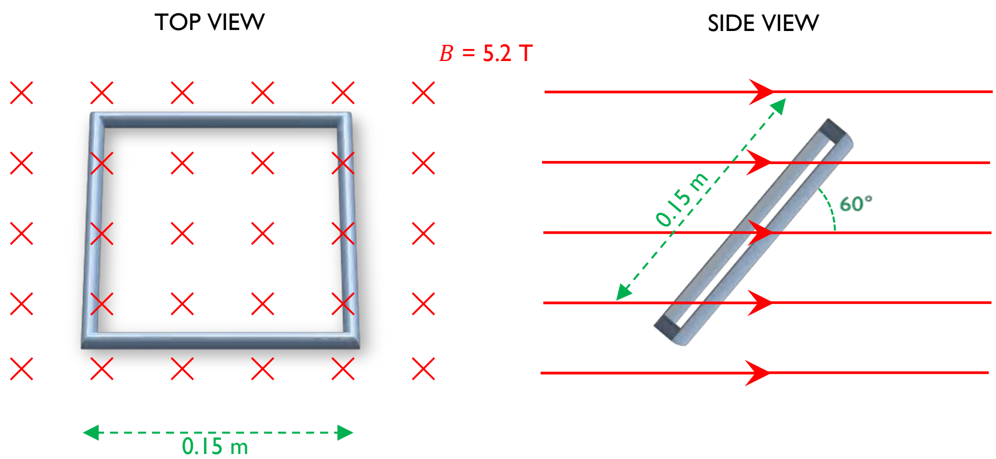
(C) $3R$

(D) $4R$

$R = u_x t$

$3R = (3u_x)t$

3 A square loop of wire of side length 0.15 m is placed in a magnetic field of 5.2 T as shown below.



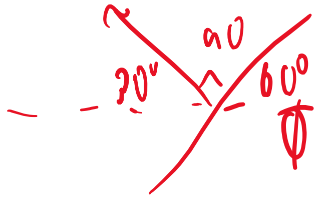
Calculate the magnetic flux, Φ, through the loop.

(A) 0.059 Wb

(B) 0.101 Wb

(C) 0.117 Wb

(D) 0.78 Wb



$\Phi = BA\cos 30^\circ$

$= (0.15)^2 \times 5.2 \cos 30^\circ$

4 A boy throws a ball upwards from the roof of a moving car and then catches it when the car has travelled 100 m down the road. He throws the ball up again and it goes vertically four times higher than before.

How far has the car travelled this time when he catches it again?

(A) 100 m

(B) 200 m

(C) 300 m

(D) 400 m

max height $v_y = 0$

$h = \frac{v_y^2 - u_y^2}{2a_y} = \frac{-u_y^2}{2\times(-9.8)} = \frac{u_y^2}{19.6}$

$\therefore$ if max height $\times 4$ then $u_y \times 2$

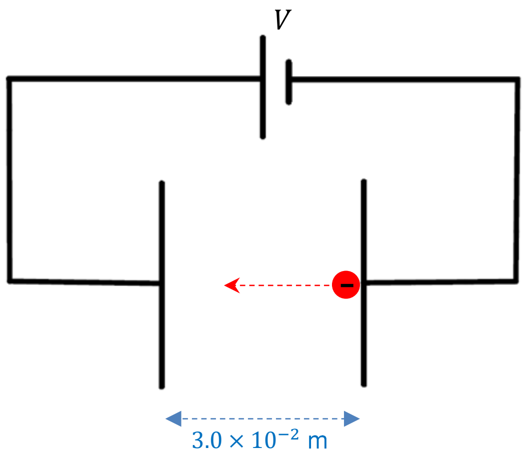
$4h \Rightarrow 2u_y$

time to max height $t = \frac{v_y - u_y}{a_y} = \frac{-u_y}{-9.8}$, $2t = \frac{2u_y}{9.8}$

Range is $2\times$ further if $u_y \to 2u_y$

$R = u_x t = u_x\left(\frac{2u_y}{9.8}\right)$

5 In the diagram below, an electron released from rest from the negative plate strikes the positive plate at a speed of 5.50×10^{6} m s^{-1}. The separation of the plates is 3.0×10^{-2} m.



Calculate the potential difference, V, between the two plates.

(A) 1.56×10^{-5} V

(B) 8.60×10^{1} V

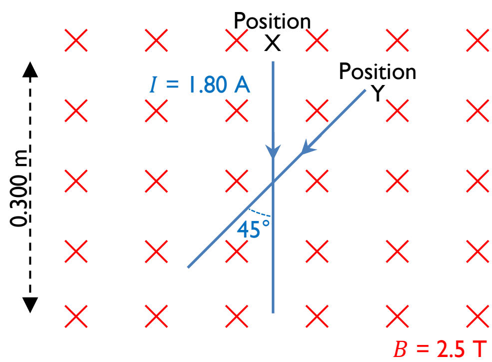
(C) 1.72×10^{2} V

(D) 1.65×10^{5} V

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

$V = \frac{mv^2}{2q} = \frac{9.109\times10^{-31}(5.5\times10^{6})^2}{2\times(1.602\times10^{-19})}$

6 In the diagram below, a wire of length 0.300 m sits in a 2.50 T magnetic field in Position X, as shown. The wire carries a current of 1.80 A. The wire is then rotated 45.0° to Position Y.



Calculate the *change* in the magnitude of the force acting on the wire after it rotates from X to Y.

(A) 0 N

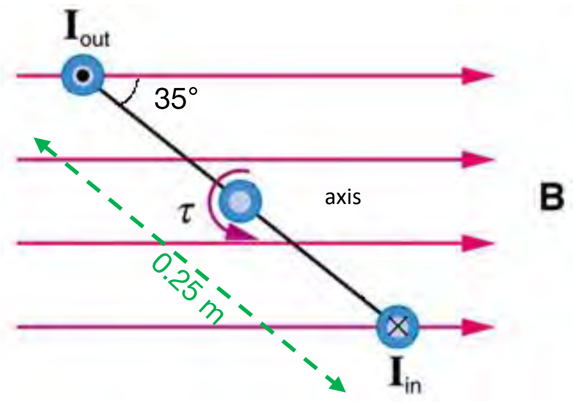
(B) 0.395 N

(C) 0.955 N

(D) 1.35 N

the wire is 90° to field at both positions

7 The diagram below shows a square coil rotating in a magnetic field at one instant in its rotation.



The square coil consists of 15 turns of wire, and has dimensions 0.25 x 0.25 m. A current of I = 3.25 A flows through it. The external magnetic field is B = 1.20 T.

Calculate the magnitude of the torque, τ, on the coil at the angle shown.

(A) 0.20 N m

(B) 2.01 N m

(C) 3.00 N m

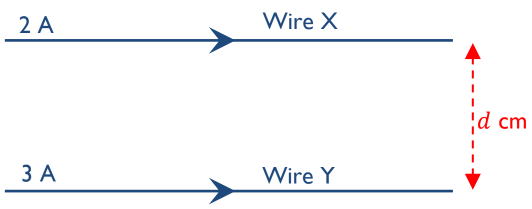
(D) 4.73 N m

$\tau = nBIA\sin\theta$

$= 15 \times 1.2 \times 3.25 \times (0.25)^2 \times \sin 55^0$

$= 2.995$ Nm

8 Two very long parallel long wires, X and Y, separated by a distance, d, have a force per unit length between them of 5.5×10^{-5} N m^{-1}. Wire X carries a current of 2 A, and Wire Y carries a current of 3 A as shown in the diagram below.



What is the separation, d, between the two wires?

(A) 1 cm

(B) 2 cm

(C) 14 cm

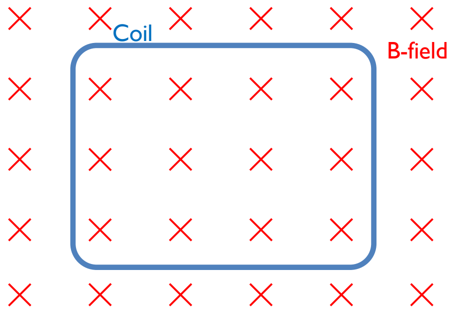
(D) 15 cm

$\frac{\mu_0}{2\pi} = \frac{4\pi \times 10^{-7}}{2\pi} = 2 \times 10^{-7}$

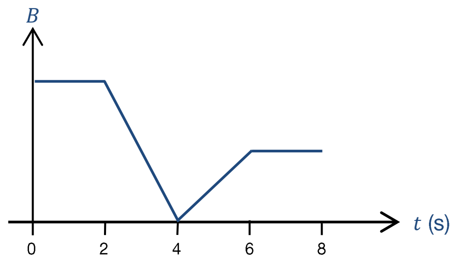
$\frac{F}{l} = \frac{\mu_0}{2\pi} \frac{I_1 I_2}{r}$

$r = d = \frac{\mu_0}{2\pi} \frac{I_1 I_2}{(F/l)} = \frac{4\pi \times 10^{-7}}{2\pi} \frac{2 \times 3}{5.5 \times 10^{-5}}$

9 In the diagram below, a coil of wire is placed in a magnetic field so that the plane of the coil is perpendicular to the direction of the magnetic field.

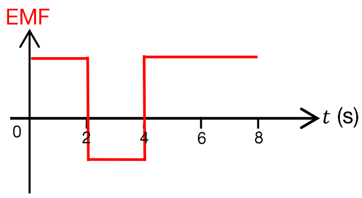


The strength of the magnetic field is then varied, as shown in the following graph.

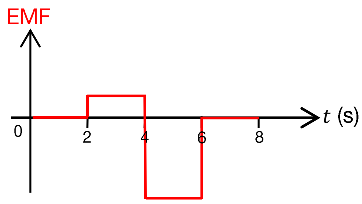


Which of the following graphs correctly shows the EMF induced across the coil?

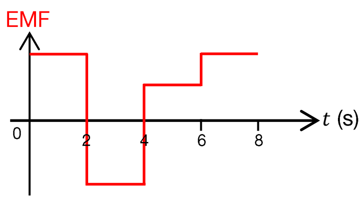
(A)



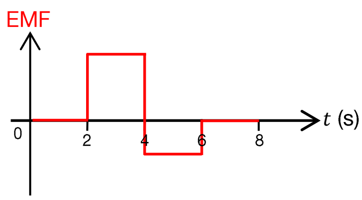
(B)



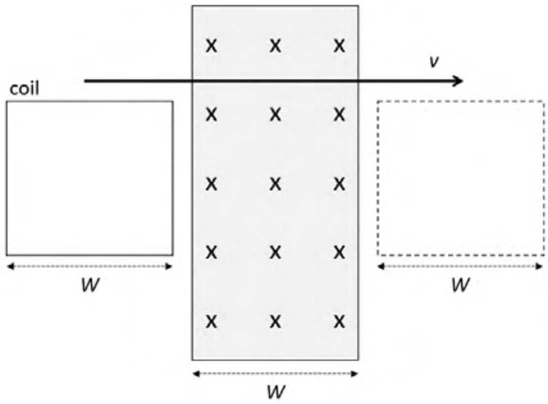
(C)



(D)



10 A square coil of conducting wire with sides of length W is moved at constant speed v left to right, through a uniform magnetic field which is directed into the page and has width W, as show below.



From the point where the coil enters the magnetic field until the point where it leaves it, which description best describes the direction of the current induced in the coil?

(A) Clockwise.

(B) Anti-clockwise.

(C) Clockwise then anti-clockwise.

(D) Anti-clockwise then clockwise.

11 A satellite of mass m is travelling in a circular orbit of radius r around a planet of mass M. If the satellite is moved to a new circular orbit where its kinetic energy is now 25% larger, then the radius of the new circular orbit will be:

(A) $\frac{\sqrt{5}r}{2}$

(B) $\frac{4r}{5}$

(C) $\frac{2r}{\sqrt{5}}$

(D) $\frac{5r}{4}$

higher orbital velocity occurs at lower radii orbits

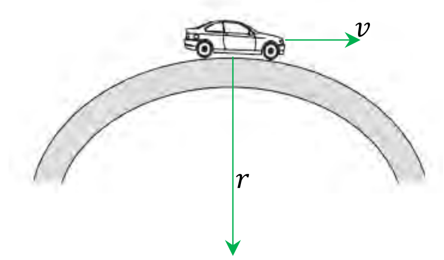
$$\frac{mv^2}{r} = \frac{GMm}{r^2}$$

$$\frac{1}{2}mv^2 = \frac{GMm}{2r}$$

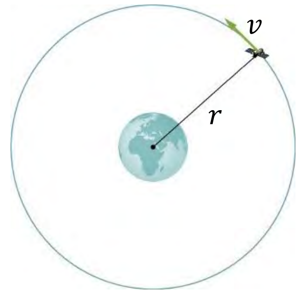
$$\frac{5}{4}\left(\frac{1}{2}m v^2\right) = \frac{5}{4}\frac{GMm}{2r} = \frac{GMm}{2(\frac{4}{5}r)}$$

12 The net force on a car at the top of a bridge is compared to the net force on a satellite in a circular orbit.

A car of mass m drives over a circular hump-back bridge of radius r with a constant speed v.



A satellite of mass m orbits with an orbital radius of r and orbital velocity v around Earth with a mass M.



Which of the following correctly represents the net force in both situations?

	Net force on car at top of bridge	Net force on Satellite in circular orbit
(A)	$\frac{mv^2}{r}$	$\frac{mv^2}{r}$
(B)	mg	$\frac{GMm}{r^2}$
(C)	$mg - \frac{mv^2}{r}$	$\frac{mv^2}{r}$
(D)	$\frac{mv^2}{r} + mg$	$\frac{mv^2}{r} - \frac{GMm}{r^2}$

Both are moving in uniform circular motion

so $\Sigma F = \frac{mv^2}{r}$

13 A red (wavelength 610 nm) laser pointer emits 0.5 mW of light.

How many photons per second are being emitted by the laser pointer?

(A) 1.5×10^{15}

(B) 1.5×10^{24}

(C) 1.2×10^{27}

(D) 4.6×10^{32}

Energy per photon $= \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{610 \times 10^{-9}}$

$= 3.258 \times 10^{-19}$ J

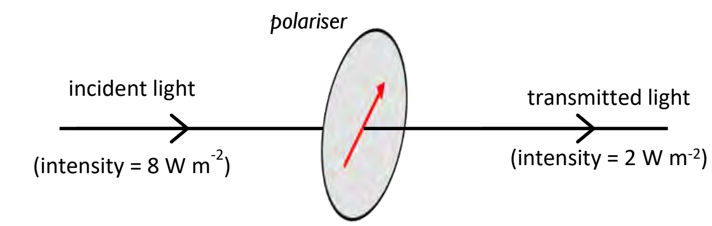
$\frac{\text{photons}}{\text{sec}} = \frac{\text{Energy}}{\text{sec}} \div \frac{\text{photon}}{\text{Energy}}$

$= \frac{\left(\frac{\text{Energy}}{\text{s}}\right)}{\left(\frac{\text{Energy}}{\text{photon}}\right)} = \frac{0.5 \times 10^{-3}}{3.258 \times 10^{-19}}$

$= 1.5 \times 10^{15}$

14 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

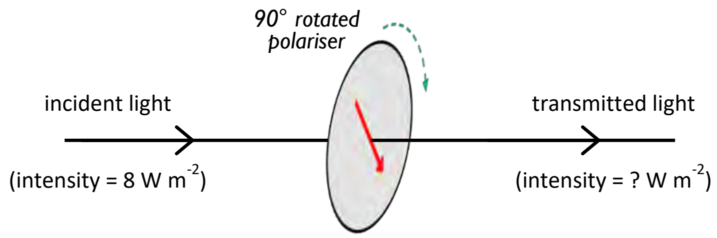


$\frac{2}{8} = \cos^2\theta$

$\cos\theta = \sqrt{\frac{2}{8}} = \frac{1}{2}$

$\theta = 60^\circ$

Diagram 2



$I = 8\cos^2(60 + 90^\circ)$

$= 8 \times 0.75$

$= 6$

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 90° from the orientation in Diagram 1.

In Diagram 2, 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}

15 An observer notes that the second-hand on a stopwatch is four times slower on a passing spacecraft.

What is the velocity of the spacecraft?

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

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

$(1-\frac{v^2}{c^2}) = \frac{1}{16}$

$\frac{v^2}{c^2} = 1 - \frac{1}{16} = \frac{15}{16}$

$\frac{v}{c} = \sqrt{\frac{15}{16}}$

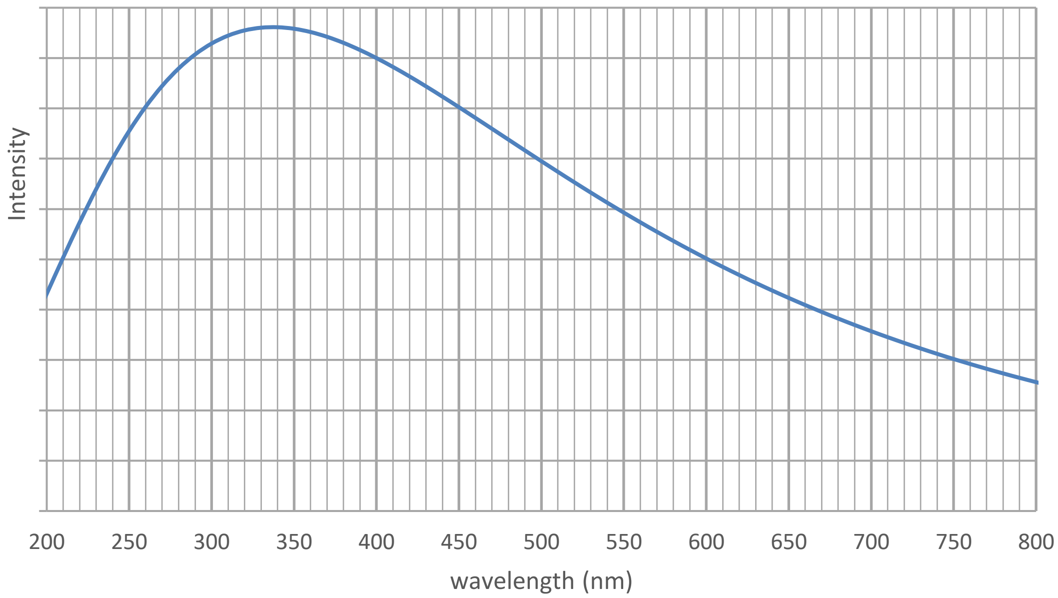
(E) $v = 0.25c$

(F) $v = 0.87c$

(G) $v = 0.94c$

(H) $v = 0.97c$

16 The spectrum of an object was measured and graphed below.



Which of the following best represents the temperature of this object?

(A) 8,280 K

(B) 8,524 K

(C) 9,348 K

(D) 14,490 K

peak at 340nm

$T(K) = \frac{2.898 \times 10^{-3}}{340 \times 10^{-9}}$

17 What is the magnitude of the relativistic momentum of a proton travelling at half the speed of light?

(A) 9.7×10^{-28} kg m s^{-1}

(B) 1.9×10^{-27} kg m s^{-1}

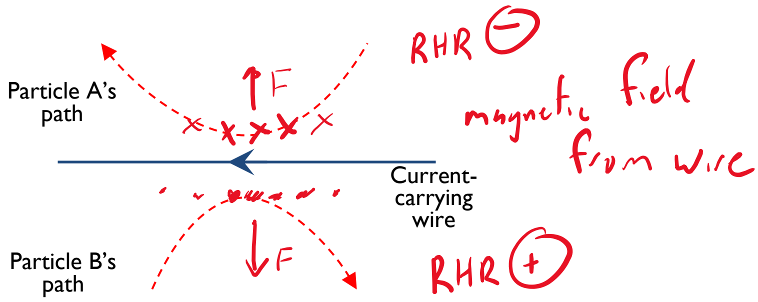
(C) 2.9×10^{-19} kg m s^{-1}

(D) 3.5×10^{-19} kg m s^{-1}

$p = \frac{mv}{\sqrt{1-(0.5)^2}} = \frac{1.673 \times 10^{-27}\left(\frac{3}{2} \times 10^{8}\right)}{\sqrt{1-0.25}}$

$= 2.89 \times 10^{-19}$

18 At two separate times, two charged particles approach a current-carrying wire and follow the trajectories depicted in the diagram below.



Determine the charge of each particle.

	Particle A	Particle B
(A)	Positively charged	Positively charged
(B)	Positively charged	Negatively charged
(C)	Negatively charged	Positively charged
(D)	Negatively charged	Negatively charged

19 The range of a projectile on horizontal surface is given by $R = \frac{u^2 \sin(2\theta)}{g}$, where R is the range, g is the acceleration due to gravity, u is the initial speed and θ is the angle of the projectile to the horizontal.

Which of the following changes would increase the range of the projectile to $2R$?

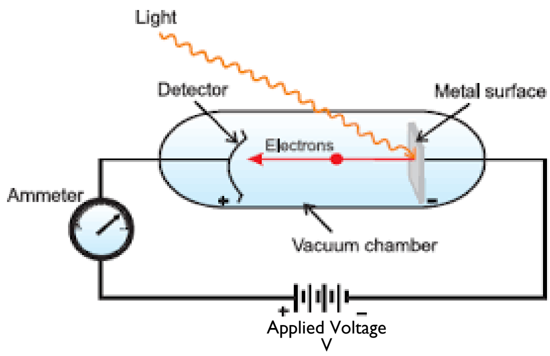
(A) u is doubled. $4R$

(B) g is doubled. $R/2$

(C) θ is changed from 30° to 45°. $\sin(2\times30) = \frac{\sqrt{3}}{2} \to \sin 90 = 1$

(D) u is multiplied by $\sqrt{2}$. ✓

20 Two experiments are conducted using a photoelectric cell where the applied voltage is varied, and the resultant photocurrent is measured by the ammeter.

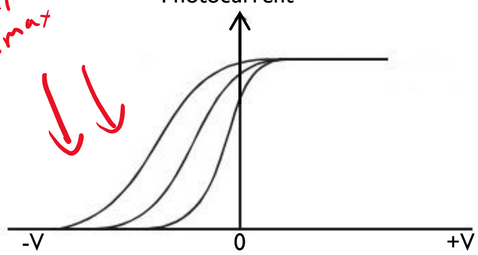


The results of both experiments are shown in the following graphs.

different frequencies

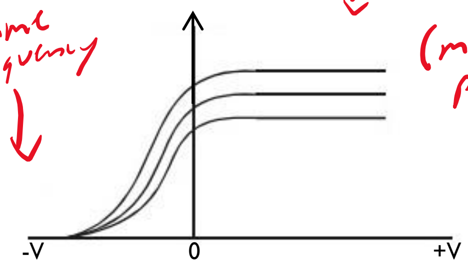
photo electrons have different Kmax which takes different voltages to stop current

EXPERIMENT A



same frequency

EXPERIMENT B



different intensity (more photons → more electrons)

Which would be the correct interpretation of these experiments?

(A)	Experiment A is where three different frequencies of light were used.	Experiment B is where three different intensities of the same frequency of light were used.
(B)	Experiment A is where three different intensities of the same frequency of light were used.	Experiment B is where three different frequencies of light were used.
(C)	Experiment A is where three different intensities of the same frequency of light were used.	Experiment B is where three different metals were used.
(D)	Experiment A is where three different frequencies of light were used.	Experiment B is where three different metals were used.

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SECTION II: Part A (17 Marks)

CANDIDATE NUMBER							

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 21 (3 marks)

Marks

Muons are particles created in the upper atmosphere by cosmic ray collisions and travel towards the ground at 0.98c. Of all the muons detected at an altitude of 10 km, only 1 in 45,000 were predicted to reach ground level with the rest decaying due to their short lifetime of 2.2 μs. However, it was measured that 1 in 8 were able to be detected at ground level.

Explain how this provides evidence to support Einstein's Special Theory of relativity. (*Calculations are not required.*)

Even moving at 0.98c, most muons created in the upper atmosphere are expected to decay before travelling 10km to the ground because of their short life-time.
As a consequence of his two postulates, Einstein predicted that time dilation would occur where the time for an event occurring in a moving frame of reference would be longer. In this scenario, for an observer on the ground the life-time of the muons is longer and as a consequence of this longer life, more would be able to reach the ground, increasing the detection rate. This measurement of more muons reaching the ground matches the prediction made by Einstein's time dilation and supports his Theory of Special Relativity.

Criteria	Mark
Correctly identifies consequence of Einstein's postulate Correctly states time dilation as time slowing down for moving objects/frames of reference. (or length contraction for moving objects)	1
Einstein's prediction What is Einstein's interpretation of this experiment? ▪ The life-time is longer (5 times longer) to an external observer because of time dilation OR ▪ The distance travelled from muon's frame of reference is shorter (5 times shorter) This must be clear which observer is experiencing this relativistic effect. The external observer does not observe length contraction [-1]. The muon does not experience time-dilation [-1]	1
Interpretation of evidence Explanation of why longer life-time means more can reach the surface ▪ (External observer) They survive/last longer so will travel a longer distance and more are detected at the ground ▪ (Muon frame of reference) they travel a shorter distance so less will decay when they reach the ground Einstein predicts time dilation from his postulates, having more reach the surface is evidence for this	1

Common misinterpretations of the question

- 1 in 45,000 is what would be predicted by classical theory, not according to another frame of reference
- You are told in the question that this is evidence for Einstein's Special Theory of relativity, therefore restating this with any justification is not worth anything

3

Common mistakes

- Many answers are not specific about which frame of reference is observing what.
- Many answers refer to 'time' without being specific if they are referring to life-time or travel time.

Better responses would

- Be specific about how the life-time of the muons is longer to an external observer.
- Link it to the Einstein's postulates.

For reference: Full calculations including radioactive decay.

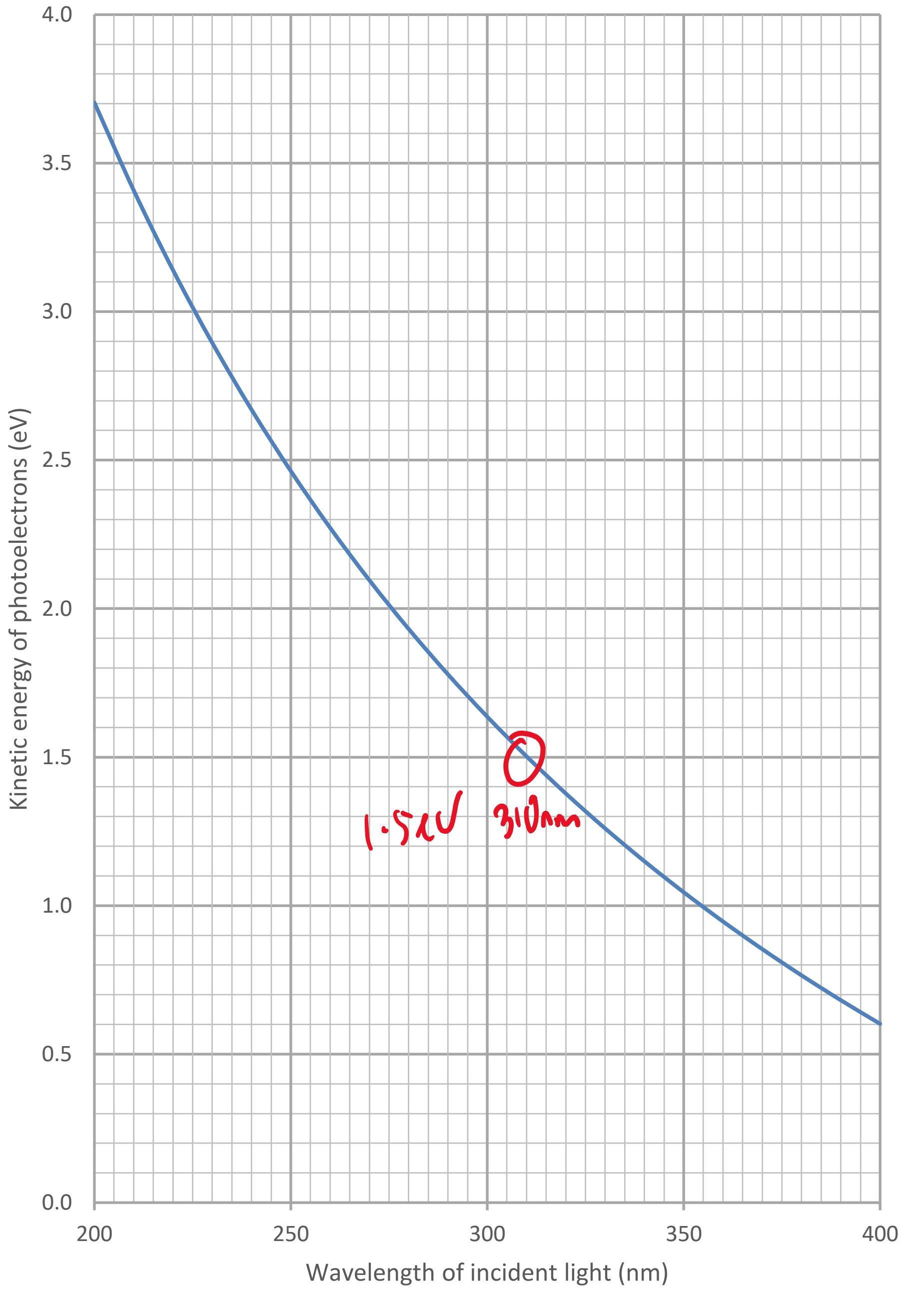
	Without special relativity (Earth frame of reference)	**With special relativity** (Earth frame of reference)
Life-time/ Half-life, $t_{1/2}$	2.2×10^{-6}s	1.11×10^{-5}s
Time to ground (10km at 0.98c)	3.4×10^{-5}s	3.4×10^{-5}s
Number of life-times	15.5	3.1
Decay constant, λ	3.15×10^{5}s^{-1}	6.27×10^{4}s^{-1}

The fraction of muons that reach the ground is $\frac{N}{N_0} = e^{-\lambda t}$ where $\lambda = \frac{\ln 2}{t_{1/2}}$

Note: life-time is used here instead of half-life because some classes may not have covered it yet.

Question 22 (6 marks) **Marks**

When light is incident on Europium metal, photoelectrons are emitted. The graph below shows how the measured kinetic energy of the photoelectrons changes when different wavelengths of light are incident on the metal.



Question 22 continued on next page.

Question 22 continued

Marks

(a) Using the graph, determine the work function of Europium.

$KE = hf - \phi$

$\lambda = 310nm$ $K = 1.5eV$

$\phi = hf - K_{max}$

$= \frac{hc}{\lambda} - K_{max}$

$= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{310 \times 10^{-9} \times 1.6 \times 10^{-19}} - 1.5$

$= 4eV - 1.5eV$

$= 2.5 eV$

$(4.01 \times 10^{-19} J)$

Criteria	Mark
Valid data point used from graph	1
Correct equation $\Phi = \frac{hc}{\lambda} - K$	1
Answer correct in either electron volts or joules	1

3

(b) For any metal there is a maximum wavelength of light after which no photoelectrons are emitted.

Use Einstein's explanation of the photoelectric effect to explain why no electrons are emitted if the wavelength is greater than this maximum.

3

Sample Answer

Einstein proposed that all the energy of a light 'photon' is $E = hf$ and when incident on a surface this energy is transferred to a single electron which it uses to escape the metal by overcoming the electrostatic attraction (called Φ the workfunction) with the remaining energy in the form of kinetic energy (K_{max}) of the escaped photoelectron. $hf = \Phi + K$ or $K = hf - \Phi$

Electrons are only emitted if the energy of the photon exceeds the workfunction ($E = hf = \frac{hc}{\lambda} > \Phi$)

This minimum energy corresponds to a maximum wavelength $\lambda < \frac{hc}{\Phi}$ or $\lambda_{max} = \frac{hc}{\Phi}$

Criteria	Mark
(hard to earn) Outline Einstein's explanation of the photoelectric effect as an energy equation – energy of one photon goes to an electron which requires energy to overcome being bound to the metal and the remaining becoming kinetic energy Workfunction must be described, not just identified	1
Links the workfunction to a minimum energy of the photon. (Cannot be just frequency > threshold frequency)	1
shows minimum photon energy is related to a maximum wavelength OR just uses equation $K = \frac{hc}{\lambda} - \Phi$ to mathematically shows there is a λ_{max} when $K = 0$	1

Common mistakes

- Many are assuming there is a threshold frequency without justifying why it exists according to Einstein's explanation.
- Some are using $mv = \frac{h}{\lambda}$ which does not have any relevance to the photoelectric effect.

Question 23 (3 marks) **Marks**

Explain why, from an observer's point of view, an object with mass would not be able to accelerate to the speed of light, c, in a vacuum. 3

Sample answer

In order for conservation of momentum to occur in all inertial frames of reference Einstein redefined momentum as $p_v = \frac{m_0 v}{\sqrt{1-\frac{v^2}{c^2}}}$. As $v \to c$ then $p_v \to \infty$. As impulse $I = \Delta p = p_f - p_i = p_v$ when starting from rest ($p_i = 0$) then an infinite impulse is required to increase a masses velocity to the speed of light. It is not possible to apply an infinite impulse to an object. As the velocity increases, an ever-increasing force ($F = \frac{\Delta p}{\Delta t}$) would be required to change the masses momentum, or the effect of a constant force would change the velocity less and less (with the acceleration asymptotically reduces to zero).

Additional/Advanced

- Since $I = \Delta p = Ft$, an infinite impulse would require a finite force to be applied for an infinite amount of time or an infinite force would be required for a finite amount of time.
- Work energy can also be considered: If work is done to an object by applying a force, then $W = Fs$. Einstein defines the total energy (kinetic energy and rest energy) of an object as $E^2 = (pc)^2 + (m_0c^2)^2$. When work is done to as mass and the momentum increases to infinity as $v \to c$ then an infinite amount of work energy would be required.

Better answers would

- Use physics equations to justify their answer.
- Identify the relativistic momentum equation as a consequence of Einstein's postulates and that it is Einstein's special relativity that places this limit of travelling at the speed of light.

Criteria	Mark
Identifies that this is a consequence of Einstein's postulates (i.e. mass dilation / momentum dilation)	1
A correct explanation of what happens to mass dilation / momentum dilation as v→c	1
A breakdown of what happens when you try to accelerate a mass to the speed of light. (acceleration cannot be constant) Needs justification from mass/momentum dilation not just unconnected statement. Infinite (force/ impulse/ work energy) needed	1

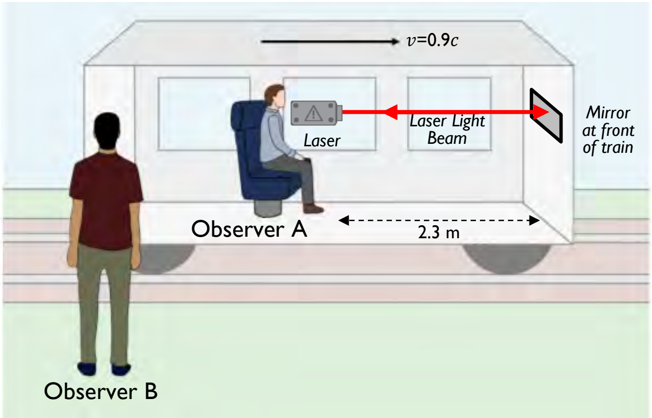
Note:

- Because equations are not defined at $v = c$ is not an explanation that answers the question asked about why it cannot accelerate to the speed of light.
- Time dilation (and length contraction) also do not answer the question. An external observer will observe time slow down in the moving reference frame, but this does not explain what they, the external observer, can see about the object moving.
- Momentum does not increase *exponentially*. Exponential mean $y = e^x$ which is defined for all x and the equation is not of this form. A correct description would be the equation increases asymptotically to infinity when $v \to c$.
- It is not covered in the course but $K \neq \frac{1}{2}mv^2$. This equation is only true when $v \ll c$.

Question 24 (5 marks) **Marks**

As a thought experiment, Observer A is on a train travelling at a velocity of $v = 0.9c$ compared to Observer B.

Observer A shines a laser beam towards a mirror at the front of the train, a distance of 2.3 m. The light beam reflects off the mirror and returns to a timing device on the laser.



(a) According to observer A, how long would it take for the light beam to complete this journey?

$v = \frac{d}{t}$, $t = \frac{d}{v}$ $= \frac{2.3\,m \times 2}{3\times10^8\,m/s}$ $= 7.67\times10^{-9}\,s \times 2$ (1)

$= 1.533\times10^{-8}\,s$ (1)

2

(b) According to observer B:

i. how long would it take for the light beam to complete this journey?

$t_v = \frac{7.67\times10^{-9}\times2}{\sqrt{1-0.9^2}}$ (1) $= 1.76\times10^{-8}\,s \times 2$ carry forward time used in (a)

$= 3.52\times10^{-8}\,s$ (1)

$\gamma = \frac{1}{\sqrt{1-0.9^2}} = 2.294$

2

ii. what is the distance he would measure between the laser and the mirror?

$L_v = L_0\sqrt{1-0.9^2}$ $= 2.3\times\sqrt{1-0.9^2}$

$= 1.0\,m$ (1)

1

Part A extra writing space

If you use this space, clearly indicate which question you are answering.

Do NOT write in this area.

SECTION II: Part B (17 Marks)

CANDIDATE NUMBER

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

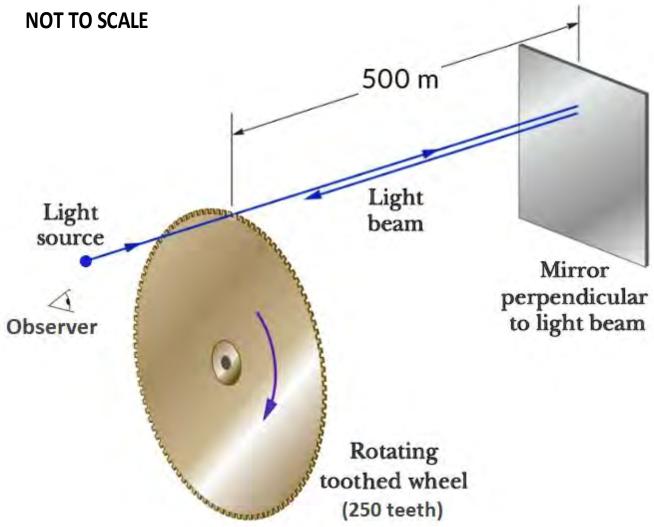
Question 25 (5 marks) **Marks**

In the 1840s, French physicist Hippolyte Fizeau performed an experiment to measure the speed of light using a rotating toothed cogwheel.

He shone an intense light source at a mirror and broke up the light beam with a rotating toothed cogwheel. He adjusted the speed of rotation of the wheel until the reflected light beam could no longer be seen returning through the gaps in the cogwheel.

The diagram below shows a similar experiment:

- The rotating toothed cogwheel has 250 teeth and 250 gaps of the same width.
- The distance between the rotating toothed cogwheel and the mirror is 500 m.



(a) Determine the minimum rotation speed of the cogwheel that would completely block the returning light. 2

• $t = \frac{2 \times 500\,m}{3.0 \times 10^8} = 3.33 \times 10^{-6}\ s$ (1)

• 250 teeth + 250 gaps $\Rightarrow \omega = \frac{\frac{2\pi}{250+250}}{3.33 \times 10^{-6}} = \underline{\underline{3773.7\ rad/s}}$ (1)

(or directly: $\omega = \frac{\pi c}{500 \times 500} = 3769.9\ rad/s$)

cogwheel m

Question 25 continued on next page.

⚠ avoid "rotations/s" or "°/s"

Question 25 continued

Marks

(b) The same experiment is performed again but this time a 500 m long rectangular tank of pure water is added between the cogwheel and the mirror. The new minimum rotation speed of the toothed cogwheel that would completely block the returning light is 2830 rad/s, which is lower than the one measured in air.

i. What conclusion about the speed of light in water can be made from this observation?

Lower rotation speed means it took longer for light to travel in water than in air
⇒ speed of light is LOWER in water than in air. 1

ii. This experiment provides evidence for Huygens model of light. Describe one other observation or experimental evidence that supports Huygens model.

The double-slit experiment shows the wave nature of light as Huygens' model suggests, through the observation of an interference pattern on a screen behind the slits. The dark and bright fringes can only happen if light is a wave. 2

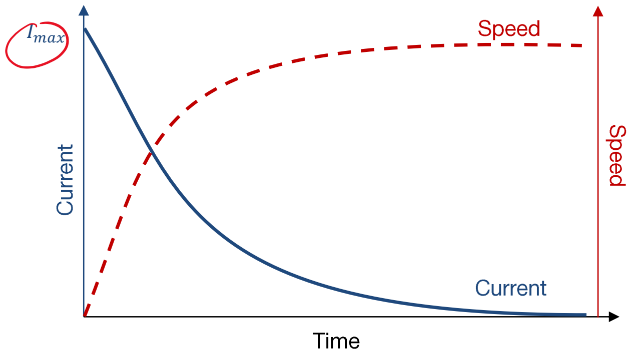
Criteria	Mark
• IDENTIFICATION and DESCRIPTION of another appropriate observation / experimental evidence AND • EXPLICIT LINK to Huygens' model of light (waves, wavelets).	2
• IDENTIFICATION and DESCRIPTION of another appropriate observation / experimental evidence OR • EXPLICIT LINK to Huygens' model of light (waves, wavelets).	1

Accepted observation / experimental evidence:
- Diffraction
- Interference
- Polarisation

Question 26 (3 marks) **Marks**

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

$\frac{V_{supply}}{R_{coil}} = I_{max}$



Explain why the current starts at a specific maximum value I_{max} then falls to zero as the motor increases its speed.

- I_{max} is determined by the physical constraints of the system, i.e. the voltage supplied to the coil and the resistance of the coil
- As the motor spins, its coil rotates in an external magnetic field and, by Faraday's Law, an emf will be generated in the coil in the opposite direction to the voltage supplied to the coil (Lenz's Law) ⇒ BACK EMF.
  So $V_{coil} = V_{supply} - \varepsilon_{back}$
- Ohm's Law: overall current in coil $I_{coil} = \frac{V_{supply}}{R_{coil}} - \frac{\varepsilon_{back}}{R_{coil}} = I_{max} - \frac{\varepsilon_{back}}{R_{coil}}$
- As the motor's speed of rotation increases, ε_{back} increases too and I_{coil} decreases (from its max value of $\frac{V_{supply}}{R_{coil}}$).
- Eventually, ε_{back} reaches the value of V_{supply} and $I_{coil} = 0$. 3

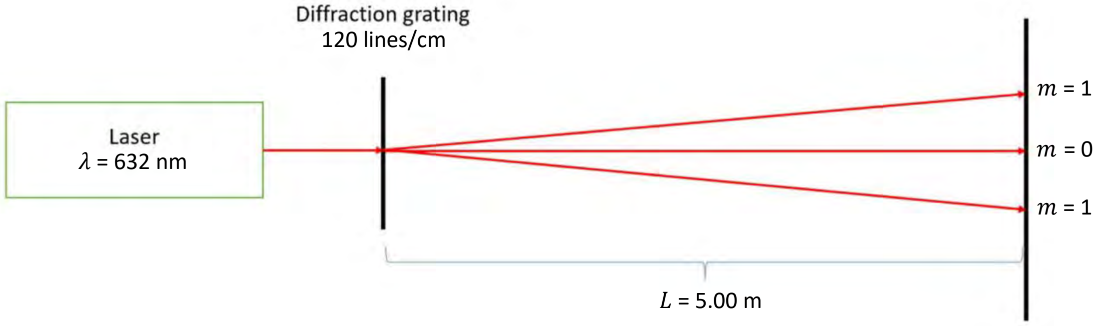
Criteria	Mark
• Explicit and thorough explanation of why the current starts at a maximum and what determines the specific value of I_{max}. AND • Explicit and thorough explanation of why the current decreases, with: - explicit mention of BACK EMF, - explicit link between speed of rotation, size of back emf and subsequent effect on current in the coil AND • Explicit explanation of why the currents reaches 0.	3
Only 2 of the above	2
Only 1 of the above	1

Better responses would

Use <u>equations</u> to support their argument.

Question 27 (4 marks) **Marks**

A helium neon laser, which emits light of wavelength λ = 632 nm, is shone through a diffraction grating with 120 lines/cm. It is placed L = 5.00 m away from a screen. *(Only the 1st order maximum m = 1 is included in the diagram).*



(a) Determine the separation between the slits in the grating. 1

$d = \frac{1}{120\,cm} = \frac{1}{120 \times 10^{-2}\,m} = 8.3 \times 10^{-5}\,m$ ($= 8.3 \times 10^{-3}\,cm$)

(m or cm accepted here)

(b) For the 3rd order maximum to occur, what is the additional distance or "path difference" that the light must have travelled from one slit on the grating to the screen compared to the adjacent slit? 1

Path difference $= 3\lambda = 3 \times 620\,nm$

$\Rightarrow 1.86 \times 10^{-6}\,m$

A lot of boys misunderstood the question and thought "adjacent slit" was refering to the adjacent order!

(c) What is the distance on the screen between the central maximum and the 3rd order maximum? 2

$d\sin\theta = m\lambda \Rightarrow \sin\theta = \frac{m\lambda}{d} = \frac{3 \times 632 \times 10^{-9}}{8.3 \times 10^{-5}} \Rightarrow \theta = 1.31°$ 1

But $\tan\theta = \frac{x}{L}$ so $x = L\tan\theta$

$x = 5.00 \times \tan(1.31°)$

$x = 0.114\,m$ 1

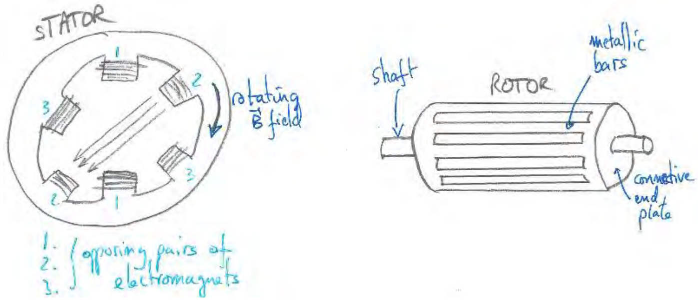
($x = 11.4\,cm$)

Question 28 (5 marks)

Marks

Explain how the stator in an AC induction motor generates torque in the rotor. **5**

- The stator of an AC induction motor is usually made of 3 pairs of electromagnets, as shown below, each opposite pairs being connected to a phase of a three-phase current generator. This setup allows for the creation of a rotating magnetic field within the cavity of the stator, where the rotor is then placed.



- The rotor consists of several metallic bars connected at the ends by 2 metallic plates, as shown above.
- The rotating B field within the stator creates a change in B flux through the metallic bars of the rotor. By Faraday's Law, an emf is induced in the bars ($\varepsilon = -\frac{\Delta \emptyset_B}{\Delta t}$). As the rotor in a closed conductor, induced eddy currents flow in the bars and through the connective end plates.
- By Lenz's Law, these eddy currents will flow in a direction such that the B field they create will oppose the change in B flux that induced them in the first place.
- The eddy currents in the bars are in the external B field of the stator and therefore, each of them will experience a force due to the Motor Effect (F = BILsin θ).
- Currents in opposite bars of the rotor flow in opposite direction so the force acting on them will be equal in magnitude but in opposite direction, creating a torque on the rotor.
- This torque makes the rotor turn in the SAME direction as that of the rotation of the B field in the stator, as a consequence of Lenz's Law, forcing the rotor to try and catch up with the rotating B field to minimise / counter the change in B flux experienced by the rotor.

Criteria	Mark
• Explicit, thorough explanation of how a ROTATING B field is created within the stator [R] AND • Explicit, thorough explanation of how an EMF is induced in the rotor [Fa], with: - explicit mention of coil experiencing a *change in B flux*, - explicit mention of *Faraday's Law*. AND • Explicit, thorough explanation of how a CURRENT is induced in the rotor [L], with: - explicit mention of coil being a *closed conductive path*, - explicit mention of *Lenz's Law*. AND • Explicit, thorough explanation of how a FORCE is applied on the rotor bars [ME], with explicit mention of the *motor effect*. AND • Explicit, thorough explanation of how a TORQUE is applied on the rotor bars [T], with: - explicit mention of *why* a torque, not just a force, - explicit mention of *direction* of the torque.	5
Only 4 of the above	4
Only 3 of the above	3
Only 2 of the above	2
Only 1 of the above	1

Better responses would

- Use <u>diagrams</u> to support their description of the structure of an AC induction motor.
- Make logical links between steps very apparent, using connective words such as "thus", "therefore", "because of that", "as a consequence", etc…

Part B extra writing space

If you use this space, clearly indicate which question you are answering.

Do NOT write in this area.

SECTION II: Part C (18 Marks)

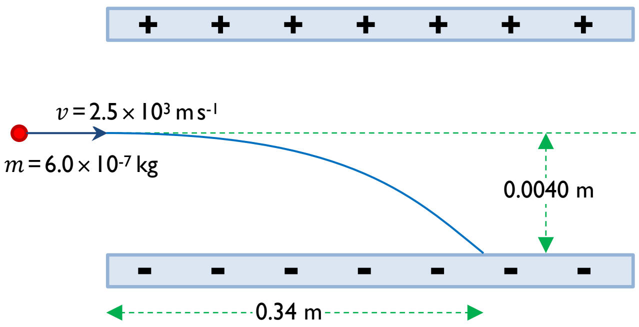
CANDIDATE NUMBER							

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 29 (4 marks) **Marks**

A charged particle of mass 6.0×10^{-7} kg is travelling at an initial velocity of 2.5×10^{3} m s^{-1}.

The particle enters a perpendicular electric field of 7.5×10^{4} NC^{-1}, and follows the trajectory shown below.



Calculate the magnitude of the charge on the particle.

MULTIPLE WAYS TO DO THIS, e.g.:

HORIZONTALLY: RANGE = $V_x t_F$ ∴ $0.34 = 2.5 \times 10^3 \times t_F$

$t_F = 1.36 \times 10^{-4}$ s — 1

VERTICALLY: $U_V = 0$

$S_V = 0.0040$ m

$t_F = 1.36 \times 10^{-4}$ s

$a = ?$

$S = \frac{1}{2} a t^2$ $a = \frac{2 \times 0.0040}{1.36 \times 10^{-4}}$

$a = 4.325 \times 10^{5}$ ms^{-2} — 2

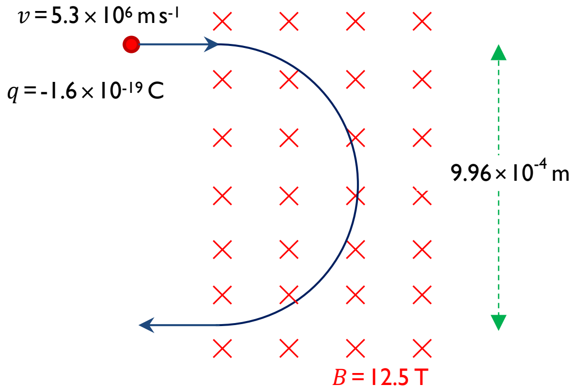
$M.a = Eq$ so $q = \frac{M.a}{E} = \frac{6.0 \times 10^{-7} \times 4.325 \times 10^{5}}{7.5 \times 10^{4}}$ — 3

$q = 3.46 \times 10^{-6}$ = (3.5×10^{-6} C to 2 s.f.) — 4 4

(Other approaches marked on their merits but, N.B. an ENERGY approach was not very successful here!)

Question 30 (3 marks) **Marks**

A subatomic particle with a charge of -1.6×10^{-19} C travels at a speed of 5.3×10^{6} m s^{-1} into a perpendicular magnetic field of strength 12.5 T. It follows the path shown in the diagram below.



Calculate the mass of the particle.

$= 1.06 \times 10^{-11}$ ~ . — 1

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

$m = \frac{qvBr}{v^2} = \frac{qBr}{v}$

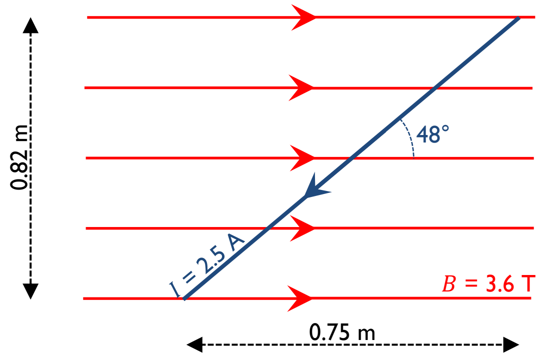
$= \frac{1.6 \times 10^{-19} \times 12.5 \times (9.96 \times 10^{-4})}{5.3 \times 10^{6} \times 2}$ → NB FORGETS THE 2 (ie USES DIAMETER NOT RADIUS) = 2

$= 1.90 \times 10^{-28}$ kg — 3

3

Question 31 (2 marks) **Marks**

The diagram below shows a current carrying wire in a uniform magnetic field.



Calculate the magnitude and direction of the magnetic force acting on the wire in the position shown.

MULTIPLE APPROACHES ARE VALID HERE :

Eg. $F = B.I.L\sin\theta$ where $L\sin\theta = 0.82\text{m}$

$= 3.6 \times 2.5 \times 0.82 = 7.4\text{N}$ — 1

OR $F = B.I.L\sin\theta$ where $L = (0.82^2 + 0.75^2)^{1/2} = 1.11$ **2**

and $\theta = 48°$

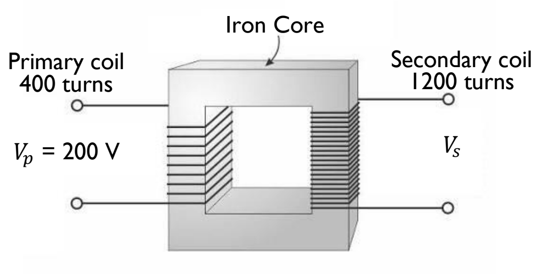
$= 3.6 \times 2.5 \times 1.11 \times \sin 48 = 7.4\text{N}$ — 1

And by RHPR, direction of Force is Out of Page — 1

* But NB, answers using $\cos 48°$ or $\sin 52°$ are Not Correct (so Max 1 for Giving Correct Direction)

Question 32 (4 marks) **Marks**

The diagram below shows a transformer. The transformer operates from an A.C. primary voltage of 200 V. The primary coil of the transformer has 400 turns, and the secondary coil has 1200 turns.



(a) Calculate the voltage across the secondary coil of the transformer.

$\frac{V_s}{V_p} = \frac{n_s}{n_p}$ $V_s = V_p \frac{n_s}{n_p} = 200 \times \frac{1200}{400}$

$= 600$ ✓ — (1)

1

(b) Identify if this is a step-up or step-down transformer.

step-up — (1)

1

(c) Explain one method of increasing the efficiency of this transformer. (1) (1)

ONE METHOD IDENTIFIED and EXPLAINED

E.g. "LAMINATE THE IRON CORE WITH INSULATING MATERIAL. THIS REDUCES EDDY CURRENTS IN THE CORE AND SO MINIMISES LOSSES DUE TO OHMIC HEATING."

(DID NOT EXPECT MUCH DETAIL FOR 2 MARKS)

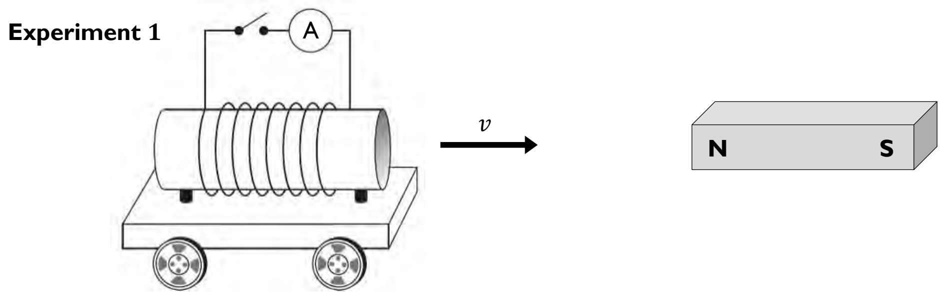
ALSO ACCEPTED : LOWER RESISTANCE / THICKER WIRES
: METHODS THAT INCREASE FLUX LINKAGE
ETC

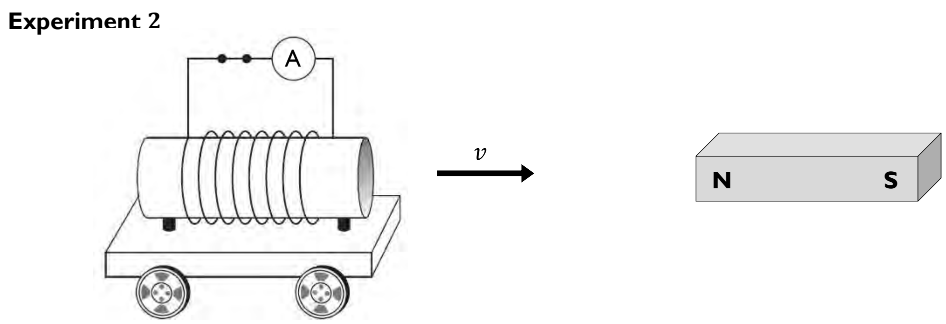
2

Question 33 (5 marks) **Marks**

A pupil performs the experiments shown below. He puts a solenoid (a coil of wire) on the back of a motion trolley connected to an ammeter and a switch and pushes it towards a powerful **fixed** magnet at an initial speed v.

In Experiment 1 the switch is open. In Experiment 2 the conditions are exactly the same as Experiment 1 but now the switch is closed.





Describe and explain, in terms of the relevant Laws of Physics, the observations that he makes of the two experiments. (Ignore the effect of friction on the trolleys).

(see next page)

Criteria	Mark
A ***very good*** answer that: • Correctly predict the reading on the ammeter in each experiment. • Correctly predicts the motion of each trolley. • Correctly explains the motion of each trolley. Refers to the appropriate laws of physics and uses correct terminology throughout.	5
A **good** answer that: • Correctly predict the reading on the ammeter in each experiment. • Correctly predicts the motion of each trolley. • Provides a reasonable explanation for the observations made, with some reference to the relevant laws of physics.	4
A **fair** answer that: • Correctly predicts the motion of each trolley, or the readings on the ammeters. • Provides a partially correct explanation of the motion of each trolley.	3
An answer that: • Correctly predicts the motion/ammeter reading of one trolley. • Provides a correct explanation of the motion of one trolley.	2
An answer that correctly predicts the motion of at least one trolley.	1

Sample Answer: 5

Experiment 1

The trolley rolls towards the magnet at a constant speed.
By Faraday's Law, a voltage is induced across the coil (due to the change influx as it approaches the magnet).
Because the switch is open, no current can flow and so no forces can act between the coil and the magnet.

Experiment 2

As with Experiment 1, a voltage is induced.
This time, a current can flow in the coil. By Lenz's Law, this flows to produce a magnetic field that acts to oppose the change in flux, i.e. to place a north pole on the right hand end of the solenoid. The trolley experiences a force to the left, which acts to slow it down.

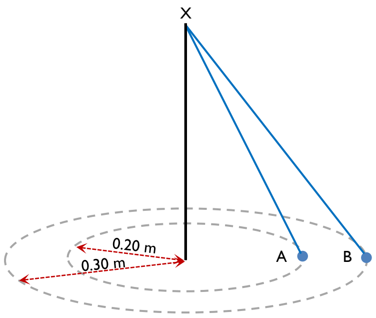
SECTION II: Part D (28 Marks)

CANDIDATE NUMBER

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 34 (4 marks) — Marks

Two spheres A and B are attached to the ends of light inextensible strings XA and XB as shown below.



They are swung in horizontal circles so that their periods are the same.

(a) Determine the ratio $\frac{v_B}{v_A}$ of the speed of sphere B (v_B) to the speed of sphere A (v_A).

$V_A = \frac{2\pi r_A}{T}$, $V_B = \frac{2\pi r_B}{T}$ $\quad \frac{V_B}{V_A} = \frac{\left(\frac{2\pi r_B}{T}\right)}{\left(\frac{2\pi r_A}{T}\right)} = \frac{r_B}{r_A} = \frac{0.3}{0.2}$

$= \omega r_A$ $\quad = \omega r_B$

ω is the same $\quad \underbrace{\frac{V_B}{V_A} = \frac{r_B}{r_A}}_{1} = 1.5$ 1

2

(b) Determine the ratio $\frac{a_B}{a_A}$ of the centripetal acceleration of sphere B (a_B) to the centripetal acceleration of sphere A (a_A).

$a = \frac{v^2}{r}$ $\quad \left(v = r\omega \text{ then } a = \frac{(r\omega)^2}{r}, \ a = \omega^2 r \right)$

$\frac{a_B}{a_A} = \frac{\left(\frac{V_B^2}{r_B}\right)}{\left(\frac{V_A^2}{r_A}\right)} = \left(\frac{V_B}{V_A}\right)^2 \frac{r_A}{r_B}$ $\rightarrow$ using above $\frac{V_B}{V_A} = \frac{r_B}{r_A}$

$\frac{a_B}{a_A} = \left(\frac{r_B}{r_A}\right)^2 \frac{r_A}{r_B} = \frac{r_B}{r_A} = 1.5$

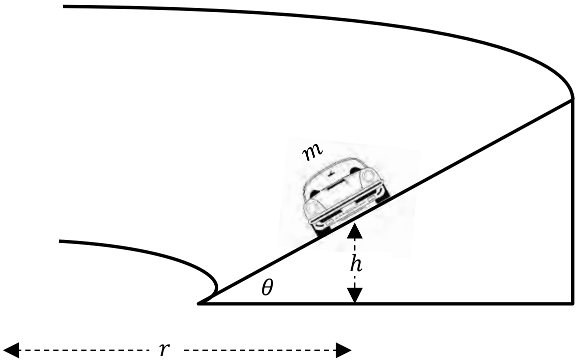
$\underbrace{\frac{a_B}{a_A} = \frac{r_B}{r_A}}_{1} = \underbrace{1.5}_{1}$

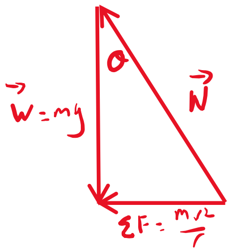
2

Question 35 (6 marks)

Marks

A car of mass m = 1000 kg is travelling around a frictionless banked track (there is no friction between the wheel and the track) at an angle of θ = 30° to the horizontal and radius of r = 60 m.





(a) For the car:

i. determine the magnitude of the force of the track on the car (i.e., the Normal force).

$N = \frac{mg}{\cos\theta}$ (1)

$= 11316N$ (1) (consistent with your formula)

2

ii. determine the speed of the car required to maintain a constant radius of 60 m.

$\tan\theta = \frac{\Sigma F}{W} = \frac{\left(\frac{mv^2}{r}\right)}{mg} = \frac{v^2}{rg}$

$v = \sqrt{rg\tan\theta}$ (1)

$= \sqrt{60 \times 9.8 \times \tan 30°}$

$= \boxed{18.4 \text{ m/s}}$ — (1)

(consistent with your formula)

2

Question 35 continued on next page.

Question 35 continued **Marks**

(b) If the speed of the car is doubled, explain why the car would have to move higher up the incline (i.e., h becomes larger) to still go around the circular track without any sideways friction from the track.

1 $v = \sqrt{rg\tan\theta}$

1 $v\uparrow \quad r\uparrow$

as θ, g constant.

$r\uparrow \Rightarrow h\uparrow$

friction $= 0$

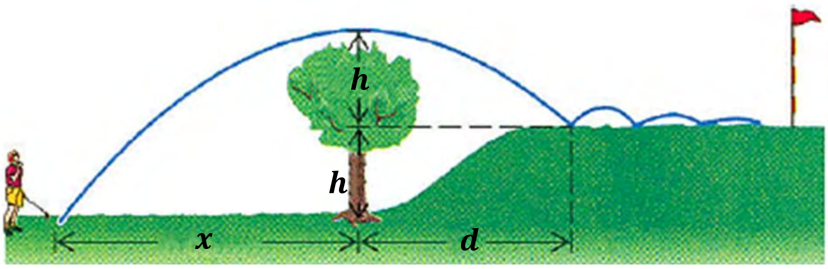
or 1 $\boxed{N \text{ is a constant.}}$

$\therefore \frac{mv^2}{r} = N\sin\theta = \text{constant}$

1 if $v\uparrow \quad r\uparrow$

Question 36 (8 marks) **Marks**

A golfer must hit a shot over a tree and onto an elevated green as shown in the diagram below.



The distance to the tree is x = 8.6 m. The height of the green the ball lands on is h = 3.0 m and the maximum height his shot reaches is $2h$.

(a) What is the initial vertical velocity of the ball?

$v^2 = u^2 + 2as$

$v = 0$ (max height) 1

$u = \sqrt{2g \times 6}$ 1 $= 10.8$ m/s

2

(b) How long will it take the ball to reach its maximum height?

$v = u + at$ 1

$t = \frac{v - u}{a} = \frac{-10.8}{-9.8} = 1.1$ sec 1

1

Question 36 continued on next page.

Question 36 continued **Marks**

(c) What is the initial launch angle of the ball above the horizontal?

$S_H = u_H t$ $u_H = \frac{8.6}{1.106} = 7.8\text{ m/s}$ 1

$u_y = 10.8\text{ m/s}$

$\tan\theta = \frac{u_y}{u_x} = \frac{10.8}{7.8}$ 1

$\therefore \theta = 54.2°$ 1

3

(d) What is the distance d?

$S = \frac{1}{2}gt^2$ 1

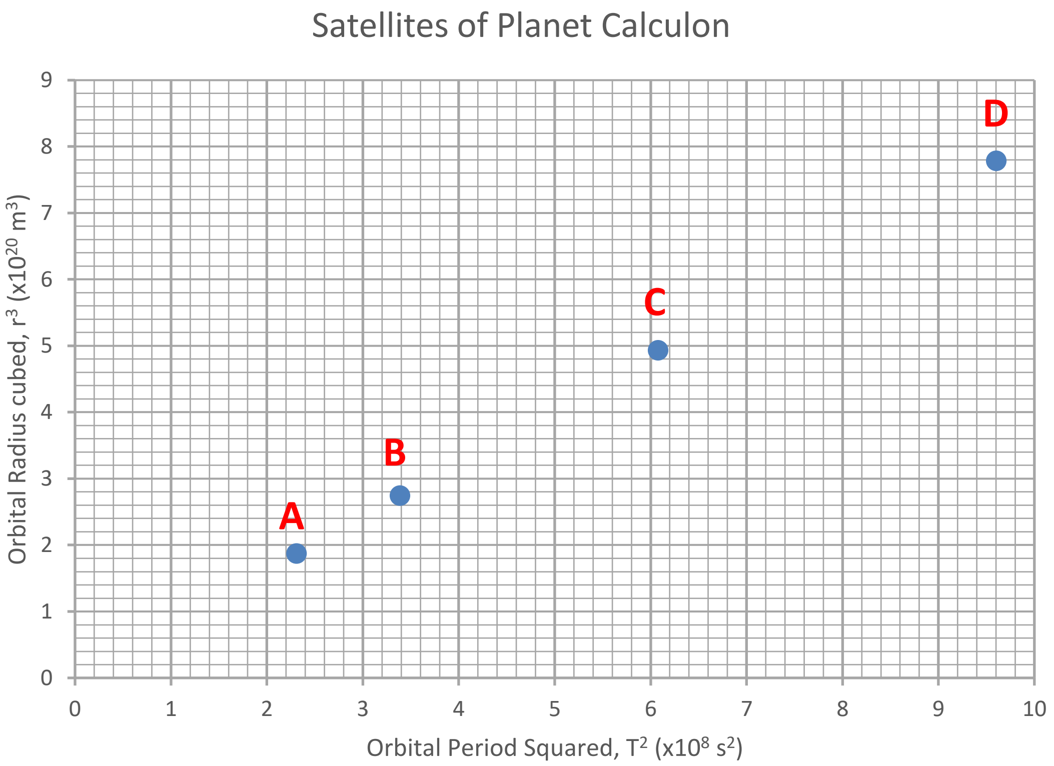
falls $3m = 4.9t^2$ $t = \boxed{0.782\text{ s}}$

$d = u_H t = \boxed{6.1\text{ m}}$ 1

2

Question 37 (6 marks) **Marks**

Four satellites labelled A, B, C and D are orbiting a distant planet called Calculon. Their orbital properties are plotted below.



(a) Determine the mass of the planet Calculon. 3

$r^3 = 7.8 \times 10^{20}\ m^3$ (1)

$T^2 = 9.6 \times 10^8\ s^2$ (1)

$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$ $M = 4.8 \times 10^{23}\ kg$ (1)

Marked according to your data

Common errors $1.53 \times 10^{11}\ kg$

$4.8 \times 10^{11}\ kg$

Question 37 continued on next page.

Satellite	r^3 (m³)	T^2 (s²)	r (m)	T (s)
A	1.9×10^{20}	2.3×10^8	5.7×10^6	1.5×10^4
B	2.7×10^{20}	3.4×10^8	6.5×10^6	1.8×10^4
C	4.9×10^{20}	6.1×10^8	7.9×10^6	2.5×10^4
D	7.8×10^{20}	9.6×10^8	9.2×10^6	3.1×10^4

Question 37 continued **Marks**

(b) Determine the orbital velocity of satellite B.

1 $V = \sqrt{\frac{GM}{r}}$ | $r^3 = 2.8 \times 10^{20}\ m^3 \Rightarrow r = 6.542 \times 10^6\ m$ 1

$T^2 = 3.4 \times 10^8\ s^2 \quad T = 1.844 \times 10^4\ s$

1 $= 2.23 \times 10^3\ m/s$ | $V = \frac{2\pi r}{T} = 2.23 \times 10^3\ m/s$ 1

2

(c) If Satellite C is in a geostationary orbit around the planet Calculon then how long is a day on the planet (i.e., the time it takes for the planet to rotate once on its axis)?

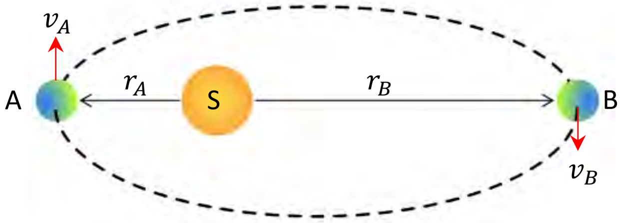
$T^2 = 6.1 \times 10^8\ s$

$T = 24700\ s$ 1

1

Question 38 (4 marks) **Marks**

A planet of mass m is orbiting a Star, S, of mass M in an elliptical orbit as shown below. The planet is shown at two points in its orbit. At position A it is at its closest to S and at position B, it is at its furthest. The distance from S to A is r_A whereas the distance S to B is r_B.



For an elliptical orbit the total energy is given by

$$E = -\frac{GMm}{r_A + r_B}$$

Use the total energy to determine the ratio of the kinetic energy $\left(\frac{K_A}{K_B}\right)$ of the planet at position A (K_A) compared to position B (K_B) if the distance r_B is three times larger than r_A. (i.e., $r_A = r$ and $r_B = 3r$ and $\frac{r_B}{r_A} = 3$). 4

$E_{Total} = -\frac{GMm}{r+3r} = -\frac{GMm}{4r}$ (1)

$\boxed{A}$ $\frac{1}{2}mv_A^2 - \frac{GMm}{r} = -\frac{GMm}{4r}$

$\therefore KE_A = \frac{3}{4}\frac{GMm}{r}$ (1)

$\boxed{B}$ $\frac{1}{2}mv_B^2 - \frac{GMm}{3r} = -\frac{GMm}{4r}$

$KE_B = \frac{1}{12}\frac{GMm}{r}$ (1)

$\frac{KE_A}{KE_B} = \frac{\frac{3}{4}}{\frac{1}{12}} = 9$ (1)

END OF EXAMINATION