Newcastle Grammar School

Student Number

2019 HSC TRIAL EXAMINATION

Year 12 PHYSICS

Examiner: SH

READING TIME – 5 MINUTES

WORKING TIME – 3 HOURS

General Instructions

- Write using blue / black pen.
- Read the instructions carefully – you may be required to answer the questions in the space provided, or on a separate multiple-choice answer sheet
- Additional writing space has been provided at the end of the examination paper if you require more space for section II responses.
- Multiple choice answer sheet may be detached from examination paper
- Write your student number clearly on each page.
- Board-approved calculators may be used, unless stated otherwise.
- Do not remove this question paper from the examination room.

Section	Guidance	Marks Available	Your Score
SECTION I	• Type of Questions – Multiple Choice • Attempt Questions 1 – 20 • Allow about 35 minutes for this section	20	
SECTION II	• Type of Questions – Short Answer • Attempt Questions 21 – 38 • Allow about 2 hours and 25 minutes for this section	80	
	TOTALS	100	

FINAL MARK		%

Your examination paper begins overleaf.

SECTION I – 20 marks
Attempt Questions 1-20
Allow about 35 minutes for this part

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

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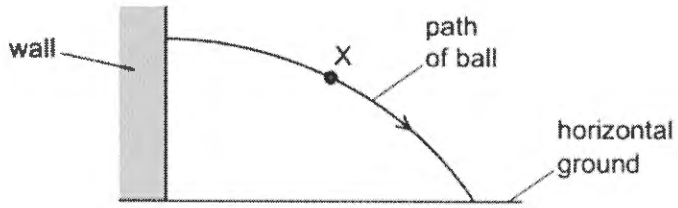
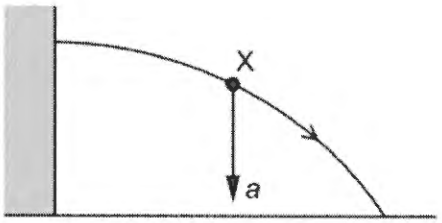
1 The diagram shows the path described by a ball after bouncing from a vertical wall.



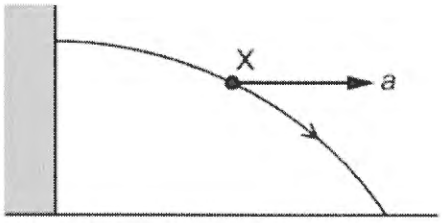
Air resistance has negligible effect on the motion of the ball.

Which diagram shows the direction of the acceleration, a, of the ball when at point X?

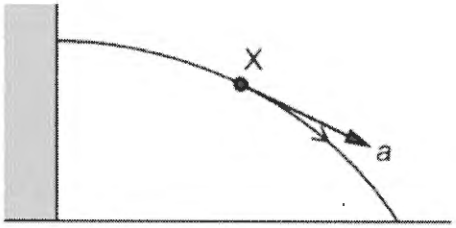
(A)



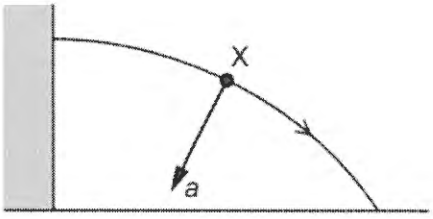
(B)



(C)



(D)



2 Using a homemade projectile launcher, a student undertook a depth study to analyse projectile motion.

The student determined that the launcher did not produce a consistent initial velocity.

The type of error this produced would be best defined as:

(A) Instrumental error

(B) Human error

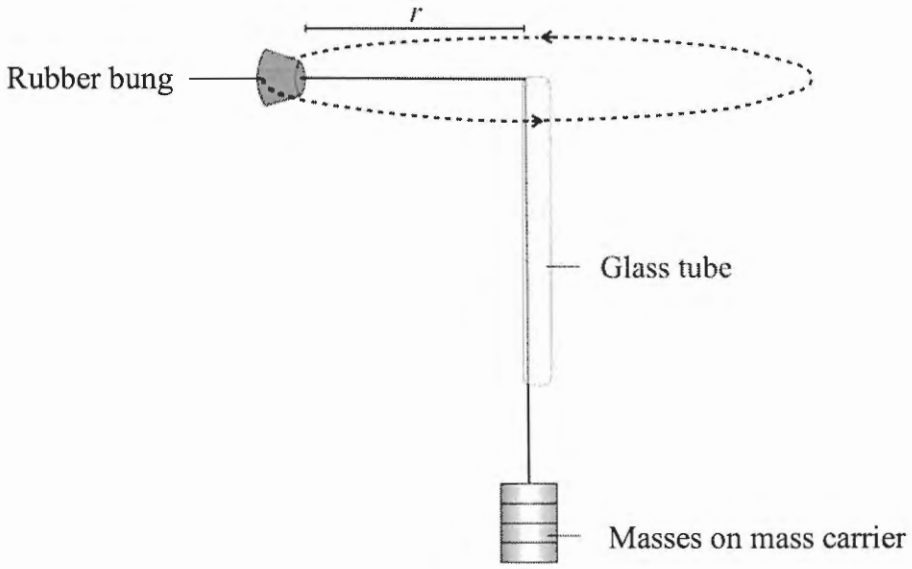
(C) Systematic error

(D) Random error

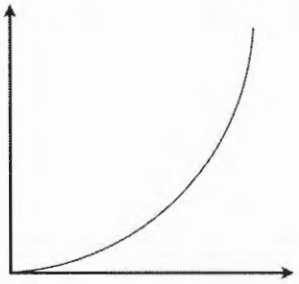
3 A satellite is moved from a low orbit to a higher orbit. Which of the following accurately describes the energy of the satellite?

	Total energy	**Gravitational potential energy**	**Kinetic energy**
(A)	Stays the same	decreases	increases
(B)	Stays the same	increases	decreases
(C)	increases	decreases	increases
(D)	increases	increases	decreases

4 A class conducted an experiment in pairs to investigate centripetal force using the apparatus below. The rubber bung was made to perform circular motion at a fixed radius and the velocity of the bung was determined. Masses were then added to the mass carrier and the velocity of the bung was once again measured at the same radius.



One day a student was sick and their partner had to interpret their results. The lab partner found a graph with unlabelled variables as shown below.



Which pair of variables was most likely graphed?

(A) F and v

(B) F and v^2

(C) v and r

(D) a and v/r

5 A plane propeller has blades that are 8 m in length that rotate with a period of 0.32 s. At what speed do the tips of the propellers travel?

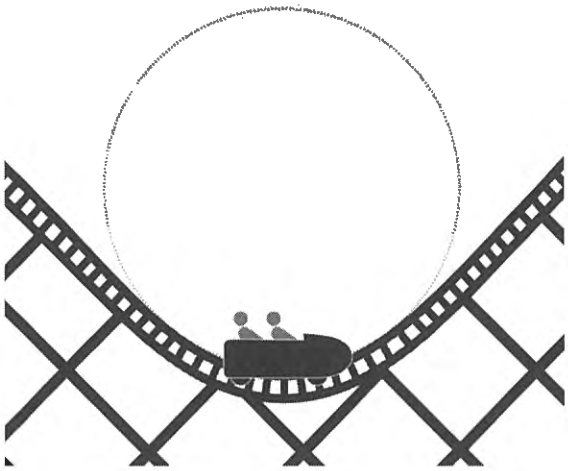
(A) 79 m s^{-1}

(B) 155 m s^{-1}

(C) 157 m s^{-1}

(D) 2035 m s^{-1}

6 A rollercoaster trolley with a constant speed on a dip has a centripetal acceleration due to the circular path, as shown in the diagram.



Which of the following descriptions best analyses the forces acting on the trolley?

(A) The gravitational force acting on the trolley is larger than when travelling on a flat surface.

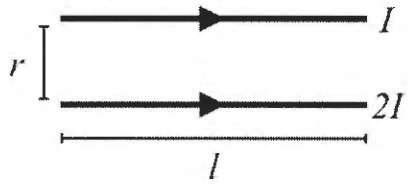
(B) The centripetal force is equal to the normal force.

(C) The sum of the normal force and the gravitational force is equal to the centripetal force.

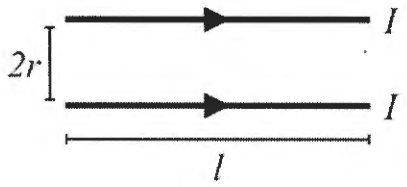
(D) The normal force is larger than when travelling on a flat surface because the centrifugal force is larger.

7 Which of the following pairs of current carrying conductors has the weakest force acting between them?

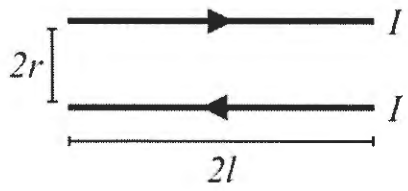
(A)



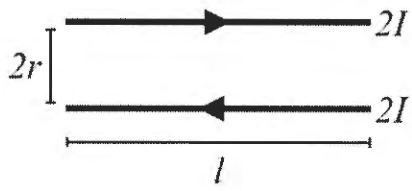
(B)



(C)

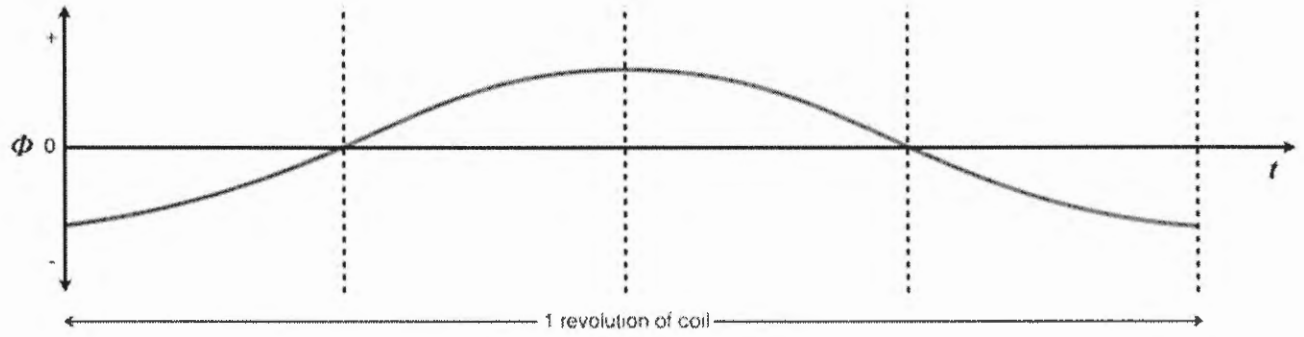


(D)



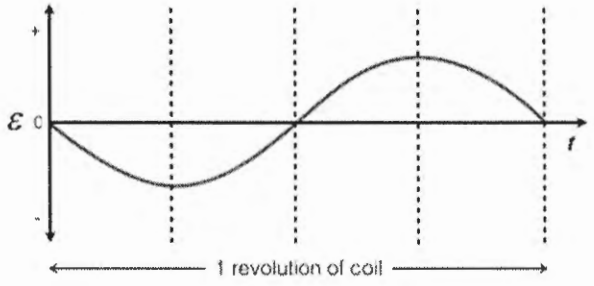
Use the following information to answer Question 8 and Question 9

The graph below shows the variation of flux of a generator coil as it completes a single revolution.

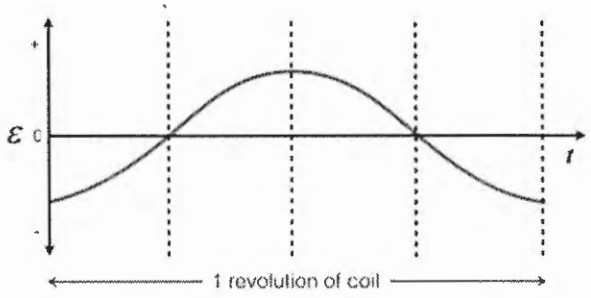


8 Which of the following graphs shows the corresponding EMF in the generator?

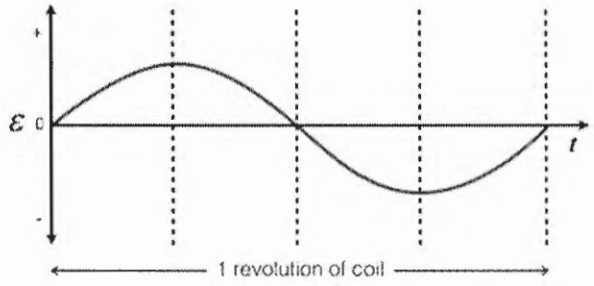
(A)



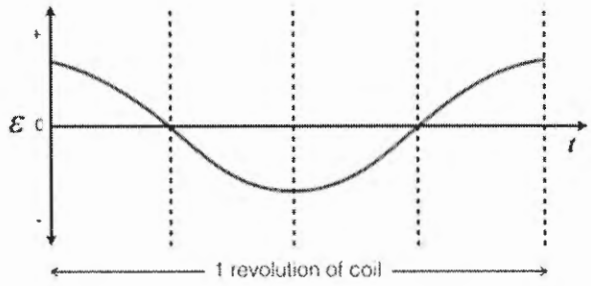
(B)



(C)

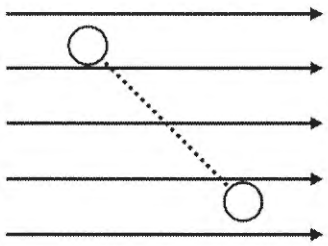


(D)

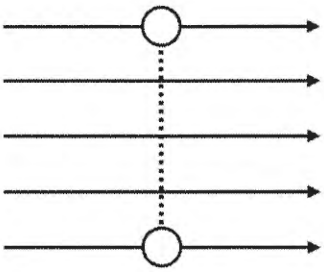


9 The following diagrams represent a cross section of the generator coil. Which position was the coil in at the beginning of the graph?

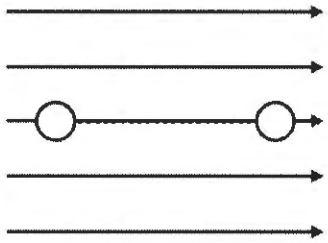
(A)



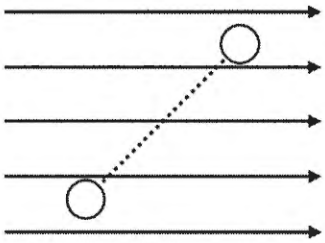
(B)



(C)



(D)



10 An old television was pulled apart in class. The teacher noticed that one side of the plate had a potential of 240 V and the plate directly opposite had a potential of 0 V. The distance between these two plates that were of parallel arrangement was 102 cm. What would be the work done to move a proton a distance of 0.47 m towards the negative plate?

(A) 8.86×10^{-18} J

(B) 200 V m^{-1}

(C) 1.77×10^{-17} J

(D) 3.76×10^{-17} J

11 An ideal transformer inside a laptop charger with 1600 turns in the primary coil and 800 turns in the secondary coil draws a current of 3.34 A. What is the current in the primary coil?

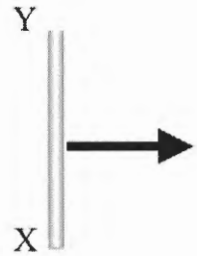
(A) 0.67 A

(B) 1.67 A

(C) 1.73 A

(D) 6.68 A

12 A wire conductor is moving to the right as shown below.

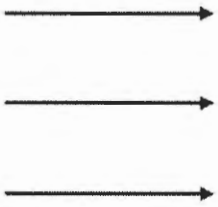


Which of the following magnetic fields would the conductor need to pass through in order to induce a current in the direction X to Y in the conductor?

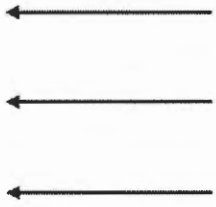
(A)

(B)

(C)



(D)



13 Foucault measured the speed of light by focusing a light onto a rotating mirror which reflected it onto a fixed mirror which in turn reflected it back. Whilst the light travelled to the fixed mirror and back, the rotating mirror rotated through an angle. By measuring the angle with a known angular velocity of the mirror, Foucault was able to calculate a value for the speed of light.

The smaller the measured angle the more uncertainty there was in the measurement.

What would be the easiest adjustment to make to the experimental design to increase the size of the angle and reduce the uncertainty in measurement?

(A) Increase the distance between the mirrors.

(B) Decrease the distance between the mirrors.

(C) Increase the rotational velocity of the rotating mirror.

(D) Decrease the rotational velocity of the rotating mirror.

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

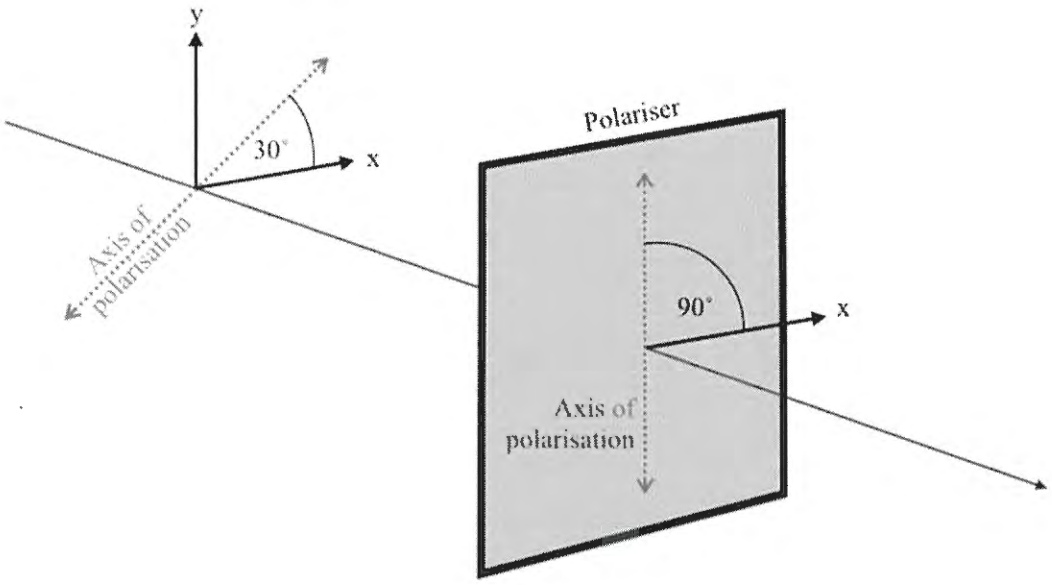
(A) 1.638×10^{-13} eV

(B) 8.19×10^{-14} eV

(C) 0.51 MeV

(D) 1.02 MeV

15 A polarised light source is entering a polarising filter as shown below.



What adjustment would produce the greatest reduction in light intensity?

(A) Rotating the light source clockwise 10°

(B) Rotating the light source counter clockwise 70°

(C) Rotating the polariser clockwise 130°

(D) Rotating the polariser counter-clockwise 110°

16 What is the magnitude of the momentum (in kgms $^{-1}$) of an electron travelling at 0.8c?

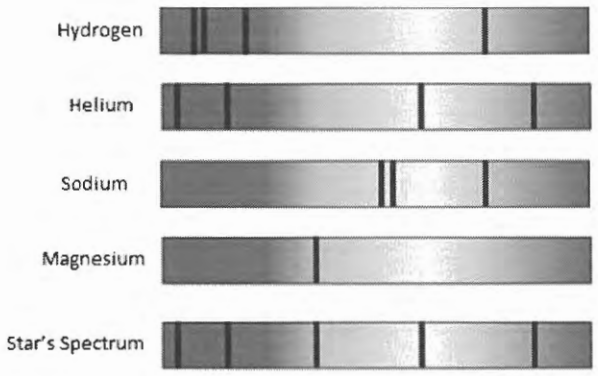
(A) 2.19×10^{-22}

(B) 3.64×10^{-22}

(C) 4.89×10^{-22}

(D) 5.99×10^{-22}

17 Use the absorption spectra provided to determine the composition of a star.



(A) Hydrogen and Sodium

(B) Helium and Sodium

(C) Magnesium and Sodium

(D) Helium and Magnesium

18 A laser with an unknown wavelength is bought from a market stall. It is pointed through a card that has a pair of small slits cut 90 μm apart. A wall is 6 m away from the card. When the laser is shone through the slits, bright spots appear on the wall and are measured to be 3 cm apart. What is the wavelength of the laser?

(A) 427 nm

(B) 439 nm

(C) 450 nm

(D) 459 nm

19 A space pilot on board a spaceship measures the length of his spaceship to be 42m. An observer on Earth sees the spaceship moving towards Earth at a speed of 2.75×10^8 ms^{-1}.

What is the length of the spaceship in the Earth observer's frame of reference?

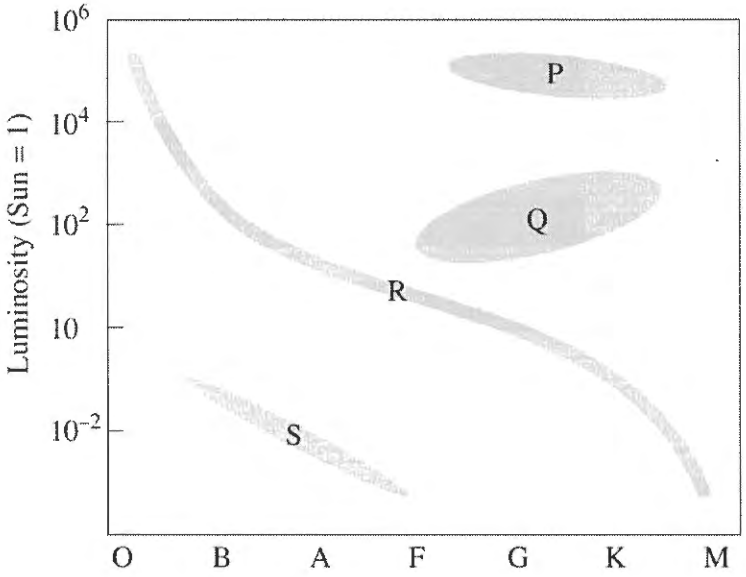
(A) 16.79 m

(B) 39.21 m

(C) 40.21 m

(D) 45.14 m

20 The Hertzsprung-Russell diagram shown is used to classify stars.



Stars in region S of the diagram are much dimmer than other stars in the same spectral class. What property of the stars in region S explains their relatively low luminosity?

(A) They are cooler than other stars.

(B) They have a smaller mass than other stars.

(C) They have a smaller surface area than other stars.

(D) They are further away from Earth than other stars.

SECTION II – 80 marks
Attempt questions 21-38
Allow about 2 hour and 25 minutes for this part

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

Question 21 (6 marks)

A teacher's demonstration with a water rocket was conducted on an oval. The teacher released the rocket from a tabletop 80 cm above the ground with an initial velocity of 17 ms^{-1} at an angle of 45° above the horizontal. The maximum height above the ground that the bottle rocket reached, according to the students, was 8.17 m.

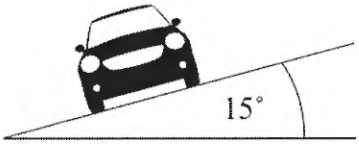
(a) How long did it take for the bottle rocket to reach the ground? **3**

(b) Calculate was the final speed of the rocket? **3**

Question 22 (6 marks)

Some banked corners are designed to allow cars to turn even without a frictional force present between the tyres and the road surface. The speed at which a car may maintain a constant turning radius around a particular banked track designed in such a way is called the design speed. **3**

A car is travelling at the design speed of a banked track with a turning radius of 26.0m, as shown in the diagram.



(a) Determine the design speed of the banked track.

(b) Explain, in terms of forces, why a car would slide off a frictionless banked track if it exceeded the design speed. **3**

Question 23 (4 marks)

An astronaut on the International Space Station was conducting maintenance on the exterior. The astronaut used a spanner to tighten a lock on a window. They used a spanner that was 46 cm long and applied a force of 92 N perpendicular to the radius.

(a) What torque did the astronaut apply? **2**

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(b) If the force was applied at an angle of 50° to the spanner length, how much force would the astronaut need to apply in order to produce the same torque as in part (a)? **2**

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Question 24 (4 marks)

Distinguish between escape velocity and orbital velocity. Include the formulae for both velocities in your answer. **4**

Question 25 (3 marks)

The planet Mars has two moons; Phobos and Deimos. **3**

Phobos completes a circular orbit of mean radius 9.4×10^3 km in 7.7 hours. Deimos completes its orbit in 30 hours.

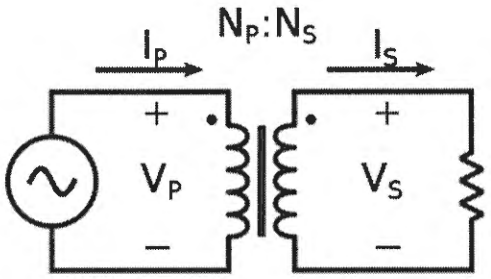
Determine the mean orbital radius of Deimos.

Question 26 (4 marks)

The ideal transformer is a device capable of changing the voltage and current characteristics of an AC power supply without dissipating any energy, according to the formulae shown below. **4**

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

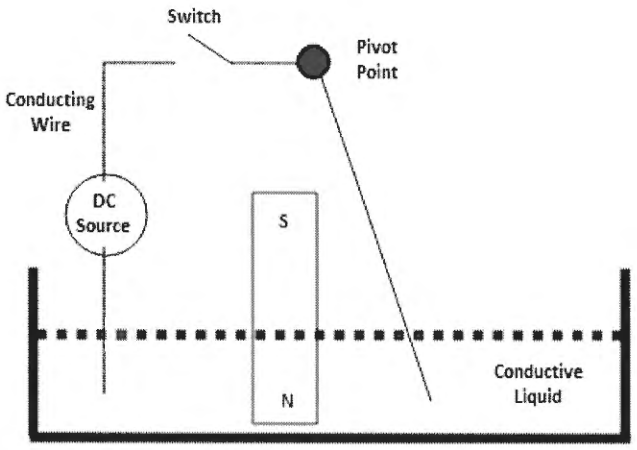
$$V_p I_p = V_s I_s$$



Identify two limitations of the ideal transformer model and outline strategies used to improve transformer efficiency.

Question 27 (2 marks)

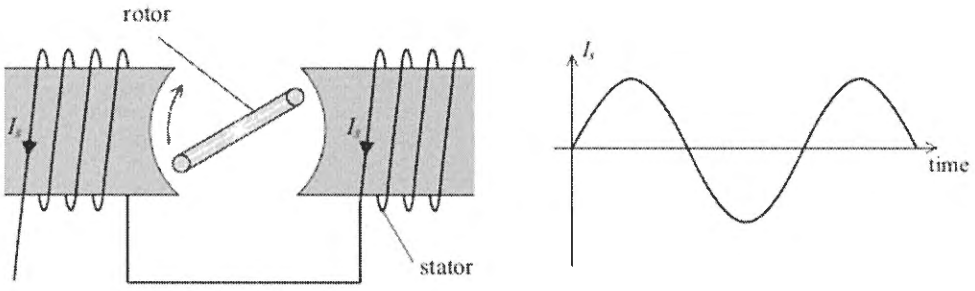
The diagram below represents a 'Faraday Motor'. When the switch is closed the wire will rotate about the magnet. Compare this rotation to uniform circular motion. **2**



Question 28 (4 marks)

The diagram represents a simple induction motor. An alternating current I_s is supplied to a stationary coil (stator). This coil is wrapped around an iron core. **4**

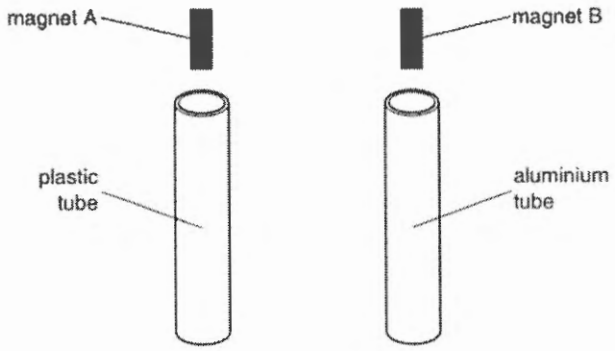
A rotating coil (rotor) is shown end on in the diagram. The graph shows the variation of the alternating current I_s with time.



Explain how a current is induced in the rotor coil

Question 29 (5 marks)

(a) Two hollow tubes of equal length hang vertically as shown in the diagram below. **5**



One tube is plastic and the other is made of aluminium.

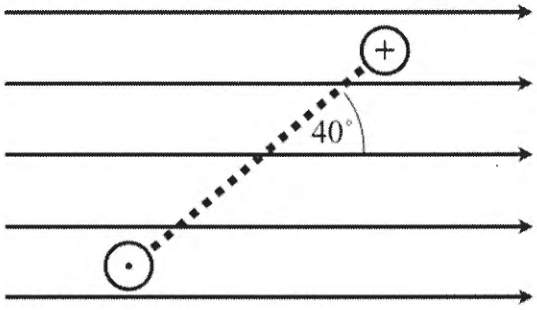
Two small identical magnets are held above the openings of each tube and released simultaneously.

The magnets do not touch the sides of the tubes.

Explain why magnet B takes much longer than magnet A to fall through the tube.

Question 30 (4 marks)

Below is a diagram of a cross section of a coil in a magnetic field. The square coil of side length 12.00 cm has 8 turns, and a current of 3.00 A. The magnetic field has a strength of 2.50×10^4 T.



(a) Calculate the torque on the coil when in the above position. **2**

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(b) Calculate the amount of flux passing through the coil when in the above position. **2**

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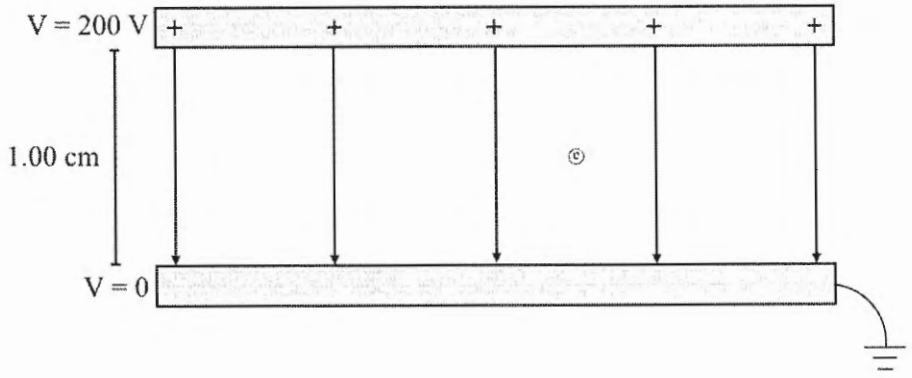
Question 31 (5 marks)

Two parallel plates are set up as shown in the diagram below so that the positive plate is above the earthed plate.



An electron is placed exactly between the plates and then released from rest.

(a) Calculate the net force acting on the electron. **2**

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(b) Determine how long it takes for the electron to touch a plate. **3**

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Question 32 (5 marks)

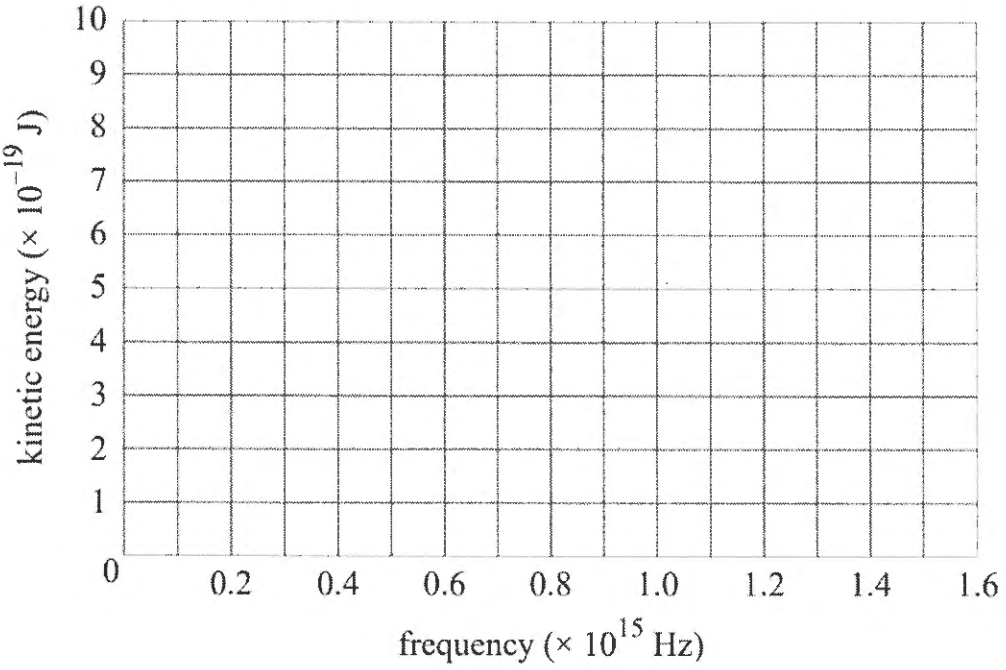
Discuss the significance of Maxwell's contribution to the development of our current understanding of electromagnetism. **5**

Question 33 (8 marks)

A group of students conducted a photoelectric experiment in class to measure the work function of a photo emitter. Their results are shown in the following table.

Wavelength of light (nm)	*Frequency of light ($\times 10^{15}$ Hz)*	*Energy carried by light beam (eV)*	*Kinetic energy of emitted electrons ($\times 10^{-19}$ J)*
200	1.49	6.21	7.30
300	1.00	4.09	3.97
400	0.76	3.10	2.33
500	0.59	2.50	1.34
600	0.50	2.02	0.66
700	0.43	1.77	0.23

(a) Graph the frequency of light ($\times 10^{15}$ Hz) on the horizontal axis against the kinetic energy ($\times 10^{-19}$ J) on the vertical axis. Include a line of best fit. **2**



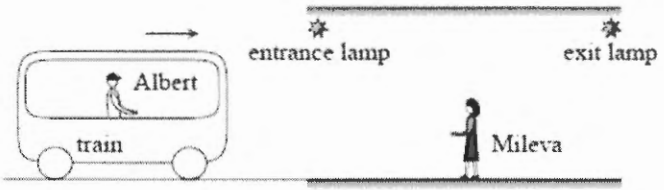
Question 38 continues on the next page

(b) Use your graph from part (a) to determine the value for the work function of the emitter. Express your answer in eV. **3**

(c) Use your graph from part (a) to determine a value for Planck's constant. Show your working. **3**

Question 34 (6 marks)

Albert is at rest in a train approaching a tunnel. Mileva is in the tunnel mid-way between the entrance and exit lamps at the ends of the tunnel.



view according to the tunnel observer

(a) The lamps in the tunnel are switched on. According to Mileva the lamps switch on simultaneously. State and explain how Albert will observe the switching on of the lamps. **3**

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(b) Albert measures the time it takes for the train to completely pass through the tunnel to be 2.00s while Mileva measures 4.39s. **3**

Determine the speed of the train as a percentage of the speed of light.

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Question 35 (2 marks)

In an experiment at CERN in 1964, a neutral pion moving at a speed of 0.99975c with respect to the laboratory decayed into two photons. The speed of each photon was measured with respect to the laboratory. **2**

Describe how the result of this experiment provided support for special relativity

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Question 36 (4 marks)

In a star the fusion of hydrogen into helium takes place in a number of stages. The final stage is: **4**

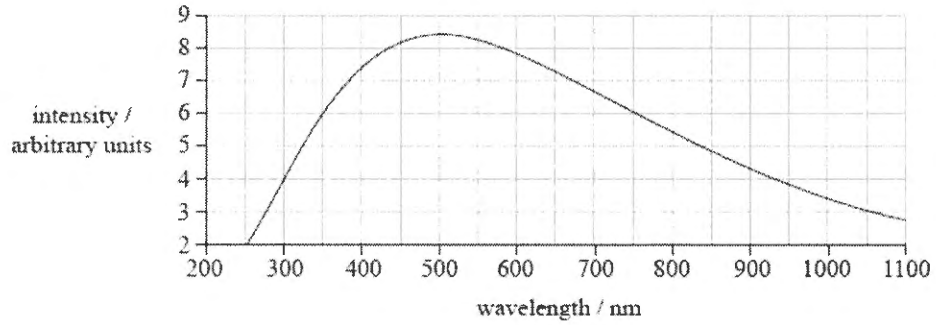
$$^{3}_{2}\text{He} + {}^{3}_{2}\text{He} \rightarrow {}^{4}_{2}\text{He} + 2 \times {}^{1}_{1}\text{H}$$

Calculate the energy released in MeV when one nucleus of $^{4}_{2}\text{He}$ is produced.

Isotope	Mass / 10^{-27} kg
^{3}He	5.008238
^{4}He	6.646483
^{1}H	1.673534

Question 37 (5 marks)

The blackbody spectrum of the Sun is shown below.



(a) Deduce that the surface temperature of the Sun is approximately 5800K **2**

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(b) The emission spectrum of the Sun is crossed by dark lines. Account for the presence of these lines in stellar spectra. **3**

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Question 38 (3 marks)

In the 1960s, Penzias and Wilson discovered a uniform cosmic background radiation (CMB) in the microwave region of the electromagnetic spectrum. **3**

Explain how the CMB is consistent with the Big Bang Model

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END OF EXAMINATION

Newcastle Grammar School

Student Number

SOLUTIONS (SH)

2019 HSC TRIAL EXAMINATION

Year 12 **PHYSICS**

Examiner: SH

READING TIME – 5 MINUTES

WORKING TIME – 3 HOURS

General Instructions

- Write using blue / black pen.
- Read the instructions carefully – you may be required to answer the questions in the space provided, or on a separate multiple-choice answer sheet
- Additional writing space has been provided at the end of the examination paper if you require more space for section II responses.
- Multiple choice answer sheet may be detached from examination paper
- Write your student number clearly on each page.
- Board-approved calculators may be used, unless stated otherwise.
- Do not remove this question paper from the examination room.

Section	Guidance	Marks Available	Your Score
SECTION I	• Type of Questions – Multiple Choice • Attempt Questions 1 – 20 • Allow about 35 minutes for this section	20	
SECTION II	• Type of Questions – Short Answer • Attempt Questions 21 – 38 • Allow about 2 hours and 25 minutes for this section	80	
	TOTALS	100	

FINAL MARK		%

Your examination paper begins overleaf.

SECTION I – 20 marks
Attempt Questions 1-20
Allow about 35 minutes for this part

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

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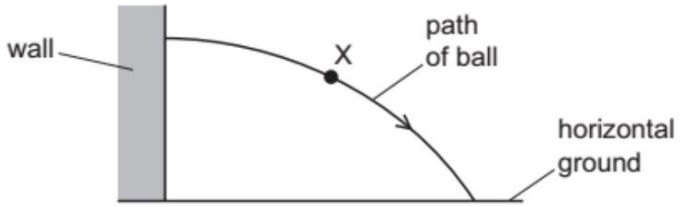
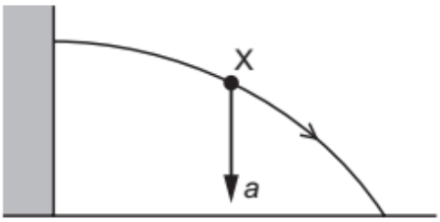
1 The diagram shows the path described by a ball after bouncing from a vertical wall.



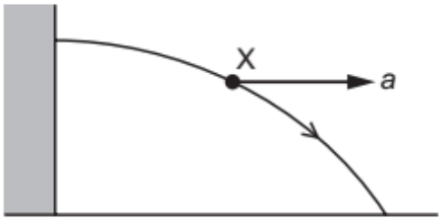
Air resistance has negligible effect on the motion of the ball.

Which diagram shows the direction of the acceleration, a, of the ball when at point X?

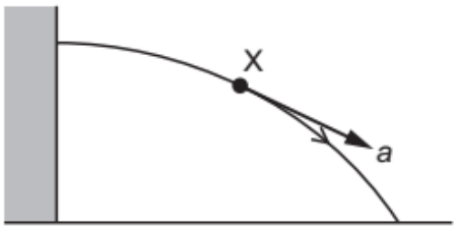
(A)



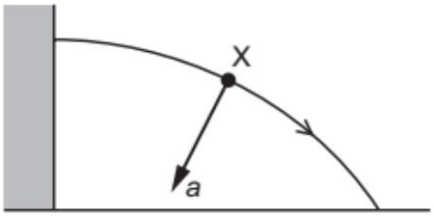
(B)



(C)



(D)



2 Using a homemade projectile launcher, a student undertook a depth study to analyse projectile motion.

The student determined that the launcher did not produce a consistent initial velocity.

The type of error this produced would be best defined as:

(A) Instrumental error

(B) Human error

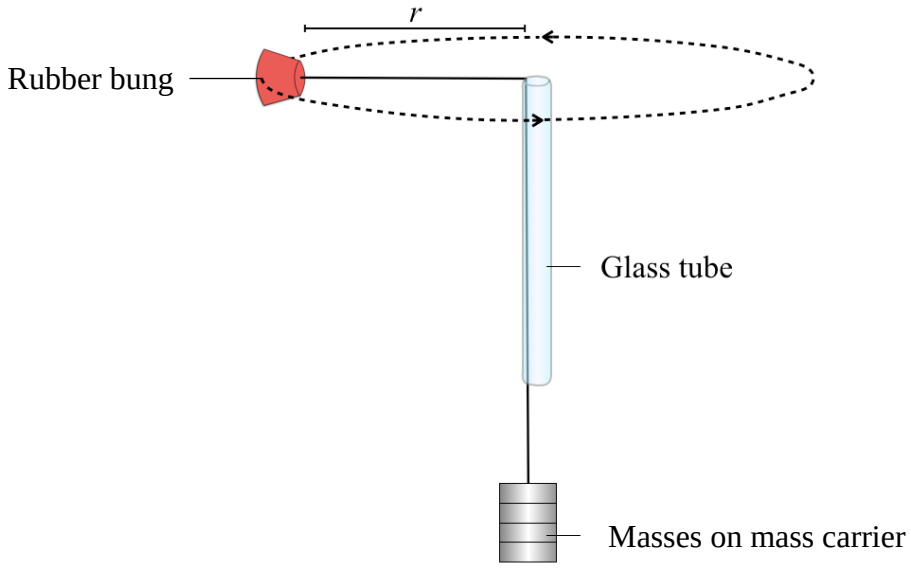
(C) Systematic error

(D) Random error

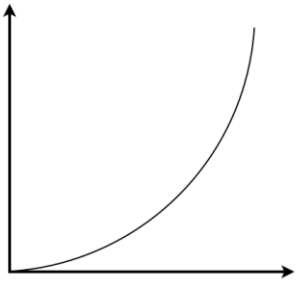
3 A satellite is moved from a low orbit to a higher orbit. Which of the following accurately describes the energy of the satellite?

	Total energy	**Gravitational potential energy**	**Kinetic energy**
(A)	Stays the same	decreases	increases
(B)	Stays the same	increases	decreases
(C)	increases	decreases	increases
(D)	increases	increases	decreases

4 A class conducted an experiment in pairs to investigate centripetal force using the apparatus below. The rubber bung was made to perform circular motion at a fixed radius and the velocity of the bung was determined. Masses were then added to the mass carrier and the velocity of the bung was once again measured at the same radius.



One day a student was sick and their partner had to interpret their results. The lab partner found a graph with unlabelled variables as shown below.



Which pair of variables was most likely graphed?

(A) F and v

(B) F and v^2

(C) v and r

(D) a and v/r

5 A plane propeller has blades that are 8 m in length that rotate with a period of 0.32 s. At what speed do the tips of the propellers travel?

(A) 79 m s^{-1}

(B) 155 m s^{-1}

(C) 157 m s^{-1}

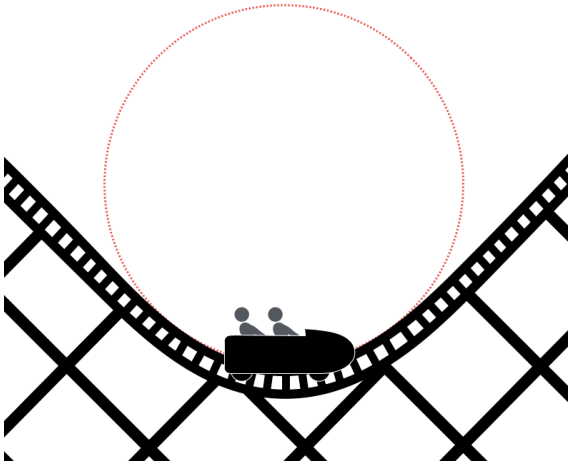
(D) 2035 m s^{-1}

$$v = \frac{2\pi r}{T}$$

$$= \frac{2 \times \pi \times 8}{0.32}$$

$$= 157 \text{ m s}^{-1}$$

6 A rollercoaster trolley with a constant speed on a dip has a centripetal acceleration due to the circular path, as shown in the diagram.



Which of the following descriptions best analyses the forces acting on the trolley?

(A) The gravitational force acting on the trolley is larger than when travelling on a flat surface.

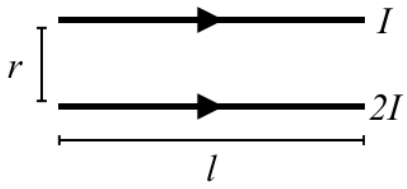
(B) The centripetal force is equal to the normal force.

(C) The sum of the normal force and the gravitational force is equal to the centripetal force.

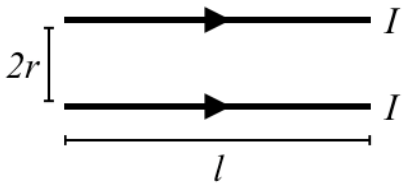
(D) The normal force is larger than when travelling on a flat surface because the centrifugal force is larger.

7 Which of the following pairs of current carrying conductors has the weakest force acting between them?

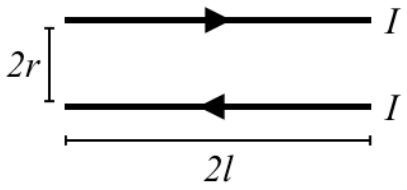
(A)



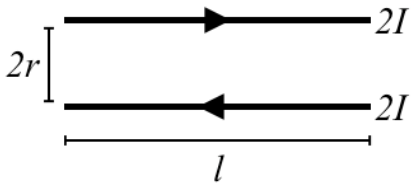
(B)



(C)

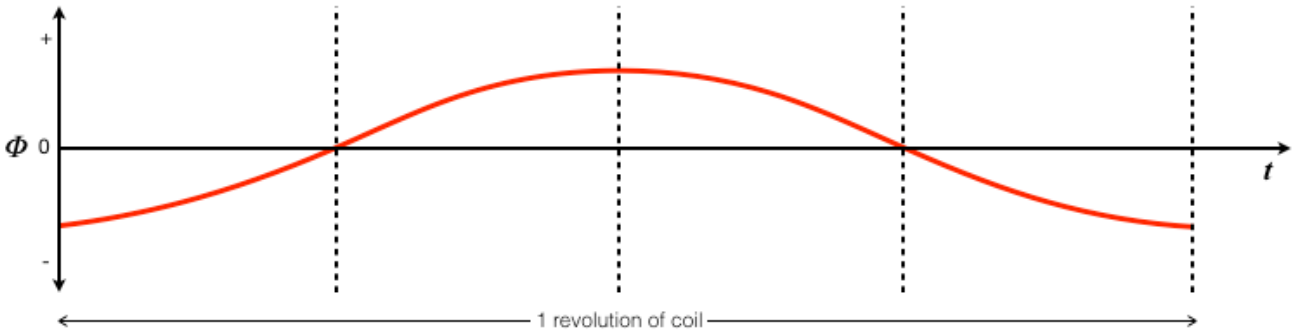


(D)



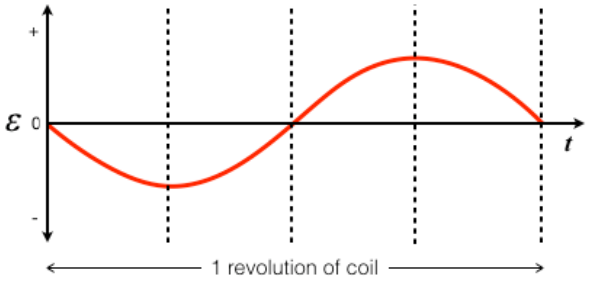
Use the following information to answer Question 8 and Question 9

The graph below shows the variation of flux of a generator coil as it completes a single revolution.

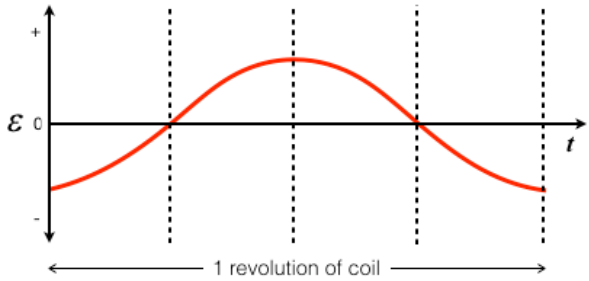


8 Which of the following graphs shows the corresponding EMF in the generator?

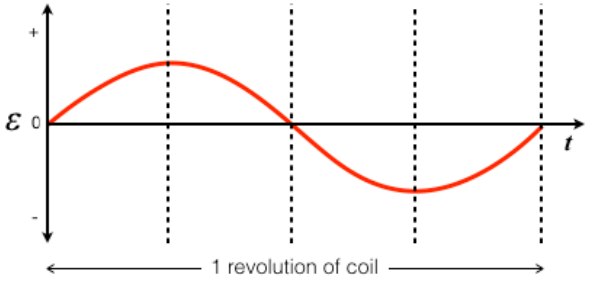
(A)



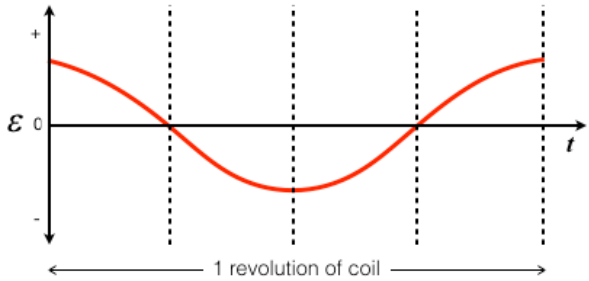
(B)



(C)

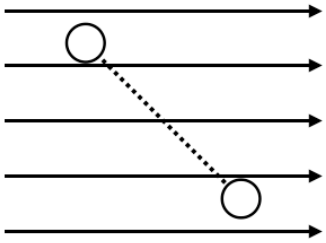


(D)

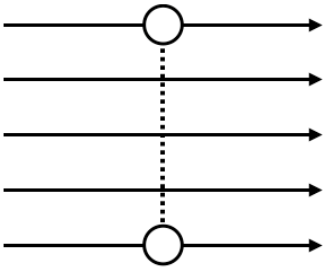


9 The following diagrams represent a cross section of the generator coil. Which position was the coil in at the beginning of the graph?

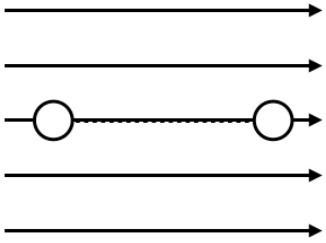
(A)



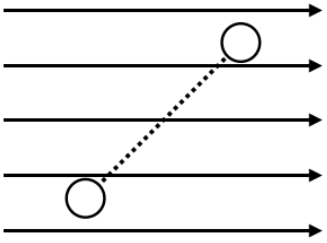
(B)



(C)



(D)



10 An old television was pulled apart in class. The teacher noticed that one side of the plate had a potential of 240 V and the plate directly opposite had a potential of 0 V. The distance between these two plates that were of parallel arrangement was 102 cm. What would be the work done to move a proton a distance of 0.47 m towards the negative plate?

(A) 8.86×10^{-18} J

(B) 200 V m^{-1}

(C) 1.77×10^{-17} J

(D) 3.76×10^{-17} J

$$E = \frac{V}{D}$$
$$= \frac{240}{1.2}$$
$$= 200 \text{ V m}^{-1}$$
$$W = qEd$$
$$= 1.602 \times 10^{-19} \times 200 \times 0.47$$
$$= 1.77 \times 10^{-17} \text{ J}$$

11 An ideal transformer inside a laptop charger with 1600 turns in the primary coil and 800 turns in the secondary coil draws a current of 3.34 A. What is the current in the primary coil?

(A) 0.67 A

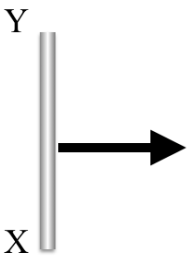
(B) 1.67 A

(C) 1.73 A

(D) 6.68 A

$$\frac{I_p}{I_s} = \frac{n_s}{n_p}$$
$$I_p = \frac{800 \times 3.34}{1600}$$
$$= 1.67 \text{ amp}$$

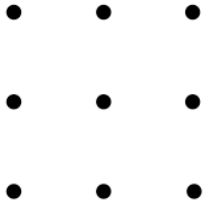
12 A wire conductor is moving to the right as shown below.



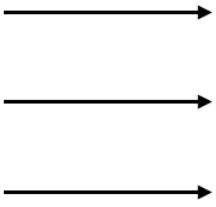
Which of the following magnetic fields would the conductor need to pass through in order to induce a current in the direction X to Y in the conductor?

(A)

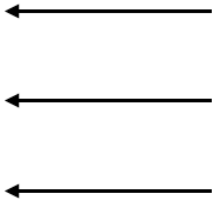
(B)



(C)



(D)



13 Foucault measured the speed of light by focusing a light onto a rotating mirror which reflected it onto a fixed mirror which in turn reflected it back. Whilst the light travelled to the fixed mirror and back, the rotating mirror rotated through an angle. By measuring the angle with a known angular velocity of the mirror, Foucault was able to calculate a value for the speed of light.

The smaller the measured angle the more uncertainty there was in the measurement.

What would be the easiest adjustment to make to the experimental design to increase the size of the angle and reduce the uncertainty in measurement?

(A) Increase the distance between the mirrors.

(B) Decrease the distance between the mirrors.

(C) Increase the rotational velocity of the rotating mirror.

(D) Decrease the rotational velocity of the rotating mirror.

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

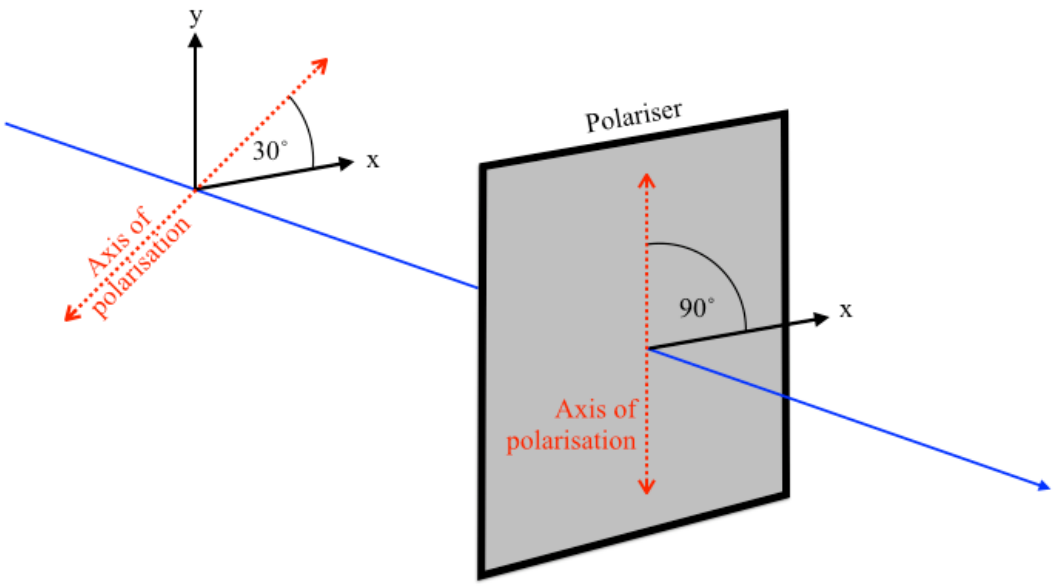
(A) 1.638×10^{-13} eV

(B) 8.19×10^{-14} eV

(C) 0.51 MeV

(D) 1.02 MeV

15 A polarised light source is entering a polarising filter as shown below.



What adjustment would produce the greatest reduction in light intensity?

(A) Rotating the light source clockwise 10°

(B) Rotating the light source counter clockwise 70°

(C) Rotating the polariser clockwise 130°

(D) Rotating the polariser counter-clockwise 110°

16 What is the magnitude of the momentum (in kgms $^{-1}$) of an electron travelling at 0.8c?
(should refer to frame of reference i.e as measured by a stationary observer relative to the electron)

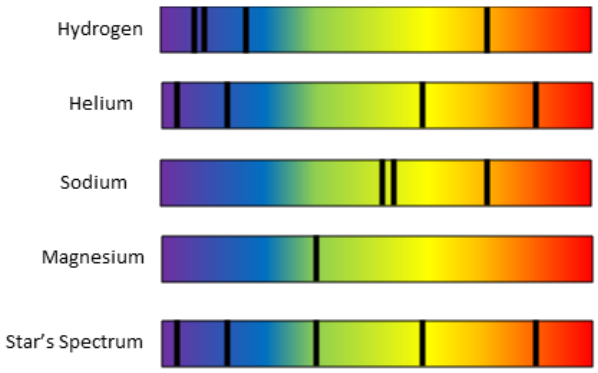
(A) 2.19×10^{-22}

(B) 3.64×10^{-22}

(C) 4.89×10^{-22}

(D) 5.99×10^{-22}

17 Use the absorption spectra provided to determine the composition of a star.



(A) Hydrogen and Sodium

(B) Helium and Sodium

(C) Magnesium and Sodium

(D) Helium and Magnesium

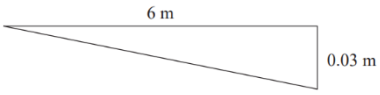
18 A laser with an unknown wavelength is bought from a market stall. It is pointed through a card that has a pair of small slits cut 90 µm apart. A wall is 6 m away from the card. When the laser is shone through the slits, bright spots appear on the wall and are measured to be 3 cm apart. What is the wavelength of the laser?

(A) 427 nm

(B) 439 nm

(C) 450 nm

(D) 459 nm



$$\text{angle} = \tan^{-1}\left(\frac{0.03}{6}\right)$$

$$= 28.65°$$

$$\lambda = \frac{90 \times 10^{-6} \times \sin(0.2865)}{1}$$

$$= 4.50 \times 10^{-7} \text{ m or } 450 \text{ nm}$$

19 A space pilot on board a spaceship measures the length of his spaceship to be 42m. An observer on Earth sees the spaceship moving towards Earth at a speed of 2.75×10^8 ms^{-1}.

What is the length of the spaceship in the Earth observer's frame of reference?

(A) 16.79 m

(B) 39.21 m

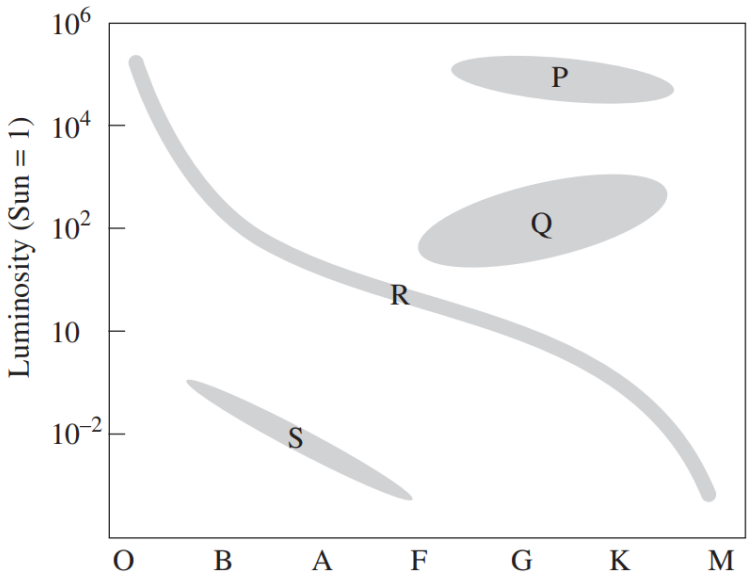
(C) 40.21 m

(D) 45.14 m

$$L = 42 \times \sqrt{\left(1 - \frac{(2.75 \times 10^8)^2}{(3.0 \times 10^8)^2}\right)}$$

$$= 16.79 \text{ m}$$

20 The Hertzsprung-Russell diagram shown is used to classify stars.



Stars in region S of the diagram are much dimmer than other stars in the same spectral class. What property of the stars in region S explains their relatively low luminosity?

(A) They are cooler than other stars.

(B) They have a smaller mass than other stars.

(C) They have a smaller surface area than other stars.

(D) They are further away from Earth than other stars.

SECTION II – 80 marks
Attempt questions 21-38
Allow about 2 hour and 25 minutes for this part

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

Question 21 (6 marks)

A teacher's demonstration with a water rocket was conducted on an oval. The teacher released the rocket from a tabletop 80 cm above the ground with an initial velocity of 17 ms^{-1} at an angle of 45° above the horizontal. The maximum height above the ground that the bottle rocket reached, according to the students, was 8.17 m.

(a) How long did it take for the bottle rocket to reach the ground? **3**

½ recognise vertical component as 17sin45

1 calculate t_{up} correctly

1 calculate t_{down} correctly

½ calculate total time

Other methods possible for 3 marks.

Look for e.c.f

Sample response/calculation

You need to find t_1 and t_2 of the projectile.

To find t_1, $vy = u_y + at$.

$$t_1 = \frac{17 \text{ m s}^{-1} \times \sin(45)}{-9.8}$$

$$= 1.23 \text{ s}$$

To find t_2, $\Delta y = u_y t + a_y t^2$.

$$t_2 = \sqrt{\frac{2x(-y)}{g}}$$

$$= \sqrt{\frac{2x(-8.17)}{-9.8}}$$

$$= 1.29 \text{ s}$$

To find total time, $t_1 + t_2 = 2.52$ s.

(b) Calculate was the final speed of the rocket? **3**

½ recognise u_x as 17cos45

½ recognise $v_x = u_x$

1 calculate v_y as 12.64ms^{-1}

½ Pythag. substitution correct

½ final answer 17.44ms^{-1}

Sample response/calculation

$$u_x = u\cos(\theta)$$

$$= 17 \times \cos(45)$$

$$= 12.02 \text{ m s}^{-1}$$

$$v_x = u_x$$

$$= 12.02 \text{ m s}^{-1}$$

$$v_y = u_y + a_y t$$

$$= 0 + (-9.8) \times 1.29 \text{ s}$$

$$= -12.64 \text{ m s}^{-1}$$

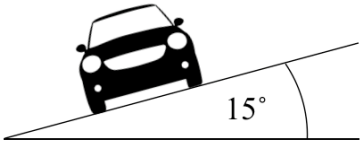
$$v^2 = (12.02 \text{ m s}^{-1})^2 + (-12.64 \text{ m s}^{-1})^2$$

$$v = 17.44 \text{ m s}^{-1}$$

Question 22 (6 marks)

Some banked corners are designed to allow cars to turn even without a frictional force present between the tyres and the road surface. The speed at which a car may maintain a constant turning radius around a particular banked track designed in such a way is called the design speed. **3**

A car is travelling at the design speed of a banked track with a turning radius of 26.0m, as shown in the diagram.



(a) Determine the design speed of the banked track.

1 recognise $f_c=mg\tan\theta$

1 rearrange and substitution into $v = \sqrt{grtan\theta}$

1 final answer $v=8.3ms^{-1}$

2 marks max if $mg\sin\theta$ used

(b) Explain, in terms of forces, why a car would slide off a frictionless banked track if it exceeded the design speed. **3**

1 – Turning a corner represents a change in velocity (acceleration) and a net force must be acting towards centre of circular curve (a centripetal force)

1 – On a banked track the F_c is provided by the horizontal component of the normal force

1 – At speeds beyond design speed $mg\tan\theta$<required F_c so car will not be able to maintain original radius and will move up (and off) the track

Sample response/calculation

A vehicle travelling at the design speed of a banked track requires no friction to turn because the horizontal component of the normal force creates a sufficient centripetal force to turn the vehicle. If the speed of a vehicle in uniform circular motion is increased a larger centripetal force is required to maintain the same radius of the turn. Beyond the design speed the horizontal component of the normal force will be less than the required centripetal force. Because there is no friction between the tyres and the road the car would slide off.

Question 23 (4 marks)

An astronaut on the International Space Station was conducting maintenance on the exterior. The astronaut used a spanner to tighten a lock on a window. They used a spanner that was 46 cm long and applied a force of 92 N perpendicular to the radius.

(a) What torque did the astronaut apply? **2**

1 – correct formula and substitution

1 – final answer correct

Sample response/calculation

$$\tau = rF\sin(\theta)$$
$$= (0.46) \times 92 \times \sin(90)$$
$$= 42.32 \text{ N m}$$

(b) If the force was applied at an angle of 50° to the spanner length, how much force would the astronaut need to apply in order to produce the same torque as in part (a)? **2**

1 – correct formula and substitution

1 – final answer correct

Sample response/calculation

$$\tau = rF\sin(\theta)$$
$$F = \frac{\tau}{r\sin(\theta)}$$
$$= \frac{42.32}{0.46 \times \sin(50)}$$
$$= 120.1 \text{ N}$$

Sin40 also accepted leading to 143N as question wording slightly ambiguous

Question 24 (4 marks)

Distinguish between escape velocity and orbital velocity. Include the formulae for both velocities in your answer. **4**

1- v_{esc} is the minimum speed required to leave the gravitational field of a massive body o.w.t.t.e

1- v_{orb} is the speed required by a satellite to maintain a stable orbit around a massive object

1- escape velocity formula: $v_{escape} = \sqrt{\frac{2GM}{r}}$

1- orbital velocity formulas: $v_{orbital} = \sqrt{\frac{GM}{r}}$

Accept $v_{orb} = \frac{2\pi r}{T}$ with quantities defined

Question 25 (3 marks)

The planet Mars has two moons; Phobos and Deimos. **3**

Phobos completes a circular orbit of mean radius 9.4 x 10^3 km in 7.7 hours. Deimos completes its orbit in 30 hours.

Determine the mean orbital radius of Deimos.

Sample response/calculation

1- rearrangement of formula $\left(\frac{R_D}{R_P}\right)^3 = \left(\frac{T_D}{T_P}\right)^2$

1 - substitution $R_D = 9.4\times10^3 \times \left(\frac{30}{7.7}\right)^{2/3}$

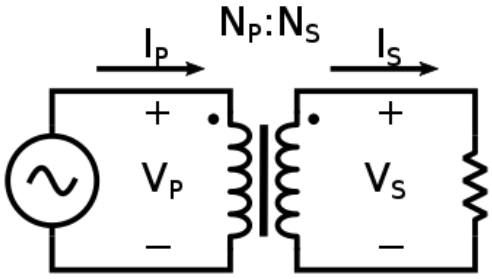
1- final answer $R_D = 2.3\times10^4 \quad \text{(km)}$

Question 26 (4 marks)

The ideal transformer is a device capable of changing the voltage and current characteristics of an AC power supply without dissipating any energy, according to the formulae shown below. **4**

$$\frac{V_\mathrm{p}}{V_\mathrm{s}} = \frac{N_\mathrm{p}}{N_\mathrm{s}}$$

$$V_\mathrm{p} I_\mathrm{p} = V_\mathrm{s} I_\mathrm{s}$$



Identify two limitations of the ideal transformer model and outline strategies used to improve transformer efficiency.

Limitations (2 max)

1 – idea of incomplete flux linkage between primary and secondary coil

1 – eddy currents in iron core and resistive heating effects (or conservation of energy idea)

1 – power dissipated due to resistance in wires (n.b.a)

Strategies (2 max)

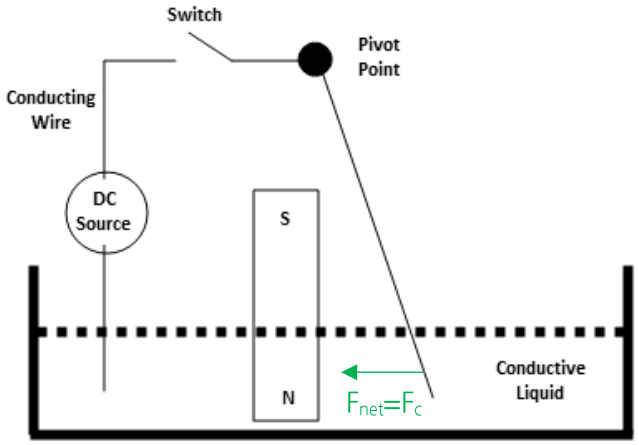
1 – Use of iron core outlined

1 – Laminations in core outlined

1 – Thicker wires (not lower resistivity wires) outlined

Question 27 (2 marks)

The diagram below represents a 'Faraday Motor'. When the switch is closed the wire will rotate about the magnet. Compare this rotation to uniform circular motion. **2**



(2 max)

1 – wire moves in continuous circular path similar to U.C.M

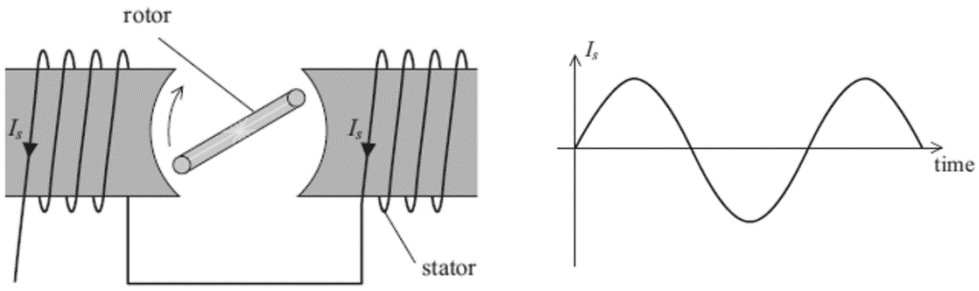
1 – correct description of the force acting on the wire due to the current in a magnetic field (motor effect) and recognising that this force is not the centripetal force because it is acting in the same direction as the wire's velocity

1 – Centripetal force is the sum of the magnetic force, drag forces and restorative force in wire (diagram may be useful)

Question 28 (4 marks)

The diagram represents a simple induction motor. An alternating current I_s is supplied to a stationary coil (stator). This coil is wrapped around an iron core. **4**

A rotating coil (rotor) is shown end on in the diagram. The graph shows the variation of the alternating current I_s with time.



Explain how a current is induced in the rotor coil

½ - Current in stator produces a magnetic field…

½ - …that is changing due to AC source

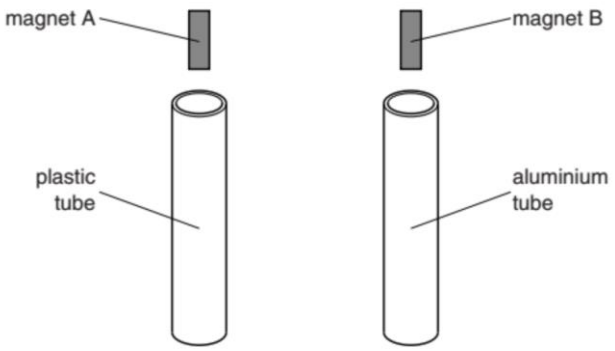
1 – This changing field passes through the rotor coil (change of flux in the rotor)

1 – $\frac{\Delta \emptyset}{\Delta t}$ induces an emf in the rotor coil

1 – This induced emf drives/induces/gives rise to a current in the rotor coil

Question 29 (5 marks)

(a) Two hollow tubes of equal length hang vertically as shown in the diagram below. **5**



One tube is plastic and the other is made of aluminium.

Two small identical magnets are held above the openings of each tube and released simultaneously.

The magnets do not touch the sides of the tubes.

Explain why magnet B takes much longer than magnet A to fall through the tube.

1 – identify that there is a change in flux in the copper tube as the magnet approaches

1 – emf is induces in the copper tube that gives rise to eddy currents in the tube

1 – whose associated magnetic field is in such as direction as to oppose the change in flux that gave rise to its creation.

1 – The opposing magnetic field will provide a magnetic force that reduces the downward net force on magnet, (reduced acceleration idea)

1 – eddy currents not induced in plastic tube as it is an insulator without free electrons, so no forces acting on magnet other than gravitational force

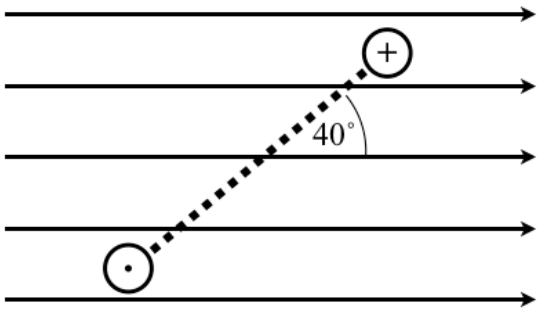
OR

1 – eddy currents represent electrical energy, or dissipate heat energy due to resistance in the copper

1 – which reduced the kinetic energy of the magnet (does not fall as quickly) according to the law of conservation of energy.

Question 30 (4 marks)

Below is a diagram of a cross section of a coil in a magnetic field. The square coil of side length 12.00 cm has 8 turns, and a current of 3.00 A. The magnetic field has a strength of 2.50×10^4 T.



(a) Calculate the torque on the coil when in the above position. **2**

1 – correct substitution into formula

1 – final answer

-1 if sin40 used
-1 if number of turns not included

Sample response/calculation

$\tau = nIAB \sin\theta$

$\tau = 8 \times 3 \times 0.0144 \times 2.5 \times 10^4 \times \sin 50$

$\tau = 6620$ Nm

(b) Calculate the amount of flux passing through the coil when in the above position. **2**

1 – correct substitution into formula

1 – final answer

-1 if cos40 used

Sample response/calculation

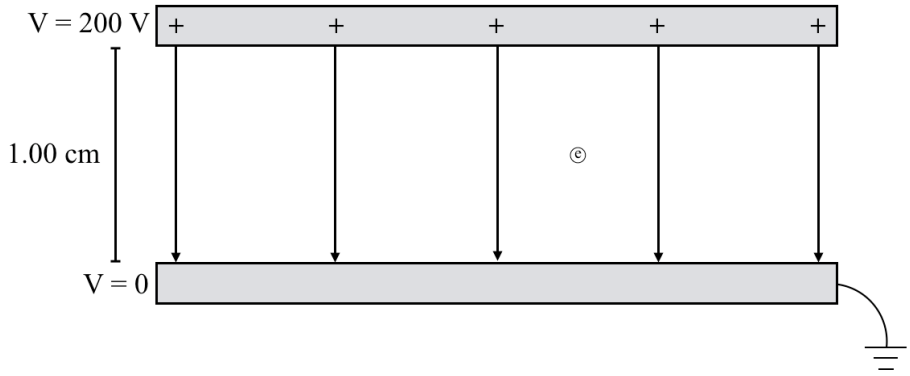
$\emptyset = BA\cos\theta$

$\emptyset = 2.5 \times 10^4 \times (0.12)^2 \times \cos 50^o$

$\emptyset = 230$Wb

Question 31 (5 marks)

Two parallel plates are set up as shown in the diagram below so that the positive plate is above the earthed plate.



An electron is placed exactly between the plates and then released from rest.

(a) Calculate the net force acting on the electron. **2**

1 – determine E
(or show correct substitution of E in combined formula)

1 – final answer

Sample response/calculation

$E = \frac{V}{d}$

$E = \frac{200}{0.01}$

$E = 20000 \text{ Vm}^{-1}$

$\Sigma F = qE$ ·

$\Sigma F = 3.2 \times 10^{-15} \text{ N}$

(b) Determine how long it takes for the electron to touch a plate. **3**

1 – Calculate a

½ - select correct suvat equation

½ - correct substitution

1 – final answer

Sample response/calculation

$a = \frac{\Sigma F}{m}$

$a = \frac{3.2 \times 10^{-15}}{9.109 \times 10^{-31}}$

$a = 3.52 \times 10^{15} \text{ m s}^{-2}$

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

$0.005 = 0 + \frac{1}{2}3.52 \times 10^{15} \times t^2$

$t =$ 1.7 x10-9s

Question 32 (5 marks)

Discuss the significance of Maxwell's contribution to the development of our current understanding of electromagnetism. **5**

Many possible responses and ways to approach the question. Clarity of written expression was important here, as was avoiding repetiting ideas and forming a cohesive discussion. Although some key words/phrases may have been mentioned, unless they were discussed appropriately, full marks were not awarded.

Contribution
1 – unified electricity and magnetism
1 – predicted forms of EM radiation other than light
1 – predicted speed of light
1 – described light as an EM wave

Significance to current understanding
1 – Led to deeper understanding of the the atom, optics (other possible areas)
1 – allowed for future discoveries such as Hertz and radio waves
1 – allowed for technological developments such as radio communications, televisions, fibre optics etc

(5 max)

Question 33 (8 marks)

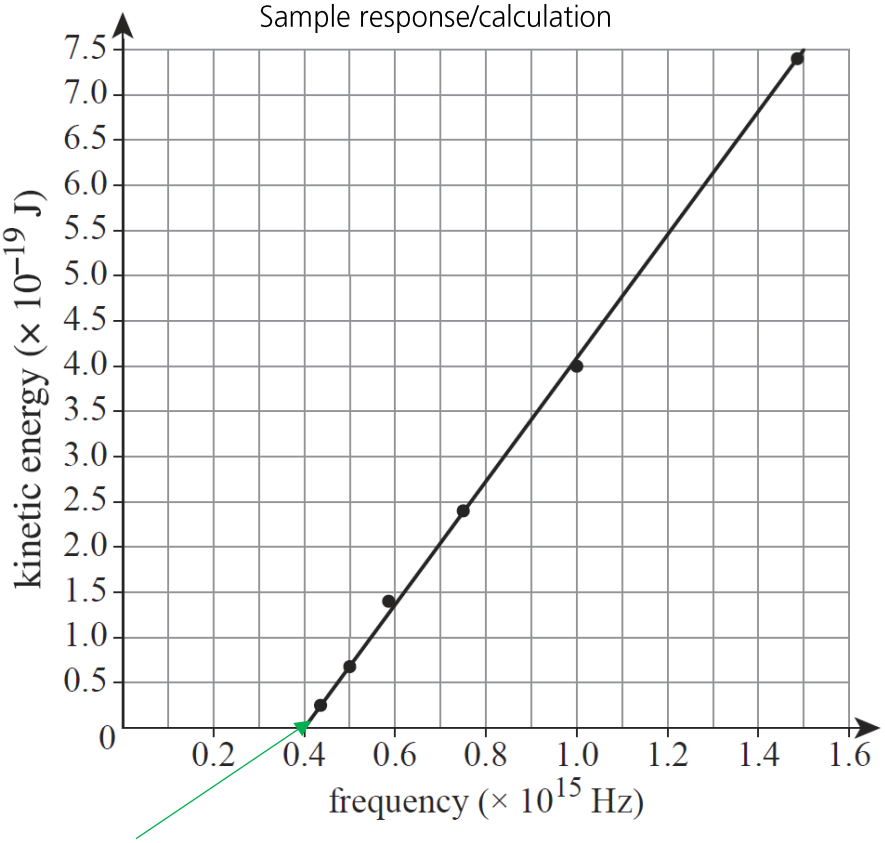
A group of students conducted a photoelectric experiment in class to measure the work function of a photo emitter. Their results are shown in the following table.

Wavelength of light (nm)	*Frequency of light ($\times 10^{15}$ Hz)*	*Energy carried by light beam (eV)*	*Kinetic energy of emitted electrons ($\times 10^{-19}$ J)*
200	1.49	6.21	7.30
300	1.00	4.09	3.97
400	0.76	3.10	2.33
500	0.59	2.50	1.34
600	0.50	2.02	0.66
700	0.43	1.77	0.23

(a) Graph the frequency of light ($\times 10^{15}$ Hz) on the horizontal axis against the kinetic energy ($\times 10^{-19}$ J) on the vertical axis. Include a line of best fit. **2**

1 – data correctly plotted
1 – straight line of best fit

Sample response/calculation



Line should be dashed here

Question 38 continues on the next page

(b) Use your graph from part (a) to determine the value for the work function of the emitter. Express your answer in eV. **3**

1 – finding x intercept

$\emptyset = hf_o$

1 – finding energy in joules using $\emptyset = hf_o$ where f_o is the x intercept (threshold frequency)

1 – converting to eV

Sample response/calculation

From the graph, the x-intercept is 0.4×10^{15} Hz.

$$\emptyset = hf_o$$
$$= 6.626 \times 10^{-34} \times 0.4 \times 10^{15}$$
$$= \frac{2.6504 \times 10^{-19}}{1.602 \times 10^{-19}}$$
$$= 1.654 \text{ eV}$$

(c) Use your graph from part (a) to determine a value for Planck's constant. Show your working. **3**

1 – recognition that gradient = h

1 – correct substitution of values taken from graph

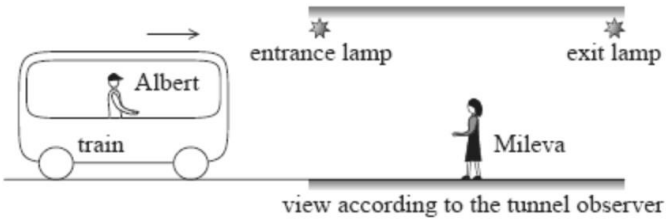
1 – final answer

Sample response/calculation

$$\frac{(7.3 \times 10^{-19} - 0.23 \times 10^{-19})}{(1.49 \times 10^{15} - 0.43 \times 10^{15})} = 6.67 \times 10^{-34} \text{ J s}^{-1}$$

Question 34 (6 marks)

Albert is at rest in a train approaching a tunnel. Mileva is in the tunnel mid-way between the entrance and exit lamps at the ends of the tunnel.



view according to the tunnel observer

(a) The lamps in the tunnel are switched on. According to Mileva the lamps switch on simultaneously. State and explain how Albert will observe the switching on of the lamps. **3**

1 – speed of light is constant

1 – both f.o.r equally valid

1 – turning on of the lights will not be simultaneous for Albert

1 – Albert sees entrance lamp light first

1 – Although in order for the turning on of the lights to be simultaneous for Mileva, the exit lamp must have been turned on before the entrance lamp, Albert is closer to the entry lamp and will therefore receive light from this lamp before the light from the exit lamp.

full marks also possible for pointing out the train may not be moving at relativistic speeds and in such case Albert would also view the lamps turning on simultaneously.

(b) Albert measures the time it takes for the train to completely pass through the tunnel to be 2.00s while Mileva measures 4.39s. **3**

Determine the speed of the train as a percentage of the speed of light.

Sample response/calculation

1 – correct formula selected

$$t = \frac{t_0}{\sqrt{\left(1-\frac{v^2}{c^2}\right)}}$$

$$4.39 = \frac{2}{\sqrt{\left(1-\frac{v^2}{1^2}\right)}}$$

1 – correct substation

1 – final answer
-½ of v not expressed as % of c

$v = 89\%c$

Question 35 (2 marks)

In an experiment at CERN in 1964, a neutral pion moving at a speed of 0.99975c with respect to the laboratory decayed into two photons. The speed of each photon was measured with respect to the laboratory. **2**

Describe how the result of this experiment provided support for special relativity

1 – Recognising that the results of the experiment were that the photons both moved at the speed of light after decay

1 – Linking the result to the postulate of S.R that states that the speed of light is independent of the speed of its source

Sample response/calculation

special relativity rests on the postulate that the speed of light (c) is independent of the speed of its source / speed of light is constant;
both photons were measured to have a speed equal to c with respect to the lab thus verifying the postulate;

Question 36 (4 marks)

In a star the fusion of hydrogen into helium takes place in a number of stages. The final stage is: **4**

$$ {}_2^3\mathrm{He} + {}_2^3\mathrm{He} \rightarrow {}_2^4\mathrm{He} + 2 \times {}_1^1\mathrm{H} $$

Calculate the energy released in MeV when one nucleus of ${}_2^4\mathrm{He}$ is produced.

Isotope	Mass / 10^{-27} kg
^{3}He	5.008238
^{4}He	6.646483
^{1}H	1.673534

½ - LHS mass calculated correctly = 10.016476 x 10^{-27}kg

½ - RHS mass calculated correctly = 9.993551 x 10^{-27}kg

1 – Δm = 2.2925 x 10^{-29}kg

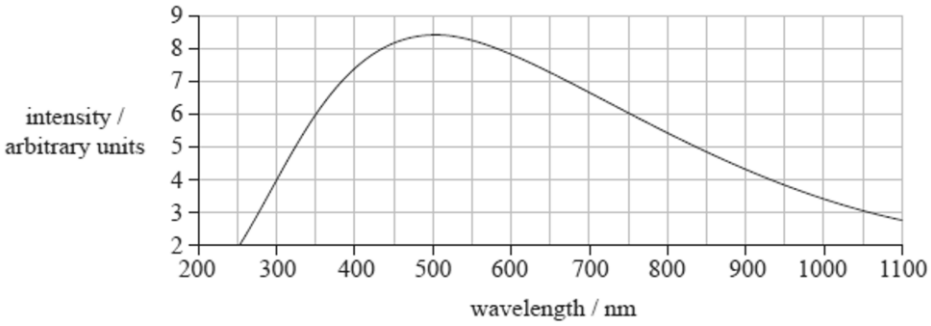
1 – E=mc2 to find E=2.063 x 10^{-12}J

1 – Conversion from J to MeV (12.9Mev)

$$ \Delta m = 2.2925 \times 10^{-29}\ \mathrm{kg} $$
$$ \Delta E = \left(3.00 \times 10^{8}\ \mathrm{ms^{-1}}\right)^2 \times 2.2925 \times 10^{-29}\ \mathrm{kg} = 2.063 \times 10^{-12}\ \mathrm{J} $$
$$ \Delta E = \frac{2.063 \times 10^{-12}\ \mathrm{J}}{1.60 \times 10^{-13}\ \mathrm{J\,MeV^{-1}}} = 12.9\ \mathrm{MeV} $$

Question 37 (5 marks)

The blackbody spectrum of the Sun is shown below.



(a) Deduce that the surface temperature of the Sun is approximately 5800K **2**

1 – Peak wavelength determined correctly

1 – Wein's Law used to find T

wavelength peak = 500 nm ;

$T = \frac{2.90 \times 10^{-3}}{5 \times 10^{-7}}$;

= 5800 K

(b) The emission spectrum of the Sun is crossed by dark lines. Account for the presence of these lines in stellar spectra. **3**

1 – dark lines due to absorption of light/photons from the core …

1 – …by the atoms/electrons in the Sun's outer shells of gas

1 – only specific wavelengths absorbed depending upon gas composition and temperature

Knowledge of atomic energy levels not required for full marks however many students aware of these energy transitions and used their knowledge in this question.

Question 38 (3 marks)

In the 1960s, Penzias and Wilson discovered a uniform cosmic background radiation (CMB) in the microwave region of the electromagnetic spectrum. **3**

Explain how the CMB is consistent with the Big Bang Model

1 – highly energetic (short wavelength) radiation formed in early stages of a hot universe

1 – idea of the universe expanding and cooling

1 – wavelength increased as temperature decreased, values agree with Big Bang predictions.

OR

1 – expanding universe has led to redshift of the original radiation and values agree with Big Bang predictions

1 – Uniformity of CMB agrees with Big Bang model (expansion from single point)

3 (max)

½ awarded is universe stated to be expanding

END OF EXAMINATION