Sydney Boys High School

Year 12 Physics Half Yearly Cohort Task 2023

Multiple Choice Answer Sheet

Please complete the answer sheet AND your NESA ID (starting with 3) below using a 2B pencil or mechanical pacer.
Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.
If you change your mind, use a clean eraser to make corrections.
Do **not** make any other markings on this page

NESA ID

1 A B C D
2 A B C D
3 A B C D
4 A B C D
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NESA ID

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3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7
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9	9	9	9	9	9	9	9	9

Student Number:

Sydney Boys High School

Physics

March 2023
Half Yearly Cohort Task
Advanced Mechanics, Electromagnetics, Special Relativity

General Instructions

- Reading time: 5 minutes
- Working time: 90 minutes
- Write using black or blue pen
- Draw diagrams using pencil
- SHOW ALL WORKING
- Board approved calculators may be used
- A data sheet, formula sheets and Periodic Table are provided at the back of this paper
- Write your student number in ALL of the boxes provided

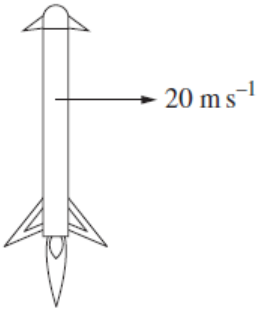
Total marks – 60

Part A – Multiple Choice
- 20 marks

Part B – Free Response
- 40 marks

PART A – Multiple Choice (20 Marks)

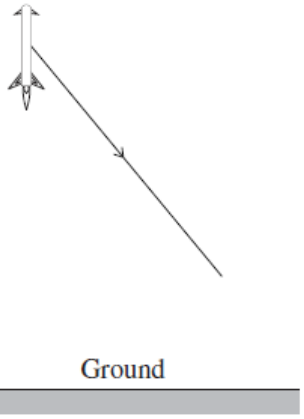
1. A rocket returns to Earth for reuse after launching satellites, using its engines to make a controlled landing.



The rocket having an initial mass of 9000 kg is on approach to the ground, travelling horizontally at 20ms^{-1} as shown in the diagram, when the engine thrust is changed to 88 200N. Changing the thrust of the rocket causes the rocket to loose 500kg of mass.

Which diagram shows the trajectory of the rocket following this change of thrust?

A.



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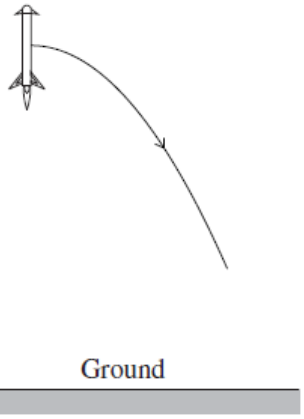

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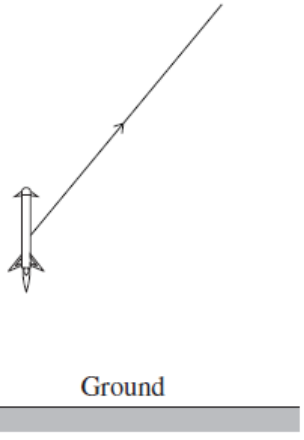
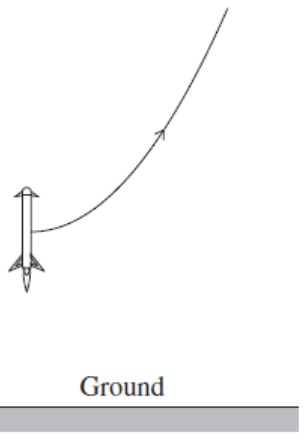
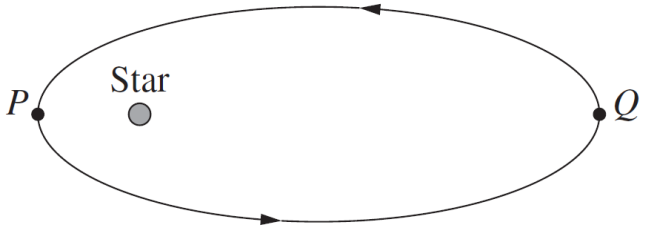


D.



2. The elliptical orbit of a planet around a star is shown.



Which type of energy is greater at position P than at Q?

(A) Kinetic

(B) Gravitational

(C) Relativistic

(D) Total

3. Which of the following statements correctly describes the gravitational interaction between the Earth and the Sun?

(A) The Earth accelerates towards the Sun.

(B) The net force acting on the Earth is zero.

(C) The Sun and Earth experience equal and opposite accelerations.

(D) The force acting on the Earth is smaller than the force acting on the Sun.

4. The purpose of transformers in electrical circuits is

(A) To change from AC to DC

(B) To increase Voltage

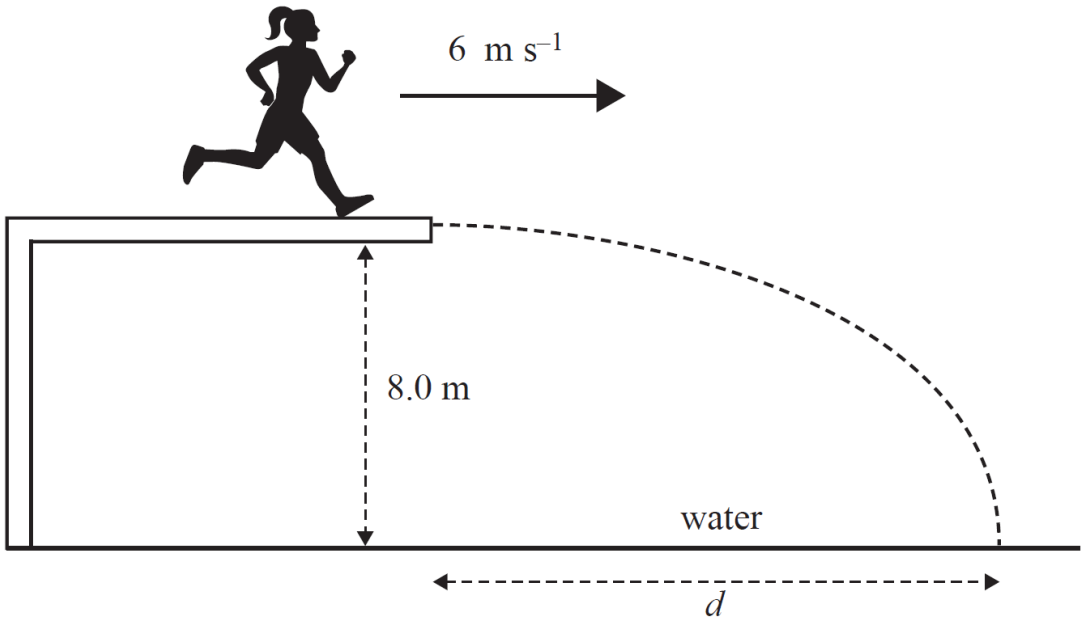
(C) To change Frequency

(D) To decrease Resistance

Use the following information to answer the next two questions

Alex is running horizontally at a speed of 6 m s^{-1} along a diving platform that is 8.0 m vertically above the water.

Alex runs off the end of the diving platform and reaches the water below after time t.
She lands feet first at a horizontal distance d from the end of the diving platform.



5. Which one of the following expressions correctly gives the distance d ?

(A) $0.8t$

(B) $6t$

(C) $5t^2$

(D) $6t + 5t^2$

6. Which one of the following is closest to the time taken, t, for Alex to reach the water below?

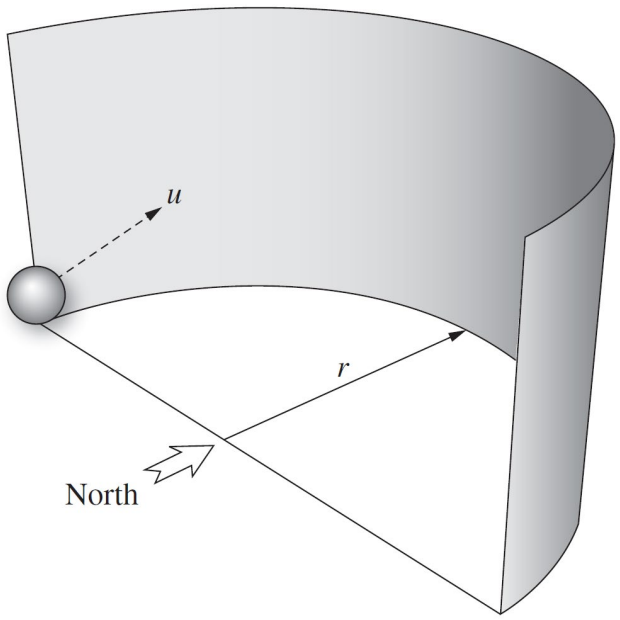
(A) 0.8 s

(B) 1.1 s

(C) 1.3 s

(D) 1.6 s

7. The diagram shows a smooth, semi-circular, vertical wall with radius, *r*. A ball is launched from the position shown with a velocity *u* towards north at an angle to the horizontal.



The ball follows a trajectory around the wall before landing on the ground, opposite its starting point. It does not reach the top of the wall.

Assume that there is no friction between the ball and the wall.

Which statement correctly describes the net force acting on the ball during its motion?

(A) The magnitude of the net force remains constant.

(B) The direction of the net force is vertically downwards.

(C) The direction of the net force is perpendicular to the wall.

(D) The magnitude of the net force reaches a minimum when the ball is at its highest point.

8. A satellite in circular orbit at a distance *r* from the centre of Earth has an orbital velocity *v*.

If the distance was increased to 3*r*, what would be the satellite's orbital velocity?

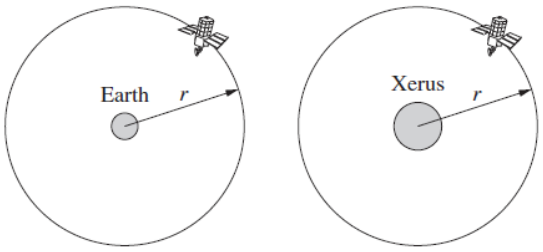
(A) $\frac{v}{3}$

(B) $0.6v$

(C) $1.7v$

(D) $3v$

9. A satellite orbits Earth with period T. An identical satellite orbits the planet Xerus which has a mass four times that of Earth. Both satellites have the same orbital radius r.



What is the period of the satellite orbiting Xerus?

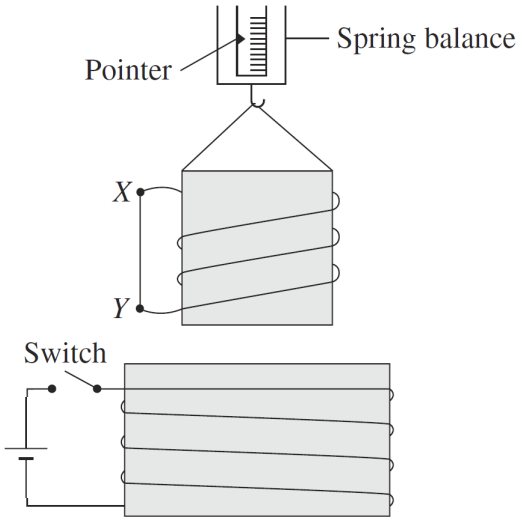
(A) T/4

(B) T/2

(C) 2T

(D) 4T

10. An experiment is set up as shown.



When the switch is opened, the reading on the spring balance changes immediately, then returns to the initial reading.

Which row of the table correctly shows the direction of the current through the straight conductor XY and the direction in which the pointer relative to the spring balance initially moves?

	Direction of current through the straight conductor	*Direction in which the pointer initially moves*
(A)	From *X* to *Y*	Down
(B)	From *X* to *Y*	Up
(C)	From *Y* to *X*	Down
(D)	From *Y* to *X*	Up

11. Calculate the maximum height reached by a projectile with and initial velocity of 15 ms^{-1} at and angle of 30° up from the horizontal

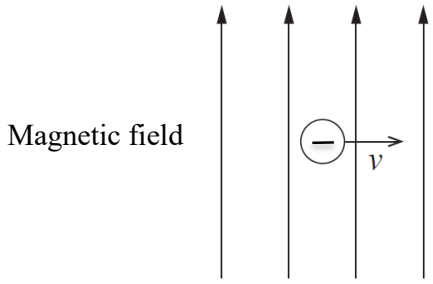
(A) 2.87m

(B) 3.83m

(C) 8.61m

(D) 11.5m

12. A negatively charged particle is moving at velocity, v, in a magnetic field as shown.



What is the direction of the force acting on the particle due to the magnetic field?

(A) Into the page

(B) Out of the page

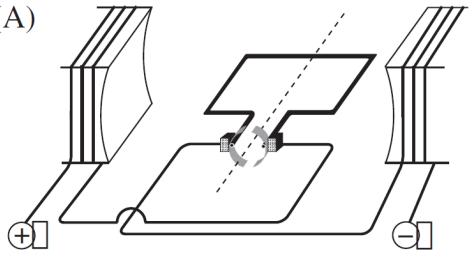
(C) Up the page

(D) Down the page

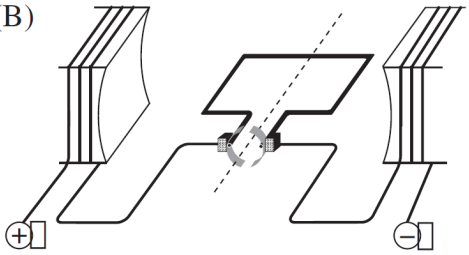
13. The diagrams show possible ways to connect the coils and rotor of a DC motor to a DC power supply.

In which circuit will the rotor turn in a clockwise direction?

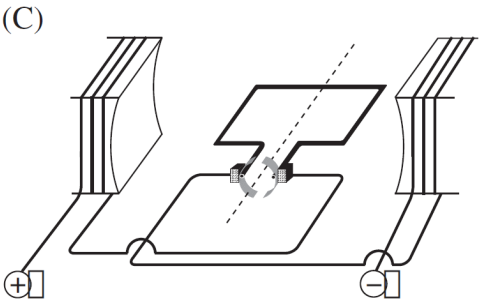
(A)



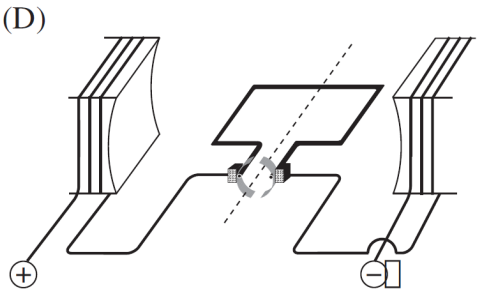
(B)



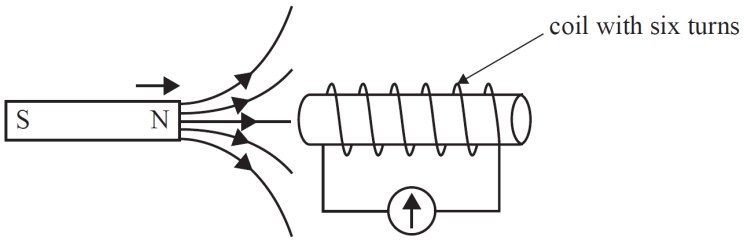
(C)



(D)



14. A magnet approaches a coil with six turns, as shown in the diagram below. During time interval Δt, the magnetic flux changes by 0.05 Wb and the average induced EMF is 1.2 V.



Which one of the following is closest to the time interval Δt?

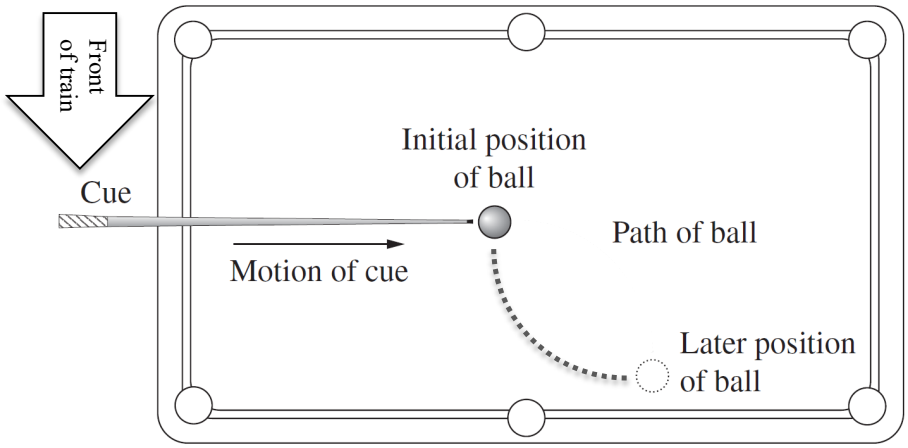
(A) 0.04 s

(B) 0.01 s

(C) 0.25 s

(D) 0.50 s

15. A passenger is playing billiards on a train that is travelling forwards as indicated on a level track. The ball takes the path shown when hit by the cue.



What can be inferred about the motion of the train?

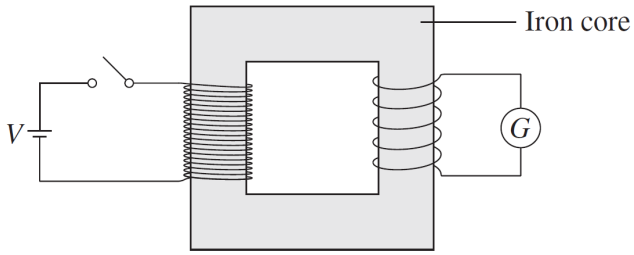
(A) It is turning left.

(B) It is speeding up.

(C) It is turning right.

(D) It is slowing down.

16. The diagram shows an ideal transformer.



When the switch is closed, the pointer on the galvanometer deflects. How could the size of the deflection be decreased?

(A) Decrease the number of primary coils.

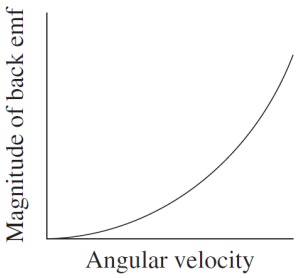
(B) Decrease the number of secondary coils.

(C) Increase the voltage of the DC power source.

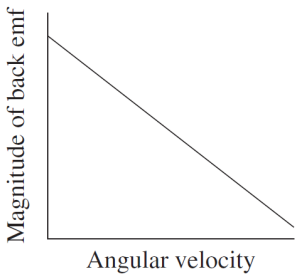
(D) Increase the current of the DC power source.

17. Which graph shows the magnitude of back emf induced in a DC motor rotating continuously at different angular velocities?

A.



B.



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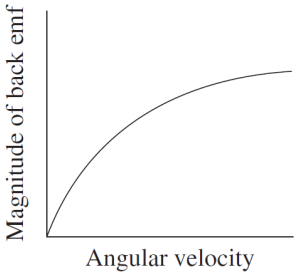
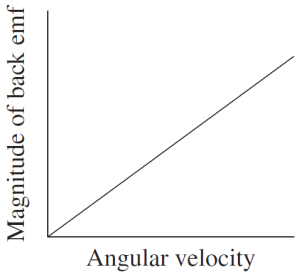
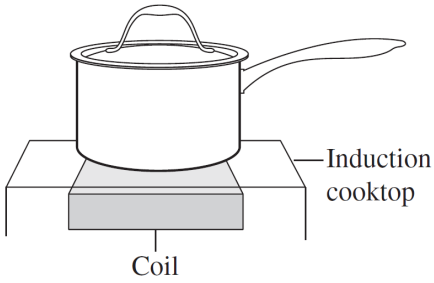


D.



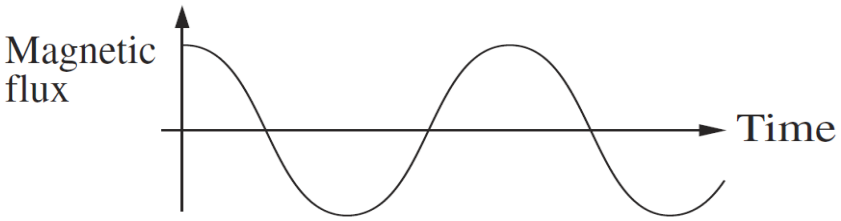
18. The diagram shows a saucepan of water on an induction cooktop.



Which row of the table correctly identifies a property of the material used to make the saucepan and the frequency of the changing magnetic field produced by the coil?

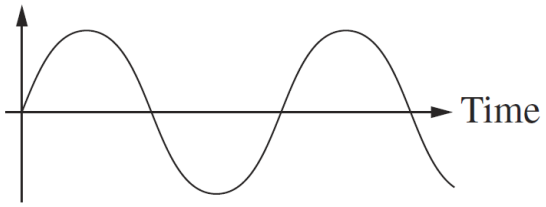
	Property of Saucepan	*Frequency*
(A)	High electrical resistance	50kHz
(B)	Low electrical resistance	50kHz
(C)	High electrical resistance	50Hz
(D)	Low electrical resistance	50Hz

19. The graph shows variation in magnetic flux through a coil with time.

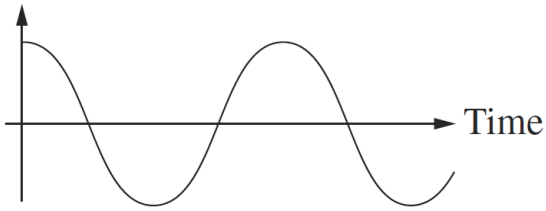


Which graph best represents the corresponding induced emf in the coil?

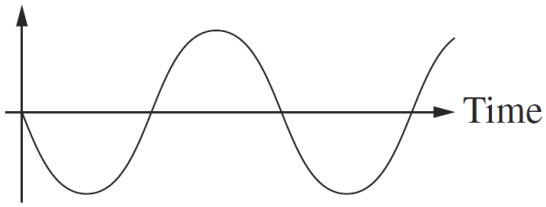
(A) Induced emf



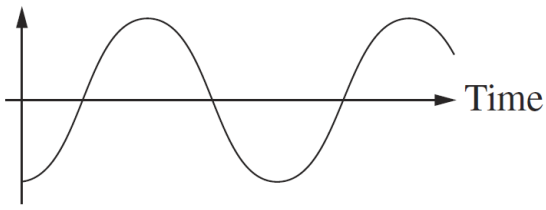
(B) Induced emf



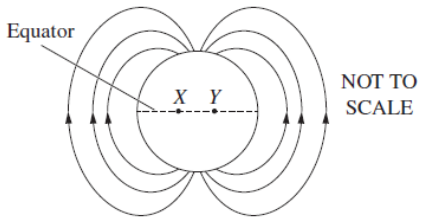
(C) Induced emf



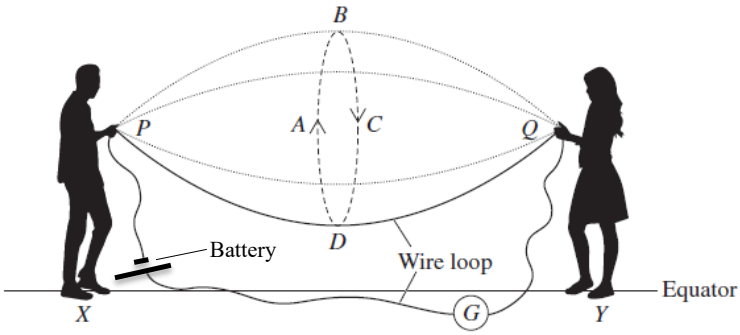
(D) Induced emf



20. Earth's magnetic field is shown in the following diagram.



Two students standing a few metres apart on the equator at points X and Y, where Earth's magnetic field is parallel to the ground, hold a loop of copper wire between them. Part of the loop is rotated like a skipping rope as shown, while the other part remains motionless on the ground. A battery is connected in series in the wire.



At what point during the rotation of the wire does the maximum current flow through the galvanometer?

(A) A

(B) B

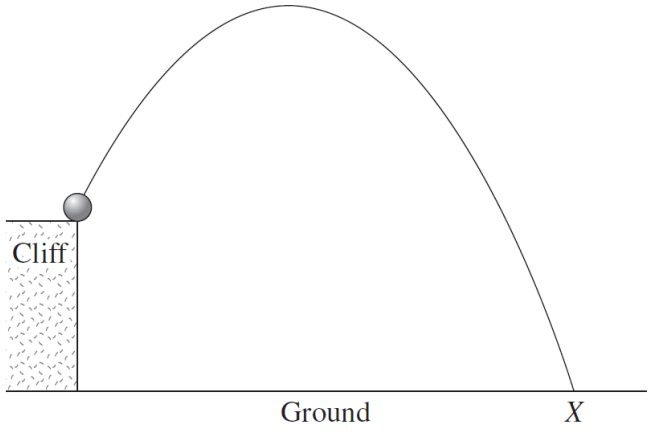
(C) C

(D) D

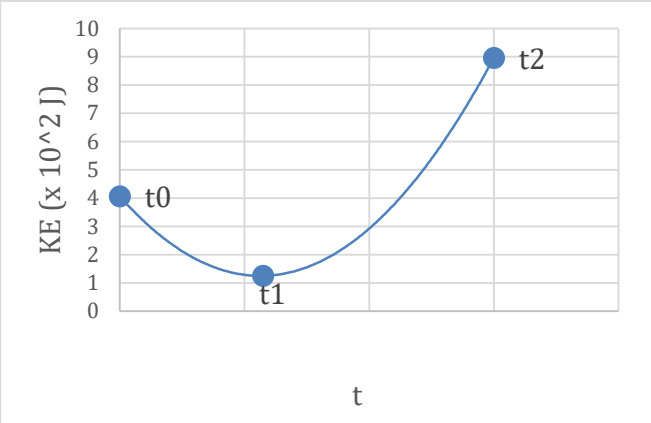
PART B – Short Answer (40 Marks)

Question 21 (5 marks)

A 2.50 kg mass is launched from the edge of a cliff.



The kinetic energy of the mass is graphed from the moment it is launched until it hits the ground at *X*. The kinetic energy of the mass is provided for times t_0, t_1 and t_2.



Time (t)	*KE (J)*
t_0	406
t_1	125
t_2	896

From the information provided, calculate the horizontal and vertical components (u_x and u_y) of the initial velocity of the ball at launch. **2**

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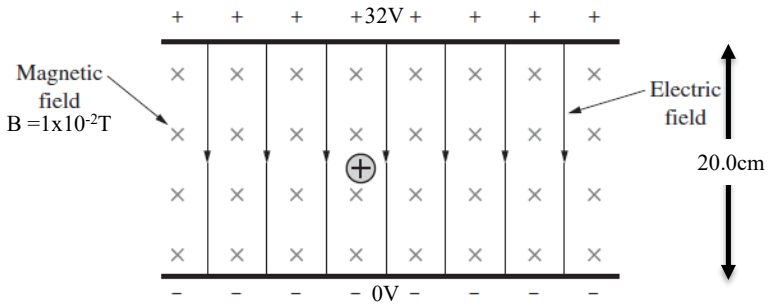
b Using the information provided, calculate the range of the ball. **3**

Question 22 (4 marks)

The diagram below shows a region in which there are uniform electric and magnetic fields. The potential difference between the plates is measured to be 32V, and they are 20.0cm apart. The magnetic field is $1x10^{-2}T$. A stationary proton is placed at the centre of the fields with no motion.

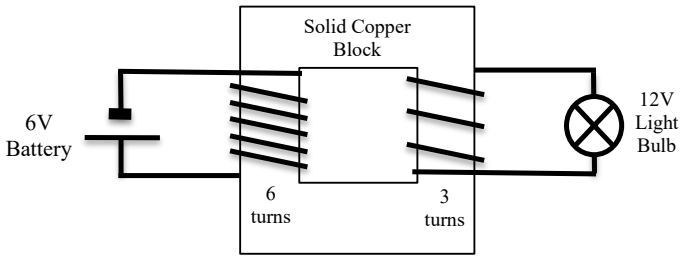


a Indicate the initial direction of the force on the proton in the diagram with a vector diagram **1**

b The proton is allowed to move towards one of the charged plates. Calculate the net force on the proton as it hits the plate. **3**

Question 23 (3 marks)

A student creates a model for a step-up transformer to power a light bulb. The student uses a 6v battery, a copper block, wires and a 12v light bulb. This is shown in the diagram below. **3**

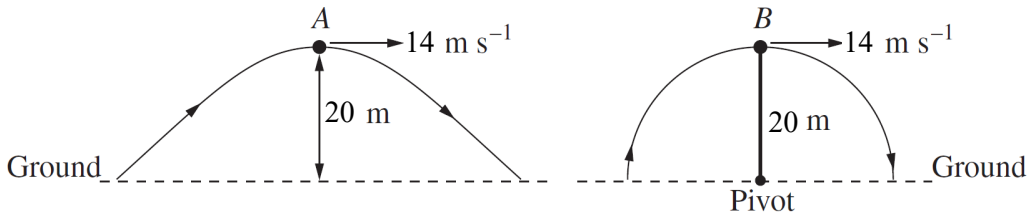


On setting up the equipment the student noticed the lightbulb failed to light up. Explain why this setup failed, and what can be done to improve it.

Question 24 (5 marks)

A 30 kg object, *A*, was fired from a cannon in projectile motion. When the projectile was at its maximum height of 20 m, its speed was 14 ms^{-1}.

To simulate this motion, an identical object, *B*, was attached to a rigid mechanical arm and moved at a constant speed of 14 ms^{-1} in a vertical half-circle. The length of the arm was 20 m**.**

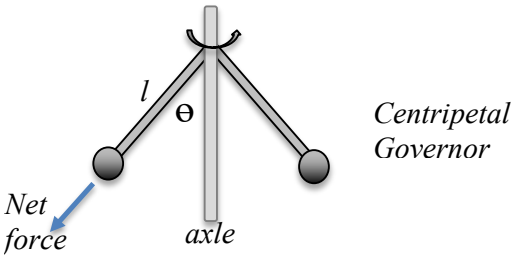


a Calculate the time of flight for objects *A* and *B*, from the time it leaves the ground to the time it returns to the ground **2**

b By comparing the net forces and the time of flight for both objects; assess whether the simulation with object *B* was valid for object *A*. **3**

Question 25 (3 marks)

A *centripetal governor* is a device used to limit the rotational speed of machines by using masses m suspended on rigid massless arms of length l around a rotating axle. As the axle rotates, the balance of forces causes the masses to move away from the axle. Once a predetermined angle Θ has been reached, the axle disengages. **3**



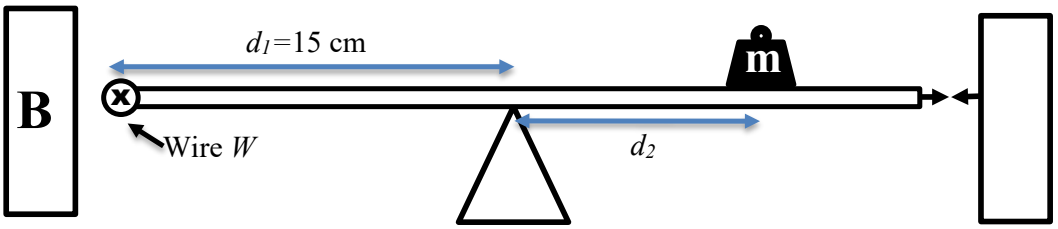
Calculate the length required to limit the rotation of the machine to 240RPM if Θ is 75°.

Question 26 (3 marks)

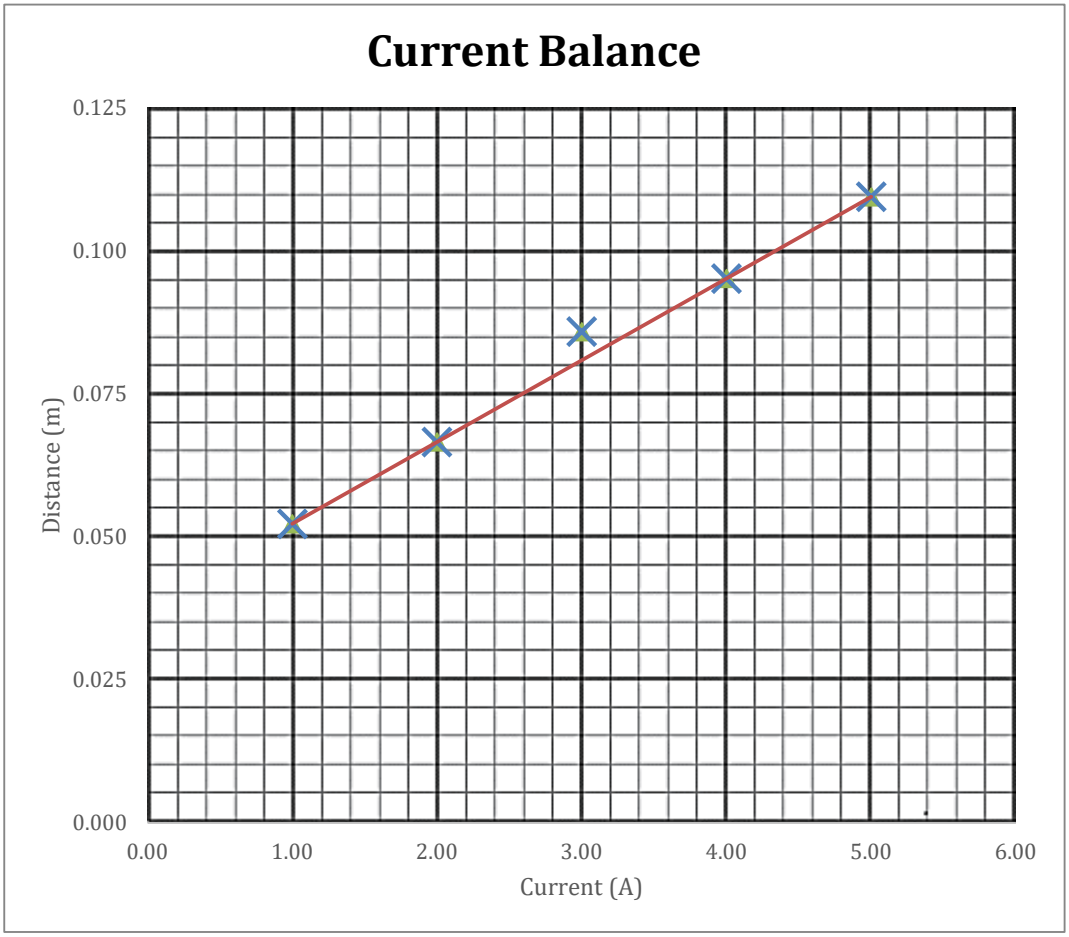
a Calculate the change in energy required to move a spacecraft of mass of 2.25×10^3 kg from a circular orbit around earth with an altitude of 3.50×10^7 m to another circular orbit with an altitude of 3.50×10^5 m. **3**

Question 27 (6 marks)

A *current balance* was set up as below. The arms of the balance are 15cm long, and a small mass of 1.5g is used to counterbalance the wire so that the balance is in equilibrium. The wire that is exposed to the magnetic field is 2cm long has a mass $\mathbf{m_w}$. A current ***I*** is passed through the wire ***W***, which deflects the balance. The mass **m** is moved along the other arm of the balance to restore the apparatus to the equilibrium. The distance of the mass from the pivot is recorded, along with the current.



The results are graphed below



a From the graph provided, calculate the strength of the magnetic field provided by the magnet B. **3**

b From the graph, calculate the mass of the wire m_w. **3**

Question 28 (7 marks)

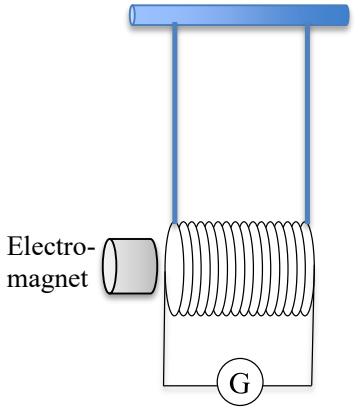
A *particle accelerator* is used to accelerate clouds of protons from a stationary position to extremely high velocities. The accelerator is measured to have accelerated the protons to a speed of $2.7 \times 10^{8}\,ms^{-1}$ in $151.0 \times 10^{-3}s$.

a Calculate the momentum of the protons. **3**

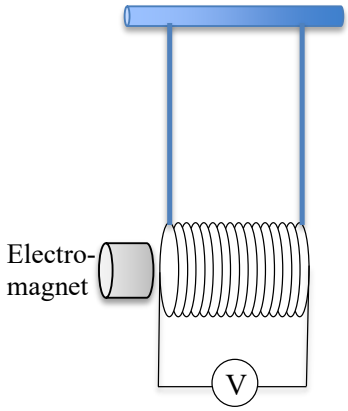
b The protons elastically collide with stationary free neutrons, which have a half-life of 15mins and a diameter of 1.7×10^{-15} m. Explain any observations that will be made about the neutrons, given the limitations of classical physics. Assume the neutrons to have an equivalent mass to that of the protons, and all the kinetic energy is transferred from the protons to the neutrons. **4**

Question 29 (4 marks)

A coil is suspended as a pendulum with an ideal galvanometer (ammeter) meter loosely attached. A powerful electromagnet is powered on, as shown in *Experiment 1*. After some time, the galvanometer is replaced with an ideal voltmeter. The electromagnet is then powered off in *Experiment 2*.



Experiment 1



Experiment 2

With reference to the physics involved, explain the measurements seen in the meters and the observed motion of the coils. **4**

END OF EXAM 😁

Sydney Boys High School

Year 12 Physics Half Yearly Cohort Task 2023

Multiple Choice Answer Sheet

Please complete the answer sheet AND your NESA ID (starting with 3) below using a 2B pencil or mechanical pacer.
Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.
If you change your mind, use a clean eraser to make corrections.
Do **not** make any other markings on this page

NESA ID

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

NESA ID

0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9

Student Number:

Sydney Boys High School

Physics

March 2023
Half Yearly Cohort Task
Advanced Mechanics, Electromagnetics, Special Relativity

General Instructions

- Reading time: 5 minutes
- Working time: 90 minutes
- Write using black or blue pen
- Draw diagrams using pencil
- SHOW ALL WORKING
- Board approved calculators may be used
- A data sheet, formula sheets and Periodic Table are provided at the back of this paper
- Write your student number in ALL of the boxes provided

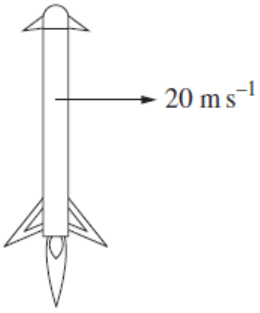
Total marks – 60

Part A – Multiple Choice
- 20 marks

Part B – Free Response
- 40 marks

PART A – Multiple Choice (20 Marks)

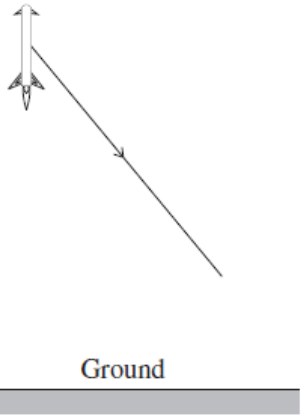
1. A rocket returns to Earth for reuse after launching satellites, using its engines to make a controlled landing.



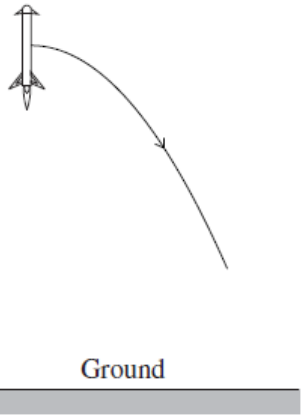
The rocket having an initial mass of 9000 kg is on approach to the ground, travelling horizontally at 20ms^{-1} as shown in the diagram, when the engine thrust is changed to 88 200N. Changing the thrust of the rocket causes the rocket to loose 500kg of mass.

Which diagram shows the trajectory of the rocket following this change of thrust?

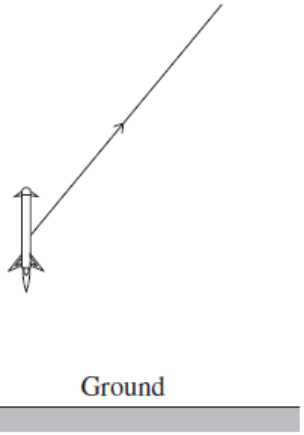
A.



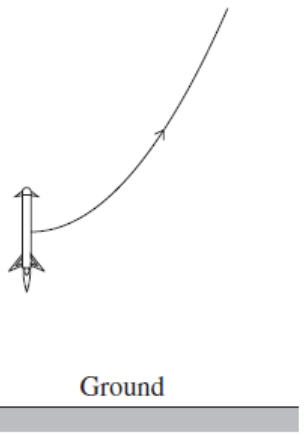
B.



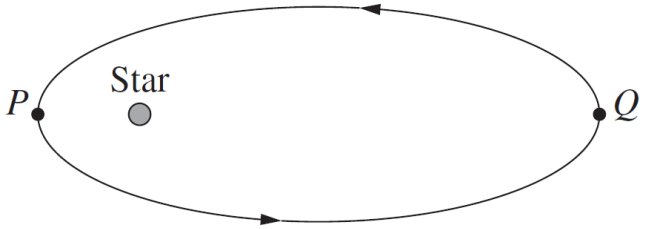
C.



D.



2. The elliptical orbit of a planet around a star is shown.



Which type of energy is greater at position P than at Q?

(A) Kinetic

(B) Gravitational

(C) Relativistic

(D) Total

3. Which of the following statements correctly describes the gravitational interaction between the Earth and the Sun?

(A) The Earth accelerates towards the Sun.

(B) The net force acting on the Earth is zero.

(C) The Sun and Earth experience equal and opposite accelerations.

(D) The force acting on the Earth is smaller than the force acting on the Sun.

4. The purpose of transformers in electrical circuits is

(A) To change from AC to DC

(B) To increase Voltage

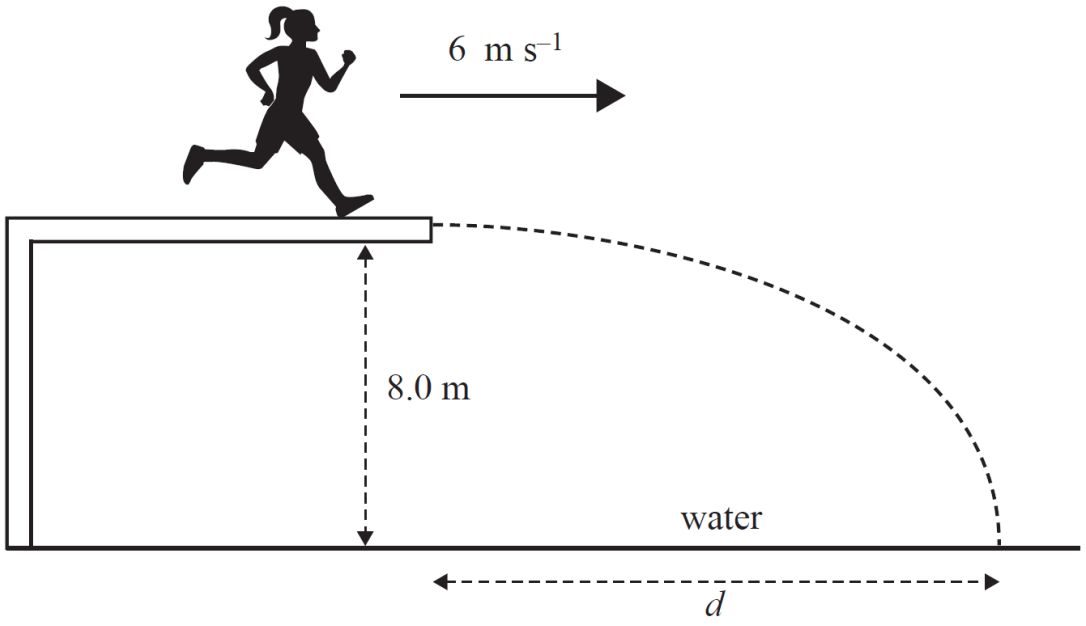
(C) To change Frequency

(D) To decrease Resistance

Use the following information to answer the next two questions

Alex is running horizontally at a speed of 6 m s^{-1} along a diving platform that is 8.0 m vertically above the water.

Alex runs off the end of the diving platform and reaches the water below after time t.
She lands feet first at a horizontal distance d from the end of the diving platform.



5. Which one of the following expressions correctly gives the distance d ?

(A) $0.8t$

(B) $6t$

(C) $5t^2$

(D) $6t + 5t^2$

6. Which one of the following is closest to the time taken, t, for Alex to reach the water below?

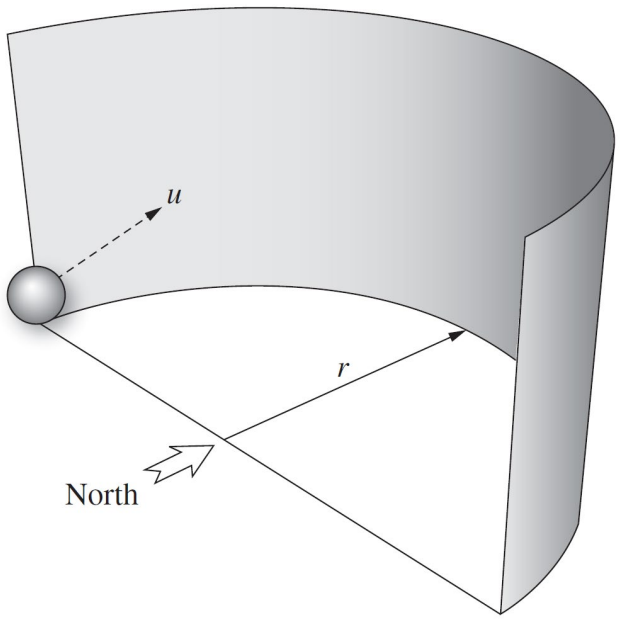
(A) 0.8 s

(B) 1.1 s

(C) 1.3 s

(D) 1.6 s

7. The diagram shows a smooth, semi-circular, vertical wall with radius, r. A ball is launched from the position shown with a velocity u towards north at an angle to the horizontal.



The ball follows a trajectory around the wall before landing on the ground, opposite its starting point. It does not reach the top of the wall.

Assume that there is no friction between the ball and the wall.

Which statement correctly describes the net force acting on the ball during its motion?

(A) The magnitude of the net force remains constant.

(B) The direction of the net force is vertically downwards.

(C) The direction of the net force is perpendicular to the wall.

(D) The magnitude of the net force reaches a minimum when the ball is at its highest point.

8. A satellite in circular orbit at a distance r from the centre of Earth has an orbital velocity v.

If the distance was increased to $3r$, what would be the satellite's orbital velocity?

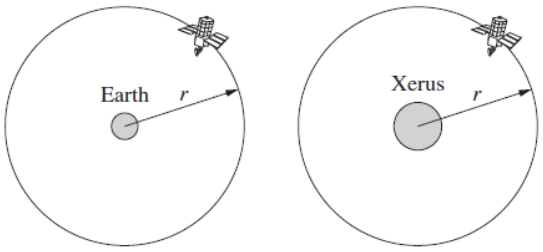
(A) $\frac{v}{3}$

(B) $0.6v$

(C) $1.7v$

(D) $3v$

9. A satellite orbits Earth with period T. An identical satellite orbits the planet Xerus which has a mass four times that of Earth. Both satellites have the same orbital radius r.



What is the period of the satellite orbiting Xerus?

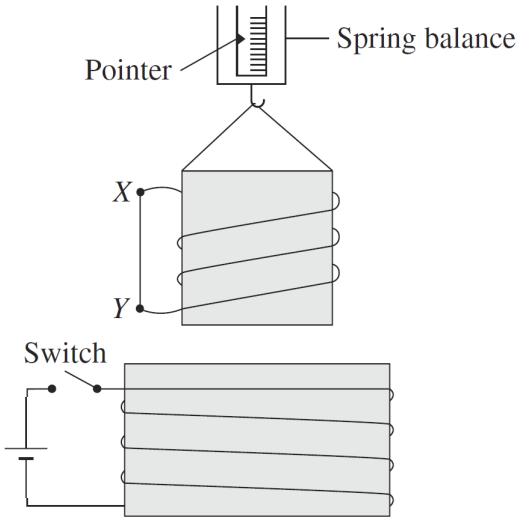
(A) T/4

(B) T/2

(C) 2T

(D) 4T

10. An experiment is set up as shown.



When the switch is opened, the reading on the spring balance changes immediately, then returns to the initial reading.

Which row of the table correctly shows the direction of the current through the straight conductor XY and the direction in which the pointer relative to the spring balance initially moves?

	Direction of current through the straight conductor	*Direction in which the pointer initially moves*
(A)	From *X* to *Y*	Down
(B)	From *X* to *Y*	Up
(C)	From *Y* to *X*	Down
(D)	From *Y* to *X*	Up

11. Calculate the maximum height reached by a projectile with and initial velocity of 15 ms^{-1} at and angle of 30° up from the horizontal

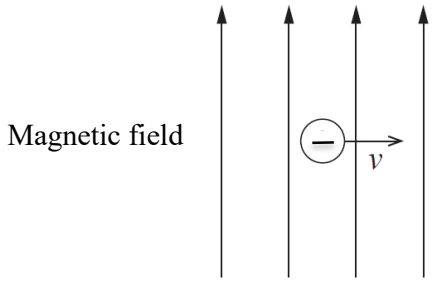
(A) 2.87m

(B) 3.83m

(C) 8.61m

(D) 11.5m

12. A negatively charged particle is moving at velocity, v, in a magnetic field as shown.



What is the direction of the force acting on the particle due to the magnetic field?

(A) Into the page

(B) Out of the page

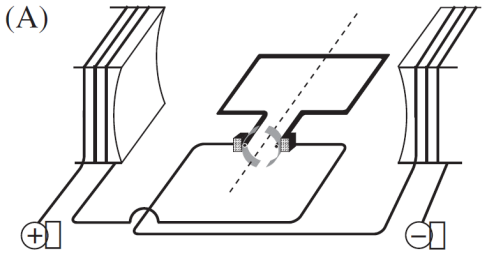
(C) Up the page

(D) Down the page

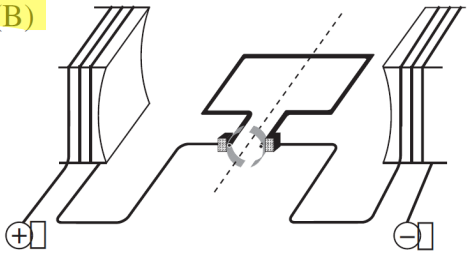
13. The diagrams show possible ways to connect the coils and rotor of a DC motor to a DC power supply.

In which circuit will the rotor turn in a clockwise direction?

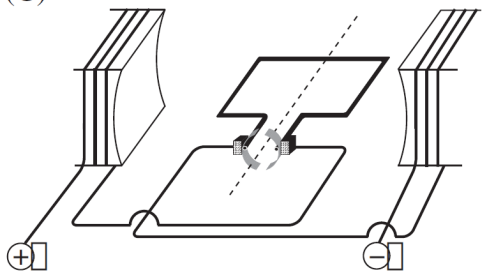
(A)



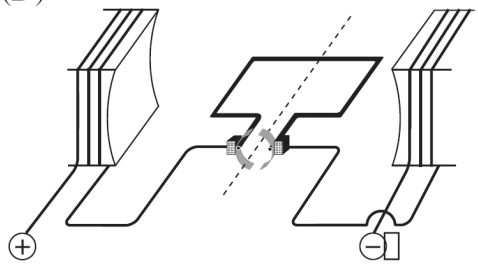
(B)



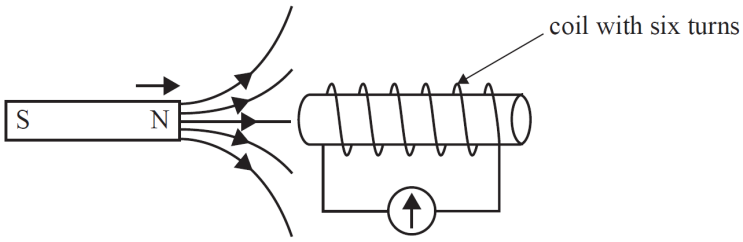
(C)



(D)



14. A magnet approaches a coil with six turns, as shown in the diagram below. During time interval Δt, the magnetic flux changes by 0.05 Wb and the average induced EMF is 1.2 V.



Which one of the following is closest to the time interval Δt?

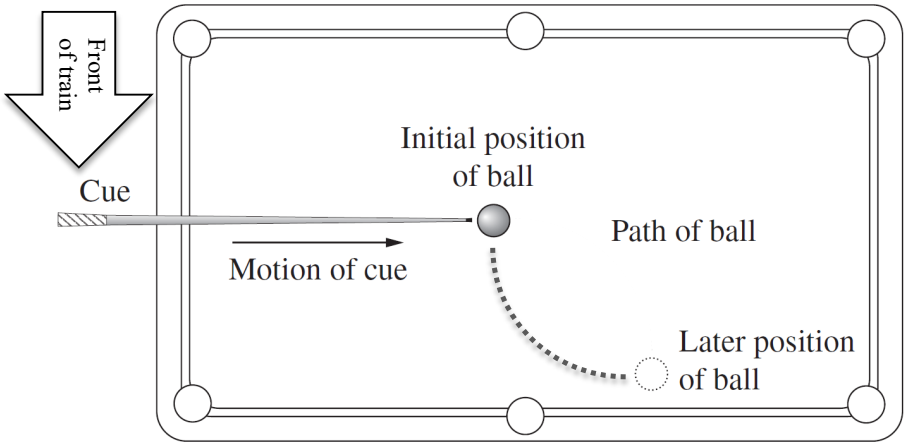
(A) 0.04 s

(B) 0.01 s

(C) 0.25 s

(D) 0.50 s

15. A passenger is playing billiards on a train that is travelling forwards as indicated on a level track. The ball takes the path shown when hit by the cue.



What can be inferred about the motion of the train?

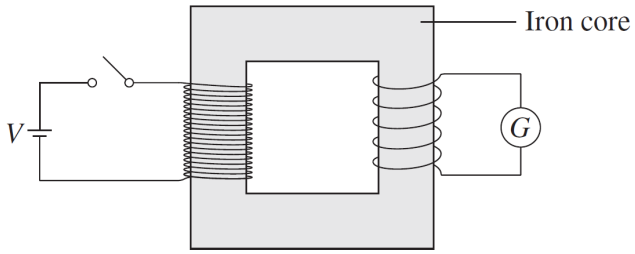
(A) It is turning left.

(B) It is speeding up.

(C) It is turning right.

(D) It is slowing down.

16. The diagram shows an ideal transformer.



When the switch is closed, the pointer on the galvanometer deflects. How could the size of the deflection be decreased?

(A) Decrease the number of primary coils.

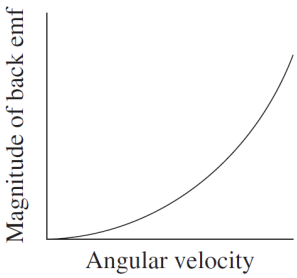
(B) Decrease the number of secondary coils.

(C) Increase the voltage of the DC power source.

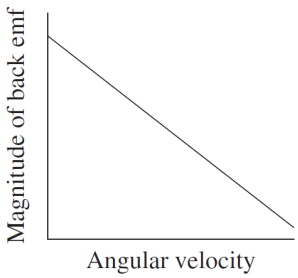
(D) Increase the current of the DC power source.

17. Which graph shows the magnitude of back emf induced in a DC motor rotating continuously at different angular velocities?

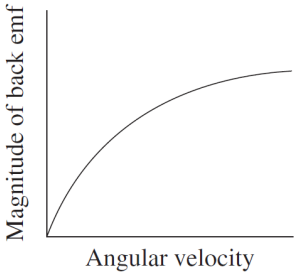
A.



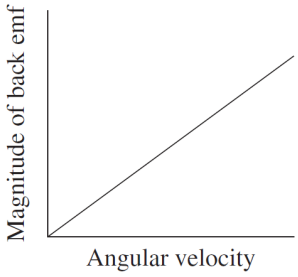
B.



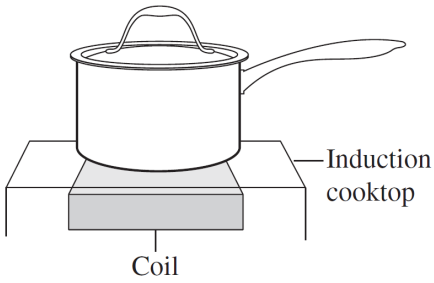
C.



D.



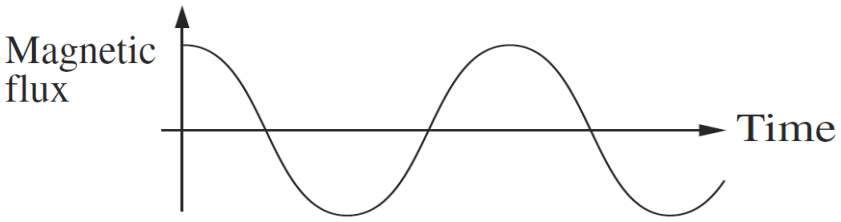
18. The diagram shows a saucepan of water on an induction cooktop.



Which row of the table correctly identifies a property of the material used to make the saucepan and the frequency of the changing magnetic field produced by the coil?

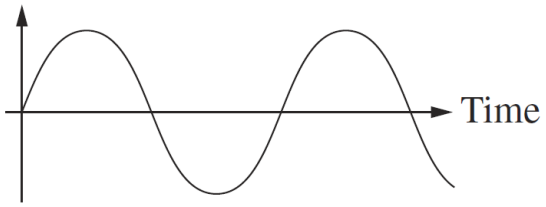
	Property of Saucepan	*Frequency*
(A)	High electrical resistance	50kHz
(B)	Low electrical resistance	50kHz
(C)	High electrical resistance	50Hz
(D)	Low electrical resistance	50Hz

19. The graph shows variation in magnetic flux through a coil with time.

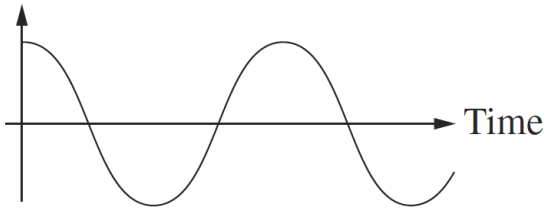


Which graph best represents the corresponding induced emf in the coil?

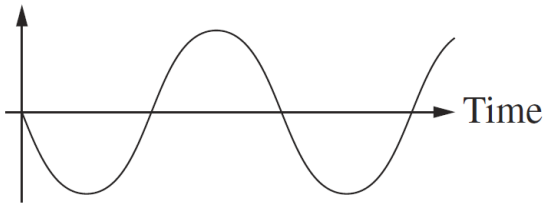
(A)



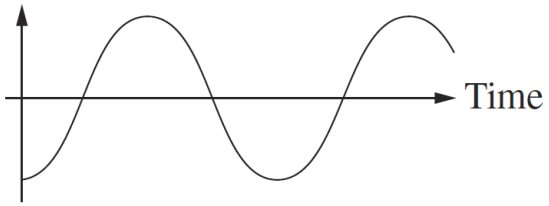
(B)



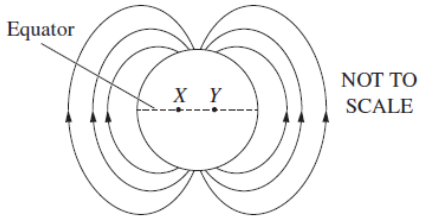
(C)



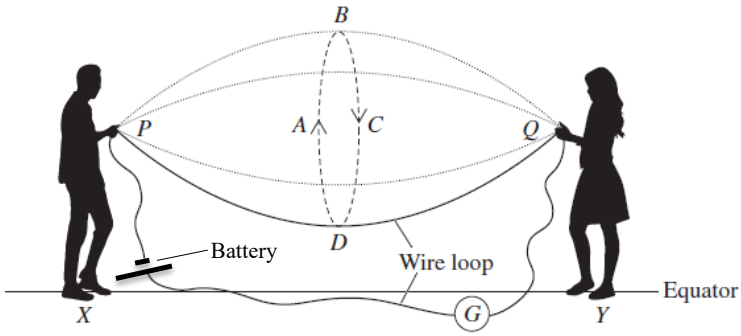
(D)



20. Earth's magnetic field is shown in the following diagram.



Two students standing a few metres apart on the equator at points X and Y, where Earth's magnetic field is parallel to the ground, hold a loop of copper wire between them. Part of the loop is rotated like a skipping rope as shown, while the other part remains motionless on the ground. A battery is connected in series in the wire.



At what point during the rotation of the wire does the maximum current flow through the galvanometer?

(A) A

(B) B

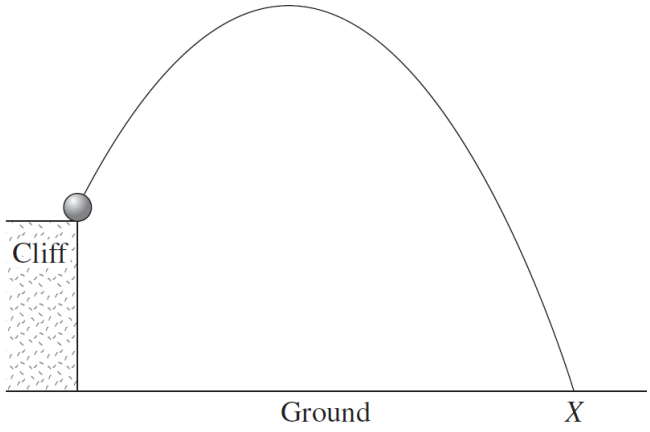
(C) C

(D) D

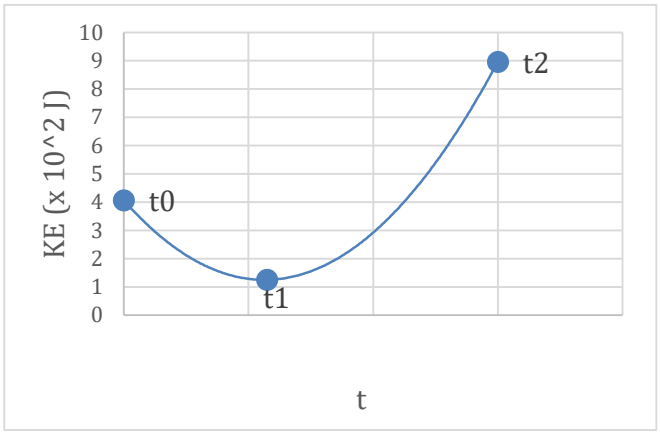
PART B – Short Answer (40 Marks)

Question 21 (5 marks)

A 2.50 kg mass is launched from the edge of a cliff.



The kinetic energy of the mass is graphed from the moment it is launched until it hits the ground at *X*. The kinetic energy of the mass is provided for times t_0, t_1 and t_2.



Time (t)	*KE (J)*
t_0	406
t_1	125
t_2	896

From the information provided, calculate the horizontal and vertical components (u_x and u_y) of the initial velocity of the ball at launch. **2**

At t_1, motion is only horizontal, so kinetic energy is only due to v_x:

$K_1 = \frac{mv_x^2}{2} \rightarrow u_x = v_x = \sqrt{\frac{2K_1}{m}} = \sqrt{\frac{2\times125}{2.50}} = 10.0 \text{ m s}^{-1}$

Given that the horizontal velocity is constant, its contribution to kinetic energy is constant. Thus,

vertical contribution at launch is:

$K_y = K_0 - K_1 = 406 - 125 = 281 \text{ J}$

$K_y = \frac{mu_y^2}{2} \rightarrow u_y = \sqrt{\frac{2K_y}{m}} = \sqrt{\frac{2\times281}{2.50}} = 14.99 = 15.0 \text{ m s}^{-1}$

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

$v^2 = v_y^2 + v_y^2$

$K = K_x + K_y$

$K_y = \frac{1}{2}mv_y^2$

$K_x = \frac{1}{2}mv_x^2$

✓ correctly calculates u_x

✓ correctly calculates u_y

b Using the information provided, calculate the range of the ball. **3**

Given that the horizontal velocity is constant, its contribution to kinetic energy is constant. Thus, vertical contribution at the landing point is:

$$K_y = K_2 - K_1 = 896 - 125 = 771 \text{ J}$$

$K_0 = \frac{mv_y^2}{2} \rightarrow v_y = \sqrt{\frac{2K_0}{m}} = \sqrt{\frac{2\times771}{2.50}} = 24.84 \text{ m s}^{-1}$

From vertical components of velocity:

$v_y = u_y + a_y t \rightarrow t = \frac{v_y - u_y}{a_y} = \frac{-24.84-14.99}{-9.8} = 4.064 \text{ s}$

From horizontal components of velocity:

$v_x = \frac{s_x}{t} \rightarrow s_x = v_x t = 10.0 \times 4.064 = 40.64 = 40.6 \text{ m}$

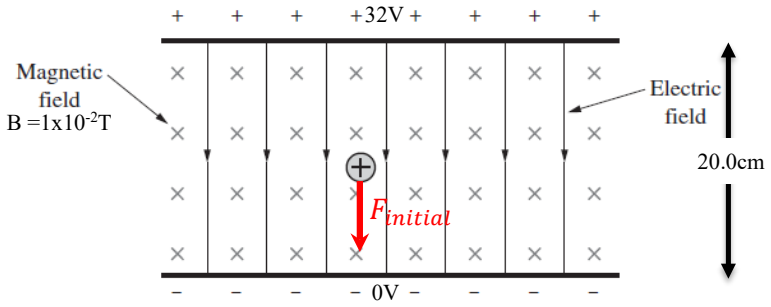
✓ correctly uses appropriate equations

✓ calculates t

✓ correct range for calculated t, including units

Question 22 (4 marks)

The diagram below shows a region in which there are uniform electric and magnetic fields. The potential difference between the plates is measured to be 32V, and they are 20.0cm apart. The magnetic field is $1\text{x}10^{-2}$T. A stationary proton is placed at the centre of the fields with no motion.



a Indicate the initial direction of the force on the proton in the diagram with a vector diagram **1**

✓ correct direction (down)

b The proton is allowed to move towards one of the charged plates. Calculate the net force on the proton as it hits the plate. **3**

$F_E = qE = q\frac{V}{d} = 1.602 \times 10^{-19} \times \frac{32}{20.0 \times 10^{-2}} = 2.563 \times 10^{-17}$ N downwards

$F = ma \quad \rightarrow \quad a = \frac{F}{m} = \frac{2.563 \times 10^{-17}}{1.673 \times 10^{-27}} = 1.532 \times 10^{10}$ m s^{-2}

$v^2 = u^2 + 2as \quad \rightarrow \quad v = \sqrt{u^2 + 2as} = \sqrt{0^2 + 2 \times 1.532 \times 10^{10} \times 0.100} = 5.535 \times 10^4$

Given that proton is moving downwards, perpendicular to the magnetic field:

$F_B = qvB = 1.602 \times 10^{-19} \times 5.535 \times 10^4 \times 1 \times 10^{-2} = 8.862 \times 10^{-17}$ N to the right

$F_{net} = \sqrt{F_E^2 + F_B^2} = \sqrt{(2.563 \times 10^{-17})^2 + (8.862 \times 10^{-17})^2} = 9.23 \times 10^{-17}$ N

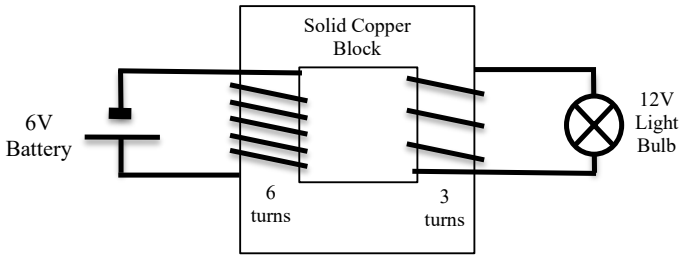
✓ correctly uses an appropriate equation

✓ additional work to correctly calculate F_E & F_B

✓ correctly adds $\vec{F}_E$ and $\vec{F}_B$ (answer has units)

Question 23 (3 marks)

A student creates a model for a step-up transformer to power a light bulb. The student uses a 6v battery, a copper block, wires and a 12v light bulb. This is shown in the diagram below. **3**



On setting up the equipment the student noticed the lightbulb failed to light up. Explain why this setup failed, and what can be done to improve it.

There are three issues that need to be rectified in order for the setup to work:

Feature	*Issue*	*Improvement*
Power supply	The battery is DC, but transformers only work with the constantly changing magnetic flux associated with an AC input.	The DC battery must be changed to an AC power supply.
~~*Transformer core*~~	~~The metal used for the transformer~~ core is copper, which is not ferromagnetic. The primary and ~~secondary coils must be~~ magnetically linked.	~~The copper block must be~~ replaced by a laminated soft iron core.
Insufficient voltage	The transformer is being used as a step-down transformer, with an output voltage of half the input voltage (3V in the above example).	(i) Swap N_p and N_s (ii) Increase N_s to 12 (iii) Change the V_p to 24 V

✓ describes ONE setup error and ONE improvement

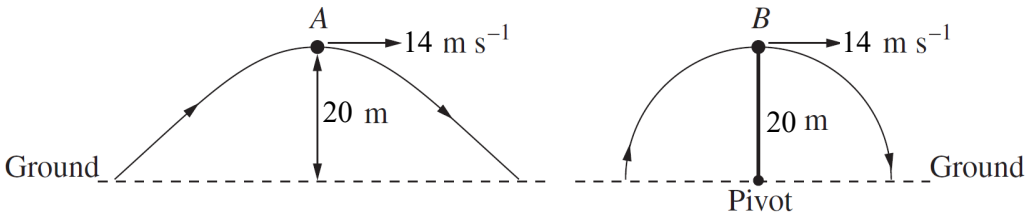
✓ describes FOUR setup errors / improvements

✓ describes SIX setup errors / improvements

Question 24 (5 marks)

A 30 kg object, *A*, was fired from a cannon in projectile motion. When the projectile was at its maximum height of 20 m, its speed was 14 ms^{-1}.

To simulate this motion, an identical object, *B*, was attached to a rigid mechanical arm and moved at a constant speed of 14 ms^{-1} in a vertical half-circle. The length of the arm was 20 m.



a Calculate the time of flight for objects *A* and *B*, from the time it leaves the ground to the time it returns to the ground **2**

$s_y = u_y t_1 + \frac{1}{2} a_y t_1^2$

$-20 = 0 - 4.9 t_1^2$

$t_1 = 2.02\ s$

total $t = 2t_1 = 4.04s$ (1)

$t_2 = \frac{s}{v} = \frac{\pi r}{v} = \frac{20\pi}{14} = 4.49s$ (1)

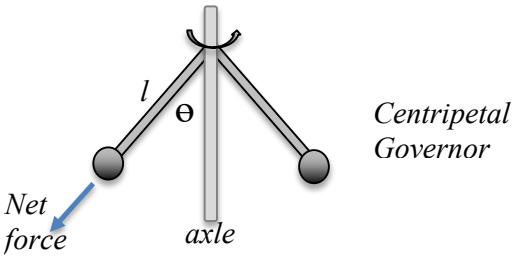
- ✓ Correctly calculates time of flight for object A (4.04s)
- ✓ Correctly calculates time of motion for object B (4.49s)

b By comparing the net forces and the time of flight for both objects; assess whether the simulation with object *B* was valid for object *A*. **3**

- ✓ Object A: 294N down, weight force; Object B: 294N towards pivot, centripetal force. Mark lost if direction of force not considered.
- ✓ Time of flight compared for objects A and B
- ✓ Object B is NOT a valid simulation of object A

Question 25 (3 marks)

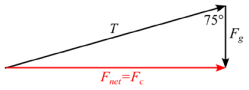
A *centripetal governor* is a device used to limit the rotational speed of machines by using masses m suspended on rigid arms of length l around a rotating axle. As the axle rotates, the balance of forces causes the masses to move away from the axle. Once a predetermined angle Θ has been reached, the axle disengages. **3**



Calculate the length required to limit the rotation of the machine to 240RPM if Θ is 75°.

The masses at the ends of the arms are subjected to F_g (force due to gravity) and T (tension in the arms). Looking at a force diagram of forces acting on the mass at the end of the left arm:

$$\tan\theta = \frac{F_c}{F_g} = \frac{\frac{mv^2}{r}}{mg} = \frac{v^2}{rg}$$



Given that $\omega = \frac{\Delta\theta}{t} = \frac{2\pi}{T}$ and $v = \frac{2\pi r}{T}$, then $v = \omega r$. Substituting gives:

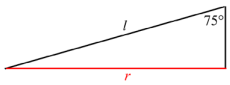
$$\tan\theta = \frac{(\omega r)^2}{rg} = \frac{\omega^2 r^2}{rg} = \frac{\omega^2 r}{g}$$

Therefore:

$$r = \frac{g\tan\theta}{\omega^2}$$

Form the geometry of the arm:

$$r = l\sin\theta$$



Therefore:

$$l\sin\theta = \frac{g\tan\theta}{\omega^2}$$

$$l = \frac{g\tan\theta}{\omega^2\sin\theta} = \frac{g}{\omega^2\cos\theta} \quad \left(\text{since } \tan\theta = \frac{\sin\theta}{\cos\theta}\right)$$

Given that $\omega = 240\times\frac{2\pi}{60} = 8\pi$, then:

$$l = \frac{g}{64\pi^2\cos\theta} = \frac{9.8}{64\times\pi^2\cos 75} = 0.0599 \text{ m} = 6.0 \text{ cm}$$

- ✓ Resolution of forces
- ✓ Geometry working out
- ✓ Correct answer (6cm)

Question 26 (3 marks)

a Calculate the change in energy required to move a spacecraft of mass of 2.25×10^3 kg from a circular orbit around earth with an altitude of 3.50×10^7 m to another circular orbit with an altitude of 3.50×10^5 m. **3**

$$E_{T\,initial} = \frac{-GMm}{2r} = \frac{-6.67\times10^{-11}\times6\times10^{24}\times2.25\times10^{3}}{2\times(3.5\times10^{7}+6.371\times10^{6})} = -1.088\times10^{10}\text{ J}$$

$$E_{T\,final} = \frac{-6.67\times10^{-11}\times6\times10^{24}\times2.25\times10^{3}}{2\times(3.5\times10^{5}+6.371\times10^{6})} = -6.699\times10^{10}\text{ J}$$

$$\Delta E = E_{final} - E_{initial}$$

$$= -6.699\times10^{10}\text{J} + 1.088\times10^{10}\text{J}$$

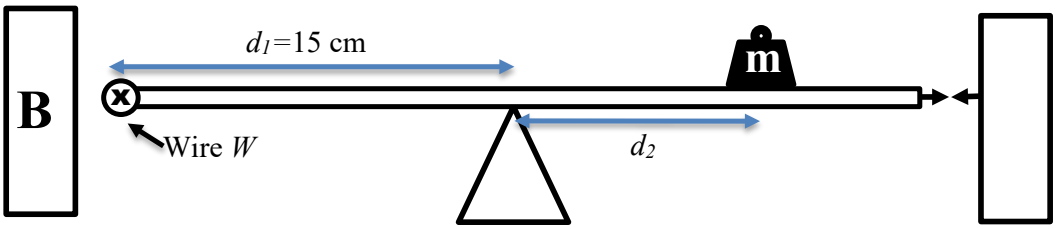
$$= -5.61\times10^{10}\text{J}$$

Energy needs to be lost

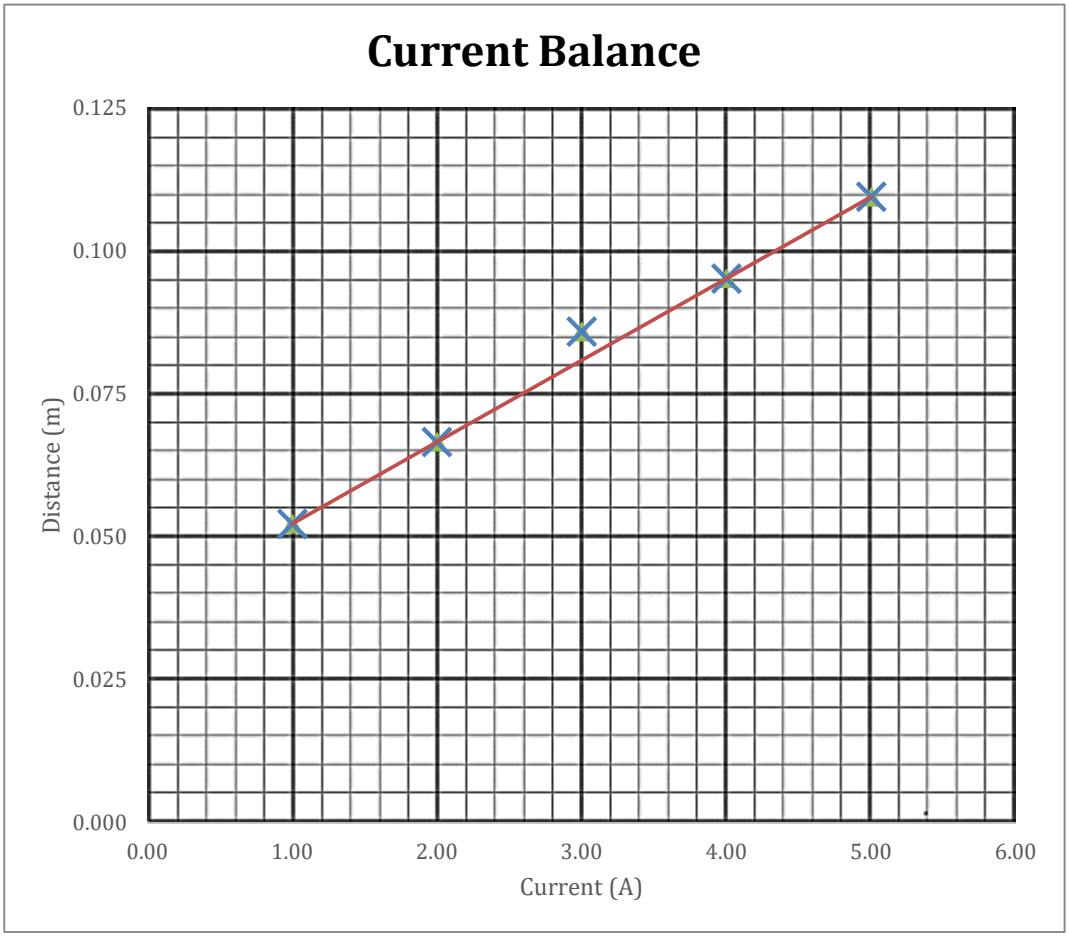
1 mark: Some energy calculated
2 marks: Total energy equation used, one of the energies calculated
3 marks: Work correctly calculated (5.61 x 10^{10}J needs to be lost, or -5.61 x 10^{10}J)

Question 27 (6 marks)

A *current balance* was set up as below. The arms of the balance are 15cm long, and a small mass of 1.5g is used to counterbalance the wire so that the balance is in equilibrium. The wire that is exposed to the magnetic field is 2cm long has a mass $\mathbf{m_w}$. A current ***I*** is passed through the wire ***W***, which deflects the balance. The mass **m** is moved along the other arm of the balance to restore the apparatus to the equilibrium. The distance of the mass from the pivot is recorded, along with the current.



The results are graphed below



a From the graph provided, calculate the strength of the magnetic field provided by the magnet B. **3**

At equilibrium, the magnitudes of the torques for each arm of the balance are equal

$$\tau = |F_B d_1| = |F_w d_2|$$

$$F_B d_1 = mgd_2$$

$$F_B = \frac{mg\, d_2}{d_1} = BIl$$

$$B = \frac{mg\, d_2}{Ild_1} = \frac{d_2}{I} \cdot \frac{mg}{ld_1}$$

$\frac{d_2}{I} = gradient$;

$from\ the\ graph,\ gradient = \frac{y_2 - y_1}{x_2 - x_1} = 0.0143mA^{-1}$;

$$B = gradient \cdot \frac{mg}{ld_1}$$

$$= 0.0143 \cdot \frac{0.0015 \times 9.8}{0.02 \times 0.15}$$

$$= 0.07T$$

- ✓ Calculates gradient from the graph
- ✓ Uses the motor effect equation F=BIl
- ✓ Correctly calculates B field

b From the graph, calculate the mass of the wire m_w. **3**

From graph, y intercept = 0.038m

At I=0

$$m_w d_1 = md_2$$

$$m_w = \frac{m\, d_2}{d_1} = \frac{0.0015 \times 0.038}{0.15}$$

$$m_w = 0.00038\ kg = 0.38g$$

- ✓ Uses y intercept from the graph (0.038)
- ✓ Uses gradient from graph
- ✓ Correctly calculates the mass of the wire (0.38g)

Question 28 (7 marks)

A *particle accelerator* is used to accelerate clouds of protons from a stationary position to extremely high velocities. The accelerator is measured to have accelerated the protons to a speed of $2.7 \times 10^{8}\ ms^{-1}$ in 151.0×10^{-3}s.

a Calculate the momentum of the protons. **3**

$$p_v = \frac{m_0 v}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$= \frac{1.673 \times 10^{-27} \times 2.7 \times 10^{8}}{\sqrt{1 - \frac{(2.7 \times 10^{8})^2}{(3.0 \times 10^{8})^2}}}$$

$$= 1.04 \times 10^{-18}\ kgms^{-1}$$

- ✓ 1 mark: Identifies that relativistic momentum must be used.
- ✓ 2 marks: Use of relativistic momentum equation (incorrect substitutions)
- ✓ 3 marks: Correct answer 1.04×10^{-18} kgms^{-1}

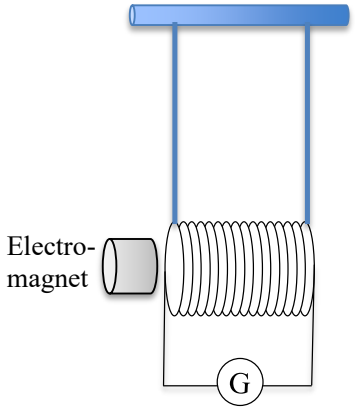
b The protons elastically collide with stationary free neutrons, which have a half-life of 15mins and a diameter of 1.7×10^{-15} m. Explain any observations that will be made about the neutrons, given the limitations of classical physics. Assume the neutrons to have an equivalent mass to that of the protons, and all the kinetic energy is transferred from the protons to the neutrons. **4**

- ✓ The speed of the particles are close to the speed of light, SR considered
- ✓ SR explained due to the constancy of c OR quantitative analysis of relativistic effects
- ✓ Length contraction seen in the diameter of the neutrons
- ✓ Time dilation in the half life of the neutron

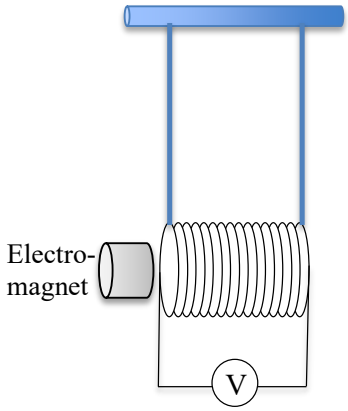
As the collision is said to be elastic, all the kinetic energy is transferred from the protons to neutrons. As such, the neutrons will travel at an equivalent velocity due to the similar masses. This velocity (2x107ms-1) is 0.9c, which would imply that special relativity needs to be considered. Under classical physics, there would be no change in the half life and the size of the neutrons, but under special relativity the neutron would undergo time dilation and length contraction. The half life of the neutron would be observed the be far longer than 15 minutes, and the radius of the neutron would be shorter than 1.7×10-15 m in the direction of travel. This is due to the constancy of the speed of light in all reference frames. The consequence to this is that observed time must dilate on objects that move at relativistic speeds, and the measured lengths of objects will appear to contract in the direction of travel.

Question 29 (4 marks)

A coil is suspended as a pendulum with an ideal galvanometer (ammeter) meter loosely attached. A powerful electromagnet is powered on, as shown in *Experiment 1*. After some time, the galvanometer is replaced with an ideal voltmeter. The electromagnet is then powered off in *Experiment 2*.



Experiment 1



Experiment 2

With reference to the physics involved, explain the measurements seen in the meters and the observed motion of the coils. **4**

- ✓ Experiment 1 will see the galavanometer deflect and the coil move (mark lost if any mention of magnet moving into the coil)
- ✓ Experiment 2 will see the voltmeter deflect but will not see the coil move
- ✓ Faraday's law explained in BOTH experiments (deflection in voltmeter, back to 0)
- ✓ Lenz's law explained in BOTH (lack of current in experiment 2)

In experiment 1, the coil will experience a change in magnetic flux when the electromagnet is powered on. By faraday's law, the coil will generate and EMF. As the galvanometer has very little electrical resistance, it will allow a current to flow. This allows the formation of a magnetic field, which by Lenz's law, will oppose the magnetic field of the electromagnet. This will cause the coil to swing away from the electromagnet to the right. The galvanometer will see a deflection, but returns to 0 as the change in flux is temporary.

When voltmeter replaces the galvanometer in experiment 2, the meter prevents the formation of any magnetic fields as a voltmeter has a large electrical resistance. When the electromagnet is powered off, the coil once again sees a change in magnetic flux, but will see no motion. The voltmeter will see a deflection as there is an EMF induced, but will drop to 0 as the change in flux drops to 0 once again.

END OF EXAM 😁