Sydney Boys High School

Year 11 Physics Half Yearly Cohort Task 2021

Multiple Choice Answer Sheet

Please complete the answer sheet AND your Student ID 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

Student ID

1	A ○	B ○	C ○	D ○
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19	A ○	B ○	C ○	D ○
20	A ○	B ○	C ○	D ○

Student ID

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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 2021
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

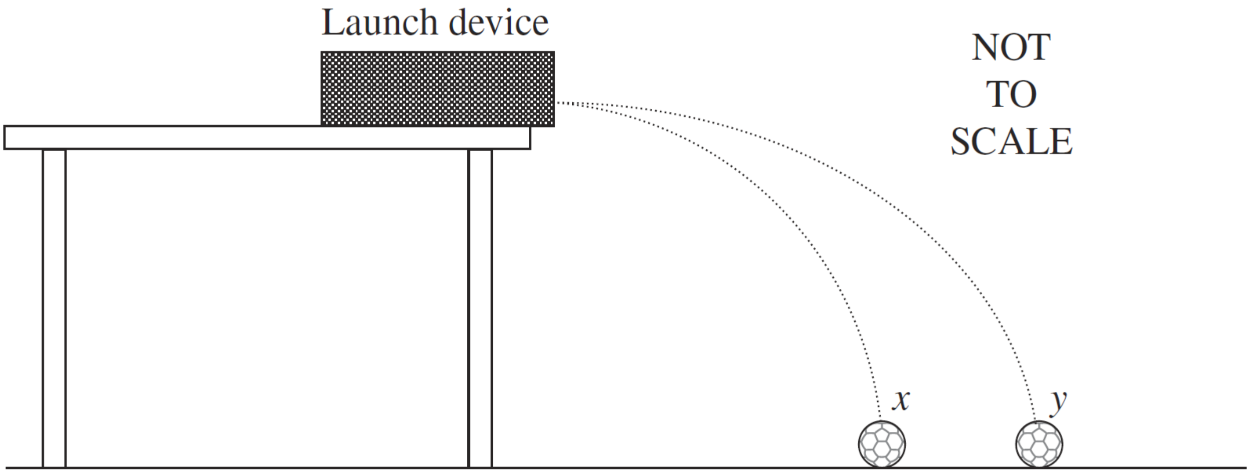
Total marks – 60

Part A – Multiple Choice
- 20 marks

Part B – Free Response
- 40 marks

PART A – Multiple Choice (20 Marks)

1. A device launches two identical balls (x and y) simultaneously in a horizontal direction from the same height. The results are shown.



Which statement correctly describes what happens?

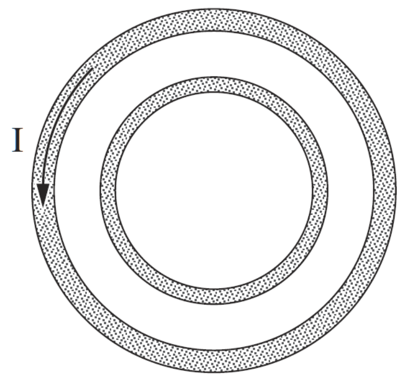
(A) *x* hits the ground before *y* as it is closer to the launch site.

(B) *y* hits the ground before *x* as it has a higher launch velocity.

(C) *x* and *y* hit the ground simultaneously with the same velocity.

(D) *x* and *y* hit the ground simultaneously with different velocities.

2. Two copper rings lie in the same plane as shown.



A decreasing current flows clockwise around the outer ring.
What happens in the inner ring?

(A) A decreasing clockwise current flows.

(B) A decreasing anticlockwise current flows.

(C) An increasing clockwise current flows.

(D) An increasing anticlockwise current flows.

3. Two masses have a gravitational force of 12 N between them.

If the distance between the masses is doubled, what would be the new gravitational force between them?

(A) 3 N

(B) 6 N

(C) 12 N

(D) 24 N

4. A scientist at a particle accelerator laboratory observes the lifetime of a particular subatomic particle to be 1.0×10^{-6} s when it is travelling at 0.9999 c.

What would the lifetime of the particle be if it were stationary in the laboratory?

(A) 1.4×10^{-8} s

(B) 4.5×10^{-8} s

(C) 1.0×10^{-6} s

(D) 7.1×10^{-5} s

5. A student throws a ball that follows a parabolic trajectory. What change to the initial velocity would make the ball's time of flight shorter?

(A) Increasing only the vertical component

(B) Decreasing only the vertical component

(C) Increasing only the horizontal component

(D) Decreasing only the horizontal component

6. A satellite, initially in a low Earth orbit, is moved to a new orbit where its gravitational potential energy is twice its initial value.

What is the gravitational force experienced by the satellite in its new orbit?

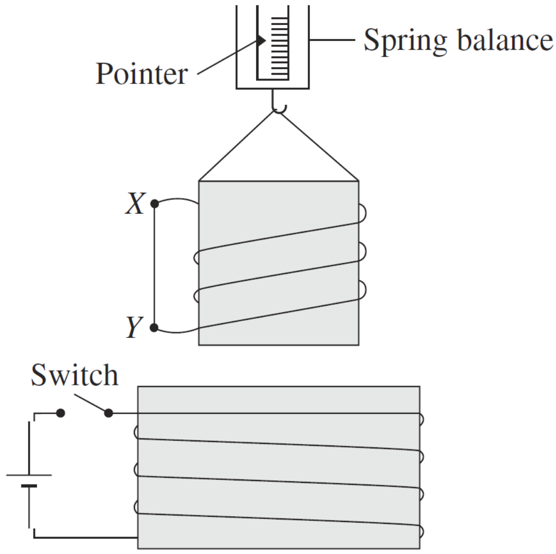
(A) Half the initial force

(B) Twice the initial force

(C) Four times the initial force

(D) One quarter the initial force

7. An experiment is set up as shown.



When the switch is closed, 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

8. A spaceship moves close to the speed of light, relative to a planet.

The rest-frame length of the spaceship can be determined by an observer who is

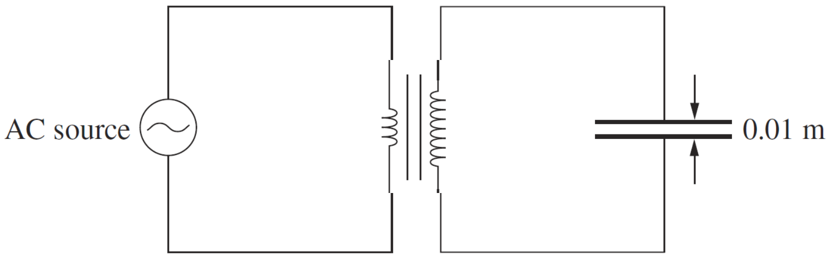
(A) on the spaceship measuring the time taken for light to travel between two points on the planet.

(B) on the planet measuring the time taken for light to travel from the front to the back of the spaceship.

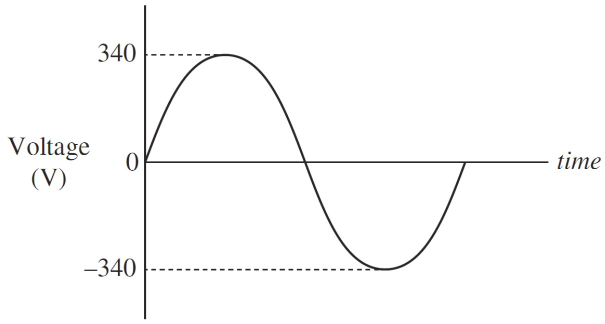
(C) on the spaceship measuring the time taken for light to travel from the front to the back of the spaceship.

(D) on the planet measuring the difference in the arrival time of light from the front and the back of the spaceship.

9. An AC source is connected to a transformer having a primary winding of 450 turns. Connected to the secondary winding of 900 turns is a pair of parallel plates 0.01 m apart.



The AC input is shown in the graph.



What is the maximum field strength (in V m^{-1}) produced between the plates?

(A) 1.7

(B) 6.8

(C) 1.7×10^4

(D) 6.8×10^4

Use the data below to answer the next two questions.

Orbital period of the Moon around Earth	2.36×10^6 s
Mean orbital radius of the Moon	3.83×10^8 m
Mass of Earth	6.00×10^{24} kg
Mass of the Moon	7.35×10^{22} kg

10. What is the orbital period of an Earth satellite having an orbital radius half that of the Moon?

(A) 5.9×10^5 s

(B) 8.3×10^5 s

(C) 1.2×10^6 s

(D) 7.5×10^6 s

11. What is the gravitational force experienced by the Moon due to Earth's influence?

(A) 2.0×10^{20} N

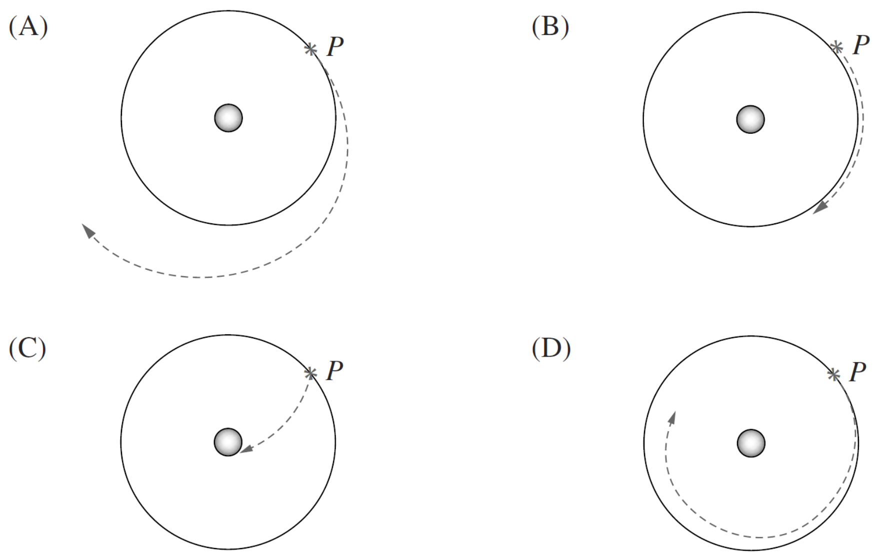
(B) 1.6×10^{22} N

(C) 4.7×10^{26} N

(D) 7.6×10^{28} N

12. A space probe, P, is in a stable orbit around a small, distant planet. The probe fires a forward-facing rocket that reduces its orbital speed by half.

Which of the following best illustrates the subsequent motion of the probe?



13. An ideal electric motor connected to a DC voltage source rotates at a constant rate of 200 revolutions per minute. There is no load on the motor.
Which of the following is a correct statement about the operation of the motor?

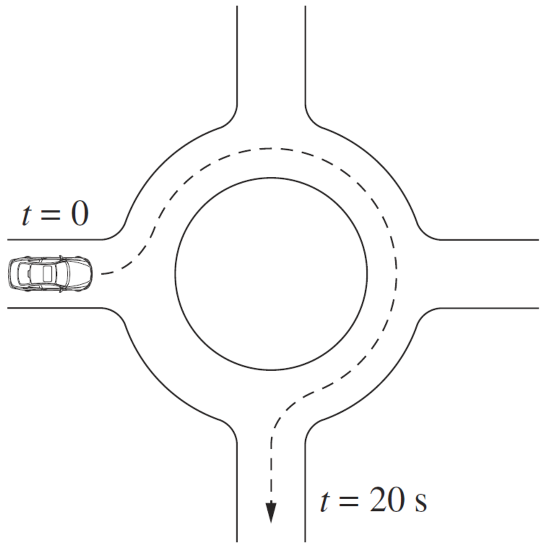
(A) The applied voltage must exceed the back emf in order to keep the motor running.

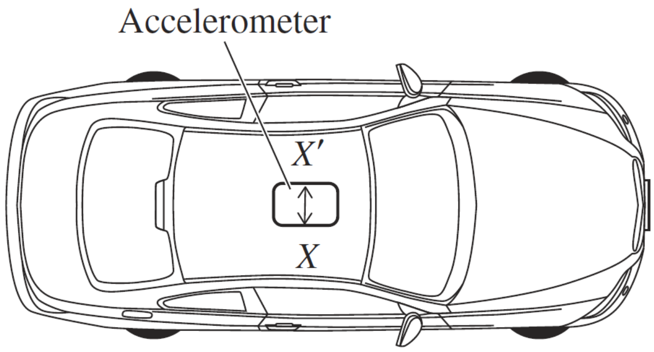
(B) There is no back emf because it is only produced in AC motors due to the changing flux.

(C) The back emf is equal to the applied voltage because no work is being done by the motor.

(D) The back emf must exceed the applied voltage to prevent the motor's speed from increasing.

14. A car travelling at a constant speed follows the path shown.

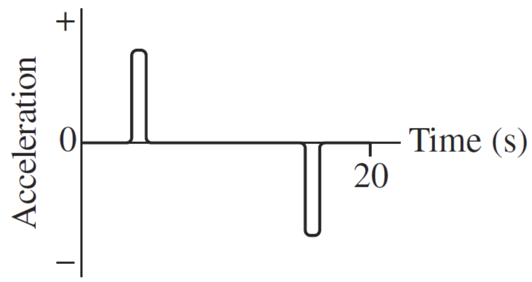




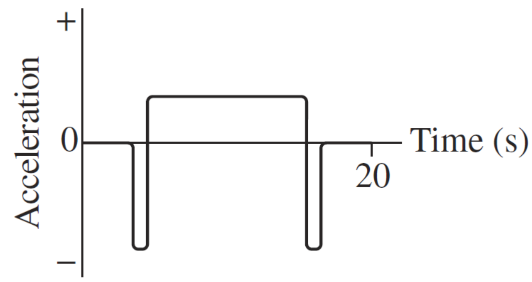
An accelerometer that measures acceleration along the *X*–*X′* direction is fixed in the car.

Which graph shows the measurements recorded by the accelerometer over the 20-second interval?

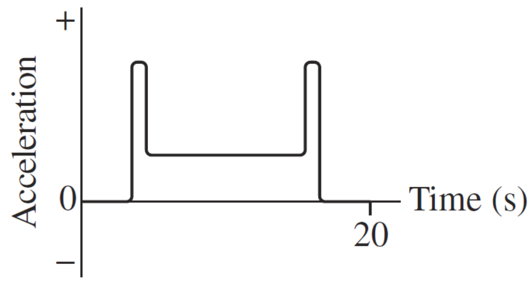
A.



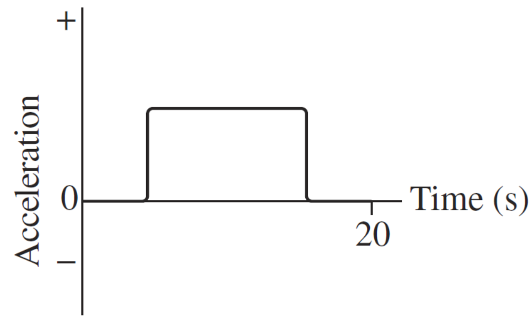
B.



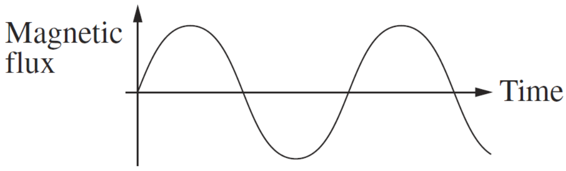
C.



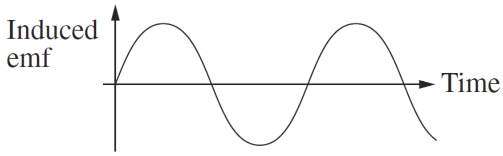
D.

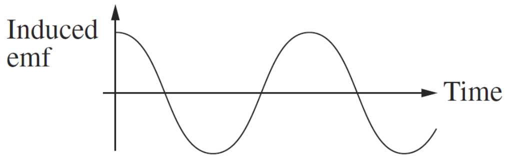


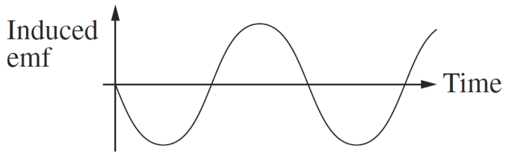
15. The graph shows variation in magnetic flux through a coil with time.

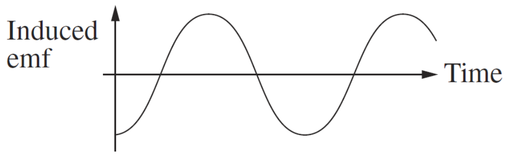


Which graph best represents the corresponding induced emf in the coil?

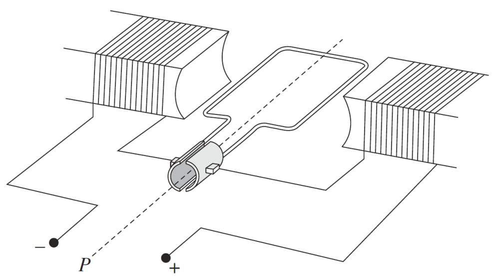
(A) 

(B) 

(C) 

(D) 

16. In the motor shown, the rotor spins clockwise, as viewed from point *P*, when connected to a DC supply



What happens when the motor is connected to an AC supply?

(A) The field magnets maintain their field orientation.

(B) The field magnets alternate their field orientation.

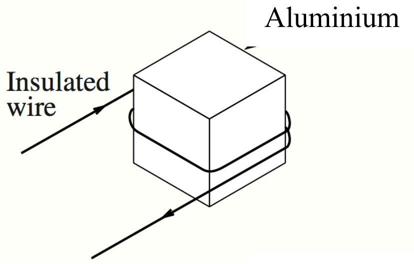
(C) The rotor vibrates at half the frequency of the AC supply.

(D) The rotor continuously turns half a rotation clockwise, then half a rotation anticlockwise.

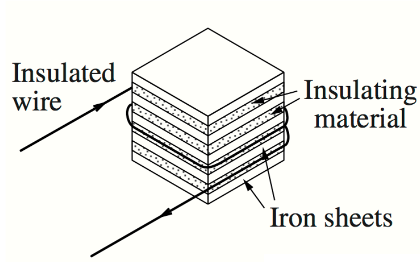
17. A transformer is to be designed so that it is efficient, with heating by eddy currents minimised. The designer has some metal and insulating material available to build the transformer core. The windings are to be made with insulated copper wire.

Which of the following designs transfers the most energy to the secondary coil?

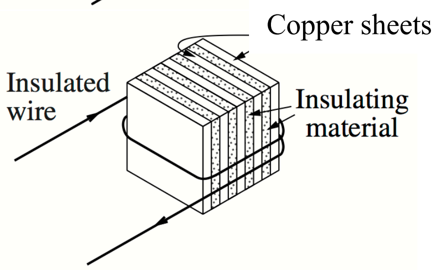
(A)



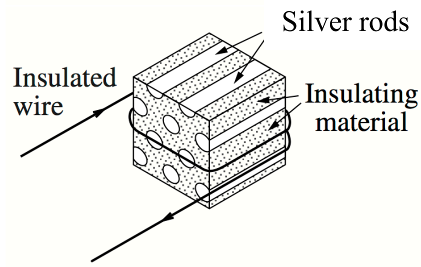
(B)



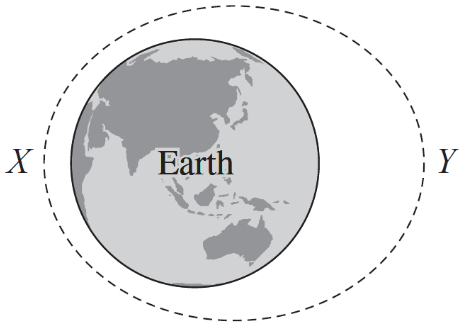
(C)



(D)



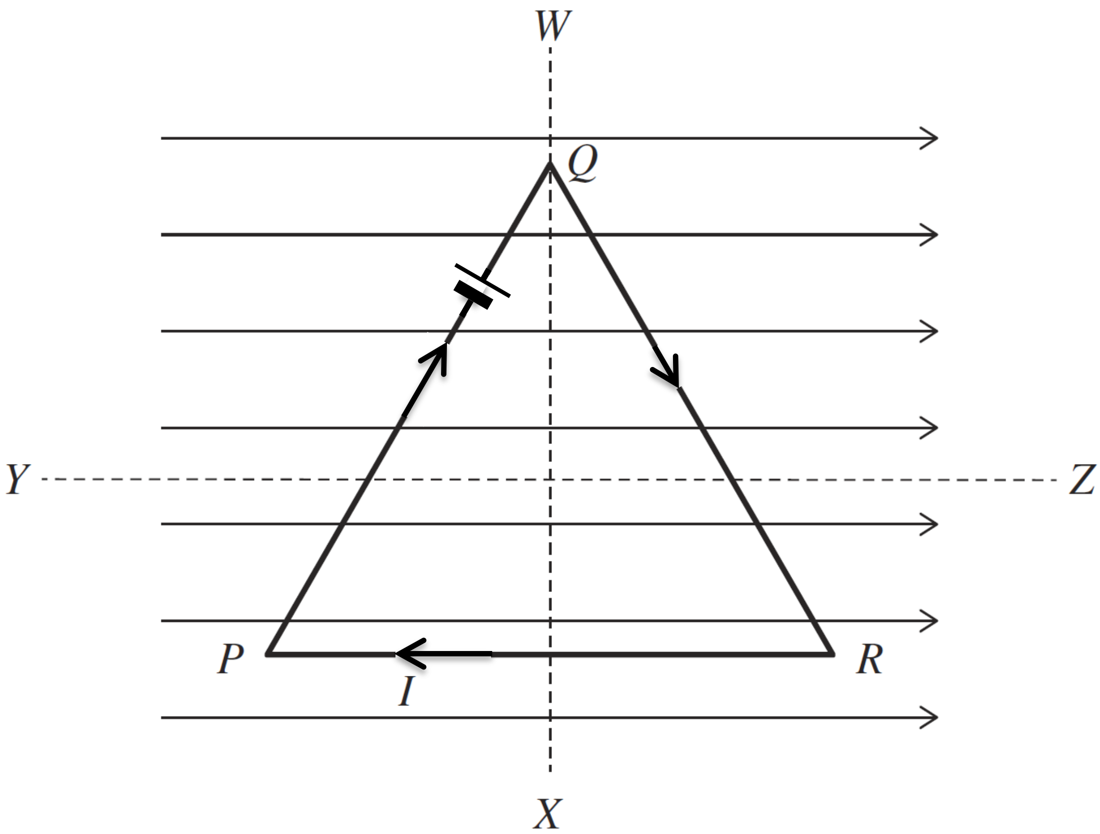
18. A satellite orbits Earth with an elliptical orbit that passes through positions X and Y.



In terms of absolute value only, which orbital positions would have least orbital speed V_{orb} and greatest gravitational potential E_P?

	Least V_{orb} (absolute value)	*Greatest E_P (absolute value)*
(A)	*X*	*X*
(B)	*X*	*Y*
(C)	*Y*	*X*
(D)	*Y*	*Y*

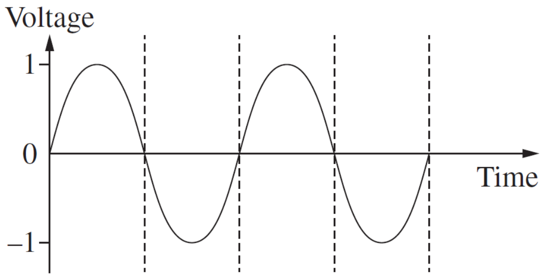
19. A triangular piece of wire is placed in a magnetic field as shown.



When current I is supplied as shown, how does the wire move?

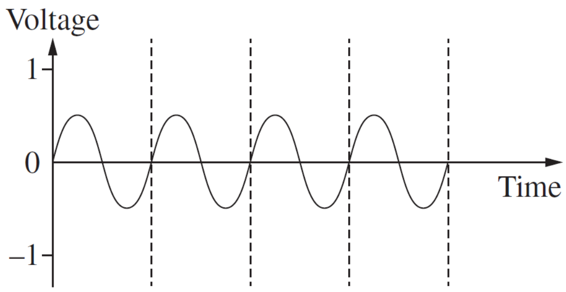
	Axis of rotation	*Direction of movement*
(A)	YZ	Q into page
(B)	YZ	Q out of page
(C)	WX	R out of page
(D)	WX	R into page

20. A simple AC generator was connected to a cathode ray oscilloscope and the coil was rotated at a constant rate. The output is shown on this graph.

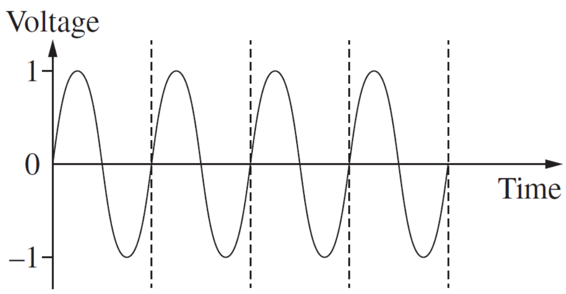


Which of the following graphs best represents the output if the rate of rotation is decreased to half of the original value?

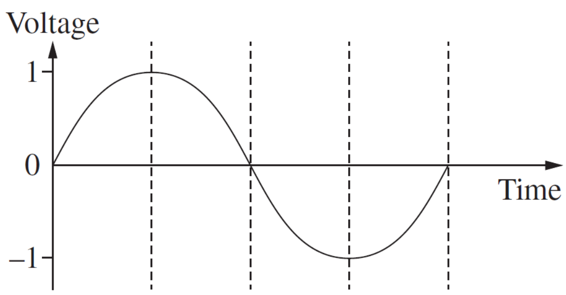
(A)



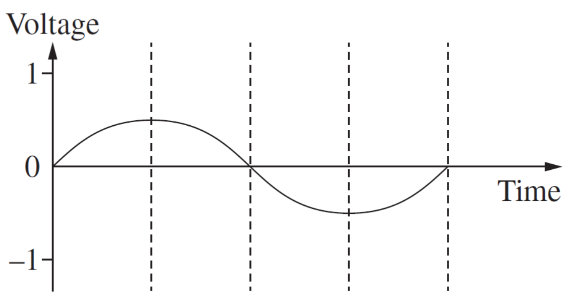
(B)



(C)



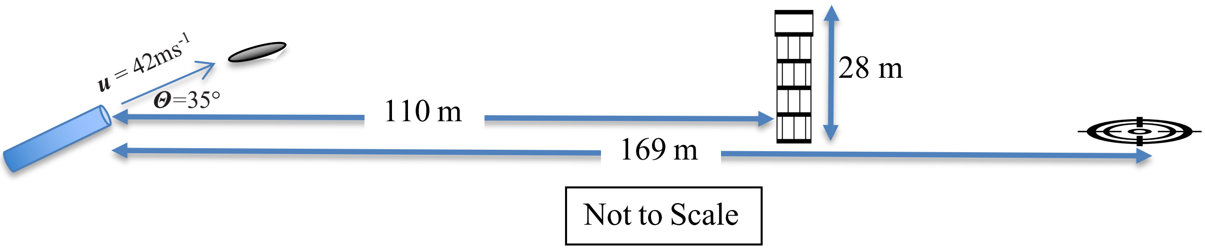
(D)



PART B – Short Answer (40 Marks)

Question 21 (3 marks) **3**

A projectile is launched with a velocity $\boldsymbol{u}$ = 42ms^{-1} at an angle of Θ=35° at a target 169m away at the same level. A 28m high wall is placed 110m away from the launcher. Calculate whether the projectile will hit the target.



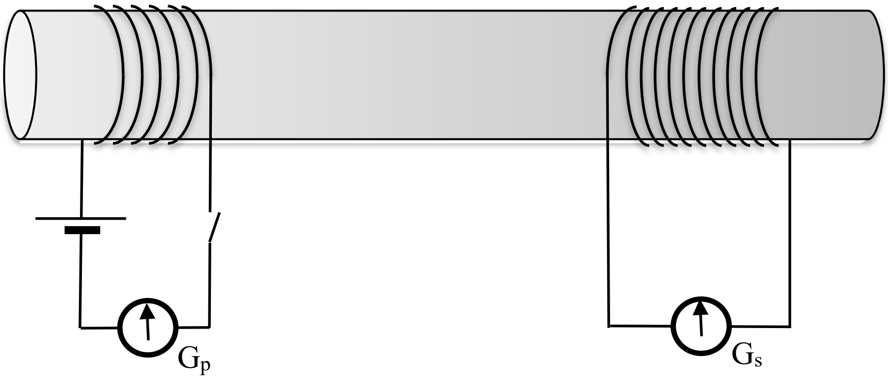
Question 22 (2 marks) **2**

Sirius A is 8.7 light years from Earth. A spaceship synchronises its clock with Earth and travels from Earth to Sirius A at constant velocity of 2.00×10^{8} ms^{-1}.

How long would this trip take as measured by the crew of the ship?

Question 23 (3 marks)

A coil (n_p=5) is wrapped around an iron core and connected to a DC power supply, an ideal galvanometer G_p, and an open switch. A second coil (n_s=10) is wrapped around the iron core connected to another galvanometer G_s, as shown below. **3**



The switch on the primary coil is closed. Compare and analyse the magnitude and the direction of the deflection of the galvanometers G_p and G_s.

Question 24 (8 marks)

a Calculate the total energy that must be supplied to move a spacecraft of mass of 3.50×10^3 kg from the Earth's surface at the equator to a circular orbit with an altitude of 3.00×10^5 m. **3**

b For the spacecraft in part **(a)**, calculate the period of this orbit to the nearest minute **2**

c The spacecraft from part **(a)** fires its engine opposite the direction of its motion, adding 3.00×10^5 ms^{-1} to its velocity. Describe the effect this will have on the spacecraft's position around the earth. Show all working **3**

Exam continues next page

Question 25 (3 marks)

A physics teacher sets up a demonstration involving a long-barrelled air rifle and a coin. It is designed in a way so that the coin will drop when the trigger of the rifle is pulled. The barrel of the rifle and coin are lined up so that they are initially at the same level. **3**

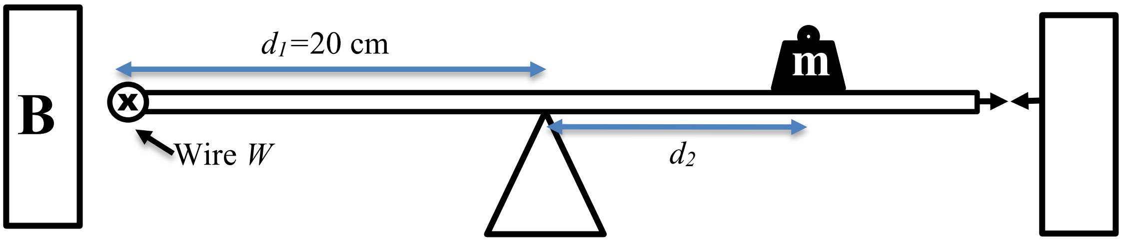
The teacher states that the bullet will always hit the centre of the coin, no matter how far away the coin is placed from the rifle. A student disagrees, and states that the coin should instead fall when the bullet leaves the barrel.

With reference to the physics involved, assess the statements made by the teacher and student.

Exam continues next page

Question 26 (10 marks)

A *current balance* was set up as below. The arms of the balance are 20cm 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 $\boldsymbol{I}$ is passed through the wire $\boldsymbol{W}$, 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.



Current I (A)	***Distance d_2 (mm)***
1.00	53.43
2.00	64.86
3.00	70.29
4.00	87.71
5.00	99.14

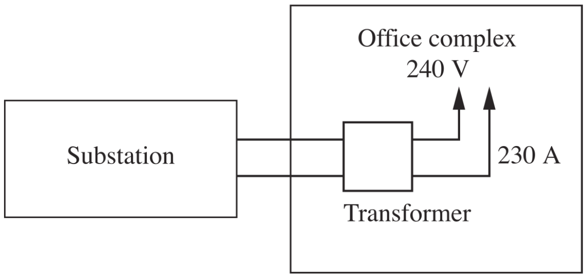
a Graph the values from the results table. **3**

b On the diagram, indicate the direction of the magnetic field. **1**

c From your line of best fit, calculate the strength of the magnetic field provided by the magnet B. **4**

d From your graph, calculate the mass of the wire m_w. **2**

Question 27 (2 marks)
An electricity substation delivers a current of 10 A at a voltage of 6 kV to an office complex. The office complex uses a transformer to provide a current of 230 A at a voltage of 240 V.



Calculate the energy lost by the transformer in four hours in joules. **2**

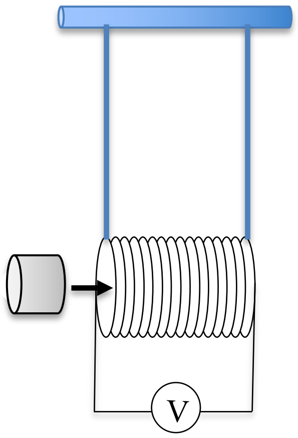
Question 28 (4 marks)
A plane traveling at $40ms^{-1}$ makes a flat turn around a mountain to fly a loop around it with a radius of 2km.

a Calculate the time it would take the plane to fly one complete loop **2**

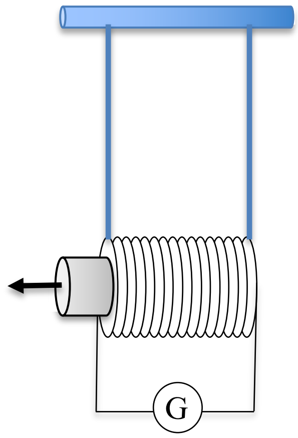
b Calculate the magnitude and direction of the acceleration as measured by the pilot **2**

Question 29 (4 marks)

A coil is suspended as a pendulum with an ideal voltmeter meter loosely attached. A strong magnet is quickly inserted into the coil and held stationary, as shown in *Experiment 1*. After some time, the voltmeter is replaced with and ideal galvanometer (ammeter). The magnet is then quickly withdrawn from the coil in *Experiment 2*.



Expriment 1



Expriment 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

Student Number:

Sydney Boys High School

Physics

March 2021
Half Yearly Cohort Task
Advanced Mechanics, Electromagnetics, Special Relativity

General Instructions

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- Working time: 90 minutes
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- SHOW ALL WORKING
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- Write your student number in ALL of the boxes provided

Total marks – 60

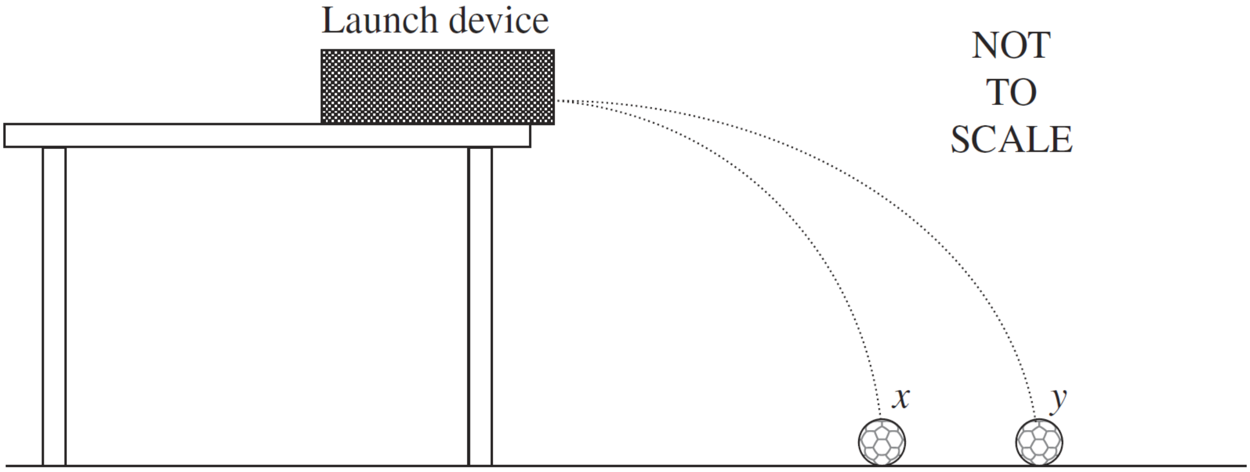
Part A – Multiple Choice
- 20 marks

Part B – Free Response
- 40 marks

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

PART A – Multiple Choice (20 Marks)

1. A device launches two identical balls (x and y) simultaneously in a horizontal direction from the same height. The results are shown.



Which statement correctly describes what happens?

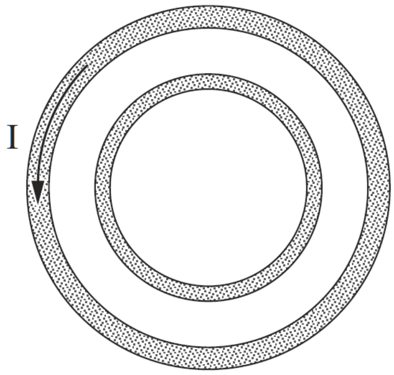
(A) x hits the ground before y as it is closer to the launch site.

(B) y hits the ground before x as it has a higher launch velocity.

(C) x and y hit the ground simultaneously with the same velocity.

(D) x and y hit the ground simultaneously with different velocities.

2. Two copper rings lie in the same plane as shown.



A decreasing current flows clockwise around the outer ring.
What happens in the inner ring?

(A) A decreasing clockwise current flows.

(B) A decreasing anticlockwise current flows.

(C) An increasing clockwise current flows.

(D) An increasing anticlockwise current flows.

3. Two masses have a gravitational force of 12 N between them.

If the distance between the masses is doubled, what would be the new gravitational force between them?

(A) 3 N

(B) 6 N

(C) 12 N

(D) 24 N

4. A scientist at a particle accelerator laboratory observes the lifetime of a particular subatomic particle to be 1.0×10^{-6} s when it is travelling at 0.9999 c.

What would the lifetime of the particle be if it were stationary in the laboratory?

(A) 1.4×10^{-8} s

(B) 4.5×10^{-8} s

(C) 1.0×10^{-6} s

(D) 7.1×10^{-5} s

5. A student throws a ball that follows a parabolic trajectory. What change to the initial velocity would make the ball's time of flight shorter?

(A) Increasing only the vertical component

(B) Decreasing only the vertical component

(C) Increasing only the horizontal component

(D) Decreasing only the horizontal component

6. A satellite, initially in a low Earth orbit, is moved to a new orbit where its gravitational potential energy is twice its initial value.

What is the gravitational force experienced by the satellite in its new orbit?

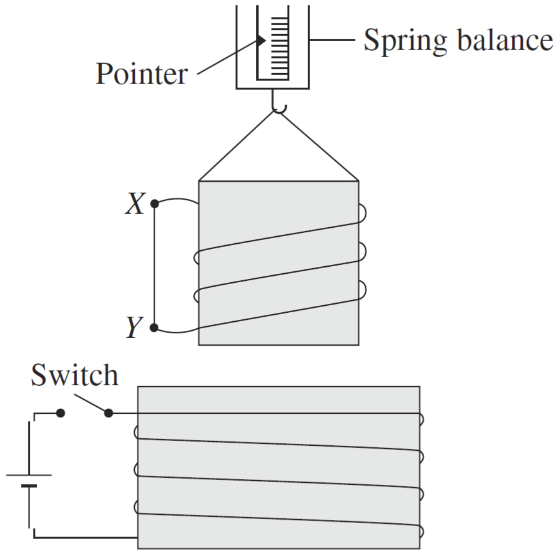
(A) Half the initial force

(B) Twice the initial force

(C) Four times the initial force

(D) One quarter the initial force

7. An experiment is set up as shown.



When the switch is closed, 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

8. A spaceship moves close to the speed of light, relative to a planet.

The rest-frame length of the spaceship can be determined by an observer who is

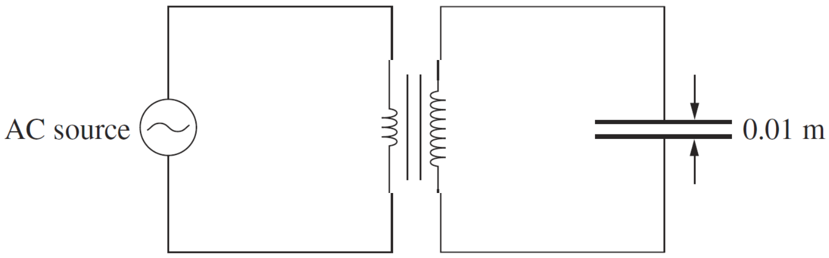
(A) on the spaceship measuring the time taken for light to travel between two points on the planet.

(B) on the planet measuring the time taken for light to travel from the front to the back of the spaceship.

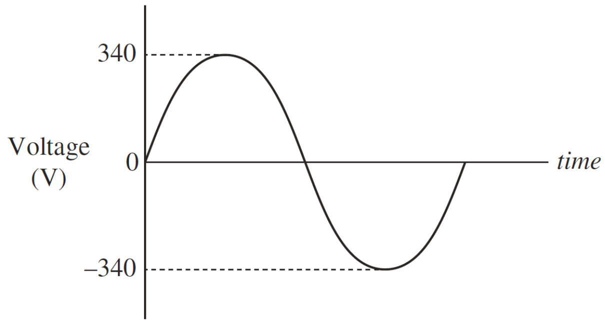
(C) on the spaceship measuring the time taken for light to travel from the front to the back of the spaceship.

(D) on the planet measuring the difference in the arrival time of light from the front and the back of the spaceship.

9. An AC source is connected to a transformer having a primary winding of 450 turns. Connected to the secondary winding of 900 turns is a pair of parallel plates 0.01 m apart.



The AC input is shown in the graph.



What is the maximum field strength (in V m^{-1}) produced between the plates?

(A) 1.7

(B) 6.8

(C) 1.7×10^4

(D) 6.8×10^4

Use the data below to answer the next two questions.

Orbital period of the Moon around Earth	2.36×10^6 s
Mean orbital radius of the Moon	3.83×10^8 m
Mass of Earth	6.00×10^{24} kg
Mass of the Moon	7.35×10^{22} kg

10. What is the orbital period of an Earth satellite having an orbital radius half that of the Moon?

(A) 5.9×10^5 s

(B) 8.3×10^5 s

(C) 1.2×10^6 s

(D) 7.5×10^6 s

11. What is the gravitational force experienced by the Moon due to Earth's influence?

(A) 2.0×10^{20} N

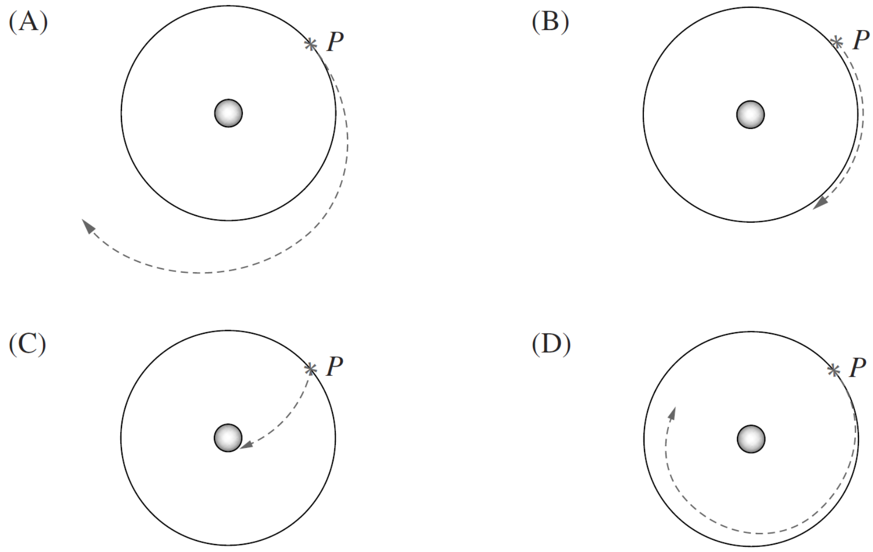
(B) 1.6×10^{22} N

(C) 4.7×10^{26} N

(D) 7.6×10^{28} N

12. A space probe, P, is in a stable orbit around a small, distant planet. The probe fires a forward-facing rocket that reduces its orbital speed by half.

Which of the following best illustrates the subsequent motion of the probe?



13. An ideal electric motor connected to a DC voltage source rotates at a constant rate of 200 revolutions per minute. There is no load on the motor.
Which of the following is a correct statement about the operation of the motor?

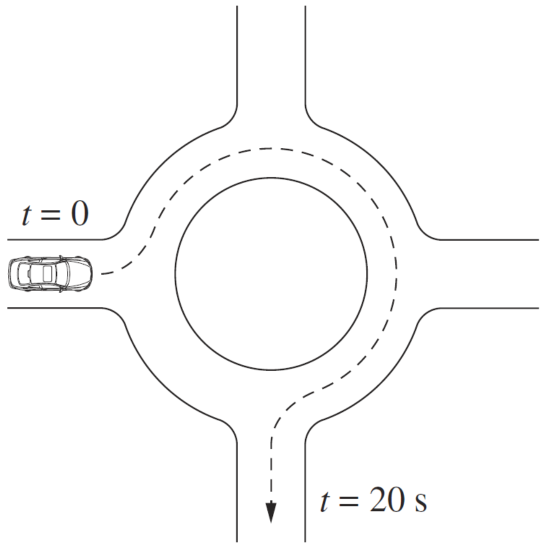
(A) The applied voltage must exceed the back emf in order to keep the motor running.

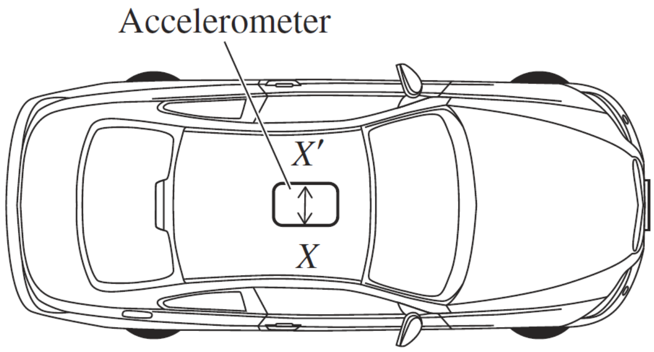
(B) There is no back emf because it is only produced in AC motors due to the changing flux.

(C) The back emf is equal to the applied voltage because no work is being done by the motor.

(D) The back emf must exceed the applied voltage to prevent the motor's speed from increasing.

14. A car travelling at a constant speed follows the path shown.

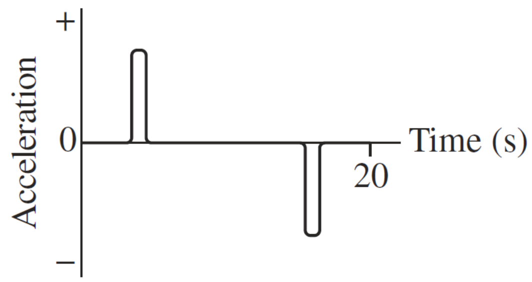




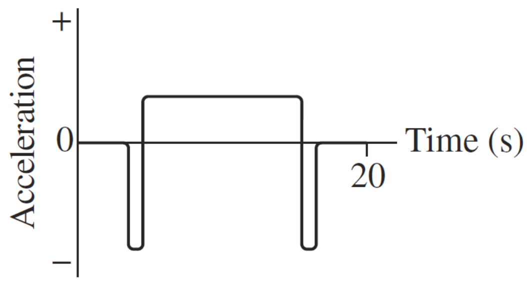
An accelerometer that measures acceleration along the *X*–*X′* direction is fixed in the car.

Which graph shows the measurements recorded by the accelerometer over the 20-second interval?

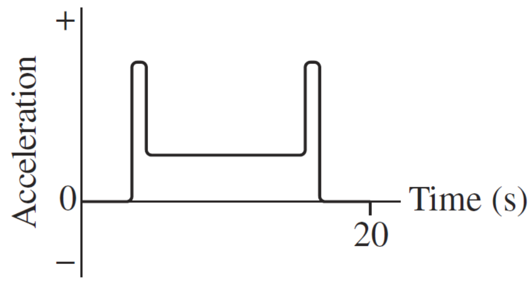
A.



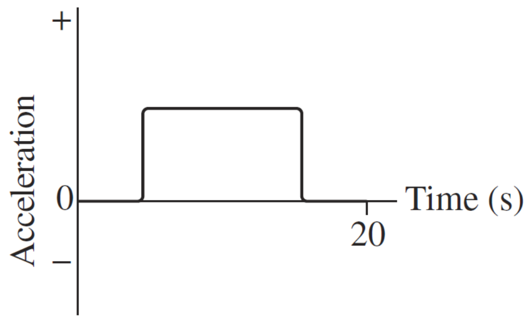
B.



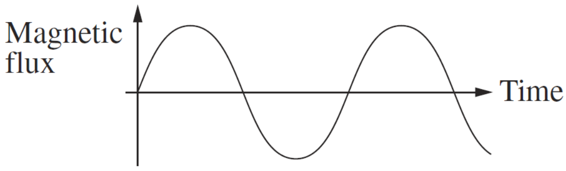
C.



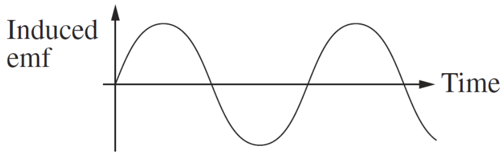
D.

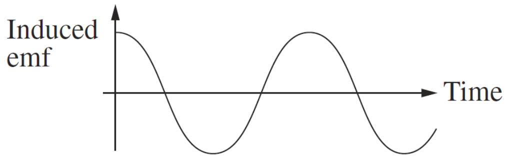


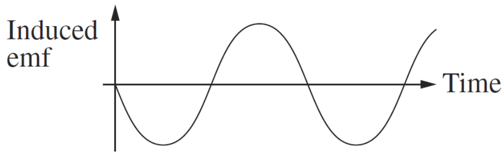
15. The graph shows variation in magnetic flux through a coil with time.

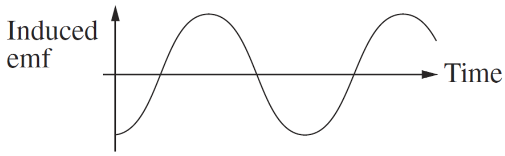


Which graph best represents the corresponding induced emf in the coil?

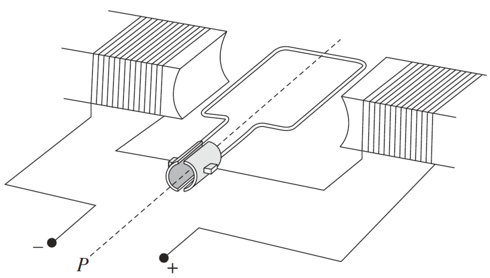
(A)


(B)


(C)


(D)


16. In the motor shown, the rotor spins clockwise, as viewed from point *P*, when connected to a DC supply



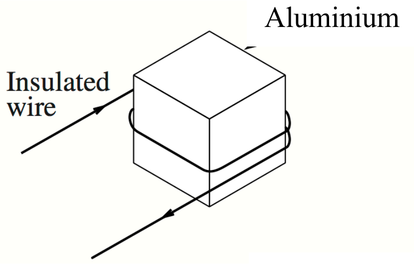
What happens when the motor is connected to an AC supply?

(A) The field magnets maintain their field orientation.
(B) The field magnets alternate their field orientation.
(C) The rotor vibrates at half the frequency of the AC supply.
(D) The rotor continuously turns half a rotation clockwise, then half a rotation anticlockwise.

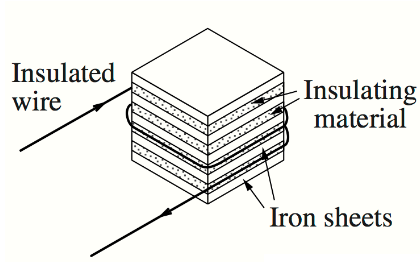
17. A transformer is to be designed so that it is efficient, with heating by eddy currents minimised. The designer has some metal and insulating material available to build the transformer core. The windings are to be made with insulated copper wire.

Which of the following designs transfers the most energy to the secondary coil?

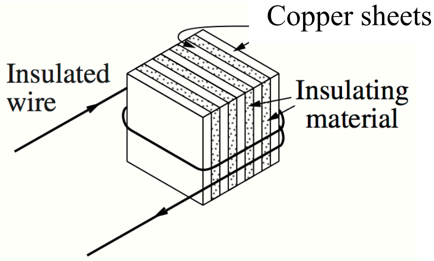
(A)



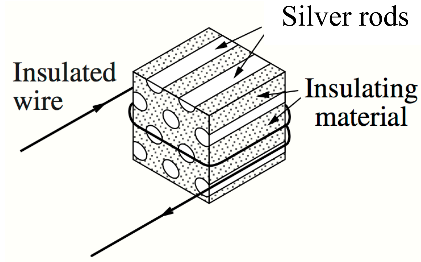
(B)



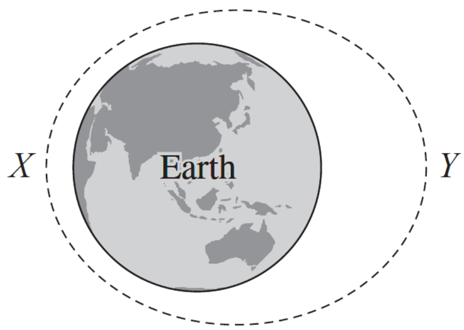
(C)



(D)



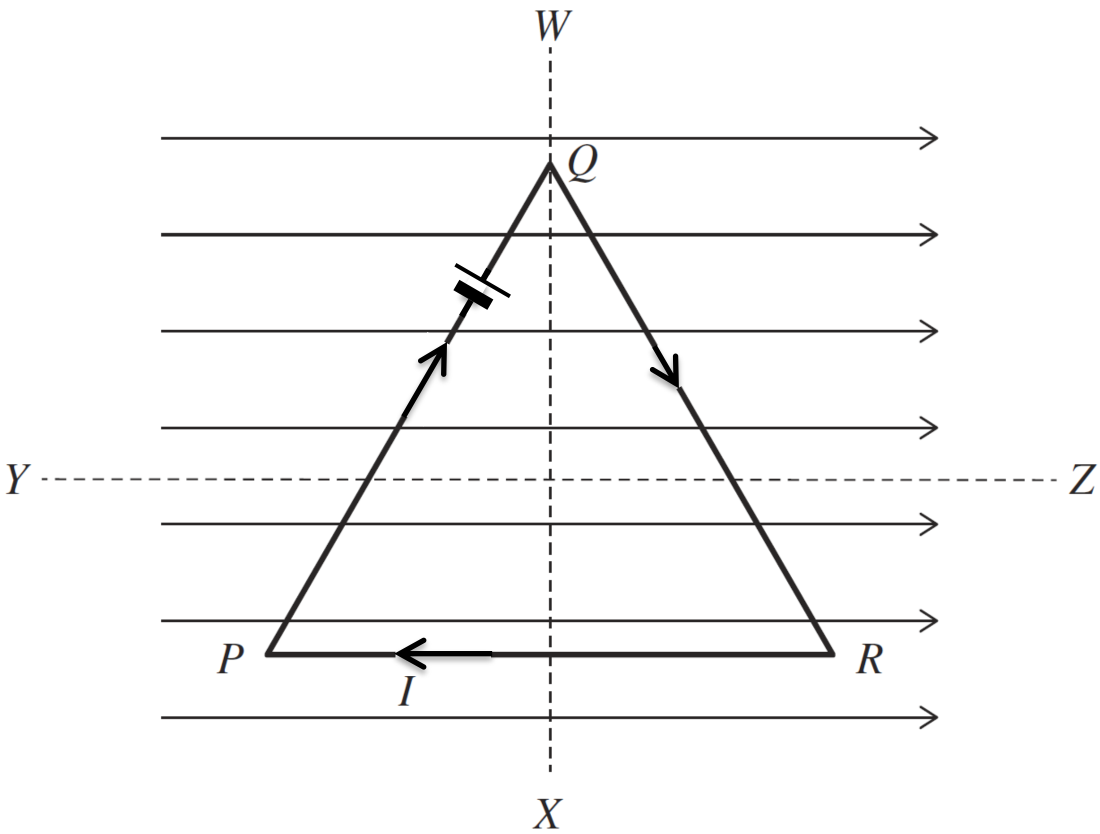
18. A satellite orbits Earth with an elliptical orbit that passes through positions X and Y.



In terms of absolute value only, which orbital positions would have least orbital speed V_{orb} and greatest gravitational potential E_P?

	Least V_{orb} (absolute value)	*Greatest E_P (absolute value)*
(A)	*X*	*X*
(B)	*X*	*Y*
(C)	*Y*	*X*
(D)	*Y*	*Y*

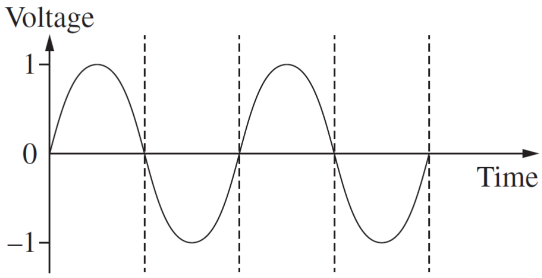
19. A triangular piece of wire is placed in a magnetic field as shown.



When current *I* is supplied as shown, how does the wire move?

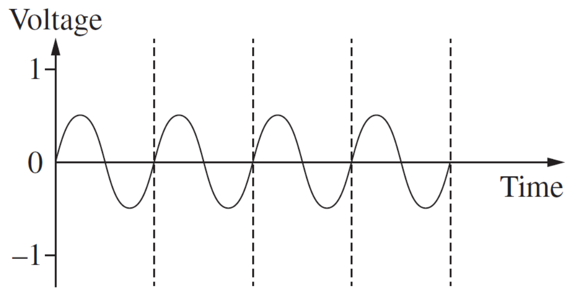
	Axis of rotation	*Direction of movement*
(A)	YZ	Q into page
(B)	YZ	Q out of page
(C)	WX	R out of page
(D)	WX	R into page

20. A simple AC generator was connected to a cathode ray oscilloscope and the coil was rotated at a constant rate. The output is shown on this graph.

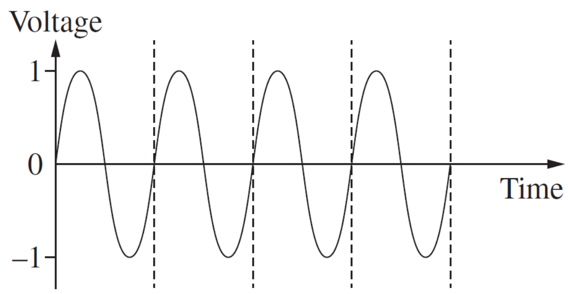


Which of the following graphs best represents the output if the rate of rotation is decreased to half of the original value?

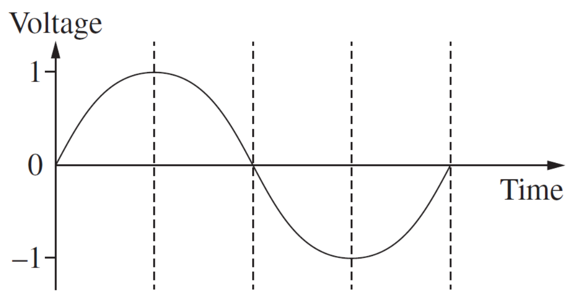
(A)



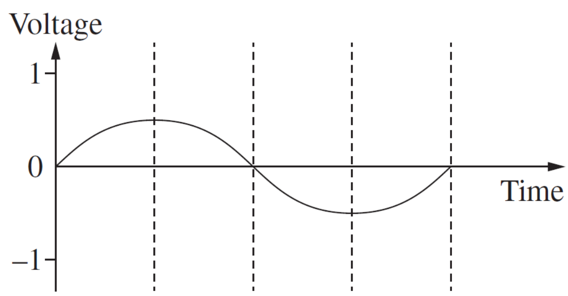
(B)



(C)



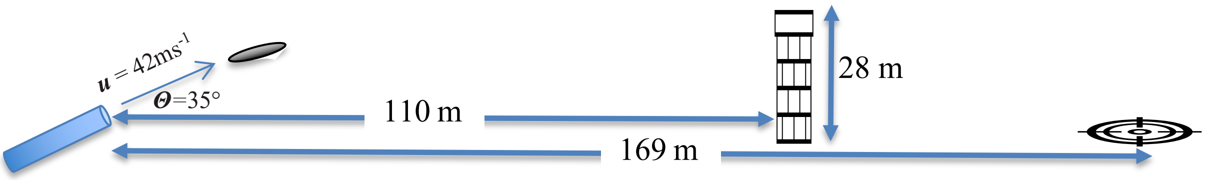
(D)



PART B – Short Answer (40 Marks)

Question 21 (3 marks) **3**

A projectile is launched with a velocity $\boldsymbol{u}$ = 42ms^{-1} at an angle of $\boldsymbol{\Theta}$=35° at a target 169m away at the same level. A 28m high wall is placed 110m away from the launcher. Calculate whether the projectile will hit the target.



Not to Scale

$u_x = u \cos\theta$ $\quad$ $u_y = u \sin\theta$

$u_x = 42 \times \cos 35 = 34.4ms^{-1}$ $\quad$ $u_y = 42 \times \sin 35 = 24.1ms^{-1}$

$s_x = u_x t$

$t = \frac{s_x}{u_x} = \frac{110}{34.4} = 3.20s$

$S_y = u_y t + \frac{1}{2}at^2 = 24.1 \times 3.20 + \frac{1}{2} \times (-9.8) \times 3.20^2 = 26.9m$

$26.9m < 28m$

Projectile does not hit the target

- ✓ Calculates time of flight to 110m
- ✓ Calculates vertical displacement at 110m (26.9m)
- ✓ Concludes that projectile does not hit the target – MUST HAVE CORRECT SUPPORTING WORKING AND EXPLANATION

Question 22 (2 marks) **2**

Sirius A is 8.7 light years from Earth. A spaceship synchronises its clock with Earth and travels from Earth to Sirius A at constant velocity of 2.00×10^8 ms^{-1}.
How long would this trip take as measured by the crew of the ship?

Time to travel at $\frac{2}{3}c$, as measured on Earth, $t_v = \frac{distance}{speed} = \frac{8.7}{\frac{2}{3}} = 13.05\ years$

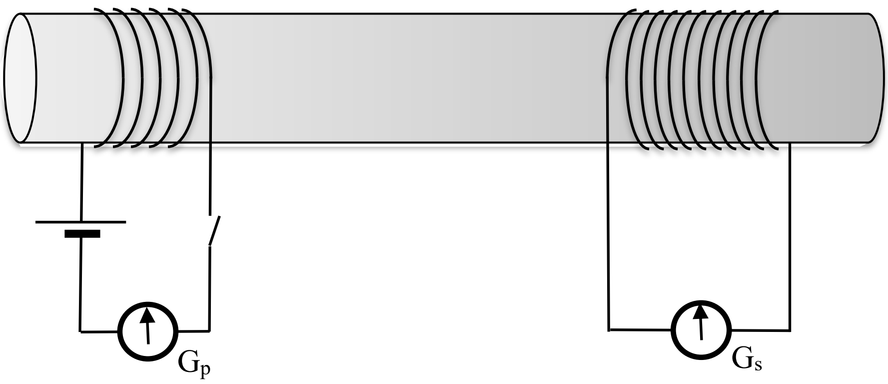
$$t_v = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}} \Rightarrow t_o = t_v\sqrt{1 - \frac{v^2}{c^2}}$$

$$t_0 = 13.05\sqrt{1 - \frac{(2.00 \times 10^8)^2}{(3.00 \times 10^8)^2}} = 9.7\ years$$

- ✓ Time dilation equation line and substitution line
- ✓ Calculates correct answer in SI units or years. 2 sig figs.

Question 23 (3 marks)

A coil (n_p=5) is wrapped around an iron core and connected to a DC power supply, an ideal galvanometer G_p, and an open switch. A second coil (n_s=10) is wrapped around the iron core connected to another galvanometer G_s, as shown below. **3**



The switch on the primary coil is closed. Compare and analyse the magnitude and the direction of the deflection of the galvanometers G_p and G_s.

NOTES- Galvanometers measure current (not voltage)
- You can't apply Ohm's Law to transformer coil induction

✓ Gs will deflect in the same direction as Gp
✓ Gs will deflect LESS than Gp and only about half as much. (Will accept that Gs reading will double relative to Gp ONLY IF ANSWER STATES THAT VOLTAGE IS BEING MEASURED)
✓ Applies the TRANSFORMER EQUATIONS plus either LENZ'S or FARADAY'S LAW.

Question 24 (8 marks)

a Calculate the total energy that must be supplied to move a spacecraft of mass of 3.50 × 10³ kg from the Earth's surface at the equator to a circular orbit with an altitude of 3.00 × 10⁵ m. **3**

$$v_{rot} = \frac{s}{t} = \frac{2\pi r_e}{t} = \frac{2 \times \pi \times 6.371 \times 10^6}{24 \times 60 \times 60} = 463.3 ms^{-1}$$

$\Delta E = E_f - E_i$ **1 MARK FOR THIS EQUATION with substitution shown.**

	KE (J)	GPE (J)	Total E (J)
Initial	3.76×10^{8}	-2.20×10^{11}	-2.19×10^{11}
Final	1.05×10^{11}	-2.10×10^{11}	-1.05×10^{11}
Change	1.05×10^{11}	9.89×10^{9}	1.14×10^{11}

$$= (U + K)_f - (U + K)_i$$

$$= -\frac{GMm}{2r_f} - \left(-\frac{GMm}{r_i} + \frac{1}{2}mv_{rot}^2\right)$$

1 MARK if accounts for KE of satellite sitting on Earth (not in orbit) and shows working

$$= -\frac{6.67 \times 10^{-11} \times 6.00 \times 10^{24} \times 3.50 \times 10^3}{2 \times (6.371 \times 10^6 + 3.00 \times 10^5)} - \left(-\frac{6.67 \times 10^{-11} \times 6.00 \times 10^{24} \times 3.50 \times 10^3}{6.371 \times 10^6} + \frac{1}{2} \times 3.50 \times 10^3 \times 463.3^2\right)$$

$= 1.14 \times 10^{11}$ J 3 sig fig max. **1 MARK**

b For the spacecraft in part **(a)**, calculate the period of this orbit to the nearest minute **2**

$$\frac{r_o^3}{T^2} = \frac{GM_e}{4\pi^2}$$

$$T = \sqrt{\frac{4\pi^2 r_o^3}{GM_e}}$$

$$= \sqrt{\frac{4 \times \pi^2 \times (6 \cdot 67 \times 10^6)^3}{6.67 \times 10^{-11} \times 6.00 \times 10^{24}}}$$

$$= 5410s$$

✓ Uses Kepler's Law
✓ Calculates the period of orbit (90mins)

T= 90 mins or 5410s (to 3 sf max)

c The spacecraft from part **(a)** fires its engine opposite the direction of its motion, adding 3.00×10^3 ms^{-1} to its velocity. Describe the effect this will have on the spacecraft's position around the earth. Show all working **3**

$$V_o = \sqrt{\frac{GM_e}{r}}$$

$$= \sqrt{\frac{6.67 \times 10^{-11} \times 6.00 \times 10^{24}}{6 \cdot 67 \times 10^6}}$$

$$V_o = 7.75 \times 10^3 ms^{-1}$$

$$V_{esc} = \sqrt{\frac{2GM_e}{r}}$$

$$= \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 6.00 \times 10^{24}}{6 \cdot 67 \times 10^6}}$$

$$V_{esc} = 1.10 \times 10^4 ms^{-1}$$

$$V_1 = V_0 + 3.00 \times 10^3$$
$$= 1.07 \times 10^4 ms^{-1}$$

The new velocity v_1 is less than the escape velocity for that radius. The spacecraft will enter into an elliptical orbit around the earth.

✓ Calculates the new final velocity
✓ Calculates the escape velocity
✓ Describes new orbit, doesn't escape (elliptical)
The spacecraft will not be in a circular orbit!

Exam continues next page

Question 25 (3 marks)

A physics teacher sets up a demonstration involving a long-barrelled air rifle and a coin. It is designed in a way so that the coin will drop when the trigger of the rifle is pulled. The barrel of the rifle and coin are lined up so that they are initially at the same level. **3**

The teacher states that the bullet will always hit the centre of the coin, no matter how far away the coin is placed from the rifle. A student disagrees, and states that the coin should instead fall when the bullet leaves the barrel.

With reference to the physics involved, assess the statements made by the teacher and student.

The student is correct, the coin should fall when the bullet leaves the barrel. Gallilean relativity states that motion in each axis does not affect each other. Both objects will experience an acceleration due to gravity. As such, both objects will be in the same vertical displacement, provided that they both fall at the same time. The horziontal motion will be such that the bullet will hit the coin at any distnace. The coin should fall after the bullet leaves, as when the bullet is in the barrel, it expereince no net verital motion.

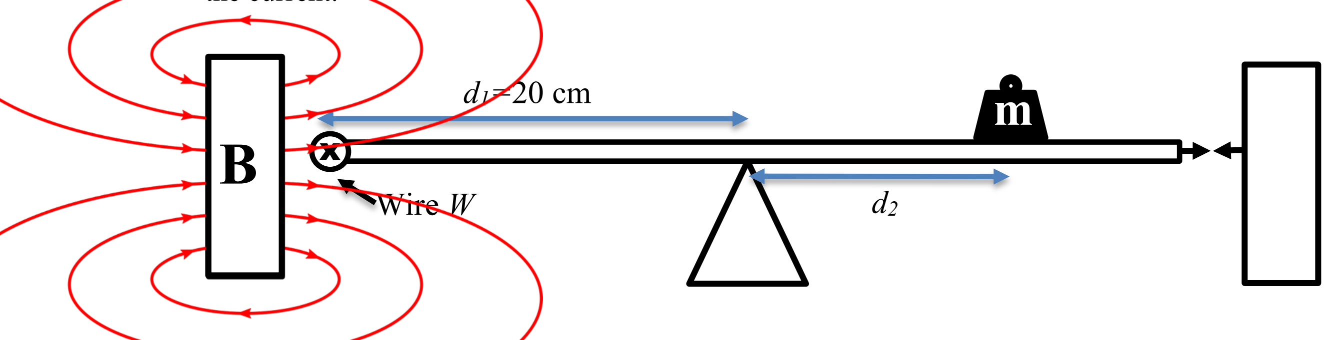
- ✓ Student is correct with justifications
- ✓ References Galilean relativity
- ✓ Analyses the vertical motion (if coin falls when the trigger is pulled, the bullet will not fall until after leaving the barrel, g affects both objects equally)

Mark lost if assesment is contradictory! Teacher and Student can not both be correct

Exam continues next page

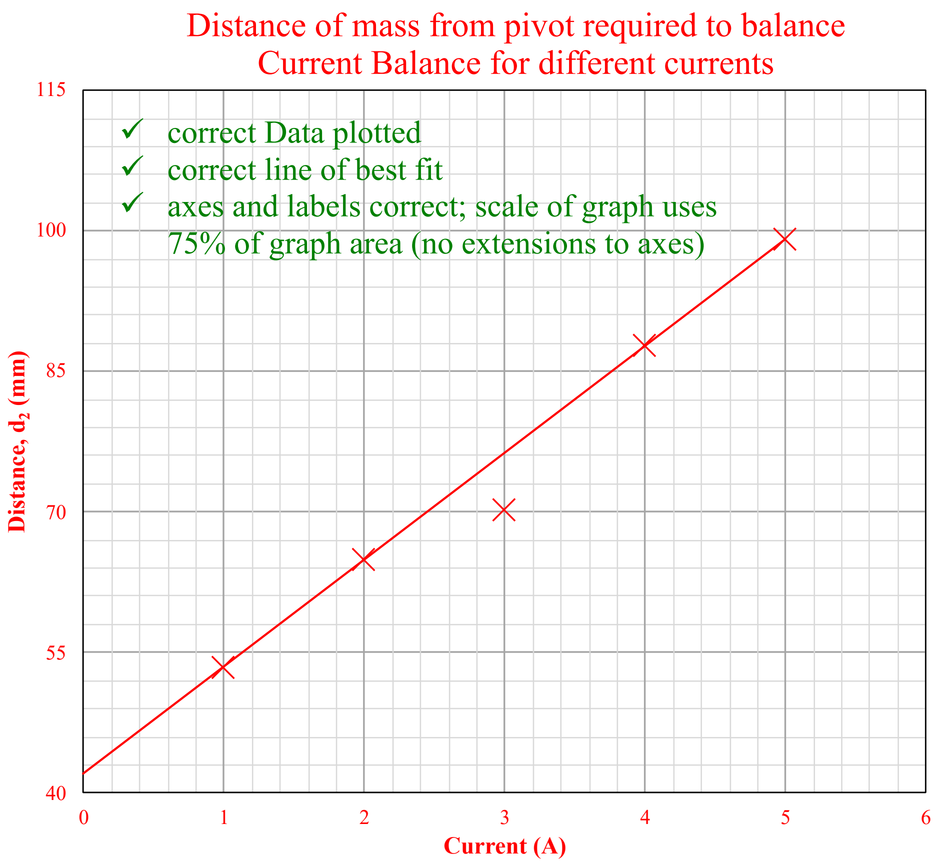
Question 26 (10 marks)

A *current balance* was set up as below. The arms of the balance are 20cm 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 $\boldsymbol{I}$ is passed through the wire $\boldsymbol{W}$, 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.



Current I (A)	*Distance d_2 (mm)*
1.00	67.43
2.00	78.86
3.00	85.01
4.00	101.71
5.00	113.14

a Graph the values from the results table. **3**



b On the diagram, indicate the direction of the magnetic field. **1**

✓ correct direction (to the right)

c From your line of best fit, calculate the strength of the magnetic field provided by the magnet B. **4**

Gradient of LOBF:

$$gradient = \frac{y_2 - y_1}{x_2 - x_1} = \frac{(99 - 58) \times 10^{-3}}{5.0 - 1.4} = 0.011389 \text{ m A}^{-1}$$

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

$$\tau_B = \tau_g$$

$$F_B d_1 = F_g d_2$$

$$lIBd_1 = mgd_2$$

$$B = \frac{mg\, d_2}{lId_1}$$

From the gradient equation:

$$gradient = \frac{rise}{run} = \frac{d_2}{I} = \frac{lBd_1}{mg}$$

$$\Rightarrow B = \frac{mg \times gradient}{ld_1} = \frac{0.0015 \times 9.8 \times 0.011389}{0.02 \times 0.20} = 0.04185 = 0.042 \text{ T}$$

✓ gradient equation with substitution from LOBF

✓ equates magnetic & gravitational torques

✓ correctly relates B to gradient

✓ correct value & units (±5%) [no carry-over from (a)]

note: you cannot use $\tau = nIA_{\perp}B$, since it is not a current loop

do **not** leave answers blank

d From your graph, calculate the mass of the wire m_w. **2**

From LOBF, y-intercept (where $I = 0$) gives $d_2 = 42$ mm:

$$\tau_{wire} = \tau_{mass}$$

$$F_{g(wire)} d_1 = F_{g(mass)} d_2$$

$$m_w g d_1 = mgd_2$$

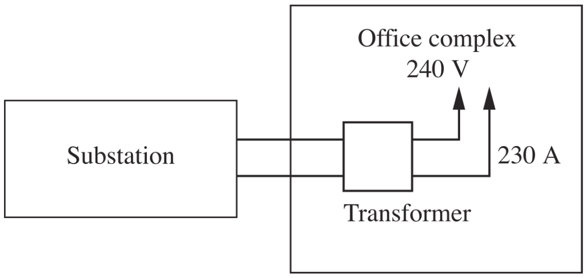
$$m_w d_1 = md_2$$

$$\Rightarrow m_w = m\frac{d_2}{d_1} = 0.0015 \times \frac{0.042}{0.20} = 0.000315 \text{ kg} = 0.315 \text{ g}$$

✓ uses data from LOBF

✓ correct mass of wire with units [carry-over allowed from (a))

Question 27 (2 marks)
An electricity substation delivers a current of 10 A at a voltage of 6 kV to an office complex. The office complex uses a transformer to provide a current of 230 A at a voltage of 240 V.



Calculate the energy lost by the transformer in four hours in joules. **2**

$P_p = V_p I_p = 6000 \times 10 = 60000$ W and $P_s = V_s I_s = 240 \times 230 = 55200$ W

$$P_{loss} = P_p - P_s = 60000 - 55200 = 4800 \text{ W}$$

$$E_{loss} = P_{loss} t = 4800 \times 4 \times 60 \times 60 = 69120000 = 69.12 \text{ MJ}$$

✓ correctly calculates power loss

✓ correctly converts power to energy

Question 28 (4 marks)
A plane traveling at 40ms^{-1} makes a flat turn around a mountain to fly a loop around it with a radius of 2km.

a Calculate the time it would take the plane to fly one complete loop **2**

$$s = 2\pi r = 2 \times \pi \times 2000 = 12566.37 \text{ m}$$

$$t = \frac{s}{v} = \frac{12566.37}{40} = 314 \text{ s} = 5.2 \text{ min}$$

✓ use of correct equation(s)

✓ correct value & units

b Calculate the magnitude and direction of the acceleration as measured by the pilot **2**

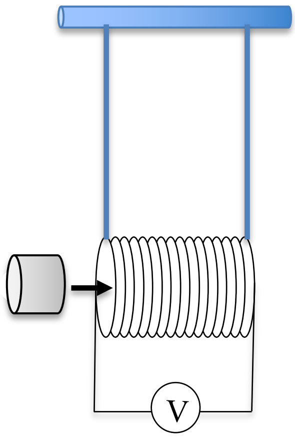
$$a = \frac{v^2}{r} = \frac{40^2}{2000} = 0.80 \text{ m s}^{-2} \text{ towards the mountain}$$

✓ correct value & units

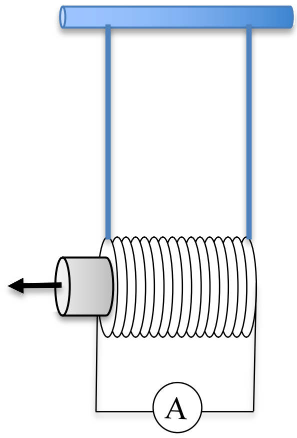
✓ correct direction

Question 29 (4 marks)

A coil is suspended as a pendulum with an ideal voltmeter meter loosely attached. A strong magnet is quickly inserted into the coil and held stationary, as shown in *Experiment 1*. After some time, the voltmeter is replaced with and ideal ammeter. The magnet is then quickly withdrawn from the coil in *Experiment 2*.



Expriment 1



Expriment 2

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

In both of the Experiments, the relative movement between the magnet and the coil will lead to a change in magnetic flux through the loop. From Faraday's Law, this change in flux will lead to an emf in the coil $\left(\varepsilon = -N\frac{\Delta\Phi}{\Delta t}\right)$.

In Experiment 1, the coil is connected to an ideal voltmeter, which will measure the emf as a voltage and a reading will be seen. Since an ideal voltmeter has an infinite electrical resistance. Thus, the current in the coil will be zero according to Ohm's Law $\left(I = \frac{V}{R} = \frac{V}{\infty} = 0\right)$. Therefore, there is no induced current, and no induced magnetic field to interact with the strong magnet. As a result, there is no movement of the coil.

In Experiment 2, the coil is connected to an ideal ammeter, which has zero electrical resistance. Thus, the induced emf will result in current in the coil, which will be seen on the ammeter as a measurement on the scale. According to Lenz's Law, this current will conduct through the coil in such a way that the induced magnetic field will oppose the change in flux that induced the emf, and, in doing so, act to oppose the cause of the change in flux. Since the change in flux was due to the movement of the strong magnet away from the coil, the induced current will generate a magnetic field that will cause the coil to move to the left, reducing the relative movement between the strong magnet and the coil.

4 MARKS for 5 ticks, with −1 MARK for each of the following missing:

✓ relates change in flux to emf in both coils (Faraday's Law)

✓ relates emf to reading on voltmeter

✓ relates voltmeter to no movement in Experiment 1

✓ relates emf to current reading on galvanometer (Lenz's Law)

✓ relates current to movement left in Experiment 2

note: need to relate to *movement* of coil, not just force/attraction on coil