Sydney Boys High School

Student Number:

Multiple Choice Answer Sheet
Physics Half Yearly Cohort Task 2020

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

Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ~~●~~ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.

correct

A ~~●~~ B ~~●~~ C ○ D ○

Start Here ➔

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

Student Number:

Sydney Boys High School

Physics

April 2020
Half Yearly Cohort Task
Advanced Mechanics, Electromagnetism, Special Relativity

General Instructions

- Reading time: 5 minutes
- Working time: 75 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 – 55

Part A – Multiple Choice
- 20 marks

Part B – Free Response
- 35 marks

PART A – Multiple Choice (20 marks)

1. An object on Earth has a weight of 380 N and experiences an acceleration due to gravity of 9.8 m s^{-2}. On Venus, this object would experience an acceleration due to gravity of 8.9 m s^{-2}.

On Venus, what would be the weight of this object?

(A) 380 N

(B) $\dfrac{380}{9.8}$ N

(C) $\dfrac{380}{8.9} \times 9.8$ N

(D) $\dfrac{380}{9.8} \times 8.9$ N

2. The table contains information related to two planets orbiting a distant star.

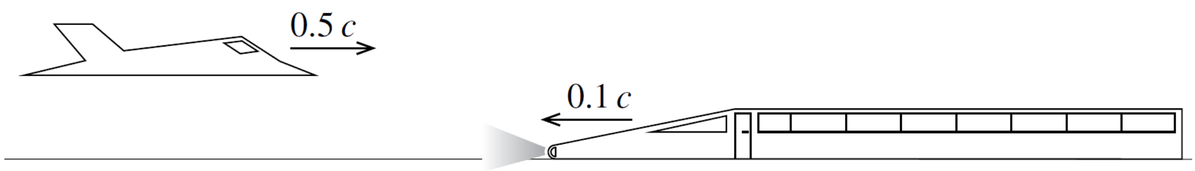
Planet	*Mass (kg)*	*Orbital radius (m)*	*Radius of Moon (m)*	*Length of day (s)*	*Orbital period (s)*
Plan	9.21×10^{24}	6.00×10^{10}	3.00×10^{6}	2.76×10^{4}	3.47×10^{7}
Net	1.25×10^{25}	3.00×10^{10}	6.00×10^{6}	1.88×10^{4}	—

The orbital period of the planet Net can be determined by using data selected from this table.

What is the orbital period of the planet Net?

(A) 1.23×10^{7} s
(B) 2.19×10^{7} s
(C) 5.51×10^{7} s
(D) 9.81×10^{7} s

3. In a thought experiment, a jet is travelling at 0.5 c relative to the ground, towards a train that is travelling at 0.1 c relative to the ground, as shown. (2016 Q6)

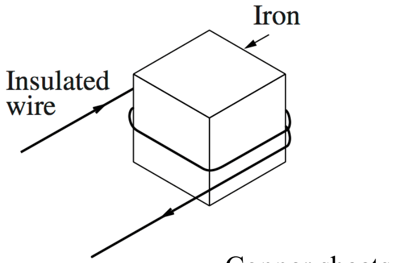


What is the speed of the light emitted from the train's headlight, as measured by a pilot in the jet?
(A) 0.1 *c*
(B) 0.4 *c*
(C) 0.6 *c*
(D) 1.0 *c*

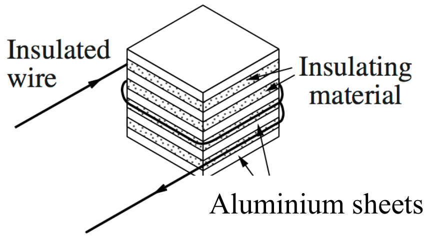
4. A transformer is to be designed so that it is efficient; transferring energy from one coil to another. The designer has some metal and insulating material available to build the transformer core. The windings are to be made with insulated copper wire.

Which of the following designs would transfer the most energy to a secondary coil?

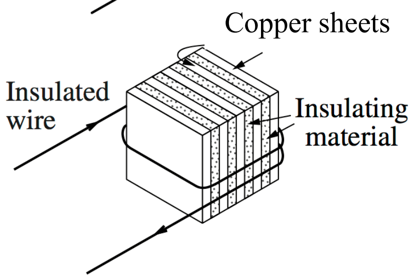
(A)



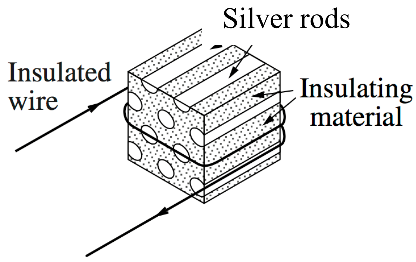
(B)



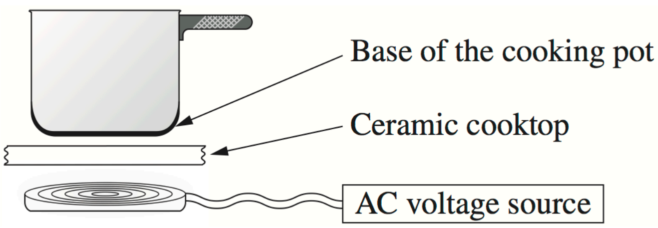
(C)



(D)



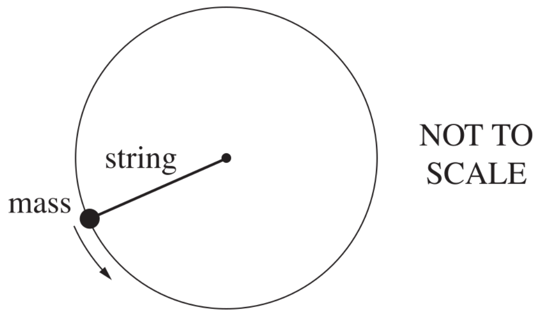
5. The diagram represents an induction cooking system.



Which row in the following table shows the set of conditions that would result in the most rapid heating of the base of the cooking pot?

	Electrical resistance of pot base	*AC voltage frequency*
(A)	Low	High
(B)	Low	Low
(C)	High	High
(D)	High	Low

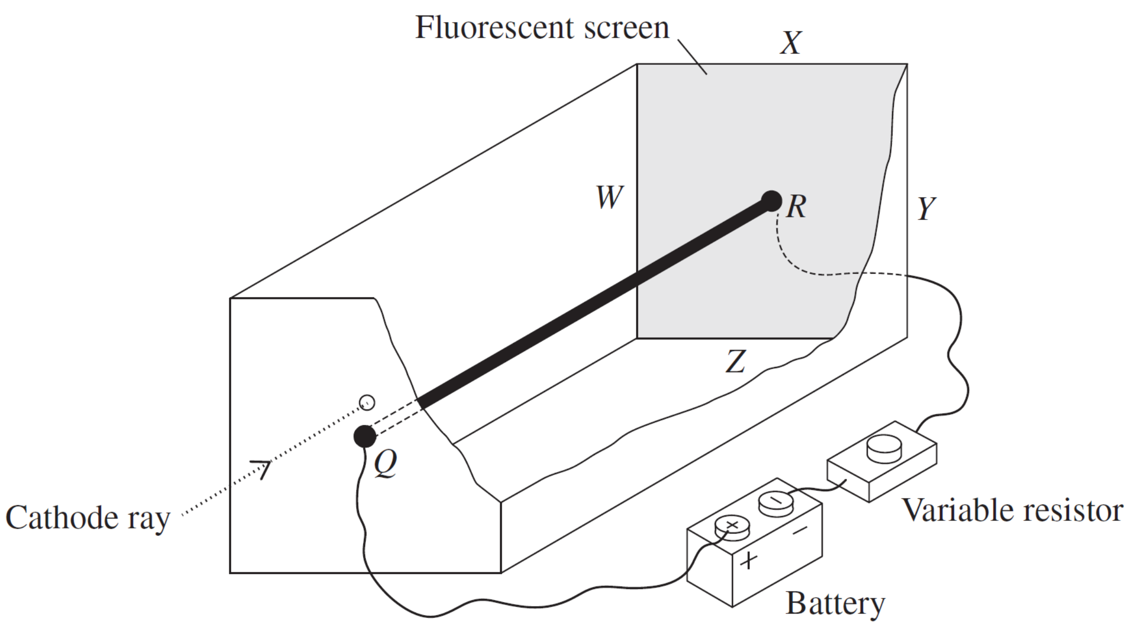
6. A 500 g mass is swung in a horizontal circle as shown. It completes 7 revolutions in 4 seconds. The circle has a 3.0 m diameter.



Which of the following forces is closest to that required to keep the mass moving in this circle?

(A) 5.0 N
(B) 25 N
(C) 45 N
(D) 90 N

7. A straight current-carrying conductor, QR, is connected to a battery and a variable resistor. QR is enclosed in an evacuated chamber with a fluorescent screen at one end.

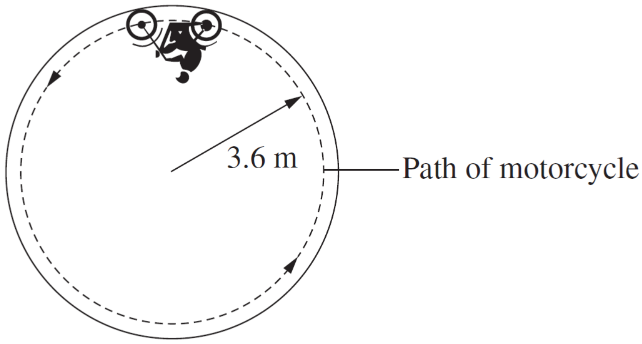


A cathode ray (a beam of electrons) enters the chamber directly above Q, initially travelling parallel to QR. It passes through the chamber and strikes the fluorescent screen causing a bright spot.

Which direction will this spot move towards if the resistance is increased? (2019 Q17)

(A) W
(B) X
(C) Y
(D) Z

8. A motorcycle travels around a vertical circular path of radius 3.6 m at a constant speed. The combined mass of the rider and motorcycle is 200 kg.



What is the minimum speed, in ms^{-1}, at which the motorcycle must travel to maintain the circular path? (2016 Q18)

(A) 0.42
(B) 1.9
(C) 5.9
(D) 35

9. Which of these statements best describes the forces acting on a satellite in orbit around Earth?

(A) Although gravity has no effect, there is still an outward force.
(B) The satellite is kept up by an outward force that balances the force due to gravity.
(C) Gravity is the only force acting on the satellite and this results in an inward acceleration.
(D) The effect of gravity is negligible, the satellite is kept in orbit by its momentum and the net force on it is zero.

10. Which of the following is an inertial frame of reference?

(A) A rocket during launch
(B) A train travelling at a constant velocity
(C) A car turning a corner at a constant speed
(D) A lift slowing down as it approaches the ground floor

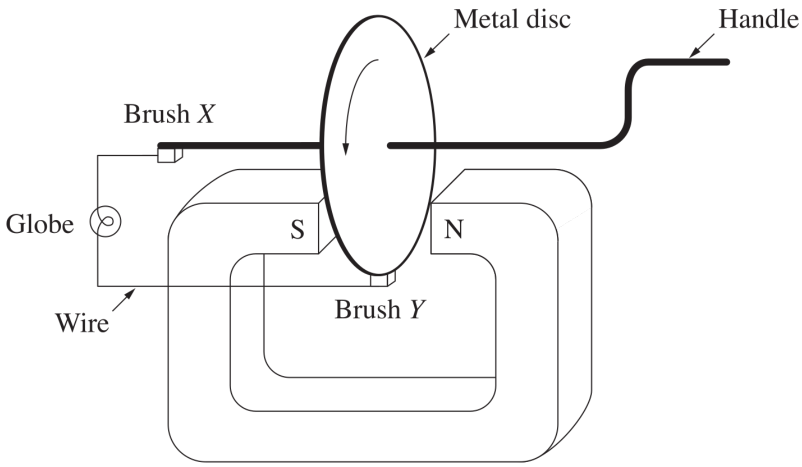
11. Two satellites have the same mass. One (LEO) is in low-Earth orbit and the other (GEO) is in a geostationary orbit.

The total energy of a satellite is half its gravitational potential energy.

Which row of the table correctly identifies the satellite with the greater orbital period and the satellite with the greater total energy? (2019, Q9)

	Greater orbital period	*Greater total energy*
(A)	LEO	LEO
(B)	LEO	GEO
(C)	GEO	LEO
(D)	GEO	GEO

12. Early electric generators were often very simple. A hand-operated version is depicted below.

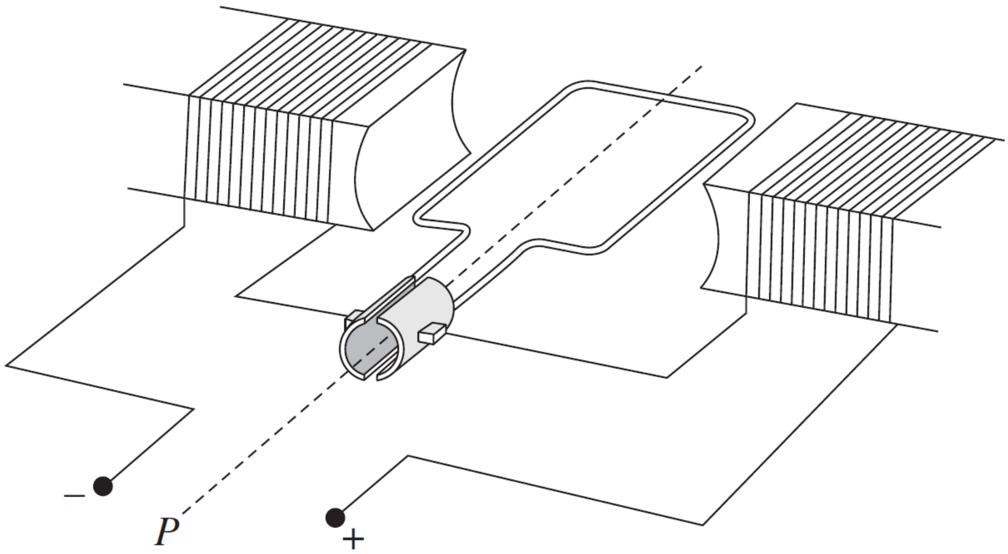


Brush X touches the metal axle and Brush Y touches the rim of the disc.

If the metal disc is rotated uniformly as shown, which statement about the current through the globe is correct?

(A) A direct current flows from Y to X.
(B) A direct current flows from X to Y.
(C) An alternating current flows between X and Y.
(D) No current flows.

13. 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? (2016 Q20)

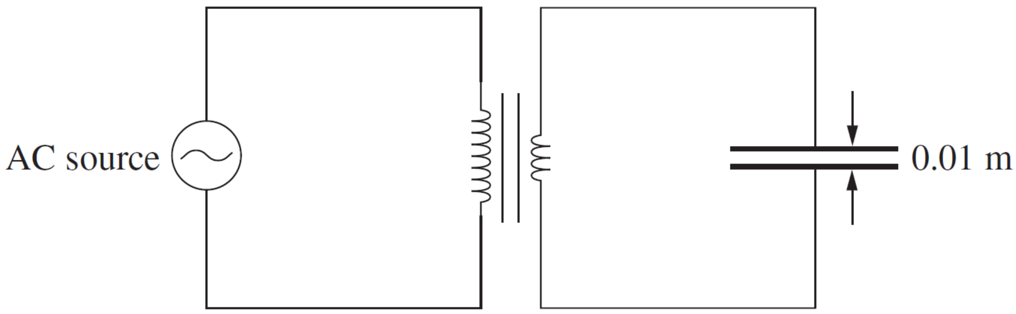
(A) There is no movement of the rotor.
(B) The rotor produces clockwise movement only.
(C) The rotor vibrates at the frequency of the AC supply.
(D) The rotor continuously turns half a rotation clockwise, then half a rotation anticlockwise.

14. A projectile was launched from the ground. It had a range of 70 metres and was in the air for 3.5 seconds.

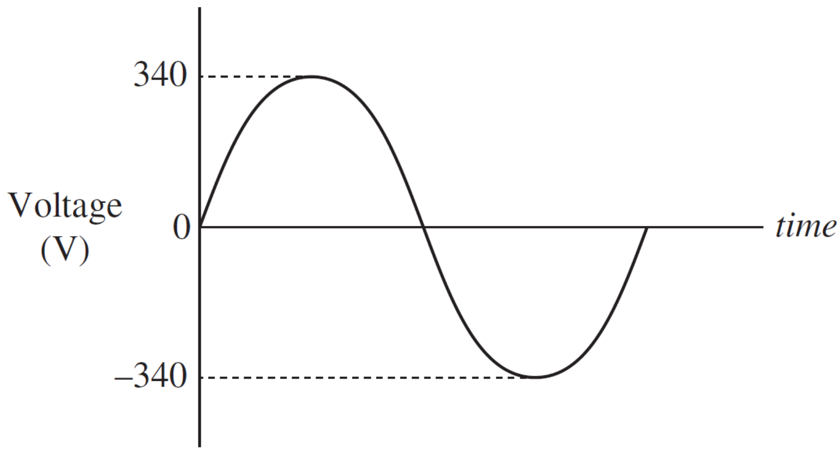
At what angle to the horizontal was it launched? (2015 Q20)

(A) 30°
(B) 40°
(C) 50°
(D) 60°

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



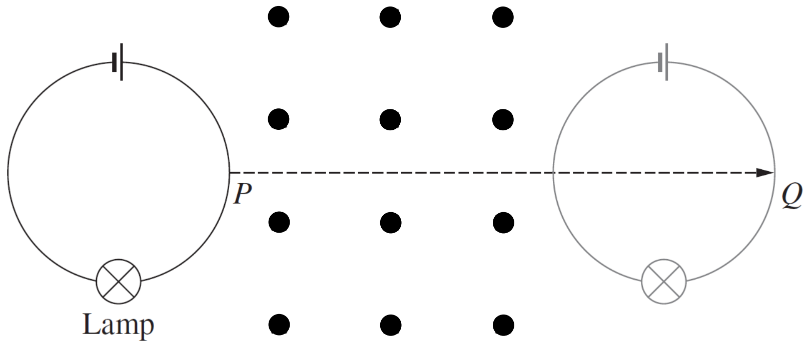
The AC input is shown in the graph.



What is the maximum field strength (in Vm^{-1}) produced between the plates? (2017 Q11)

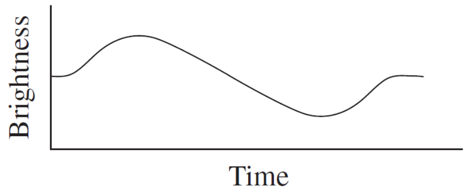
(A) 1.7
(B) 6.8
(C) 1.7×10^4
(D) 6.8×10^4

16. A circular loop of wire is connected to a battery and a lamp. The apparatus is moved from P to Q along the path shown at a constant velocity through a region containing a uniform magnetic field.

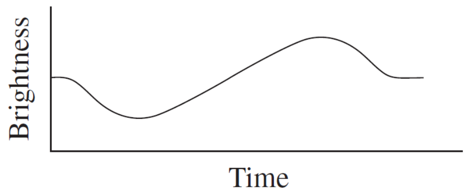


Which graph shows the brightness of the lamp as the apparatus moves between P and Q? (2019 Q18)

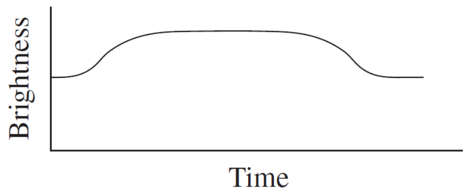
A.



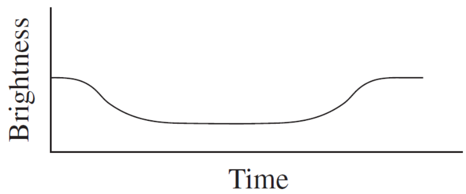
B.



C.



D.

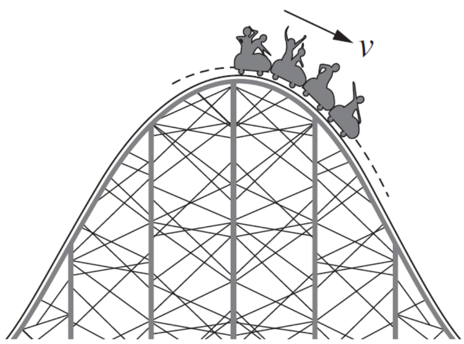


17. During the launch of a space vehicle from Earth, an astronaut feels an increased downward g force.

In which of the following situations would a person also feel an increased downward g force?

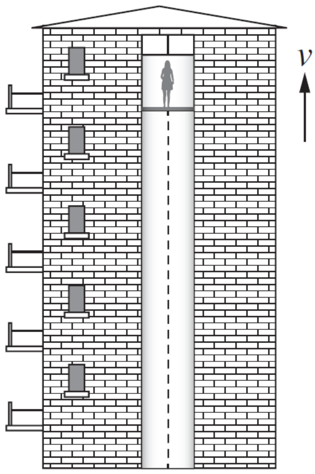
2018 Q11

A.



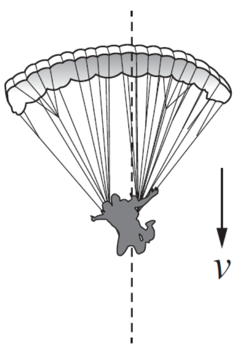
Roller-coaster speeding up

B.



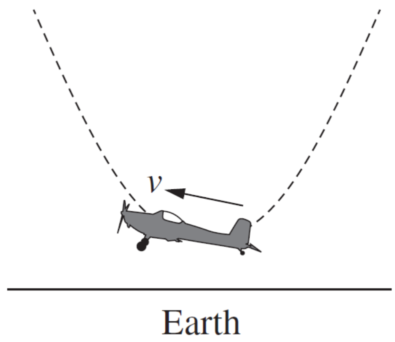
Lift slowing down

C.



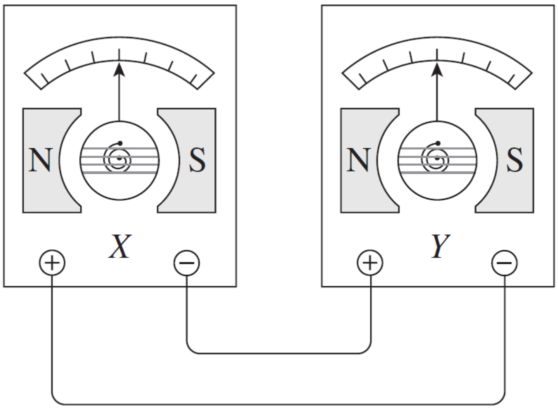
Parachute falling at a constant velocity

D.

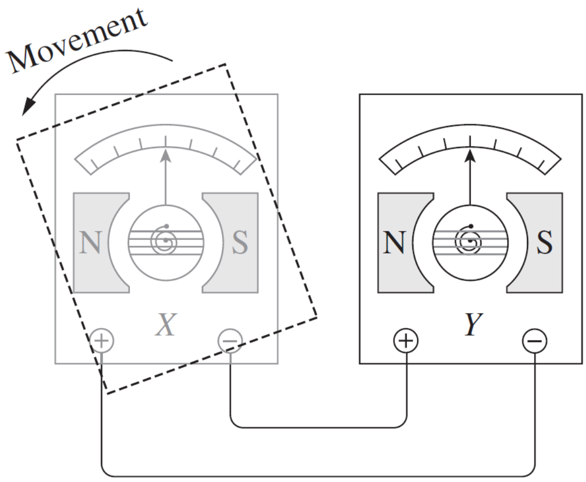


Plane pulling out of a dive

18. Two identical galvanometers X and Y were connected as shown and placed on a desk.



The meter X was then picked up and rotated suddenly anticlockwise to the position shown by the dotted outline, while the meter Y remained stationary on the desk.

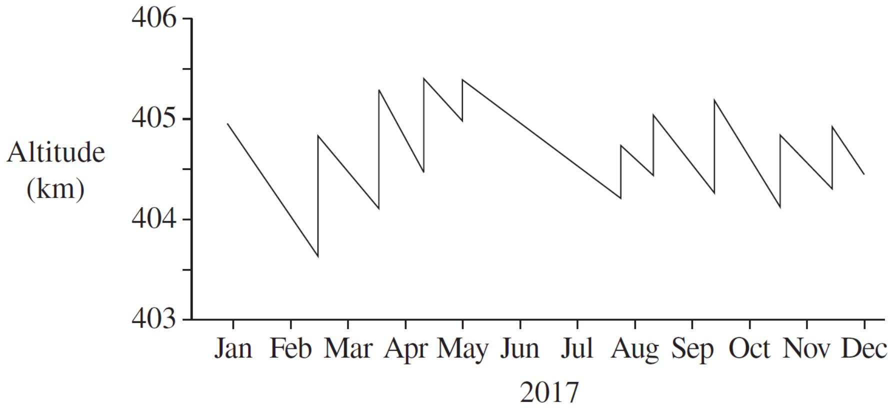


When this action is carried out, the pointers on both meters move relative to the scales on the meters.

Which row of the table correctly identifies the movement of the pointer on Y and the reason for its behaviour?

	Movement of pointer	*Reason*
(A)	Towards right	The movement of *X* produces a current that flows into the opposite terminal of *Y*.
(B)	Towards right	According to Lenz's law the effect produced must oppose the cause of the flux.
(C)	Towards left	*Y* behaves as a motor with the current flowing through it from right to left.
(D)	Towards left	For every force, there is an equal and opposite force.

19. The graph shows the altitude of the International Space Station (ISS) during 2017.



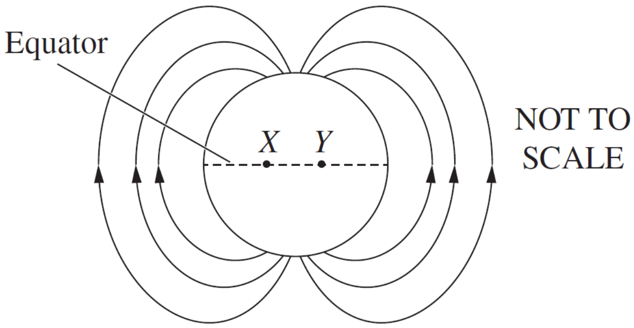
The altitude can only be boosted by supply craft visiting the ISS.

Why does the altitude decrease in the times between height boosts? (2018 q3)

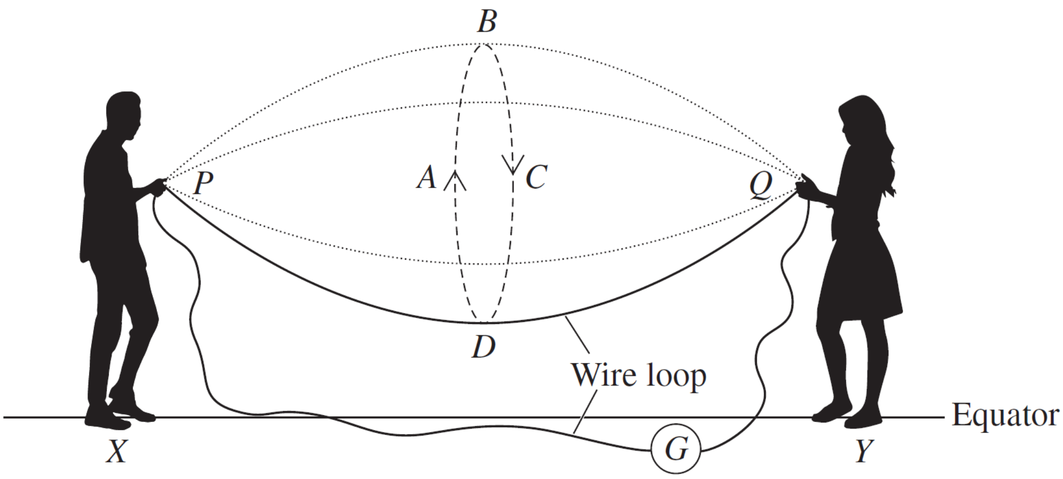
(A) Momentum of the ISS is being transferred to air molecules.
(B) The moon's gravity changes the net force on the ISS as it orbits Earth.
(C) The decrease in altitude makes it possible for a supply craft to reach the ISS.
(D) The total mass of the ISS changes with the deliveries from each supply craft.

Exam continues next page

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.



At what point during the rotation of the wire does the maximum current flow in a direction from P to Q through the moving part of the wire?

(A) *A*
(B) *B*
(C) *C*
(D) *D*

Student Number:

PART B – Free Response (40 marks)

Question 21 (6 marks)

The Earth has a mass of 6.00×10^{24} kg and a radius of 6370 km.

a A geosynchronous orbit is defined as an orbit whose period is the same as rotation of the earth about its axis. Given that the earth has a rotational period of 23.93 hours, calculate the radius of such an orbit. **2**

----

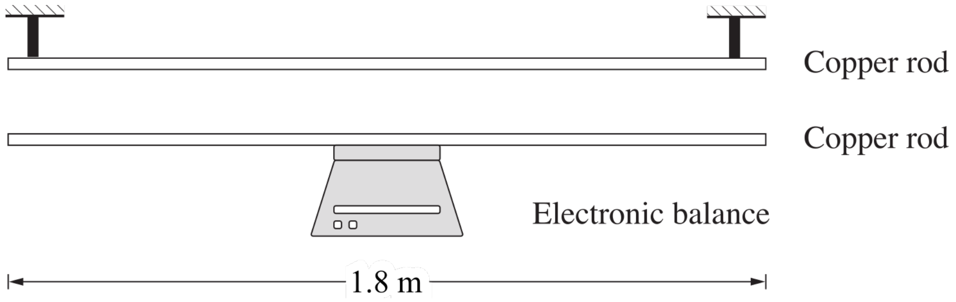
b A 2000 kg satellite is placed in orbit around the Earth at an altitude of 2.02×10^3 km. Calculate the total energy required to move this satellite to a geosynchronous orbit. **2**

----

c For the satellite in part (b), justify the use of a geosynchronous orbit with examples. **2**

Question 22 (6 marks)

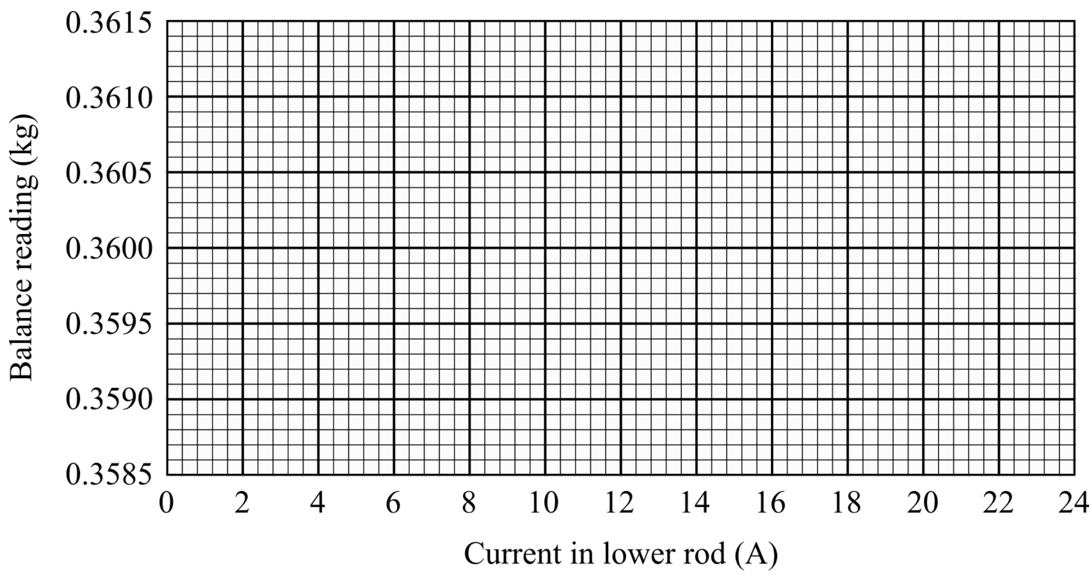
A balance was used to investigate the relationship between current and force. The balance was set up with one copper rod fixed to it and a second rod fixed above it, as shown in the diagram. Each rod was connected to a source of current. The diagram is not to scale.



The copper rods were rigid, each was 1.8 m long, and they were parallel. The current in the upper rod was kept constant at 60 A. Different currents were passed through the lower rod and the balance reading recorded for each current. The readings are given in the table below.

Current in lower rod (A)	*Balance reading (kg)*
4.0	0.3593
8.0	0.3598
12.0	0.3604
16.0	0.3610
20.0	0.3612

a Plot the data from the table onto the graph, using the scales and axes as indicated, and add the line of best fit (trend line). **2**



b Find the mass of the copper rod on the balance. **1**

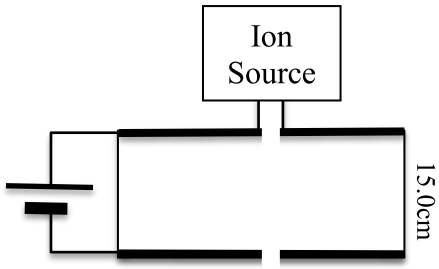
c Calculate the distance between the two copper rods. **3**

Exam continues next page

Question 23 (8 marks)

An ion thruster works by accelerating charged particles (ions) to a high velocity using electric and magnetic fields.

The device shown below has Xenon particles fired into the acceleration chamber at a velocity of $u = 20\ ms^{-1}$. The particles have a charge of $q_{Xe} = +4.81 \times 10^{-19} C$, and a mass of $m_{Xe} = 2.18 \times 10^{-25} kg$.



NOT TO SCALE

a Upon leaving the acceleration chamber, the particles are measured to have an exit velocity of $u = 2.57 \times 10^4\ ms^{-1}$. Calculate the potential difference across the acceleration chamber required to do this work **3**

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b In the diagram above, draw the direction of a magnetic field required to deflect the ion beam to the right **1**

c Given that the space between the plates of the acceleration chamber is 15.0cm, calculate the time the particles spend in the chamber, and the power the acceleration chamber provides one particle of xenon. **2**

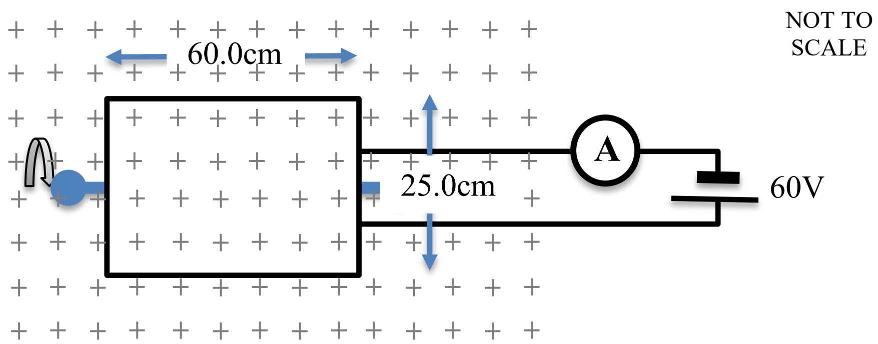
----

d After running for an hour, $1.31 \times 10^{-6} kg$ of xenon fuel has been consumed. What is the magnitude of the current in the chamber? **2**

Question 24 (4 marks) **4**

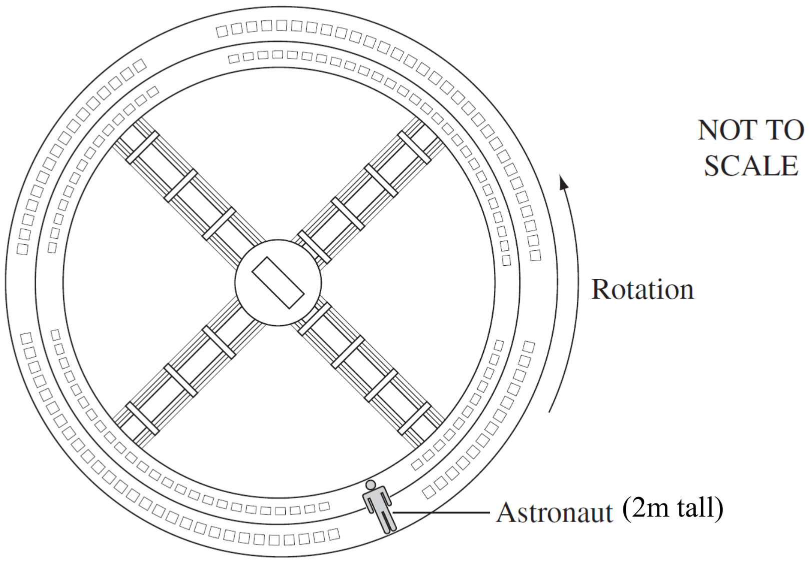
In an electric motor, *Back EMF* limits the amount of current flowing through the armature.

A 60V DC motor consists of 50 turns of wire formed into a rectangular loop 60.0 cm by 25.0 cm placed entirely in a uniform magnetic field B. The resistance of the armature is 1.2Ω. When a small load is placed on the motor, it is measured to draw 2A, with a rotation speed of 7200RPM. Calculate the strength of the magnetic field.



Question 25 (4 marks)

The diagram below shows a space station designed to simulate gravity in a weightless environment.



a Explain how rotating the space station simulates gravity for the astronaut. **2**

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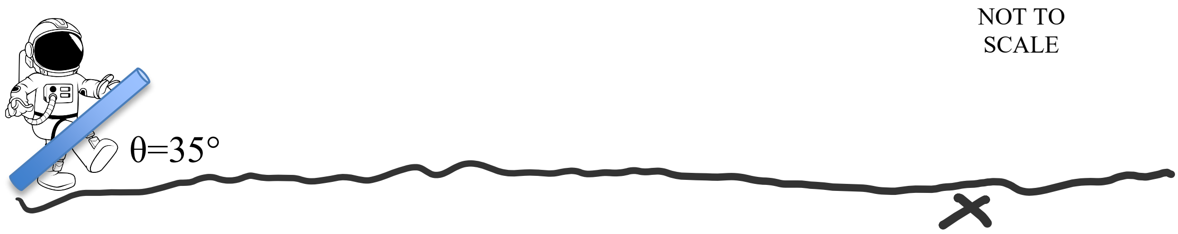
b Assuming that the astronauts are 2m tall, calculate the radius the space station would need for astronauts to experience $9.8 ms^{-2}$ of acceleration at their feet and $8.8\ ms^{-2}$ at their head. **2**

Question 26 (2 marks)

An astronaut stranded on Mars ($g_{mars} = 3.71\ ms^{-2}$) needs to send a package away from their current position, at the same level. The astronaut has access to a projectile launcher which can accelerate objects to a velocity of u=25.0ms^{-1} at an angle of θ=35°. How far away will the projectile land? **2**



Question 27 (2 marks)

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 $2.00 \times 10^8 ms^{-1}$. How long would this trip take as measured by the crew of the ship? **2**

Question 28 (4 marks)

Orbital velocity is the velocity required to maintain a circular orbit. *Escape velocity* is the minimum velocity required to escape the gravitational influence of a planet or star. **4**

A 3.5×10^3 spacecraft is in a circular orbit around the Earth with an orbital altitude of 300km. The spacecraft fires its engine opposite the direction of its motion, adding $3.30 \times 10^3 ms^{-1}$ to its velocity. Describe the effect this will have on the spacecraft's position around the earth. Show all working

NOT TO SCALE

Question 29 (4 marks)

The Large Hadron Collider (LHC) is capable of accelerating protons to significant fractions of the speed of light, colliding them together to create normally short-lived particles. These new particles also travel at high velocities and have longer lifetimes. At the current setting, the LHC can give protons 7.00TeV of kinetic energy. With working out, discuss why classical physics cannot explain the motion of the protons moving at this energy and the lifetimes of the particles created **4**

– End of Paper –

5TRB

Sydney Boys High School

Student Number:

Multiple Choice Answer Sheet
Physics Half Yearly Cohort Task 2020

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

Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ⊗ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.

correct

A ⊗ B ⊗ C ○ D ○

Start Here ➔

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

Student Number:

Sydney Boys High School

Physics

April 2020
Half Yearly Cohort Task
Advanced Mechanics, Electromagnetism, Special Relativity

General Instructions

- Reading time: 5 minutes
- Working time: 75 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 – 55

Part A – Multiple Choice
- 20 marks

Part B – Free Response
- 35 marks

PART A – Multiple Choice (20 marks)

1. An object on Earth has a weight of 380 N and experiences an acceleration due to gravity of 9.8 m s^{-2}. On Venus, this object would experience an acceleration due to gravity of 8.9 m s^{-2}.

On Venus, what would be the weight of this object?

(A) 380 N

(B) $\frac{380}{9.8}$ N

(C) $\frac{380}{8.9} \times 9.8$ N

(D) $\frac{380}{9.8} \times 8.9$ N

2. The table contains information related to two planets orbiting a distant star.

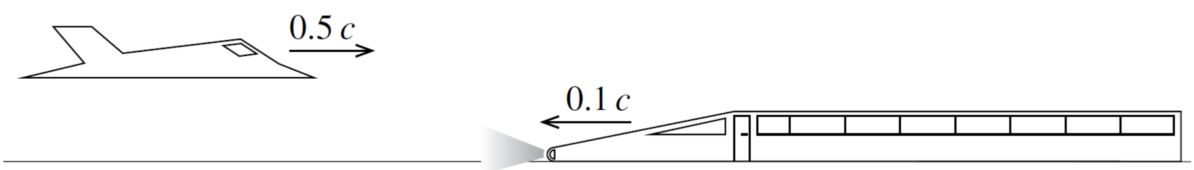
Planet	*Mass (kg)*	*Orbital radius (m)*	*Radius of Moon (m)*	*Length of day (s)*	*Orbital period (s)*
Plan	9.21×10^{24}	6.00×10^{10}	3.00×10^{6}	2.76×10^{4}	3.47×10^{7}
Net	1.25×10^{25}	3.00×10^{10}	6.00×10^{6}	1.88×10^{4}	—

The orbital period of the planet Net can be determined by using data selected from this table.

What is the orbital period of the planet Net?

(A) 1.23×10^{7} s ???
(B) 2.19×10^{7} s
(C) 5.51×10^{7} s
(D) 9.81×10^{7} s

3. In a thought experiment, a jet is travelling at 0.5 c relative to the ground, towards a train that is travelling at 0.1 c relative to the ground, as shown. (2016 Q6)



What is the speed of the light emitted from the train's headlight, as measured by a pilot in the jet?
(A) 0.1 c

(B) 0.4 c

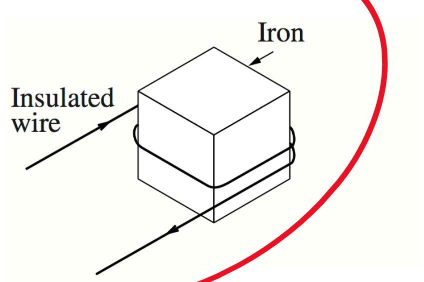
(C) 0.6 c

(D) 1.0 c

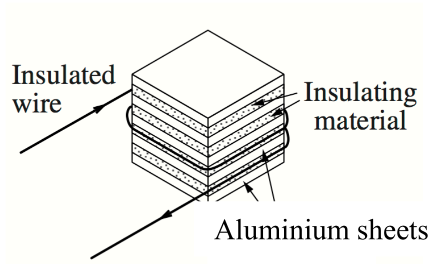
4. A transformer is to be designed so that it is efficient; transferring energy from one coil to another. The designer has some metal and insulating material available to build the transformer core. The windings are to be made with insulated copper wire.

Which of the following designs would transfer the most energy to a secondary coil?

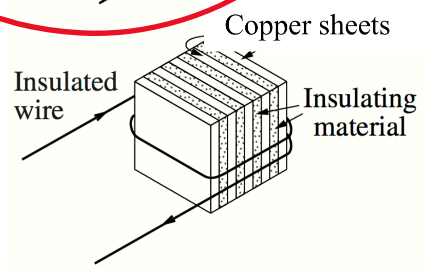
(A)



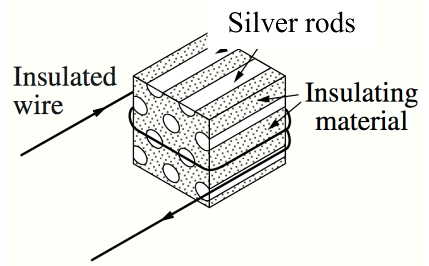
(B)



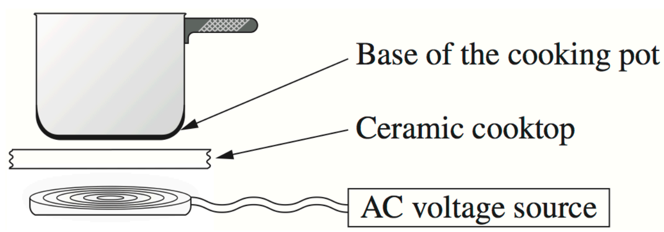
(C)



(D)



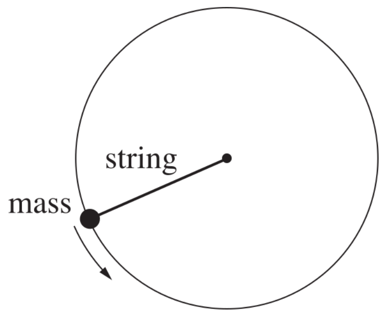
5. The diagram represents an induction cooking system.



Which row in the following table shows the set of conditions that would result in the most rapid heating of the base of the cooking pot?

	Electrical resistance of pot base	*AC voltage frequency*
(A)	Low	High
(B)	Low	Low
(C)	High	High
(D)	High	Low

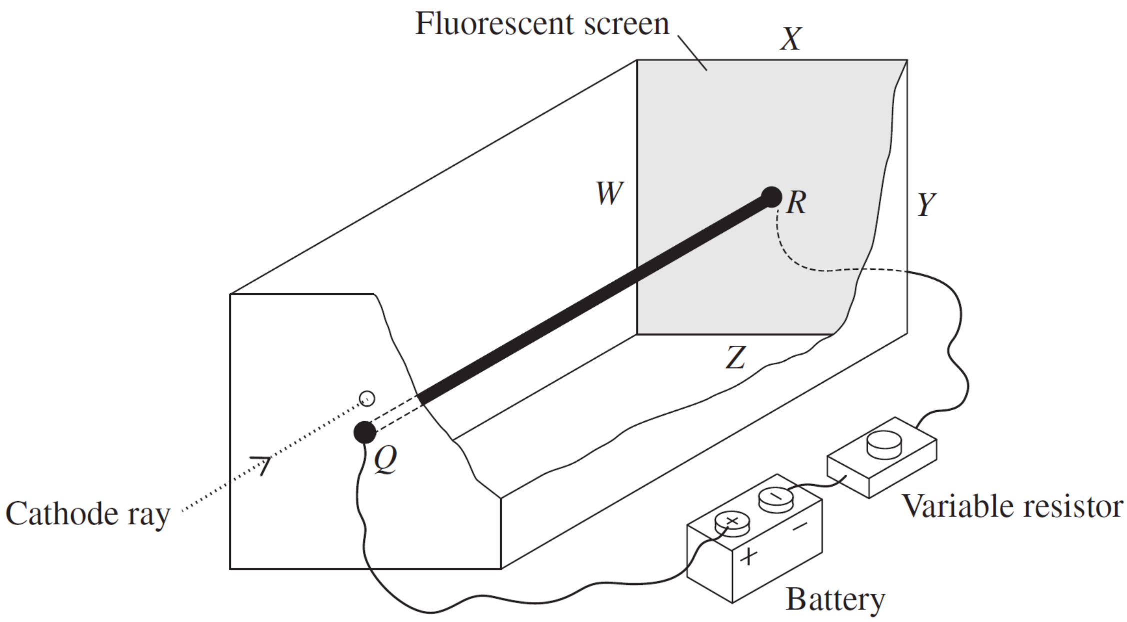
6. A 500 g mass is swung in a horizontal circle as shown. It completes 7 revolutions in 4 seconds. The circle has a 3.0 m diameter.



Which of the following forces is closest to that required to keep the mass moving in this circle?

(A) 5.0 N
(B) 25 N
(C) 45 N
(D) 90 N

7. A straight current-carrying conductor, *QR,* is connected to a battery and a variable resistor. *QR* is enclosed in an evacuated chamber with a fluorescent screen at one end.



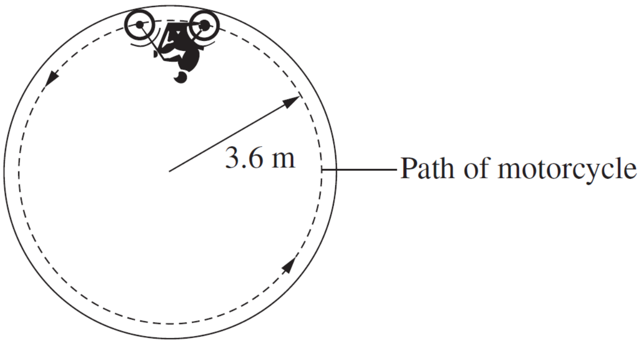
A cathode ray (a beam of electrons) enters the chamber directly above Q, initially travelling parallel to QR. It passes through the chamber and strikes the fluorescent screen causing a bright spot.

Which direction will this spot move towards if the resistance is increased? (2019 Q17)

(A) *W*

(B) X
(C) Y
(D) Z

8. A motorcycle travels around a vertical circular path of radius 3.6 m at a constant speed. The combined mass of the rider and motorcycle is 200 kg.



What is the minimum speed, in ms^{-1}, at which the motorcycle must travel to maintain the circular path? (2016 Q18)

(A) 0.42
(B) 1.9
(C) 5.9
(D) 35

9. Which of these statements best describes the forces acting on a satellite in orbit around Earth? (2015Q 11)
(A) Although gravity has no effect, there is still an outward force.
(B) The satellite is kept up by an outward force that balances the force due to gravity.
(C) Gravity is the only force acting on the satellite and this results in an inward acceleration.
(D) The effect of gravity is negligible, the satellite is kept in orbit by its momentum and the net force on it is zero.

10. Which of the following is an inertial frame of reference?

(A) A rocket during launch
(B) A train travelling at a constant velocity
(C) A car turning a corner at a constant speed
(D) A lift slowing down as it approaches the ground floor

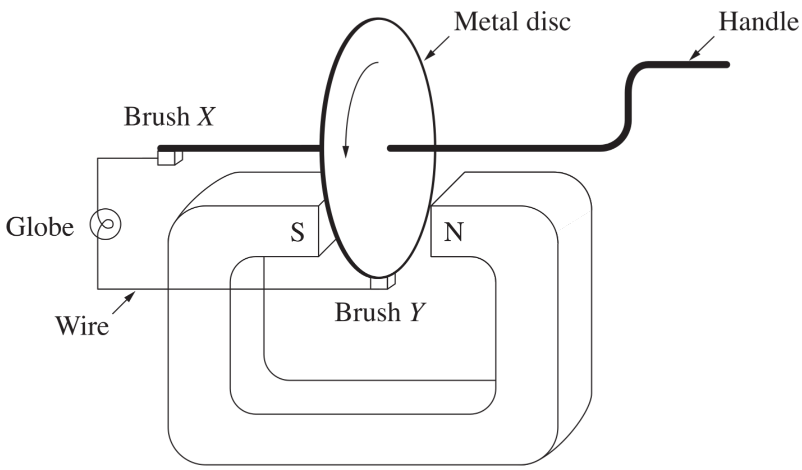
11. Two satellites have the same mass. One (LEO) is in low-Earth orbit and the other (GEO) is in a geostationary orbit.

The total energy of a satellite is half its gravitational potential energy.

Which row of the table correctly identifies the satellite with the greater orbital period and the satellite with the greater total energy? (2019, Q9)

	Greater orbital period	*Greater total energy*
(A)	LEO	LEO
(B)	LEO	GEO
(C)	GEO	LEO
(D)	GEO	GEO

12. Early electric generators were often very simple. A hand-operated version is depicted below.

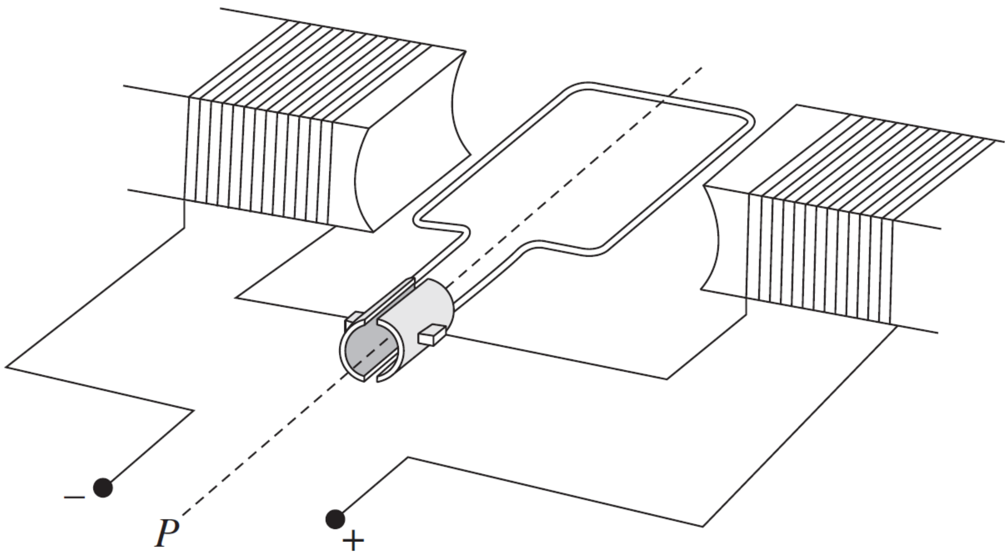


Brush X touches the metal axle and Brush Y touches the rim of the disc.

If the metal disc is rotated uniformly as shown, which statement about the current through the globe is correct?

(A) A direct current flows from Y to X.
(B) A direct current flows from X to Y.
(C) An alternating current flows between X and Y.
(D) No current flows.

13. 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? (2016 Q20)

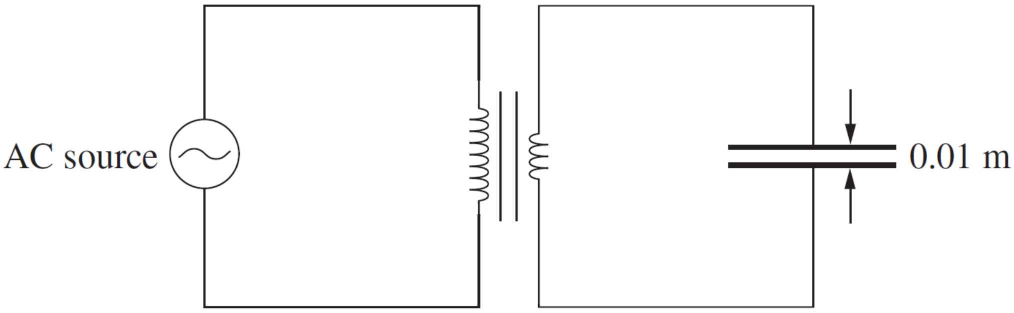
(A) There is no movement of the rotor.
(B) The rotor produces clockwise movement only.
(C) The rotor vibrates at the frequency of the AC supply.
(D) The rotor continuously turns half a rotation clockwise, then half a rotation anticlockwise.

14. A projectile was launched from the ground. It had a range of 70 metres and was in the air for 3.5 seconds.

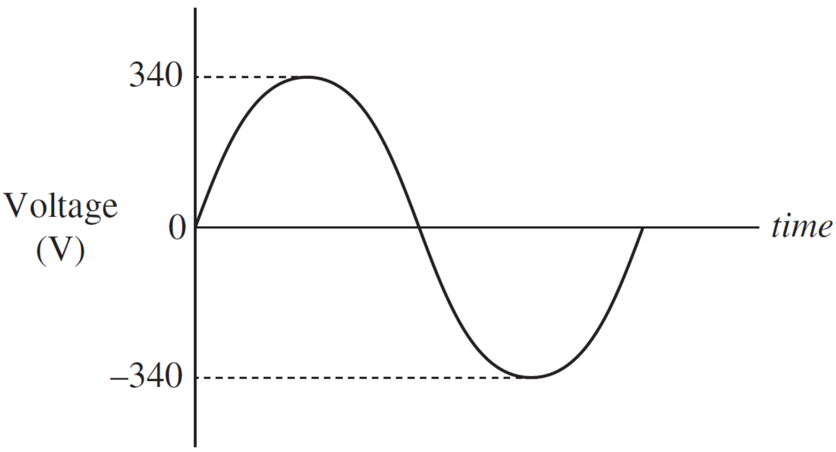
At what angle to the horizontal was it launched? (2015 Q20)

(A) 30°
(B) 40°
(C) 50°
(D) 60°

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



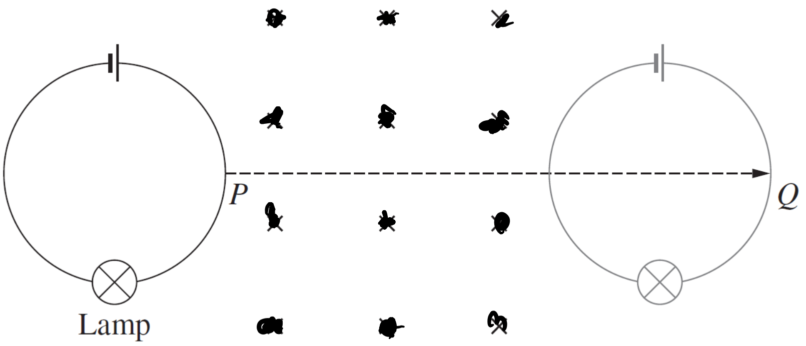
The AC input is shown in the graph.



What is the maximum field strength (in Vm^{-1}) produced between the plates? (2017 Q11)

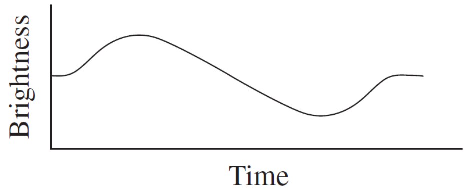
(A) 1.7
(B) 6.8
(C) 1.7×10^4
(D) 6.8×10^4

16. A circular loop of wire is connected to a battery and a lamp. The apparatus is moved from P to Q along the path shown at a constant velocity through a region containing a uniform magnetic field.

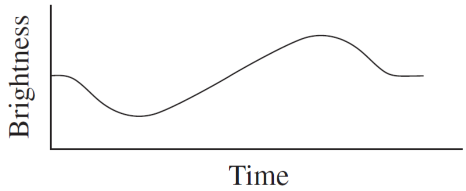


Which graph shows the brightness of the lamp as the apparatus moves between P and Q? (2019 Q18)

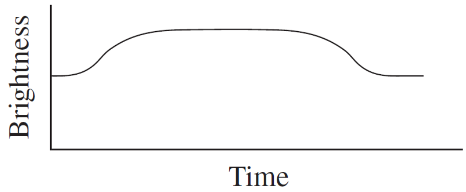
A.



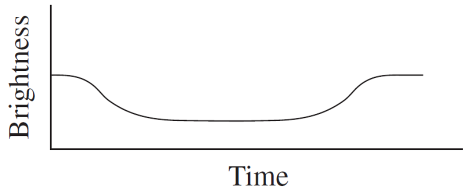
B.



C.



D.

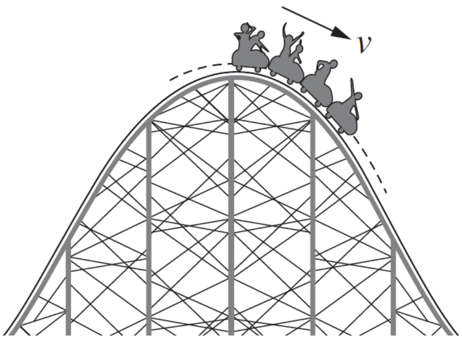


17. During the launch of a space vehicle from Earth, an astronaut feels an increased downward g force.

In which of the following situations would a person also feel an increased downward g force?

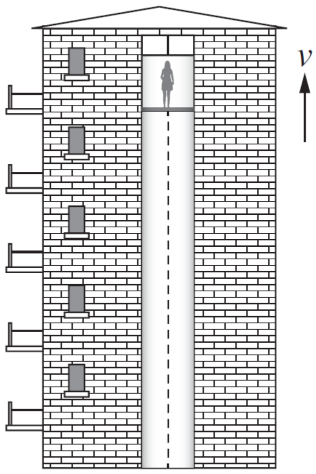
2018 Q11

A.



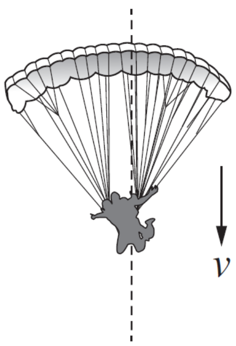
Roller-coaster speeding up

B.



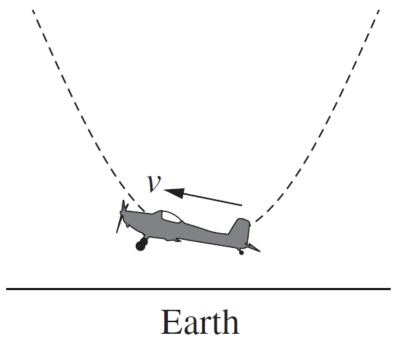
Lift slowing down

C.



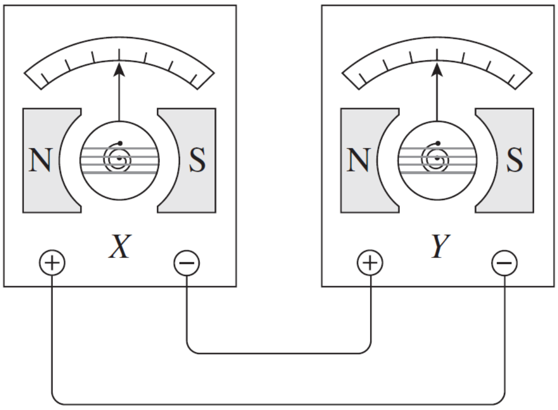
Parachute falling at a constant velocity

D.

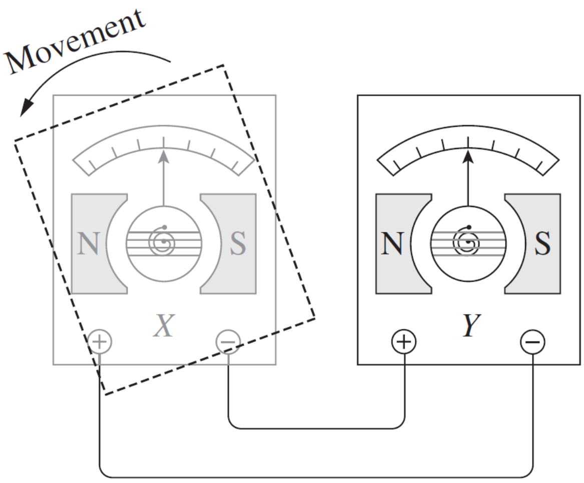


Plane pulling out of a dive

18. Two identical galvanometers X and Y were connected as shown and placed on a desk.



The meter X was then picked up and rotated suddenly anticlockwise to the position shown by the dotted outline, while the meter Y remained stationary on the desk.

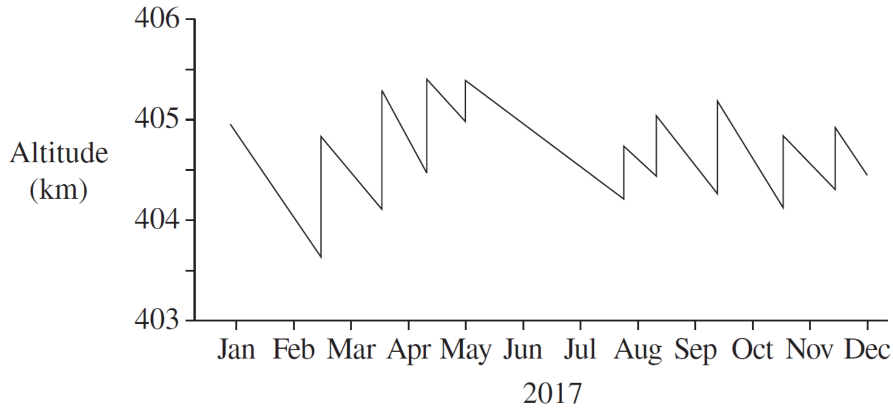


When this action is carried out, the pointers on both meters move relative to the scales on the meters.

Which row of the table correctly identifies the movement of the pointer on Y and the reason for its behaviour?

	Movement of pointer	*Reason*
(A)	Towards right	The movement of *X* produces a current that flows into the opposite terminal of *Y*.
(B)	Towards right	According to Lenz's law the effect produced must oppose the cause of the flux.
(C)	Towards left	*Y* behaves as a motor with the current flowing through it from right to left.
(D)	Towards left	For every force, there is an equal and opposite force.

19. The graph shows the altitude of the International Space Station (ISS) during 2017.



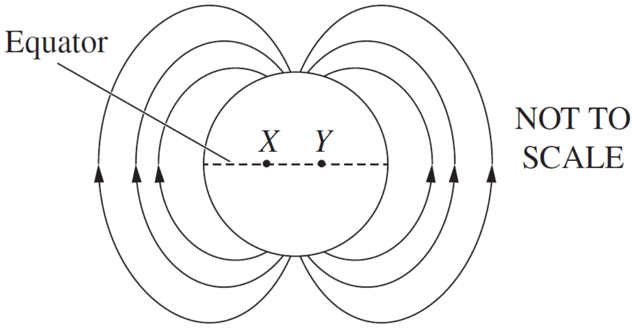
The altitude can only be boosted by supply craft visiting the ISS.

Why does the altitude decrease in the times between height boosts? (2018 q3)

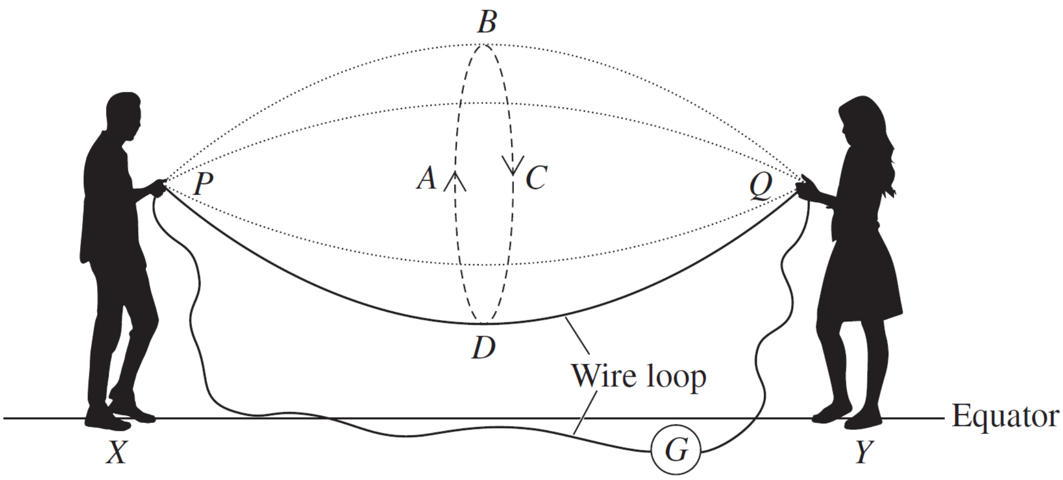
(A) Momentum of the ISS is being transferred to air molecules.
(B) The moon's gravity changes the net force on the ISS as it orbits Earth.
(C) The decrease in altitude makes it possible for a supply craft to reach the ISS.
(D) The total mass of the ISS changes with the deliveries from each supply craft.

Exam continues next page

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.



At what point during the rotation of the wire does the maximum current flow in a direction from Q to P through the moving part of the wire? (2019Q19)

(A) *A*
(B) *B*
(C) *C* ???
(D) *D*

Student Number:

PART B – Free Response (40 marks)

Question 21 (6 marks)

The Earth has a mass of 6.00×10^{24} kg and a radius of 6370 km.

a A geosynchronous orbit is defined as an orbit whose period is the same as rotation of the earth about its axis. Given that the earth has a rotational period of 23.93 hours, calculate the radius of such an orbit. **2**

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

$$r = \sqrt[3]{\frac{GMT^2}{4\pi^2}} = \sqrt[3]{\frac{6.67 \times 10^{-11} \times 6.00 \times 10^{24} \times (23.93 \times 60 \times 60)^2}{4\pi^2}}$$

$$= 42215239 = 4.22 \times 10^7 \text{ m}$$

✓ use of correct equation

✓ correct value & units (maximum 3 s.f.)

b A 2000 kg satellite is placed in orbit around the Earth at an altitude of 2.02×10^3 km. Calculate the total energy required to move this satellite to a geosynchronous orbit. **2**

$$F_g = F_c \quad \Rightarrow \quad \frac{GMm}{r^2} = \frac{mv^2}{r} \quad \Rightarrow \quad v^2 = \frac{GM}{r}$$

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

$$E = U + K = -\frac{GMm}{r} + \frac{GMm}{2r} = -\frac{GMm}{2r}^{*}$$

	initial	*final*	*change*
U	-9.54×10^{10}	-1.90×10^{10}	7.64×10^{10}
~~K~~	~~4.77×10^{10}~~	~~9.48×10^{9}~~	~~-3.82×10^{10}~~
E	-4.77×10^{10}	-9.48×10^{9}	3.82×10^{10}

$$\Delta E = E_f - E_i = -\frac{GMm}{2r_f} - \left(-\frac{GMm}{2r_i}\right) = -\frac{GMm}{2}\left(\frac{1}{r_f} - \frac{1}{r_i}\right)$$

$$= -\frac{6.67 \times 10^{-11} \times 6.00 \times 10^{24} \times 2000}{2}\left(\frac{1}{42215239} - \frac{1}{6370 \times 10^3 + 2.02 \times 10^6}\right)$$

$$= 38219653464 = 3.8 \times 10^{10} \text{ J}$$

* remember $E = -K = \frac{1}{2}U$ (not on data sheet)

✓ 2 MARKS: correct value with units

✓ −1 MARK for each error (ΔU rather than ΔE, E_f rather

✓ than ΔE, not including r_E, using 2.02×10^3, etc.)

c For the satellite in part (b), justify the use of a geosynchronous orbit with examples. **2**

Geosynchronous orbits are used because the satellite is always visible to a given position on the surface of the earth. A special case is a geostationary orbit, where the satellite appears stationary with respect to a given position on the surface of the earth. This orbit makes tracking of the satellite very easy, because it only needs to be set up once. This is particularly useful for satellite television broadcasting. This orbit also allows the satellite to have a continuous view of the same area on the surface of the earth, which is particularly useful for meteorological applications (such as weather forecasting).

✓ valid justification related to applications

✓ 2 or more applications used

* less atmospheric drag relevant to <u>all</u> high-earth orbits, not just geosynchronous

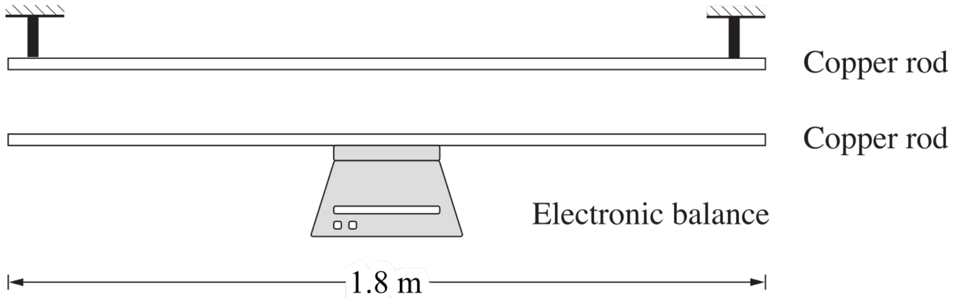
* GPS satellites are <u>not</u> geosynchronous ($r_{GPS} = 2.66 \times 10^7$ m, $T_{GPS} = 12$ h)

* geosynchronous ≠ geostationary (only geo<u>stationary</u> are stationary relative to surface of earth)

* saying that satellite is stationary relative to surface of earth is not enough – why is this useful?

Question 22 (6 marks)

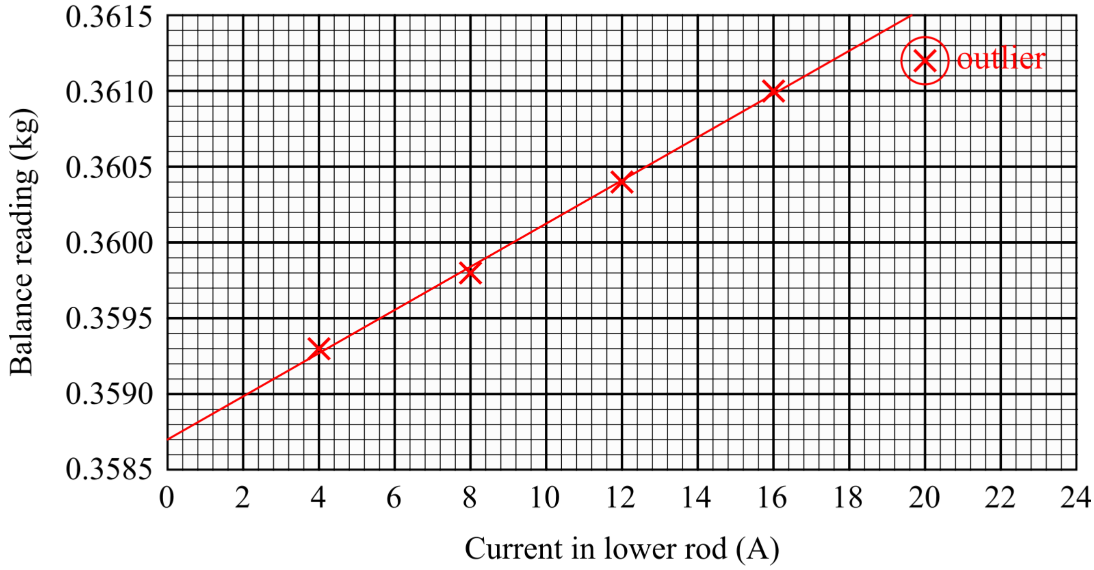
A balance was used to investigate the relationship between current and force. The balance was set up with one copper rod fixed to it and a second rod fixed above it, as shown in the diagram. Each rod was connected to a source of current. The diagram is not to scale.



The copper rods were rigid, each was 1.8 m long, and they were parallel. The current in the upper rod was kept constant at 60 A. Different currents were passed through the lower rod and the balance reading recorded for each current. The readings are given in the table below.

Current in lower rod (A)	*Balance reading (kg)*
4.0	0.3593
8.0	0.3598
12.0	0.3604
16.0	0.3610
20.0	0.3612

a Plot the data from the table onto the graph, using the scales and axes as indicated, and add the line of best fit (trend line). **2**



✓ correctly plotted data using appropriate symbols

✓ appropriate LOBF (ignores outlier)

b Find the mass of the copper rod on the balance. **1**

From the y-intercept, the mass of the copper rod is 0.3587 kg.

✓ correct value from LOBF

c Calculate the distance between the two copper rods. **3**

Given that changes in the balance readings are due to changes in the force between the parallel wires:

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

$$gradient = \frac{rise}{run} = \frac{m}{I_2} = \frac{\mu_0 I_1 l}{2\pi r g}$$

From the LOBF, $gradient = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0.3612 - 0.3587}{17.6 - 0.0} = 1.42 \times 10^{-4}\ \text{kg A}^{-1}$

Therefore, $r = \frac{\mu_0 I_1 l}{2\pi g \times gradient} = \frac{4\pi \times 10^{-7} \times 60 \times 1.8}{2\pi \times 9.8 \times 1.42 \times 10^{-4}} = 0.0155\ \text{m} = 15.5\ \text{mm}$

✓ use of correct equation

✓ use of LOBF for calculation

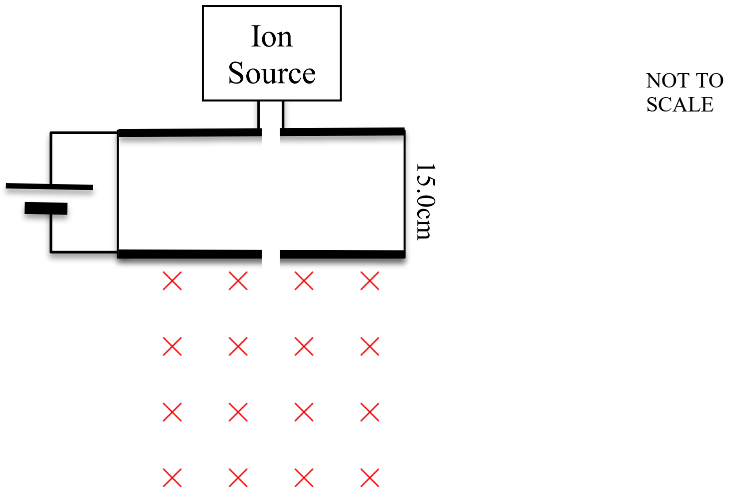
✓ correct answer & units

Exam continues next page

Question 23 (8 marks)

An ion thruster works by accelerating charged particles (ions) to a high velocity using electric and magnetic fields.

The device shown below has Xenon particles fired into the acceleration chamber at a velocity of $u = 20\ ms^{-1}$. The particles have a charge of $q_{Xe} = +4.81 \times 10^{-19} C$, and a mass of $m_{Xe} = 2.18 \times 10^{-25} kg$.



a Upon leaving the acceleration chamber, the particles are measured to have an exit velocity of $u = 2.57 \times 10^4\ ms^{-1}$. Calculate the potential difference across the acceleration chamber required to do this work **3**

From work done by electric field to accelerate ions to this speed:

$$W = \Delta K = \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = \frac{1}{2}m(v^2 - u^2)$$

$$= \frac{1}{2} \times 2.18 \times 10^{-25} \times ((2.57 \times 10^4)^2 - 20^2) = 7.199 \times 10^{-17}\ \text{J}$$

$$W = qV \quad \Rightarrow \quad V = \frac{W}{q} = \frac{7.199 \times 10^{-17}}{4.81 \times 10^{-19}} = 149.67 = 150\ \text{V}$$

✓ correct calculation of W or a (2.202×10^9 m s^{-2})

✓ correctly relates calculation to V

✓ correct value & units (maximum 3 s.f.)

b In the diagram above, draw the direction of a magnetic field required to deflect the ion beam to the right **1**

✓ correct direction of field

c Given that the space between the plates of the acceleration chamber is 15.0cm, calculate the time the particles spend in the chamber, and the power the acceleration chamber provides one particle of xenon. **2**

From uniform linear acceleration:

$$v^2 = u^2 + 2as \quad \Rightarrow \quad a = \frac{v^2 - u^2}{2s} = \frac{(2.57 \times 10^4)^2 - 20^2}{2 \times 0.15} = 2.2016 \times 10^9\ \text{m s}^{-2}$$

$$v = u + at \quad \Rightarrow \quad t = \frac{v - u}{a} = \frac{2.57 \times 10^4 - 0}{2.2016 \times 10^9} = 1.1664 \times 10^{-5}\ \text{s}$$

Therefore, power for one ion is:

$$P = \frac{W}{t} = \frac{7.199 \times 10^{-17}}{1.1664 \times 10^{-5}} = 6.1722 \times 10^{-12} = 6.17 \times 10^{-12}\ \text{W}$$

✓ correct time (with units)

✓ correct power (with units)

d After running for an hour, $1.31 \times 10^{-6} kg$ of xenon fuel has been consumed. What is the magnitude of the current in the chamber? **2**

Assuming constant consumption rate for 1 h:

$$n = \frac{M_{Xe}}{m_{Xe}} = \frac{1.31 \times 10^{-6}}{2.18 \times 10^{-25}} = 6.009 \times 10^{18} \text{ ions}$$

$$I = \frac{Q}{t} = \frac{nq}{t} = \frac{6.009 \times 10^{18} \times 4.81 \times 10^{-19}}{60 \times 60} = 8.03 \times 10^{-4} \text{ A}$$

✓ use of correct Physics equation(s)

✓ correct value & units

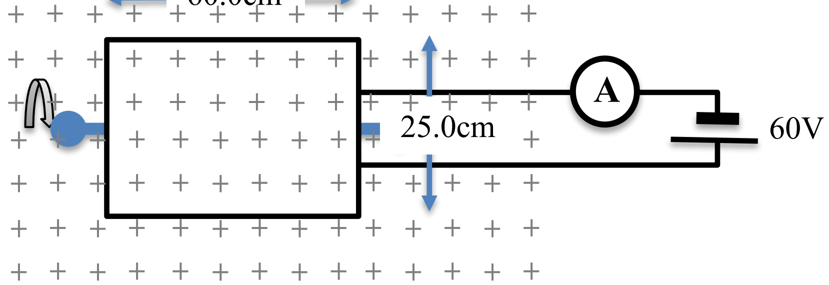
* cannot use $P = VI$ because the ions are not in the circuit containing the power supply (they do not originate from the top plate)

Question 24 (4 marks) **4**

In an electric motor, *Back EMF* limits the amount of current flowing through the armature.

A 60V DC motor consists of 50 turns of wire formed into a rectangular loop 60.0 cm by 25.0 cm placed entirely in a uniform magnetic field B. The resistance of the armature is 1.2Ω. When a small load is placed on the motor, it is measured to draw 2A, with a rotation speed of 7200RPM. Calculate the strength of the magnetic field.

NOT TO SCALE



$\Sigma \mathcal{E} = \mathcal{E}_{supply} - \mathcal{E}_{back}$

$\Sigma \mathcal{E} = I \cdot R$
$= 2 \times 1.2$
$= 2.4 V$

$\therefore \mathcal{E}_{back} = 60 - 2.4$
$= 57.6 V$

$V_s = 60 V$
$n = 50$
$A = 0.6 \times 0.25$
$= 0.15 m^2$
$B = ?$
$R = 1.2 \Omega$
$I_{net} = 2 A$

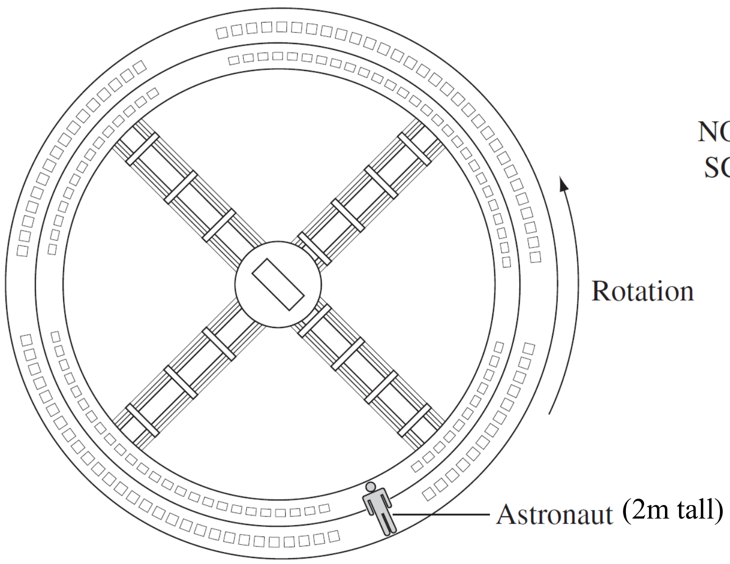
RPM $= 7200$
$= 120 Hz$

$\mathcal{E} = \frac{n \Delta \Phi}{\Delta t} = n \frac{BA_{max} - BA_{min}}{T/4}$ $T = 1/f = 8.33 \times 10^{-3} s$

$B = \frac{\mathcal{E} T}{n \cdot 4 \cdot A_{max}} = \frac{57.6 \times 8.33 \times 10^{-3}}{50 \times 4 \times 0.15} = 1.59 \times 10^{-2} T$

or $1.6 \times 10^{-2} T$

✓ $\Sigma \mathcal{E}$
✓ $\mathcal{E}_{back}$
✓ correct formula
✓ correct answer



a Explain how rotating the space station simulates gravity for the astronaut. **2**

- rotation causes a_c → which feels like g because Astron feels R force.
- must say a_c same as gravity.
reaction force

b Assuming that the astronauts are 2m tall, calculate the radius the space station would need for astronauts to experience 9.8ms^{-2} of acceleration at their feet and 8.8 ms^{-2} at their head. **2**

for astronauts to experience 9.8ms^{-2} of acceleration at their feet and ...

$a_{feet} = \frac{v_1^2}{r} = 9.8$ but $v_1 = \frac{2\pi r}{T}$

$9.8 = \frac{\left(\frac{2\pi r}{T}\right)^2}{r}$

$9.8 = \frac{4\pi^2 r}{T^2}$

$T^2 = \frac{4\pi^2 r}{9.8}$

$a_{head} = \frac{v_2^2}{(r-2)} = 8.8$ $v_2 = \frac{2\pi(r-2)}{T}$

$\therefore 8.8 = \frac{\left(\frac{2\pi(r-2)}{T}\right)^2}{r}$

$\cancel{8.8 = \frac{4\pi^2(r-2)}{8.8}}$

$T^2 = \frac{4\pi^2(r-2)}{8.8}$

$\therefore \frac{4\pi^2 r}{9.8} = \frac{4\pi^2(r-2)}{8.8}$

$8.8r = 9.8(r-2)$

$8.8r = 9.8r - 19.6$

$r = 19.6\text{ m}$

② correct answer

① attempts to use any correct formula

Question 26 (2 marks)

An astronaut stranded on Mars ($g_{mars} = 3.71\ ms^{-2}$) needs to send a package away from their current position, at the same level. The astronaut has access to a projectile launcher which can accelerate objects to a velocity of u=25.0ms^{-1} at an angle of θ=35°. How far away will the projectile land? **2**

$25ms^{-1}$, $35°$

$u_y = 25\sin 35$
$= 14.3ms^{-1}$

at $v=0$ t ½ flight

$t = \frac{v-u}{g}$
$= \frac{0-14.3}{-3.71}$
$= 3.87s$

$\Delta t = 7.73s$

$u_x = 25\cos 35$
$= 20.5ms^{-1}$

$u = 25ms^{-1}$ @ $35°$
$g = 3.71\ ms^{-2}$
$x = ?$

$\Delta x = u_x \Delta t$
$= 20.5 \times 7.73$
$= 158.5m$

✓✓ correct answer
✓ some attempt @ projectile equation

Question 27 (2 marks)

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 $2.00 \times 10^8 ms^{-1}$. How long would this trip take as measured by the crew of the ship? **2**

(1)

$L_v = L_0\sqrt{\left(1-\frac{v^2}{c^2}\right)}$

$= 8.7\sqrt{\left(1-\frac{(2\times10^8)^2}{(3\times10^8)^2}\right)}$

$= 8.7 \times \sqrt{1-\frac{4}{9}}$

$= 6.4\ ly$

$= 6.05\times10^{16}\ m$

$v_{SA} = 2.00\times10^8$
$L_0 = 8.7\ ly$

$t = \frac{d}{v}$

$= \frac{6.05\times10^{16}\ m}{2\times10^8\ ms^{-1}}$

$= 3.07\times10^8 s$

$= 9.7$ years

✓ uses L or t equation
✓ correct answer (incl. units)

$3.06\times10^8 s$

Question 28 (4 marks)

Orbital velocity is the velocity required to maintain a circular orbit. *Escape velocity* is the minimum velocity required to escape the gravitational influence of a planet or star. **4**

A $3.5 \times 10^3 kg$ spacecraft is in a circular orbit around the Earth with an orbital altitude of 3.00km. The spacecraft fires its engine opposite the direction of its motion, adding $3.30 \times 10^3 ms^{-1}$ to its velocity. Describe the effect this will have on the spacecraft's position around the earth. Show all working

NOT TO SCALE

$m_{sc} = 3.5 \times 10^3 kg$
alt $= 3.0 \times 10^6 m$
$r_E = 6.371 \times 10^6 m$
$m_E = 6.0 \times 10^{24} kg$

$$v_o = \sqrt{\frac{G m_E}{r}}$$

$$= \sqrt{\frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(6.37 \times 10^6 + 3.0 \times 10^5)}}$$

$$= 7.745 \times 10^3 ms^{-1}$$

adding rocket boost $v_f = 7.75 \times 10^3 + 3.3 \times 10^3$
$= 1.105 \times 10^4 ms^{-1}$

$$v_{escape} = \sqrt{\frac{2GM}{r}}$$

$$= \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{(6.37 \times 10^6 + 3 \times 10^5)}}$$

$$= 1.095 \times 10^4 ms^{-1}$$

✓ cal. v_o correct
✓ cal v_{esc} corret
✓ relates v_f / v_{esc}.
✓ correct statement based on student answer regarding spacecraft loc. comparing v_f & v_{esc}

1 mark if some valid attempt to cal. v_o or v_{esc}.

rocket boost brings v_f to greater than v_{escape}

∴ rocket leaves earths grav pull & escapes.

Question 29 (4 marks)

The Large Hadron Collider (LHC) is capable of accelerating protons to significant fractions of the speed of light, colliding them together to create normally short-lived particles. These new particles also travel at high velocities and have longer lifetimes. At the current setting, the LHC can give protons 7.00TeV of kinetic energy. With working out, discuss why classical physics cannot explain the motion of the protons moving at this energy and the lifetimes of the particles created **4**

$7.00TeV = 7\times10^{12}eV$

$7\times10^{12}eV = 1.12\times10^{-6}J$

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

$v = \sqrt{\frac{2E_k}{m}}$

$= \sqrt{\frac{2\times1.12\times10^{-6}}{1.673\times10^{-27}}}$

$= 3.7\times10^{10}\ ms^{-1}$

✓ attempt

✓✓ correct v.

2

- $v > c$ impossible. can't move that fast
  - ~~speed light constant~~
- ∴ time dialation doesn't work.
- need spec rel. because ... explain

then, any 2 of above.

− End of Paper −