NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2020

PHYSICAL SCIENCES: PAPER I

Time: 3 hours | 200 marks

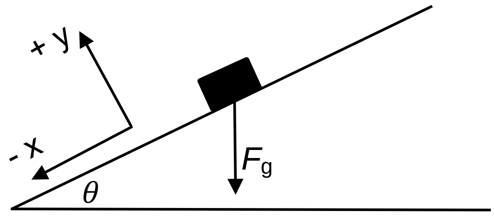
PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 16 pages, an Answer Sheet of 2 pages (i–ii), and a Data Sheet of 2 pages (i–ii). Please check that your question paper is complete.
2. Read the questions carefully.
3. Answer ALL the questions.
4. Start each question on a new page.
5. Number your answers as the questions are numbered.
6. Use the data and formulae whenever necessary.
7. Show your working in all calculations.
8. Units need not be included in the working calculations, but appropriate units should be shown in the answer.
9. Answers must be expressed in decimal format, not left as proper fractions.
10. Where appropriate, express answers to TWO decimal places.
11. It is in your own interest to write legibly and to present your work neatly.

QUESTION 1 MULTIPLE CHOICE

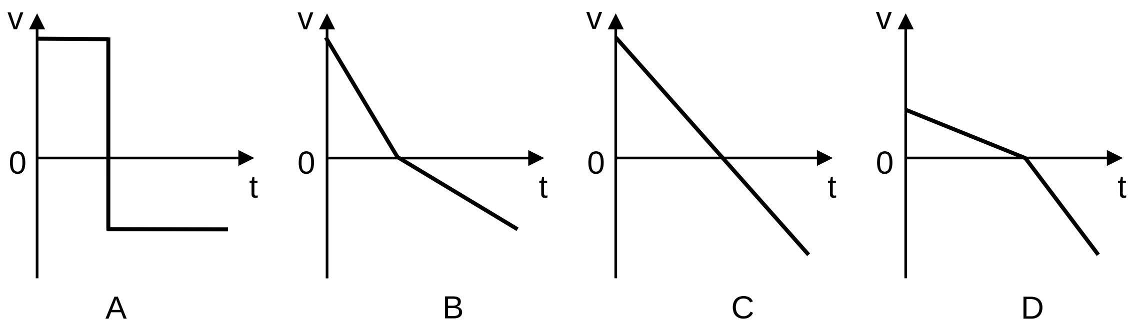
Answer these questions on the multiple-choice grid on the inside front cover of your Answer Book. Make a cross (X) in the box corresponding to the letter that you consider to be correct.

1.1 An object of weight F_g is on a plane inclined at an angle of θ to the horizontal as shown. Which of the following options correctly state the components of the weight in the plane of the coordinate axes shown in the diagram?



	x-component	y-component
A	$-F_g \sin\theta$	$-F_g \cos\theta$
B	$-F_g \cos\theta$	$-F_g \sin\theta$
C	$+F_g \sin\theta$	$+F_g \cos\theta$
D	$+F_g \cos\theta$	$+F_g \sin\theta$

1.2 A block slides up and then down a rough incline. Which of the following graphs could represent the velocity of the block as a function of time? All graphs take uphill as the positive direction.



1.3 A stone X is thrown vertically upwards with speed v from the top of a building. At the same time, a second stone Y is thrown vertically downwards with the same speed v. Air resistance is negligible.

Which one of the following statements is true about the speeds at which the stones hit the ground?

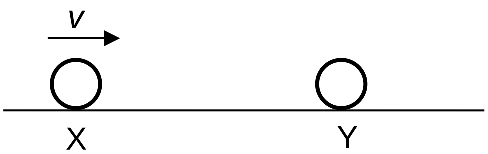
A the speed of stone X is greater than the speed of stone Y
B the speed of stone Y is greater than the speed of stone X
C the speed of stone X is equal to the speed of stone Y
D The speed of stone X can only be compared to the speed of stone Y when the height of the building is known

1.4 A car has a mass m. A person pushes the car with a force F in order for the car to have an acceleration of a. The person then pushes the car with a force $2F$ to achieve an acceleration of $3a$.

Which expression is equal to the constant resistive force opposing the motion of the car?

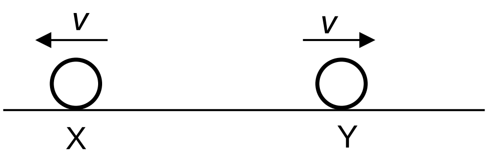
A $\frac{1}{2}ma$
B ma
C $2ma$
D $3ma$

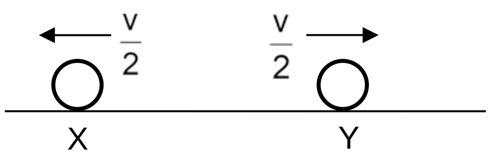
1.5 A ball X moving horizontally collides with an identical ball Y that is at rest.

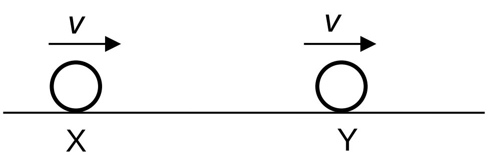


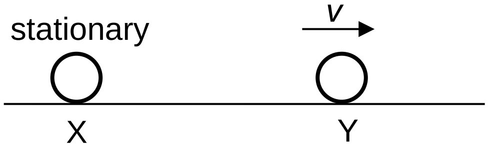
Ball X strikes ball Y with a velocity v.

Which of the following is a possible outcome of the collision?

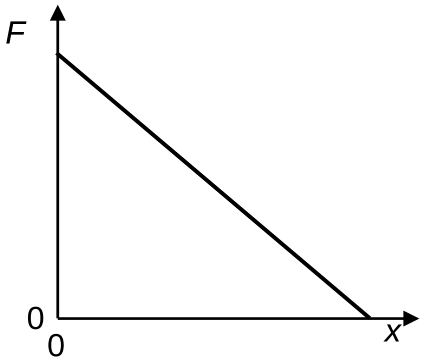
A


B


C


D


1.6 The graph below shows how the magnitude of the resultant force acting on an object changes as the object moves a distance *x*. The object is initially at rest.

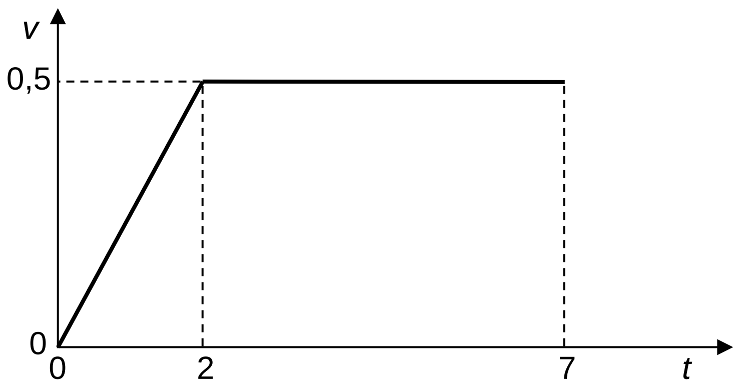


Which of the following describes how the kinetic energy and the acceleration of the object change with distance?

	Kinetic Energy	**Acceleration**
A	decrease	decrease
B	decrease	increase
C	increase	decrease
D	increase	increase

1.7 A box is pushed with a force of 3 N for 2 s along a frictionless track as shown.

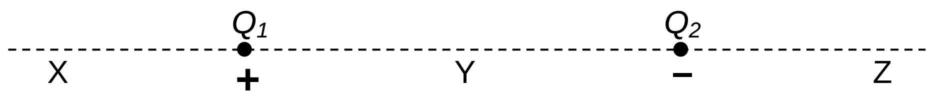
The graph represents the velocity of the box vs time.



How much work is done by the force acting on the box?

A 1,5 J
B 3,0 J
C 6,0 J
D 9,0 J

1.8 A positive point charge Q_1 and a negative point charge Q_2 of equal magnitude are held at fixed positions. Y is halfway between Q_1 and Q_2.



Which of the following combinations gives the direction of the net electric field due to the charges Q_1 and Q_2 at positions X, Y and Z?

	X	**Y**	**Z**
A	right	left	right
B	right	right	left
C	left	right	right
D	left	right	left

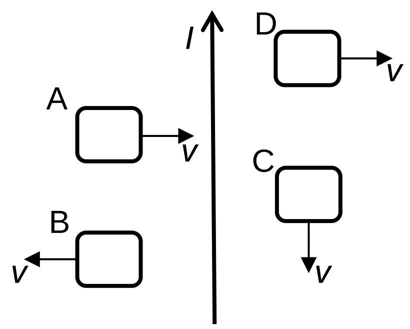
1.9 A battery with internal resistance is connected to a fixed resistor. A voltmeter is connected across the battery.

The battery is replaced by one with the same emf but with a larger internal resistance.

What happens to the reading on the voltmeter and the current through the fixed resistor?

	Voltmeter reading	**Current through resistor**
A	decreases	decreases
B	decreases	stays the same
C	stays the same	decreases
D	stays the same	stays the same

1.10 Four loops of wire move with velocity *v* near a long straight conductor carrying a current ***I*** as shown in the diagram.



Which loop will have an induced **anti-clockwise** current?

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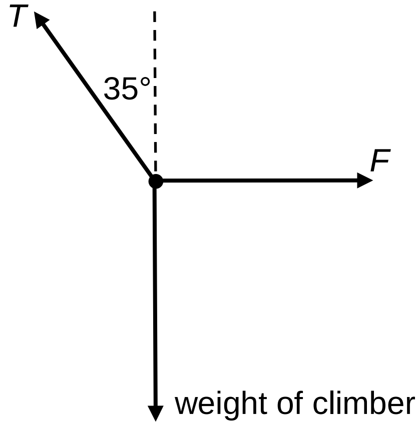
QUESTION 2 KINEMATICS

2.1 A rock climber descends a cliff face by abseiling down it.



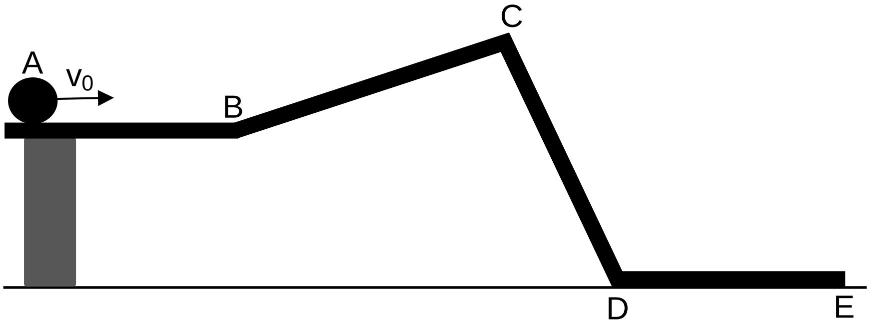
The mass of the climber is 64 kg. The climber stops to rest for a moment. A photograph and a free-body diagram of the climber at rest is shown above. While the climber is stationary, the rope under tension *T* is at an angle of 35° to the vertical. Ignore any friction between the climber and the cliff face.

2.1.1 The climber is in equilibrium. Describe equilibrium in terms of the forces acting on the climber. (2)

2.1.2 Calculate the magnitude of the tension *T* in the rope while the climber is at rest. (4)

2.1.3 Hence, calculate the magnitude of the horizontal force *F* acting on the climber from the cliff face. (3)

2.2 A ball is given an initial velocity of v_0 as it is rolled across a horizontal track. The ball then rolls up a gentle incline and down a steeper incline before reaching another horizontal section of track. The tracks are frictionless.



2.2.1 Define *velocity*. (2)

2.2.2 Sketch a position vs time graph on the axes provided **on the Answer Sheet** for the ball as it rolls along the tracks from A to E. Consider only the ball's horizontal position. (4)

2.2.3 Sketch the corresponding velocity vs time graph on the axes provided **on the Answer Sheet** for the ball as it rolls along the tracks from A to E. (4)

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QUESTION 3 KINEMATICS

3.1 While on the moon, astronauts dropped a golf ball from rest and measured the time taken for the ball to reach specific heights.

The results that the astronauts obtained are recorded in the table.

height (m)	time (s)	time^2 (s^2)
1,2	0,32	0,10
1,1	0,52	0,27
0,8	0,77	0,59
0,6	0,94	0,88
0,3	1,10	1,21
0,2	1,17	1,37

3.1.1 Plot a graph of height (on y-axis) vs time^2 (on x-axis) on the graph paper provided **on the Answer Sheet**. (6)

3.1.2 Why is height plotted vs time^2 and not time? (2)

3.1.3 Calculate the gradient of your graph. Show the values you used on your graph and include the appropriate unit in your answer. (5)

3.1.4 Hence, use an equation of motion and your gradient calculated in Question 3.1.3 to determine the acceleration of the golf ball on the moon. (3)

3.1.5 Without doing any further calculations, use your graph to determine the height that the golf ball was dropped from. (2)

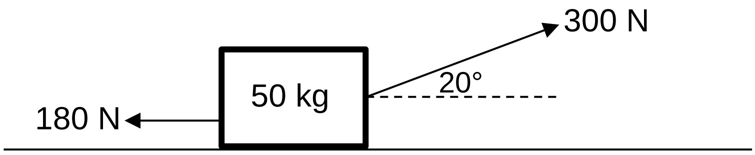
3.2 A sprinter runs a 100 m race. The sprinter starts from rest and accelerates at 2,5 $m \cdot s^{-2}$ until reaching their top speed of 15 $m \cdot s^{-1}$. The sprinter maintains this speed to complete the race.

How long does it take the sprinter to run the 100 m race? (6)

[24]

QUESTION 4 NEWTON

4.1 A 50 kg metal box is pulled across a rough horizontal surface with a force of 300 N acting at an angle of 20° to the surface. The frictional force acting on the metal box is 180 N.



4.1.1 Draw a free-body diagram showing all the forces acting on the metal box. (4)

4.1.2 State *Newton's second law of motion*. (2)

4.1.3 Calculate the magnitude of the acceleration of the metal box. (5)

4.1.4 Calculate the magnitude of the normal force that the ground is exerting on the box. (4)

The box continues being pulled with a force of 300 N at an angle of 20° to the surface but the box now slides up an inclined plane.

4.1.5 Will the frictional force acting on the metal box increase, decrease or stay the same? Briefly explain your answer making use of a relevant equation. (3)

4.2 A 200 kg wooden crate is at rest in the back of a truck travelling on a horizontal road with constant velocity.

4.2.1 Does the wooden crate experience a resultant force? (2)

The truck then accelerates but the crate stays in the same place. The coefficient of static friction between the crate and the truck is 0,9 and the coefficient of kinetic friction is 0,5.

4.2.2 Draw a labelled free-body diagram showing the horizontal force(s) acting on the crate while the truck is accelerating. You must also indicate the direction of motion of the truck. (2)

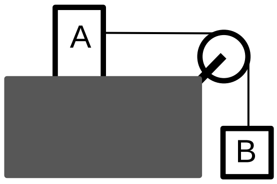
4.2.3 Calculate the maximum static friction acting on the crate. (3)

4.2.4 Calculate the maximum acceleration of the truck so that the crate does not slide backwards. (3)

4.2.5 Calculate the acceleration of the crate if the truck has a greater acceleration than that calculated in Question 4.2.4. (3)

4.3 Block A and block B are joined by a light inextensible string. Block A can slide across a frictionless table when pulled by a falling block B.

Initially block A is held in place by someone's hand.



4.3.1 Compare the tension in the string while the system is at rest (T_{rest}), to the tension in the string once the hand has released block A (T_{moving}). (2)

4.3.2 Will the acceleration of the system be the same as, smaller than or greater than the acceleration due to gravity? (2)

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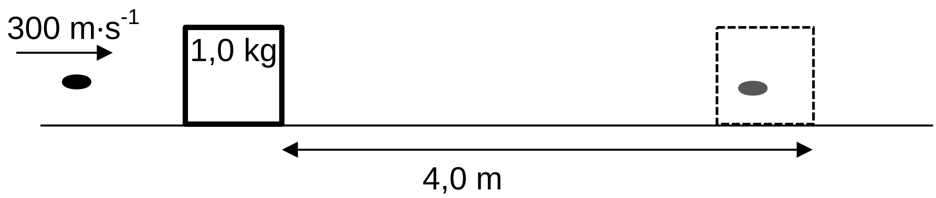
QUESTION 5 MOMENTUM, WORK, ENERGY & POWER

5.1 A bullet of 0,02 kg traveling at a velocity of 300 m·s^{-1} east embeds in a 1,0 kg wooden block resting on a horizontal surface. The block slides 4,0 m horizontally before stopping.



5.1.1 State *the law of conservation of linear momentum*. (2)

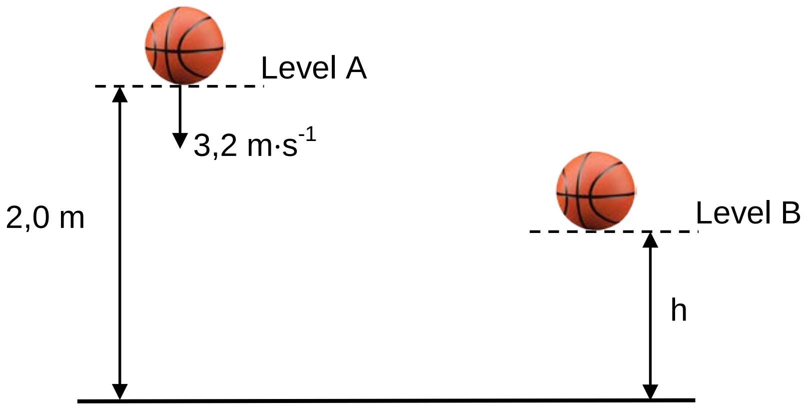
5.1.2 Calculate the velocity of the block with the bullet embedded immediately after the collision. (5)

5.1.3 State *the work-energy theorem*. (2)

5.1.4 Hence, calculate the magnitude of the frictional force that brought the block to rest. (4)

5.2 During a recent basketball tournament, a student analyses the motion of a ball. The ball is thrown vertically downwards and rebounds as shown.

A ball is measured to have a velocity of 3,2 m·s^{-1} down as it passes level A. The height of A is 2,0 m above the ground. The ball strikes the ground and bounces back up to level B. The mass of the ball is 0,60 kg. Assume air resistance is negligible.



5.2.1 Define *mechanical energy*. (2)

5.2.2 Calculate the magnitude of the velocity of the ball as it reaches the ground. (5)

The ball rebounds vertically and leaves the ground with a velocity of 1,6 m·s^{-1} upwards. The ball is in contact with the ground for a time of 0,02 s and reaches a maximum height *h* at level B.

5.2.3 Define *impulse*. (2)

5.2.4 Calculate the magnitude of the average force that the ground exerts on the basketball while the ball is in contact with the ground. (7)

[29]

QUESTION 6 FIELDS

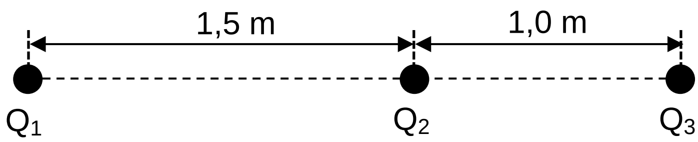
6.1 The force on a mass of 5,0 kg falling near the surface of Jupiter is 125 N. The radius of Jupiter is $7,0 \times 10^7$ m.

6.1.1 Define *gravitational field*. (2)

6.1.2 Calculate the gravitational field near the surface of Jupiter. (3)

6.1.3 Use your answer to Question 6.1.2 to calculate the mass of Jupiter. (4)

6.2 In the diagram below, Q_1, Q_2 and Q_3 are three point charges placed along a straight line. All three charges are fixed in position. The distance between Q_1 and Q_2 is 1,5 m and the distance between Q_2 and Q_3 is 1,0 m as shown in the diagram below.



6.2.1 State *Coulomb's law*. (2)

The magnitude of charges Q_1 and Q_2 are unknown. The charge on Q_1 is positive. The charge on Q_3 is + 2 μC and Q_3 experiences a net electrostatic force of 0,3 N to the left (towards Q_1)

6.2.2 Is the sign of charge Q_2 positive or negative? (2)

Charge Q_2 is now removed. The magnitude of the electrostatic force experienced by Q_3 due to Q_1 is now 0,012 N.

6.2.3 Calculate the magnitude of the unknown charge Q_1. (4)

[17]

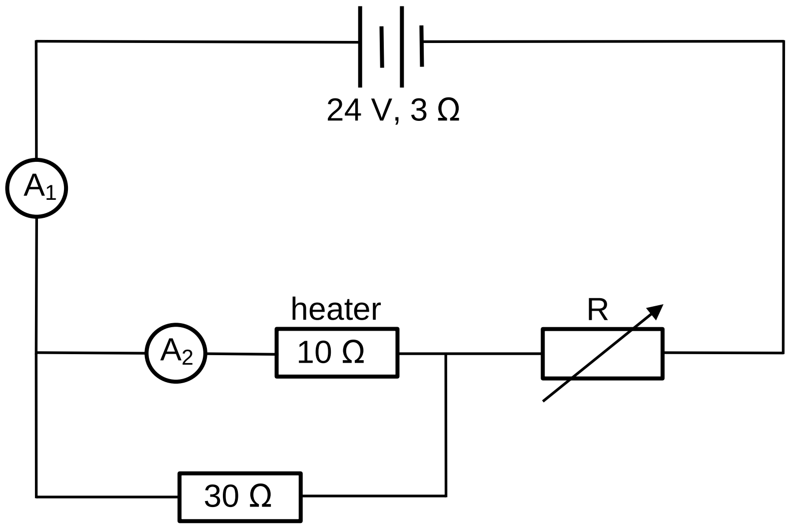
QUESTION 7 ELECTRIC CIRCUITS

7.1 A 12 V, 24 W kettle is connected to a supply of 12 V. The internal resistance of the supply is negligible.

7.1.1 Define *resistance*. (2)

7.1.2 Calculate the resistance of the kettle. (3)

7.2 In the circuit represented below, the battery has an emf of 24 V and an internal resistance of 3 Ω. The heater has a resistance of 10 Ω and the fixed resistor has a resistance of 30 Ω. The variable resistor, R, can vary between 0 Ω and 15 Ω. Ammeters have zero resistance and the voltmeters have infinite resistance.



When the variable resistor, R, has a resistance of 4,5 Ω:

7.2.1 Calculate the effective resistance of the external circuit. (5)

7.2.2 State *Ohm's law.* (2)

7.2.3 Calculate the current measured by ammeter A_1. (4)

7.2.4 Calculate the current measured by ammeter A_2. (5)

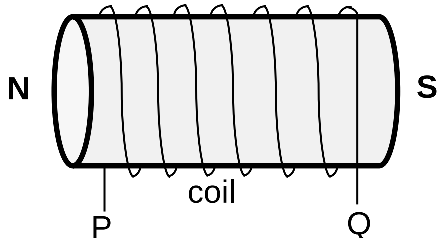
The variable resistor is now adjusted to have a higher resistance value.

7.2.5 Will the **heater** dissipate more heat, less heat or the same amount of heat? Explain your answer by making use of a suitable equation. (3)

[24]

QUESTION 8 ELECTRODYNAMICS

8.1 An electromagnet is shown in the diagram below and the north and south poles are indicated.

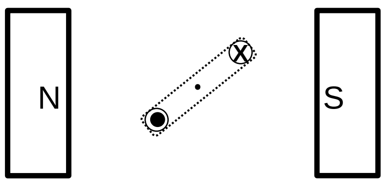


8.1.1 Does the current flow around the coil from P to Q or from Q to P? (2)

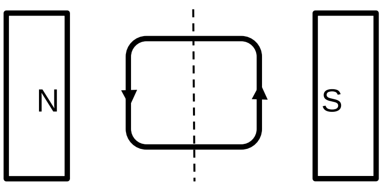
8.1.2 What will be the effect on the electromagnet of increasing the current in the coil? (2)

8.2 A loop of wire is placed between permanent magnets as shown in a side-view and a top-view. The direction of the current in the loop is indicated.

Side-view



Top-view

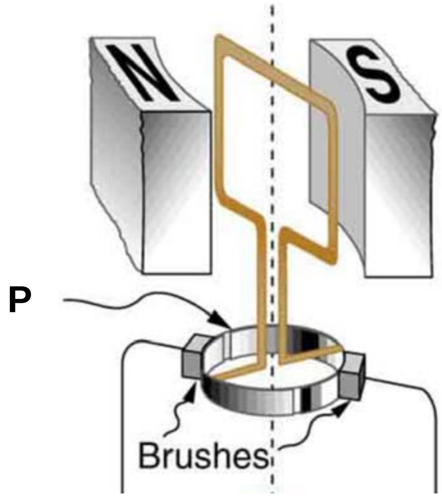


The loop of wire experiences a force.

8.2.1 Using the side-view diagram, will the loop rotate clockwise or anti-clockwise? (2)

8.2.2 Using the side-view diagram, will the equilibrium position of the coil be vertical or horizontal? (2)

8.3 The diagram shows a device that can be used either as a d.c. electric motor or a d.c. electric generator.



[Image from: <https://openstax.org/books/college-physics-ap-courses/pages/23-5-electric-generators>]

8.3.1 What is indicated in the diagram by the letter **P**? (2)

8.3.2 Explain how this device would work as a **d.c. electric motor**. You must refer to the input required and how it functions. (3)

8.3.3 Explain how this device would work as a **d.c. electric generator**. You must refer to the input required and how it functions. (3)

8.3.4 Suggest one change that would improve its operation as a motor and as a generator. (2)

[18]

QUESTION 9 PHOTONS AND ELECTRONS

9.1 The work function for zinc is $6{,}90 \times 10^{-19}$ J.

9.1.1 Define *work function*. (2)

9.1.2 Calculate the smallest frequency of light that will release electrons from a zinc surface. (3)

Photons with energy of $8{,}8 \times 10^{-19}$ J are incident on a zinc surface.

9.1.3 Calculate the maximum kinetic energy of the ejected electrons. (3)

9.2 Green is the most common colour observed in the Aurora Borealis (Northern Lights). The wavelength of the green light is 557,7 nm.

9.2.1 Calculate the energy emitted for this green emission line. (4)

Scientists are able to identify the green emission line as originating in atomic oxygen in the atmosphere.

9.2.2 How can the scientists use the energy of the emission line to uniquely identify an element? (2)

[14]

Total: 200 marks