NATIONAL SENIOR CERTIFICATE EXAMINATION
MAY 2021

PHYSICAL SCIENCES: PAPER I

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 17 pages, an Answer Sheet of 3 pages (i–iii) 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. Use the data and formulae whenever necessary.
5. Start each question on a new page.
6. Show your working in all calculations.
7. Units need not be included in the working of calculations, but appropriate units should be shown in the answer.
8. Answers must be expressed in decimal format, not left as proper fractions.
9. Where appropriate, express answers to TWO decimal places.
10. It is in your own interest to write legibly and to present your work neatly.

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QUESTION 1 MULTIPLE CHOICE

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

1.1 Consider the quantities: *momentum; speed; work.*

Of these quantities, how many are vectors and how many are scalars?

A one vector and two scalars
B two vectors and one scalar
C three vectors
D three scalars

1.2 Which of the following units is **NOT** a unit for power?

A Watt
B kilowatt-hour
C $J \cdot s^{-1}$
D $N \cdot m \cdot s^{-1}$

1.3 An astronaut with a mass of 70 kg is on a planet where her weight is 550 N. The acceleration due to gravity on that planet is … $m \cdot s^{-2}$.

A 0,13
B 7,86
C 56,12
D 686

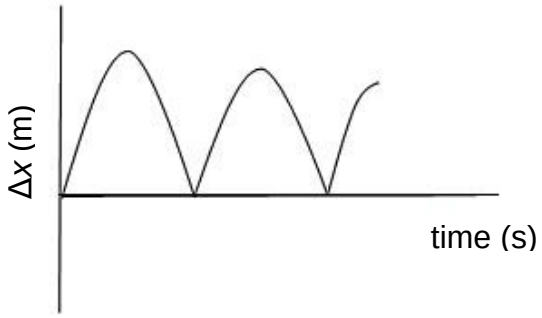
1.4 Two forces of magnitude 100 N and 300 N act together at a point. Which of the values below does NOT represent a possible resultant force of the two forces?

A 200 N
B 277 N
C 400 N
D 500 N

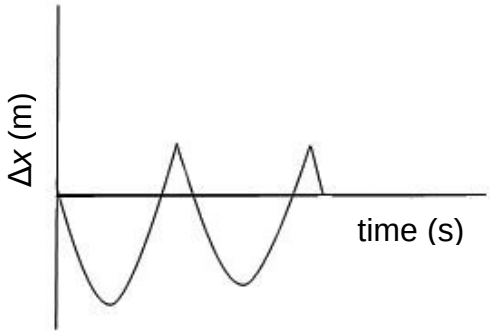
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1.5 A girl throws a ball vertically upwards from a height of 1 m above the ground. The ball then proceeds to bounce twice before she catches it at a height of 1 m above the ground. Which of the following graphs is **NOT** a possible displacement–time graph for the ball?

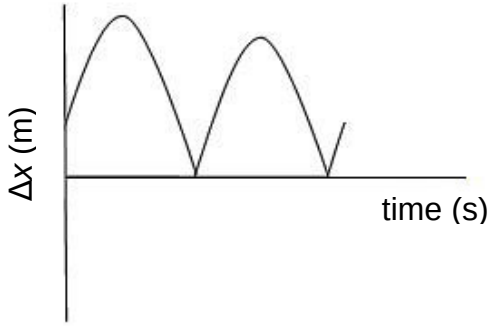
A



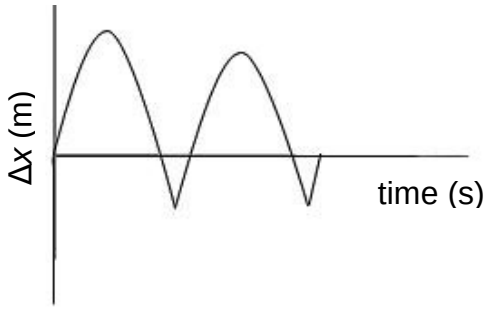
B



C



D

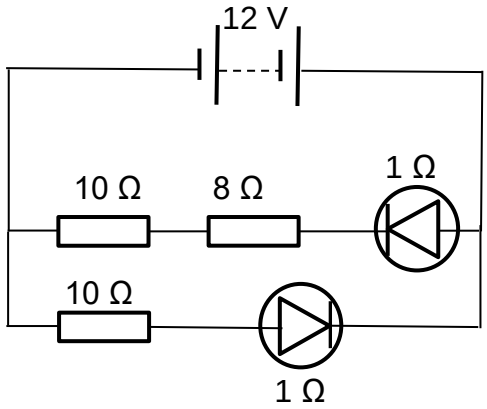


1.6 A student demonstrates a law of physics by quickly jerking a tablecloth out from under a cup and saucer, leaving the cup and saucer in the same position on a table. Which physics law is he/she demonstrating?

A Lenz's law
B Newton's first law
C Newton's third law
D Coulomb's law

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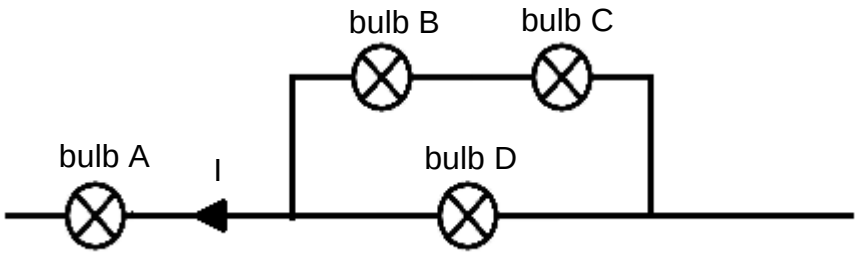
1.7 In the circuit shown below, the 12 V battery has negligible internal resistance.



The current flowing through the battery is:

A 0,63 A
B 1,09 A
C 6,97 A
D 7,25 A

1.8 Four identical bulbs, A, B, C and D, with the same resistance, R, are connected in a circuit as shown below. A current, I, flows through bulb A.

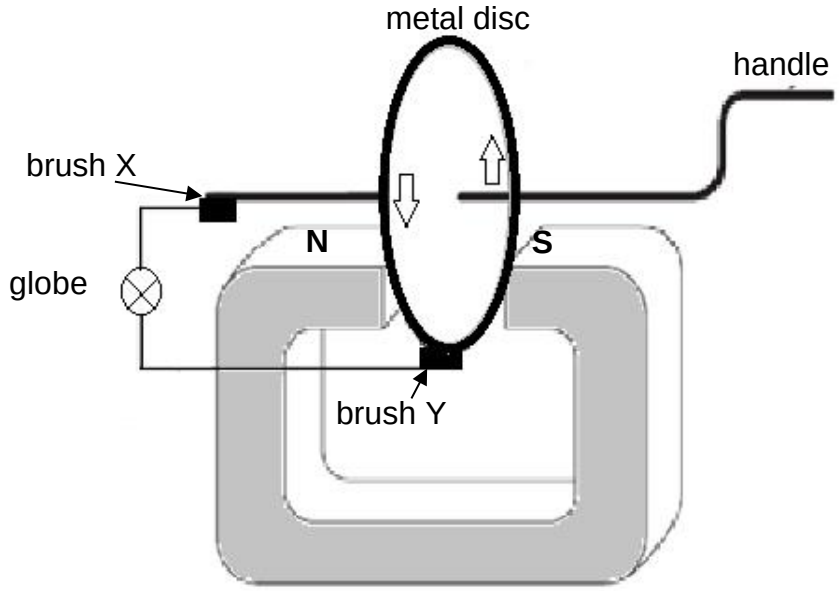


If the power in bulb A is equal to *P*, which combination of expressions regarding the power in bulbs B, C and D is correct?

	Power in bulb B	**Power in bulb C**	**Power in bulb D**
A	$\frac{4}{9}P$	$\frac{4}{9}P$	$\frac{1}{9}P$
B	$2\,P$	$2\,P$	$\frac{1}{2}P$
C	$\frac{1}{2}P$	$\frac{1}{2}P$	P
D	$\frac{1}{9}P$	$\frac{1}{9}P$	$\frac{4}{9}P$

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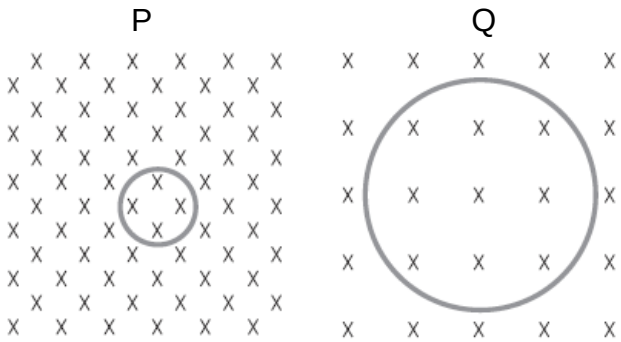
1.9 A simple hand-operated generator is depicted below. The turning of the handle causes the metal disc to rotate. The handle is joined to a metal axle that rotates with the metal disc.



Brush X touches the metal axle and brush Y touches the rim of the disc.
If the metal disc is rotated uniformly in the direction as shown, which statement about the current flowing through the globe will be correct?

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

1.10 Two copper rings of different sizes are placed in different magnetic fields, P and Q, as shown below.



In which one of the following combinations is the magnetic flux and the magnetic flux density greater? Choose the option corresponding to the correct combination.

	Greater magnetic flux	Greater magnetic flux density
A	P	P
B	Q	Q
C	P	Q
D	Q	P

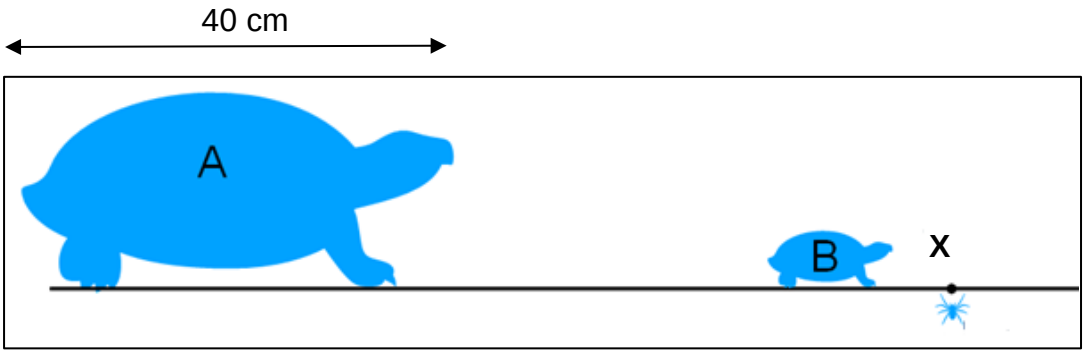
[20]

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QUESTION 2 SPEEDING TORTOISES

Two tortoises, A and B, are walking at the same speed to the right. Tortoise A is 40 cm long.

2.1 A spider at a point X on the ground notices that it takes 8 s for tortoise A to pass by from nose to tail.

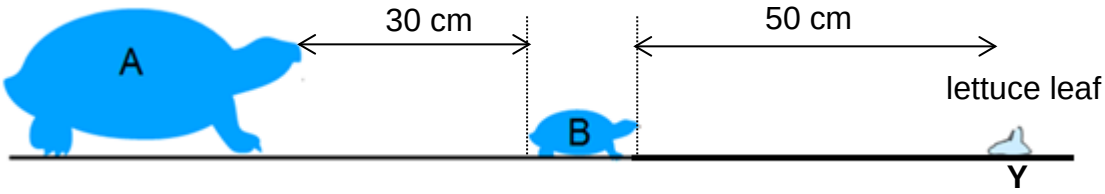


2.1.1 Define the term *speed.* (2)

2.1.2 Calculate the speed of tortoise A. (2)

2.1.3 If it takes tortoise B 3,2 s to pass point X, calculate the length of tortoise B. (3)

2.2 When the tortoises are 30 cm apart, a lettuce leaf is placed in front of them at point Y which is 50 cm in front of tortoise B as shown below.



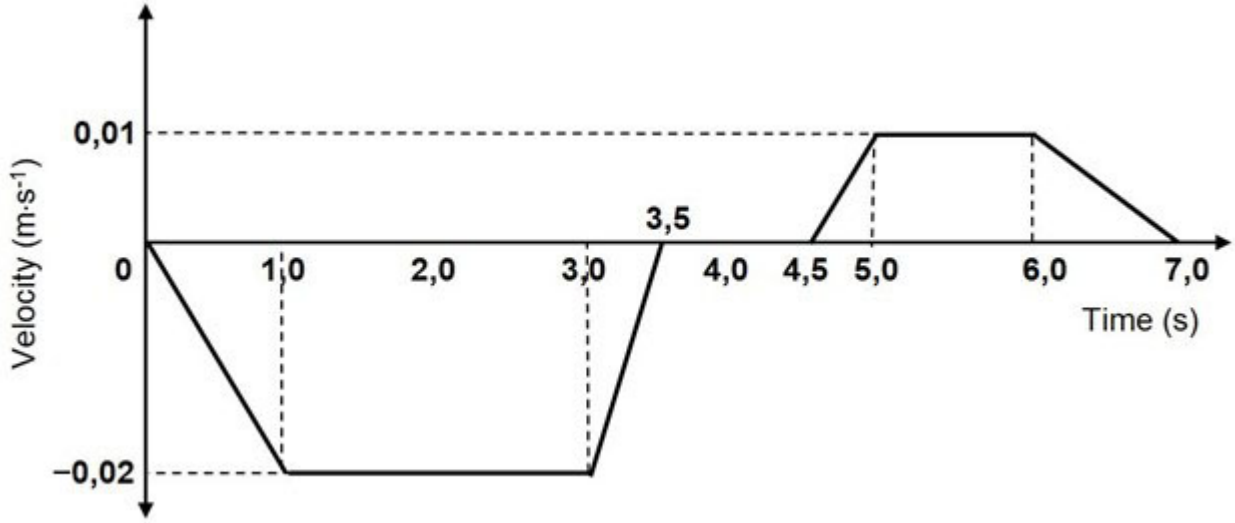
If tortoise B continues walking at the same speed (calculated in 2.1.2), and tortoise A accelerates towards the lettuce leaf, calculate the magnitude of the acceleration required by A for the tortoises to reach the leaf at the same time. (6)

[13]

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QUESTION 3 RUNNING ANTS AND RACING CARS

3.1 An ant runs east along a straight line and eventually stops. After a short rest the ant runs west. The graph below shows the relationship between velocity and time for the ant.



3.1.1 Calculate the acceleration of the ant for the following periods:

(a) 0 s to 1,0 s (3)
(b) 6,0 s to 7,0 s (2)

3.1.2 Fully describe the motion of the ant from:

(a) 3 s to 3,5 s (3)
(b) 5 s to 6 s (2)

3.1.3 Define the term *displacement.* (2)

3.1.4 Calculate the **total displacement** of the ant. (4)

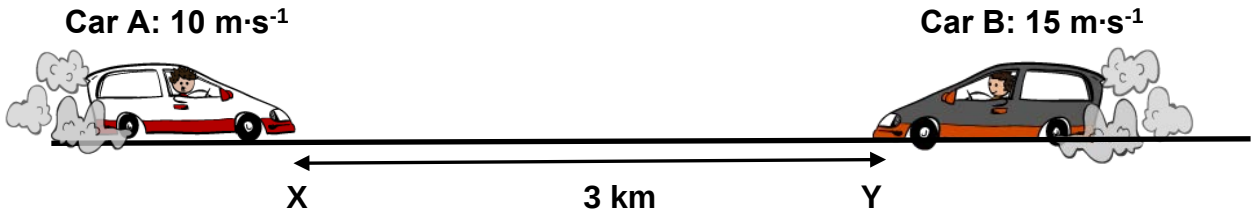
3.1.5 Calculate the magnitude of the average velocity of the ant for the whole journey. (2)

3.1.6 On the axes provided on the Answer Sheet, draw the graph showing the relationship between acceleration and time for 0 s to 3,5 s. (4)

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3.2 Car A and Car B are travelling on a straight, level track. Points X and Y are 3 km apart on the track.

- Car A passes point X at precisely 10:00 travelling to the right at 10 $m \cdot s^{-1}$.
- Car B passes point Y at 10:02 (2 minutes after Car A passed point X), travelling to the left at 15 $m \cdot s^{-1}$.

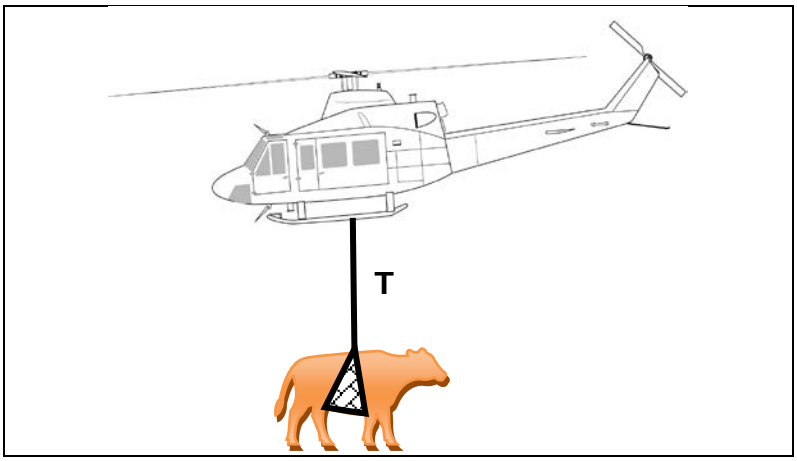


Calculate the time when and the position where Car A and Car B will pass each other. Round the time off to the nearest minute and state the position in metres to the right of X. (7)

[29]

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QUESTION 4 COW RESCUE



[Source: <http://www.supercoloring.com>]

A cow is rescued using a helicopter. The cow of mass M is lifted, using a special harness as shown in the sketch.

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

The upward acceleration of the helicopter and cow as the cow leaves the ground is 1,5 $m \cdot s^{-2}$.

4.2 Draw a labelled free-body diagram for the cow as she accelerates upwards. (3)

4.3 The tension in the rope attaching the cow in the harness to the helicopter is 7 000 N. Calculate the mass of the cow. (5)

4.4 After accelerating upwards for some time, the helicopter rises at a constant velocity of 2,5 $m \cdot s^{-1}$. Calculate the magnitude of the tension in the rope attached to the harness while the helicopter and cow rise at constant velocity. (2)

4.5 State the direction of the acceleration of the helicopter as it begins to reduce its upwards velocity. (1)

4.6 Calculate the magnitude of the acceleration of the helicopter and cow if they take 4 s to come to rest, when they were initially travelling at 2,5 $m \cdot s^{-1}$ upwards. (3)

4.7 Calculate the magnitude of the tension (T) in the cable during these 4 s. (3)

4.8 State Newton's third law. (2)

4.9 Referring to a moment when the cow hangs stationary from the helicopter, name one action-reaction pair of forces that exists. (2)

[23]

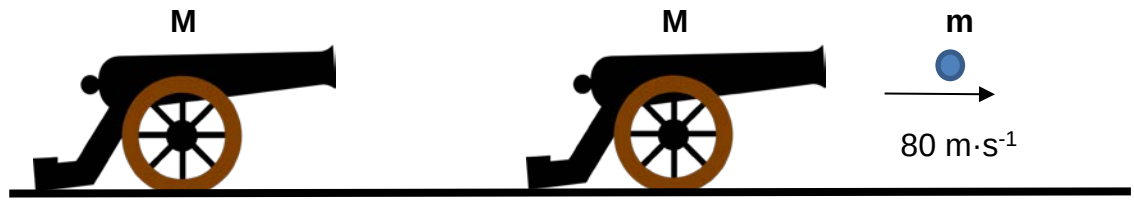
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QUESTION 5 CANNON AND ELECTRIC WHEELCHAIR

5.1 A cannon of mass **M** is 1 000 times heavier than the cannonball of mass **m** that it fires. The cannonball leaves the barrel with a velocity of 80 m·s^{-1}.

Cannon before firing:
Velocity of cannon and cannonball is zero.

Cannon after firing:



5.1.1 Calculate the maximum velocity with which the cannon recoils immediately after firing. (4)

The magnitude of the impulse experienced by the cannonball while in the barrel is 96 N·s.

5.1.2 Define the term *impulse.* (2)

5.1.3 Calculate the mass of the cannonball. (3)

5.2 A person of mass 65 kg is on his journey on an electric wheelchair of mass 55 kg. The average power output of the wheelchair is 200 W. During the journey, forces of air resistance and other resistive forces act on the wheelchair and the person. The wheelchair maintains a constant velocity of 1,5 m·s^{-1}.



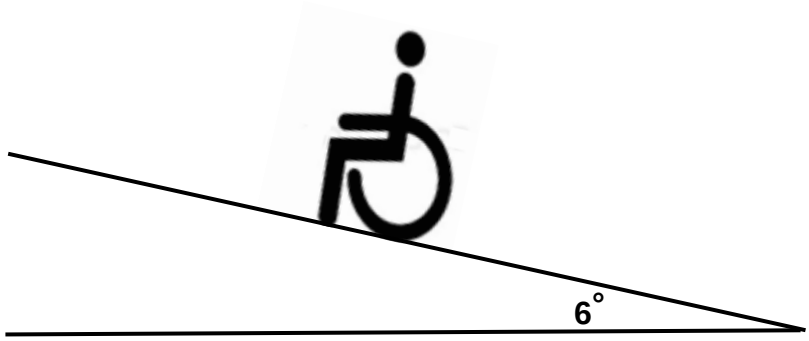
5.2.1 Give the magnitude of the net force acting on the wheelchair and the person during the journey. (1)

5.2.2 Calculate the magnitude of the total force of resistance (friction) that acts on the wheelchair and the person during the journey. (4)

5.2.3 Given that the length of the journey on a flat level road is 3 km, calculate the work done by the motor in overcoming friction. (3)

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The wheelchair and the person reach a gentle slope that makes an angle of 6^o to the horizontal as shown below.



5.2.4 Calculate the magnitude of the component of the weight of the wheelchair and the person parallel to the slope. (3)

5.2.5 Assuming that the resistive (friction) forces are the same as those calculated in 5.2.2, calculate the maximum speed of the wheelchair when the power output is 200 W. Give your answer correct to three decimal places. (4)

5.2.6 The maximum range of the wheelchair on level ground, assuming a person of mass 65 kg, is given as 12 km.

Suppose that the person in the wheelchair has a mass of 80 kg.

How will this affect the maximum range of the wheelchair? (Write only INCREASE, DECREASE OR REMAIN THE SAME) (1)

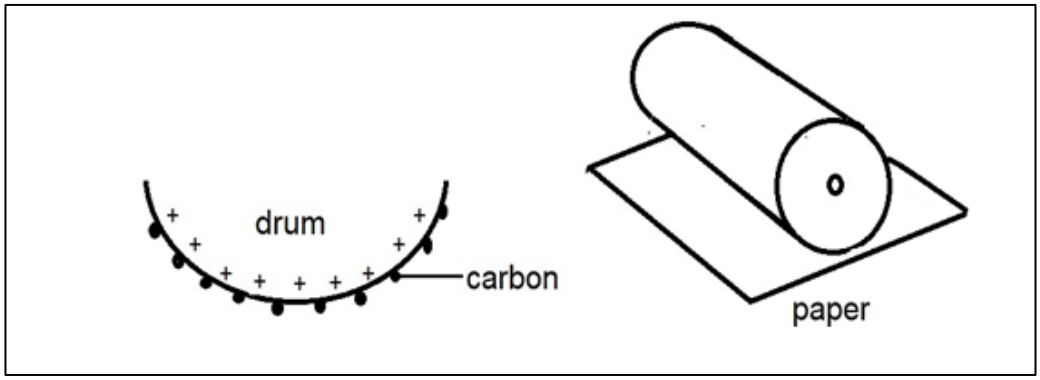
5.2.7 Explain your answer to Question 5.2.6. (3)

[28]

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QUESTION 6 PHOTOCOPIER AND CELESTIAL BODIES

6.1 In a photocopying machine, positive charges are arranged on the surface of a drum in the pattern to be copied. Powdered carbon particles are given a negative charge and are then attracted to the positively charged parts of the drum in the desired pattern. The drum then rolls over the paper, transferring the pattern.



Each carbon particle has a mass of $9,0 \times 10^{-16}$ kg and each particle carries 20 extra electrons to provide the negative charge.

6.1.1 Calculate the magnitude of the negative charge attained by each carbon particle. (3)

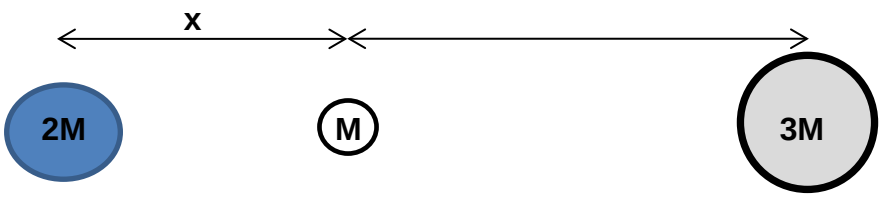
6.1.2 Each carbon particle adheres to the drum with a force equal to twice its weight. Calculate the magnitude of this electrostatic force. (2)

6.1.3 Define the *magnitude of an electric field.* (2)

6.1.4 Calculate the magnitude of the electric field on the surface of the drum to which the particles are adhering. (3)

6.1.5 Calculate the electrostatic force between two carbon particles 1 cm apart when they carry charges of $4,0 \times 10^{-17}$ C each. (5)

6.2 Three hypothetical heavenly bodies are called by their masses which are **M, 2M and 3M**. They are situated in a straight line as shown below. The distance between 2M and M is x.



M experiences zero gravitational force as a result of the two masses 2M and 3M.

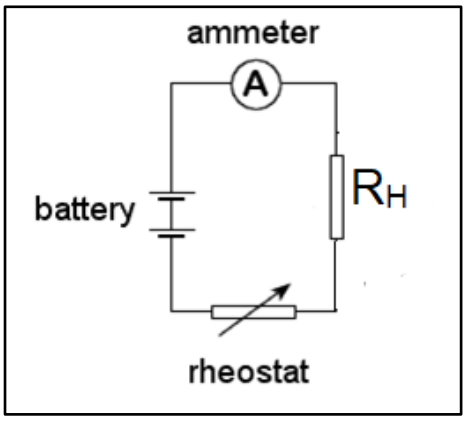
Calculate the distance between M and 3M in terms of x. (4)

[19]

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QUESTION 7 ELECTRIC CIRCUIT EXPERIMENTS

7.1 A student sets up a circuit containing a heating element R_H, a rheostat (variable resistor) and an ammeter connected in series with a battery that has negligible internal resistance as shown in the diagram below.

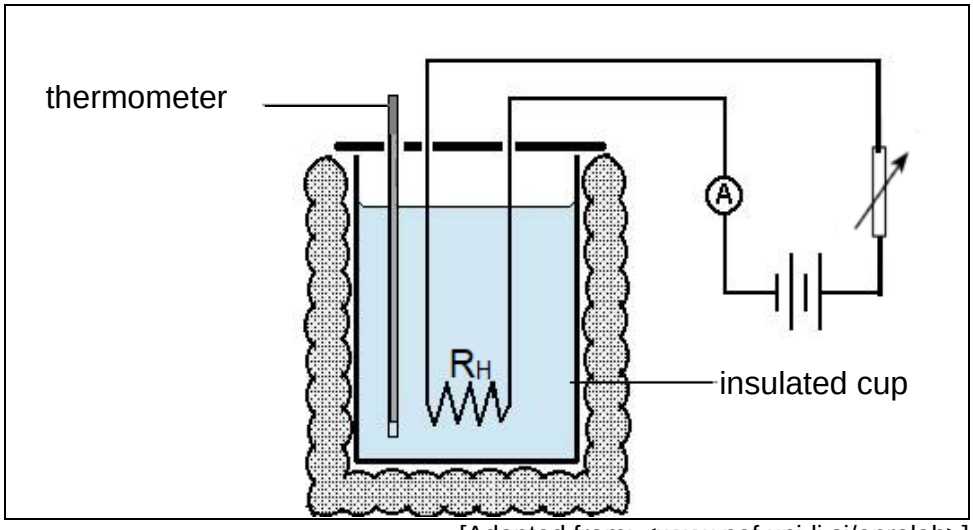


The student wishes to investigate the relationship between the current (I) in the heating element and the energy dissipated. The student follows the instructions given below:

(a) Place the heating element (R_H) into an insulated cup containing 100 g of water.
(b) Place a thermometer through a hole in the lid of the cup to measure the temperature of the water.
(c) Vary the current using the rheostat and allow the current to flow for two minutes.
(d) For each current, measure the rise in temperature of the water when the current has been allowed to flow for two minutes.

Assume that the resistance of the heating element remains constant and that all the heat dissipated in the resistor is transferred to the water.

The experiment is set up as shown below.



[Adapted from: <www.pef.uni-lj.si/eprolab>]

The student uses a formula to calculate the energy dissipated in the resistor by referring to the temperature change of the water. The results of these calculations are given in the right-hand column of the table below:

Results of the experiment to investigate the relationship between energy dissipated in a resistor and the current flowing through it for two minutes

I (A)	I^2 (A^2)	Temperature change ΔT (^oC)	Energy dissipated in R_H (J)
0,18	$3,42 \times 10^{-2}$	0,6	252
0,44	(a)	3,2	1344
0,61	$37,2 \times 10^{-2}$	6,0	2520
0,70	$49,0 \times 10^{-2}$	8,0	3360

7.1.1 Calculate the missing value (a) in the table. (1)

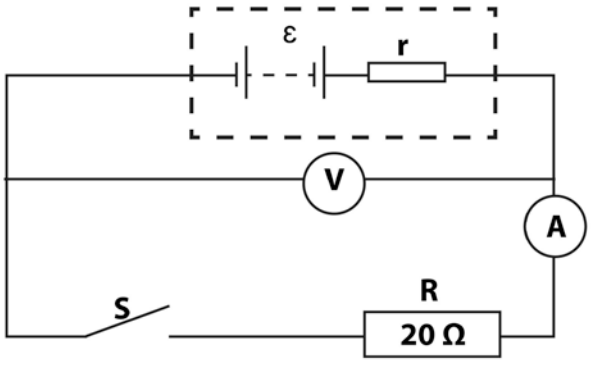
7.1.2 On the graph paper provided on the Answer Sheet, plot a graph showing the relationship between energy dissipated and I^2. (The X-axis scale has been provided for you.) (7)

7.1.3 Calculate the gradient of the graph, showing your working and clearly marking the two points you are using on your graph. (3)

7.1.4 Use the gradient of the graph to calculate the resistance of R_H. (3)

7.1.5 Given that the potential difference across the power supply is 48 V and that the internal resistance can be ignored, calculate the **potential difference across the rheostat** when the current strength is 0,61 A. (4)

7.2 In the circuit below, a battery with internal resistance is connected to a circuit with a 20 Ω resistor, an ammeter and a switch.



When the switch is open, the voltmeter reads 12 V and when it is closed, it reads 10 V.

7.2.1 Define *emf.* (2)

7.2.2 Write down the emf of the battery. (1)

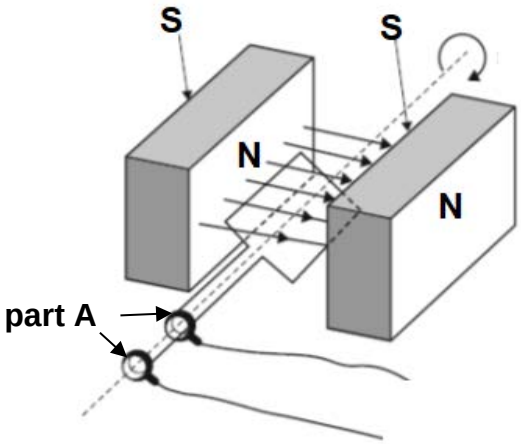
7.2.3 Calculate the internal resistance of the battery. (5)

[26]

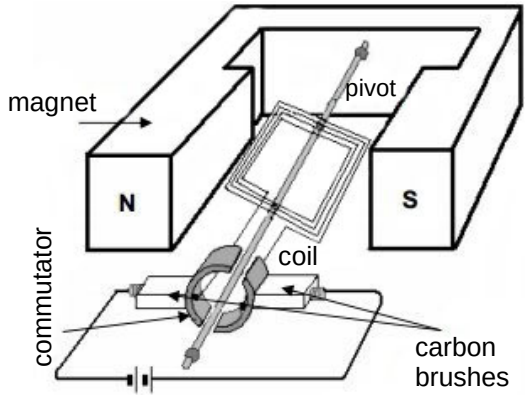
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QUESTION 8 GENERATING AND USING ELECTRICITY

8.1 The sketch below shows a small simple generator and motor.



Generator



Motor

[diagram sources: <https://www.vcaa.vic.edu.au/Documents/exams/physics/2013> and <http://www.smartlearner.mobi/science>]

8.1.1 Name the parts labelled **A**. (2)

8.1.2 State whether the coil in the motor will rotate clockwise or anti-clockwise. (2)

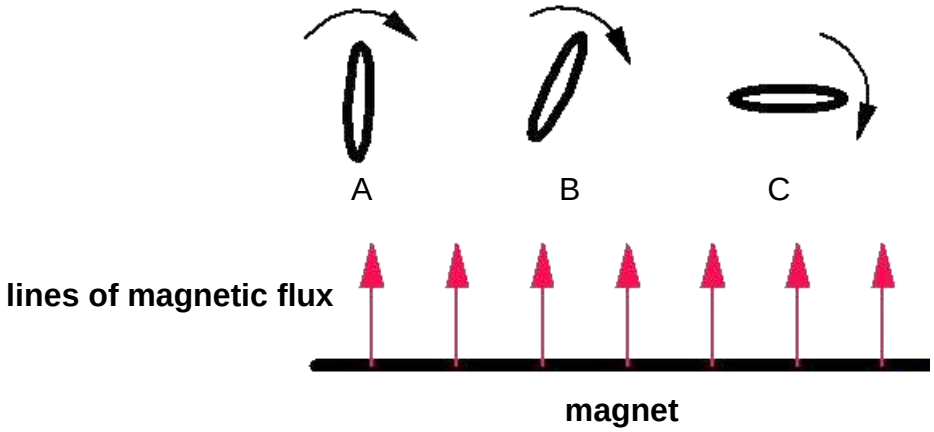
8.1.3 Name the rule you used to determine the direction of movement of the coil in 8.1.2. (1)

The coil makes one complete turn in 0,1 s and then speeds up to make a second complete turn in 0,05 s. Assume that the speed of rotation for the first complete turn is constant and that the speed of rotation for the second complete turn is constant. Assume that the coil instantly changes speed at the end of the first turn.

8.1.4 On the axes provided on the Answer Sheet, sketch a graph showing the relationship between emf and time for the generator for the two turns described above. Start your graph with the emf at zero. (You need not give numerical values on the Y-axis.) (4)

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8.2 Consider the coil in positions A, B and C with magnetic field direction from the bottom to the top of the page, as shown below.



Write down only the letter A, B or C to answer each question below.

8.2.1 In which position is the magnetic flux linkage the greatest? (1)

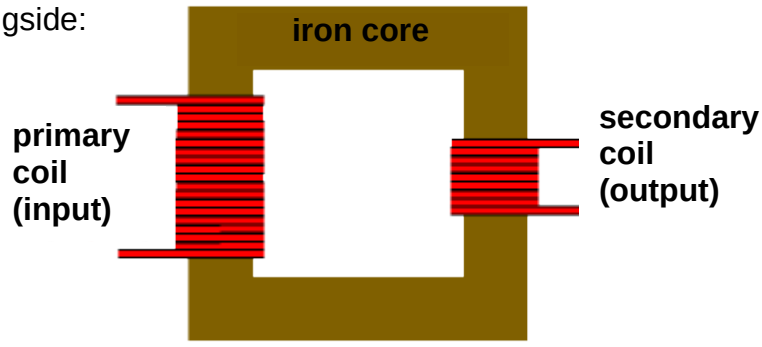
8.2.2 In which position is the magnetic flux linkage the smallest? (1)

8.2.3 In which position is the rate of change of flux linkage the greatest? (1)

8.2.4 Given the equation $\varphi = BA\cos\theta$, in which position is $\theta = 90°$? (1)

8.2.5 In which position is the induced emf between minimum and maximum? (1)

8.3 Refer to the device shown alongside:



8.3.1 Name this device. (2)

8.3.2 Give one use of this type of device in the home. (2)

8.3.3 There are 300 turns in the primary coil and 15 turns in the secondary coil. The input potential difference is 220 V. Calculate the output potential difference. (3)

[21]

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QUESTION 9 PHOTONS AND ELECTRONS

9.1 The table below gives the frequency range of photons of different types of electromagnetic radiation.

Electromagnetic radiation type	Frequency range of photons (Hz)
ultraviolet	greater than $7,9 \times 10^{14}$
violet – blue visible light	$6,11–7,9 \times 10^{14}$
yellow – green visible light	$5,11–6,11 \times 10^{14}$
red – orange visible light	$4,0–5,11 \times 10^{14}$
infrared	less than $4,0 \times 10^{14}$

9.1.1 Convert 2,2 eV to Joules. (2)

9.1.2 Calculate the frequency of a photon of radiation with energy 2,2 eV. (3)

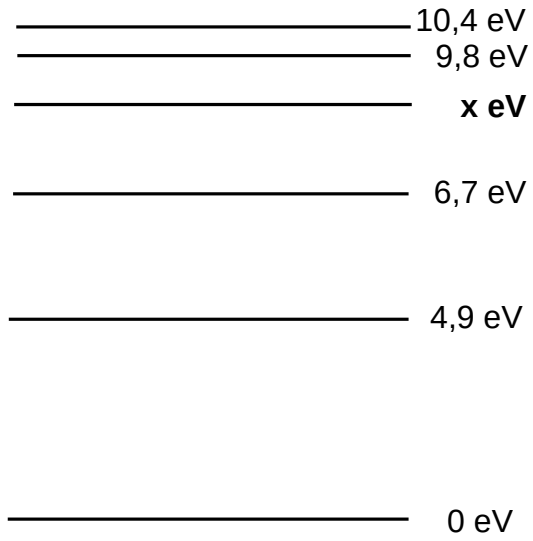
9.1.3 What colour of light does a photon of 2,2 eV produce? (1)

9.1.4 Define the term *work function.* (2)

9.1.5 UV light ($8,9 \times 10^{14}$ Hz) falls on a calcium surface with work function of $4,59 \times 10^{-19}$ J. Calculate the maximum kinetic energy of a photon emitted from the surface of the calcium due to the incident UV radiation. (5)

9.1.6 Explain how the photoelectric effect provides evidence for the particle nature of light. (3)

9.2 In a sample of excited mercury atoms, all of the energy levels shown in the figure below are occupied. One of the energy levels in the figure is labelled x eV. The emission spectrum of mercury shows lines at approximately 0,9 eV, 1,5 eV and 2,2 eV.



Calculate **x**, showing all your working. (5)

[21]

Total: 200 marks

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