



NATIONAL SENIOR CERTIFICATE EXAMINATION  
NOVEMBER 2017

**PHYSICAL SCIENCES: PAPER I**

Time: 3 hours

200 marks

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**PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY**

1. This question paper consists of 15 pages, an answer sheet of 2 pages and a data sheet of 2 pages (i–ii). Please make sure that your question paper is complete.
  2. Answer ALL the questions.
  3. Read the questions carefully.
  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. Where appropriate express answers to TWO decimal places.
  9. It is in your own interest to write legibly and to present your work neatly.
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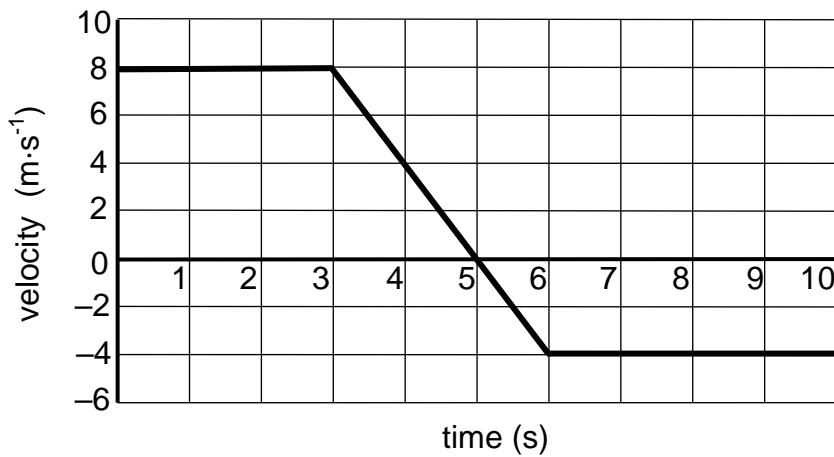
**QUESTION 1      MULTIPLE CHOICE**

**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 that you consider to be correct.**

1.1 Which set of physical quantities consists only of vector quantities?

- A velocity, time
- B momentum, electric field
- C acceleration, speed
- D work, impulse

1.2 The velocity vs time graph for the motion of a car on a straight road is shown in the diagram. Assume that the car starts at the origin  $x = 0$  at time  $t = 0$ .



At which time is the car the greatest distance from the origin?

- A 10 s
- B 6 s
- C 5 s
- D 3 s

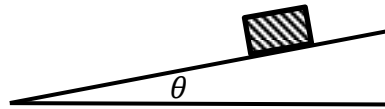
1.3 An object moves along a horizontal line with **increasing speed**. Which one of the following choices could be the best description of the velocity and the acceleration for the object to achieve this motion?

	<b>Velocity</b>	<b>Acceleration</b>
A	Positive	Zero
B	Positive	Negative
C	Negative	Positive
D	Negative	Negative

1.4 A student weighing 500 N stands on a scale in an elevator (lift) moving down. When the scale reads 520 N, the elevator must be

- A increasing in speed
- B decreasing in speed
- C moving at a constant speed
- D accelerating down

1.5 A block rests on an inclined rough surface that makes an angle  $\theta$  with the horizontal.



The block remains at rest as  $\theta$  is slowly increased. Which is the best description of how the magnitudes of the normal force and the static frictional force of the rough surface on the block change as  $\theta$  is slowly increased?

	Normal Force	Static Frictional Force
A	Increase	No change
B	Decrease	Decrease
C	Increase	Increase
D	Decrease	Increase

1.6 A collision of two blocks takes place along a frictionless horizontal surface. A block of mass  $M_1 = 3 \text{ kg}$  moves to the right with a speed of  $5 \text{ m} \cdot \text{s}^{-1}$  and collides with a block of mass  $M_2 = 5 \text{ kg}$  which was initially moving to the left with a speed of  $2 \text{ m} \cdot \text{s}^{-1}$ .



After colliding, the block of mass  $M_1$  moves to the left with a speed of  $1 \text{ m} \cdot \text{s}^{-1}$ .

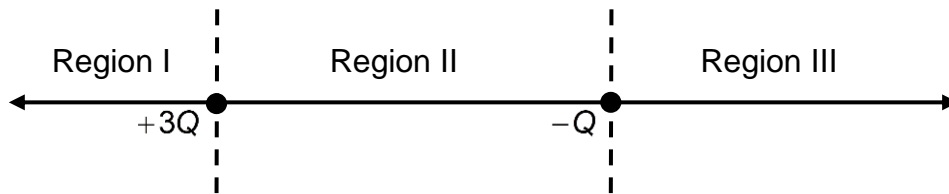
Which of the blocks experienced a larger magnitude of acceleration during the collision?

- A The block with mass  $M_1$ .
- B The block with mass  $M_2$ .
- C The magnitude of the acceleration was the same for both blocks.
- D The answer depends on whether the collision was elastic.

1.7 A person throws an object of mass  $M$  straight up with an initial speed  $v$ . The object rises to a maximum height  $H$  above the launch point. The person now throws an object of mass  $\frac{1}{2}M$  straight up with a speed of  $2v$ . In terms of  $H$ , to what maximum height does the object of mass  $\frac{1}{2}M$  rise above the launch point? Ignore air resistance.

- A  $4H$
- B  $2H$
- C  $\sqrt{2}H$
- D  $H$

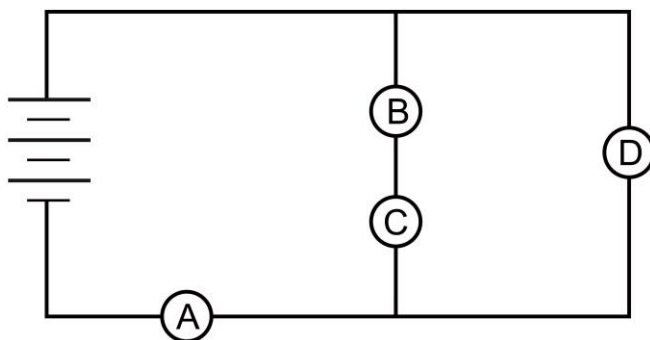
1.8 Two point charges  $+3Q$  and  $-Q$  are fixed on the  $x$ -axis in otherwise empty space as shown below.



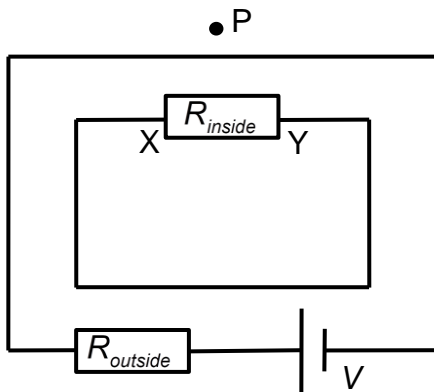
In which Region(s) is there a point on the  $x$ -axis at which the electric field is equal to zero?

- A Region I
- B Region II
- C Region III
- D Region I and Region III

1.9 In the circuit diagram below, all of the bulbs are identical. Which bulb will be the brightest?



1.10 Two circuits are shown in the diagram.



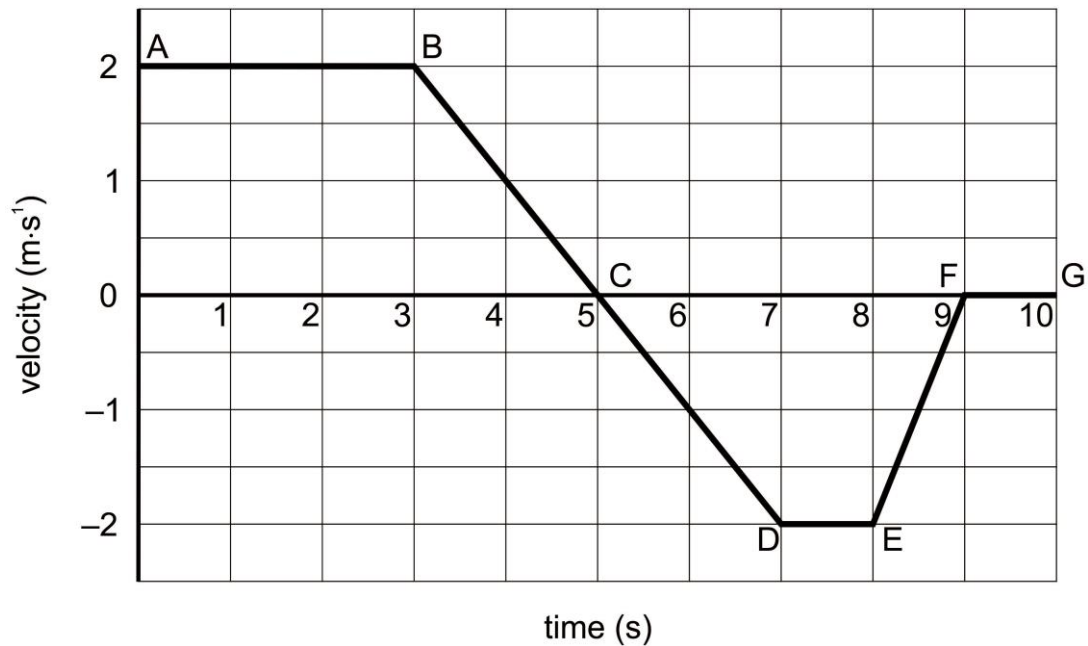
The resistance in the outside circuit,  $R_{outside}$  is **decreasing** at a constant rate. In which direction is the magnetic field at point P pointing and in which direction is the conventional current through the resistor,  $R_{inside}$ , in the smaller inside circuit?

	<b>Magnetic field at P</b>	<b>Current through <math>R_{inside}</math></b>
A	Into the page	From X to Y
B	Into the page	From Y to X
C	Out of the page	From X to Y
D	Out of the page	From Y to X

[20]

**QUESTION 2 KINEMATICS**

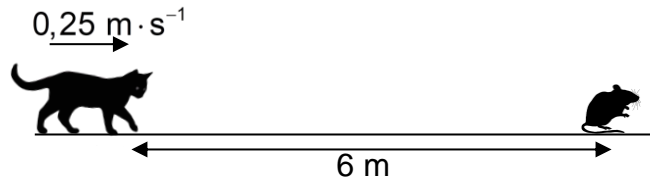
A cyclist is riding **north** at  $2 \text{ m} \cdot \text{s}^{-1}$  along a long straight road. A velocity vs time graph of the motion of the cyclist for 10 s is shown below.



- 2.1 Define *velocity*. (2)
  - 2.2 During which time interval(s) is the cyclist's velocity constant? (3)
  - 2.3 During which time interval(s) is the cyclist slowing down? (2)
  - 2.4 During which time interval(s) is the cyclist travelling south? (2)
  - 2.5 Define *acceleration*. (2)
  - 2.6 Calculate the acceleration of the cyclist between 3 s and 7 s. (4)
  - 2.7 Sketch a position vs time graph for the cyclist on the axes provided **on the answer sheet**. Values are not required but you must use the labels A–G. The cyclist's position is zero at  $t = 0$  s. (6)
- [21]**

**QUESTION 3 KINEMATICS**

- 3.1 A child is holding a red ball and a blue ball over the edge of a roof. The child throws the red ball vertically up in the air and, at the same moment drops the blue ball over the edge. On the same set of axes, sketch the **velocity vs time** graph for both balls. Label the two lines red and blue. Choose **up** as the **positive** direction for your graph. (3)
- 3.2 A cat is 6 m from a mouse and walking slowly.



[Images from: <<http://www.clipartqueen.com/cat-clip-art.html>> and [https://img.clipartfest.com/18ff66cc649f8ea29e418f6cfa8c811f\\_mouse-clip-art-house-for-a-mouse-clipart-black-and-white\\_698-548.png](https://img.clipartfest.com/18ff66cc649f8ea29e418f6cfa8c811f_mouse-clip-art-house-for-a-mouse-clipart-black-and-white_698-548.png)]

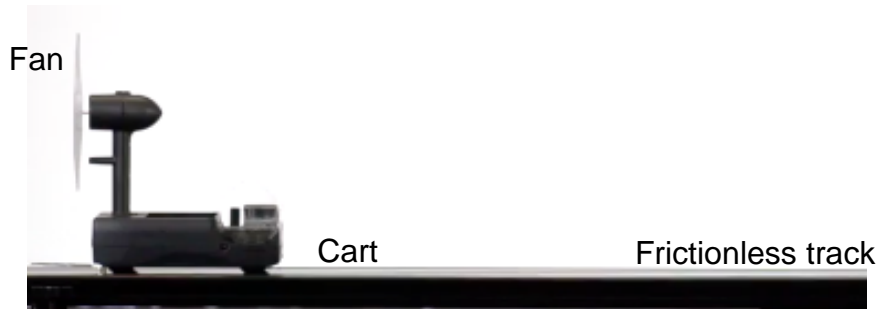
The cat hunts the mouse for 10 s in two stages. For the first 8 s the cat stalks the mouse slowly at a constant  $0,25 \text{ m} \cdot \text{s}^{-1}$  and for the last 2 s runs at a constant faster speed and catches the mouse. The mouse did not see the cat coming and sat still.

- 3.2.1 Calculate how far the cat is from the mouse after 8 s. (3)
- 3.2.2 Draw a position vs time graph for the cat for 0–10 s. Relevant values of position and time must be shown on the axes. Consider the mouse's position as position zero. (3)
- 3.2.3 Calculate how fast the cat ran for the last 2 s of the hunt. (2)
- 3.3 A model rocket is fired vertically upwards from rest at ground level. The rocket accelerates upwards at  $20 \text{ m} \cdot \text{s}^{-2}$  for 15 s and then runs out of fuel. Air resistance is negligible.
- 3.3.1 Calculate the rocket's maximum height above the ground. (6)
- 3.3.2 Calculate the time the rocket is in the air from launch to crashing on the ground. (5)
- 3.3.3 At which position will the rocket experience a maximum velocity? (2)

**[24]**

**QUESTION 4      NEWTON'S LAWS**

4.1 An experiment was conducted to investigate the relationship between the force exerted on an object and the object's acceleration. An electric fan is mounted on a zero-friction cart to accelerate the cart along a **smooth** track. The speed of the fan and hence the force exerted on the cart is adjusted and the acceleration of the cart determined.



[Image from: <[http://serc.carleton.edu/dmvideos/videos/fan\\_cart\\_lab.html](http://serc.carleton.edu/dmvideos/videos/fan_cart_lab.html)>]

- 4.1.1 Name and state the Newton's Law that is under investigation. (3)
- 4.1.2 State the dependent variable in the investigation. (2)

The experimental results are recorded in the table.

Force (mN) due to fan	Acceleration ( $m \cdot s^{-2}$ )
25	0,09
80	0,30
135	0,52
190	0,68
245	0,92
300	1,05

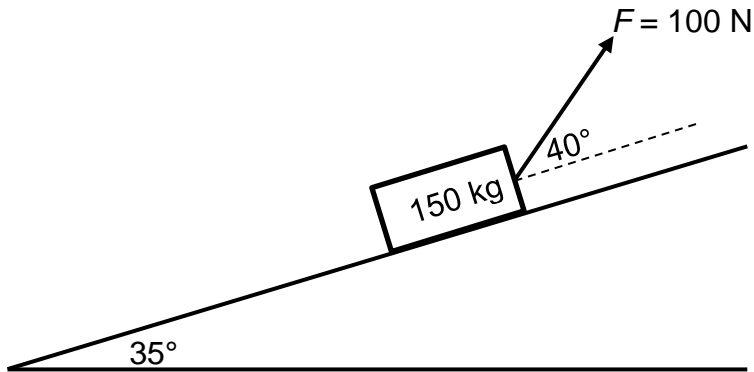
- 4.1.3 Plot a graph of acceleration (on the y-axis) against force due to fan (on the x-axis) on the graph paper provided **in the answer sheet**. (6)
- 4.1.4 Calculate the gradient of the graph. Include the appropriate unit in your answer. (4)
- 4.1.5 Use your answer for Question 4.1.4 to determine the mass of the cart. (3)

The experiment is conducted again, but on a track with friction. The cart experiences a frictional force of **50 mN**.

- 4.1.6 On the same set of axes used for Question 4.1.3, sketch a line that you would expect to obtain for the experiment conducted with friction. Label your predicted line P. (2)



- 4.2 A box of mass 150 kg is **prevented** from sliding down the slope by a force,  $F$ , of 100 N acting at  $40^\circ$  to the rough inclined plane as shown. The plane is inclined at  $35^\circ$  to the horizontal and the coefficient of static friction between the box and the surface is 0,7.



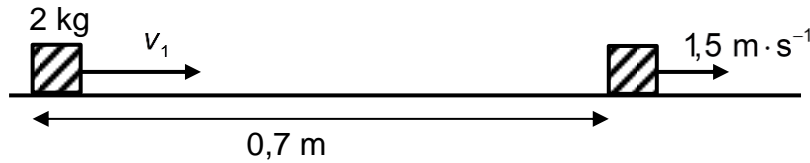
- 4.2.1 Draw a labelled free-body diagram showing all the forces acting on the box. (4)
- 4.2.2 Calculate the component of the weight parallel to the inclined plane. (3)
- 4.2.3 Calculate the magnitude of the frictional force that is acting on the box. (4)

The size of force  $F$  is slowly reduced from 100 N until the box is about to slide.

- 4.2.4 Calculate the minimum value of the force  $F$  for the box to remain at rest. (4)
- [35]**

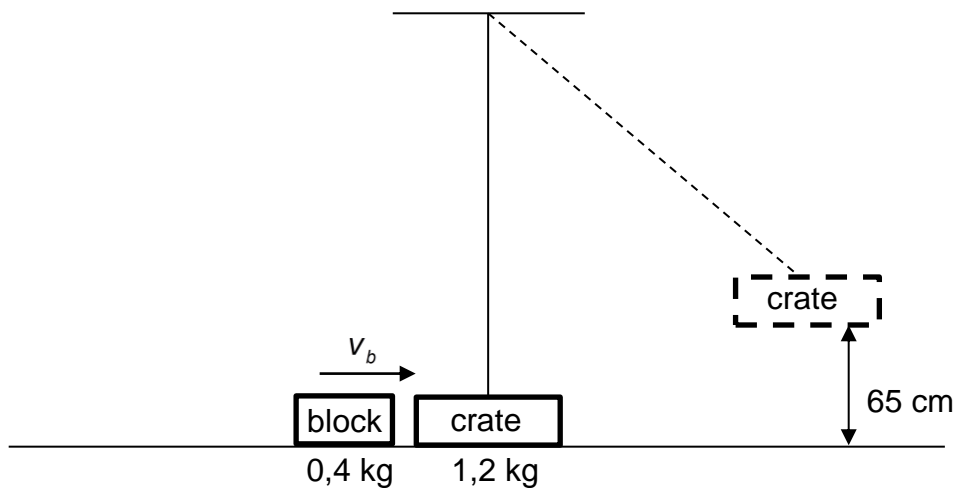
**QUESTION 5      MOMENTUM, WORK, ENERGY & POWER**

5.1 A box of mass 2 kg has an initial speed of  $v_1$ . The box travels across a rough surface and has a speed of  $1,5 \text{ m} \cdot \text{s}^{-1}$  after it has travelled 0,7 m. The frictional force acting on the box is 26 N.



- 5.1.1 Define *frictional force*. (2)
- 5.1.2 Calculate the kinetic energy of the box while it is travelling at  $1,5 \text{ m} \cdot \text{s}^{-1}$ . (3)
- 5.1.3 Calculate the work done on the box by the frictional force. (3)
- 5.1.4 State the *work-energy theorem*. (2)
- 5.1.5 Calculate the initial speed  $v_1$  of the box. (4)

5.2 A 1,2 kg crate is attached to a long string as shown in the diagram. A block of mass 0,4 kg collides with the stationary crate with a velocity  $v_b$  and rebounds with a velocity of  $0,36 \text{ m} \cdot \text{s}^{-1}$  causing the crate to swing up through a vertical height of 65 cm. (Frictional forces are negligible)



- 5.2.1 State *the principle of conservation of mechanical energy*. (2)
- 5.2.2 Calculate the magnitude of the velocity of the crate immediately after the block collided with the crate. (4)
- 5.2.3 State *the law of conservation of linear momentum*. (2)
- 5.2.4 Calculate the magnitude of the velocity of the block,  $v_b$ , just before it collides with the crate. (4)

**[26]**

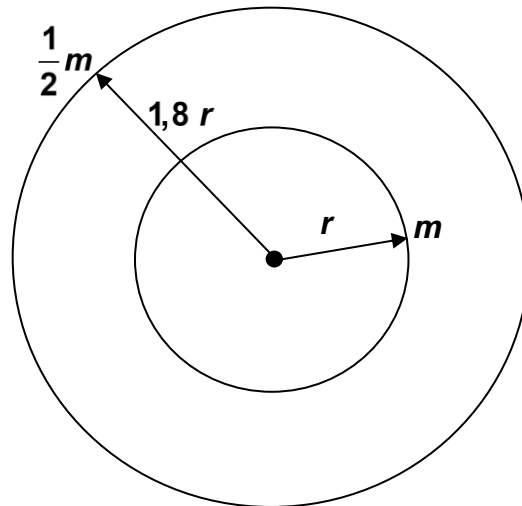
**QUESTION 6      FIELDS**

6.1 A satellite of mass  $m = 700 \text{ kg}$  is in orbit around a planet of mass  $5,8 \times 10^{24} \text{ kg}$  at a distance  $r = 7,4 \times 10^6 \text{ m}$ . The planet is treated as a point mass.

6.1.1 State *Newton's Law of Universal Gravitation*. (2)

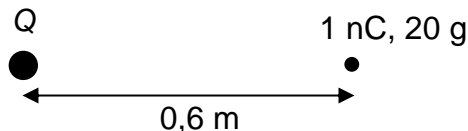
6.1.2 Calculate the magnitude of the gravitational force,  $F_1$ , that the planet exerts on the satellite. (3)

A second satellite of half the mass  $\left(\frac{1}{2}m\right)$  is in a different orbit at a distance of 1,8 times the distance of the 700 kg satellite and experiences a force  $F_2$ .



6.1.3 Calculate the ratio of the forces  $\frac{F_2}{F_1}$ . (3)

6.2 A small test charge of mass 20 g and charge 1 nC, is released from rest 0,6 m from a charge Q in empty space. The test charge takes 3,3 s to reach charge Q.



6.2.1 Calculate the magnitude of the average acceleration experienced by the test charge. (3)

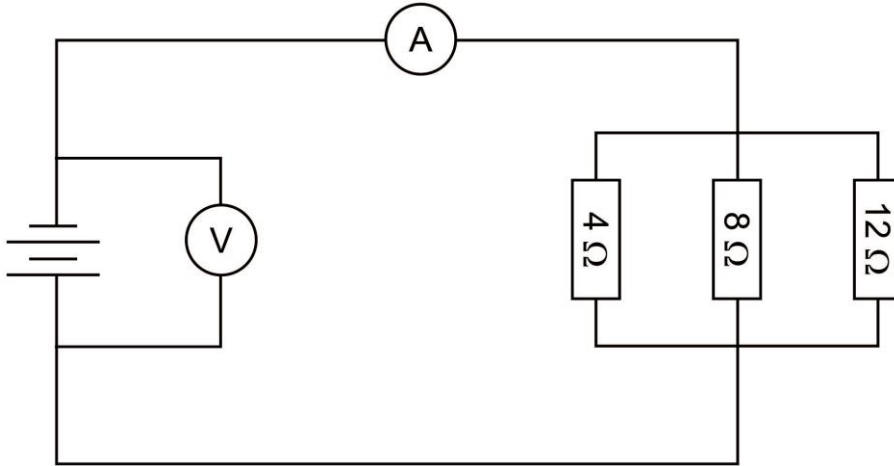
6.2.2 Calculate the magnitude of charge Q. Assume the acceleration calculated in Question 6.2.1 is the acceleration 0,6 m from charge Q. (4)

6.2.3 Why was it necessary in Question 6.2.2 to specify the acceleration at 0,6 m from the charge Q? Briefly explain your answer. (3)

**[18]**

**QUESTION 7 ELECTRIC CIRCUITS**

7.1 A circuit consists of a battery with an emf of **16,5 V** and an unknown internal resistance, three resistors, an ammeter and a voltmeter. The circuit is connected as shown in the diagram below. The voltmeter measures a potential difference of **12 V**.



- 7.1.1 State *Ohm's Law*. (2)
- 7.1.2 Calculate the current in the 8 Ω resistor. (3)
- 7.1.3 Calculate the effective resistance of the resistors connected in parallel. (3)
- 7.1.4 Calculate the current measured by the ammeter. (3)
- 7.1.5 Calculate the internal resistance of the battery. (3)

7.2 An electrical heater which has a resistance of 50 Ω is operated by connecting the heater to a potential difference of 220 V.

- 7.2.1 Define *power*. (2)
- 7.2.2 Calculate the power output of the heater. (3)

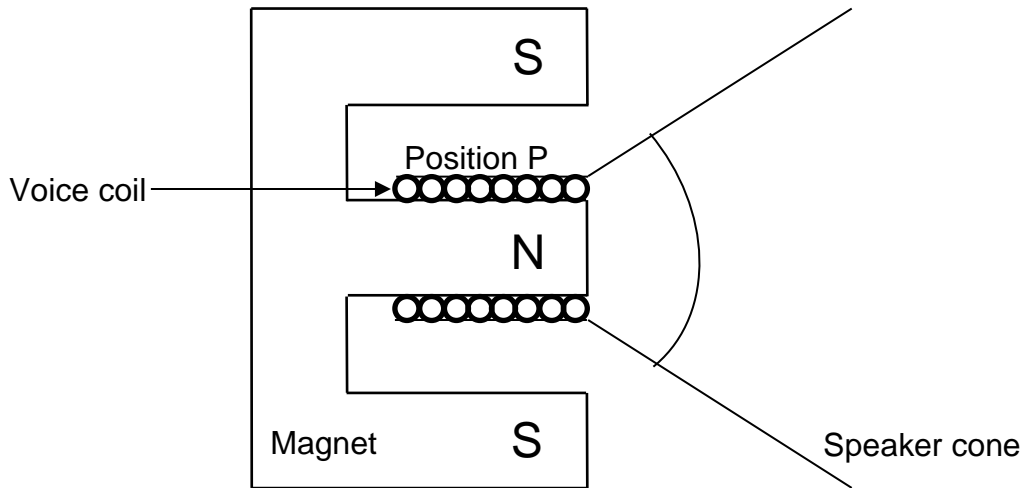
Electricity costs R1,24 per kWh.

- 7.2.3 For how long can you operate the heater with R80 of prepaid electricity? (4)
- [23]**

**QUESTION 8 ELECTRODYNAMICS**

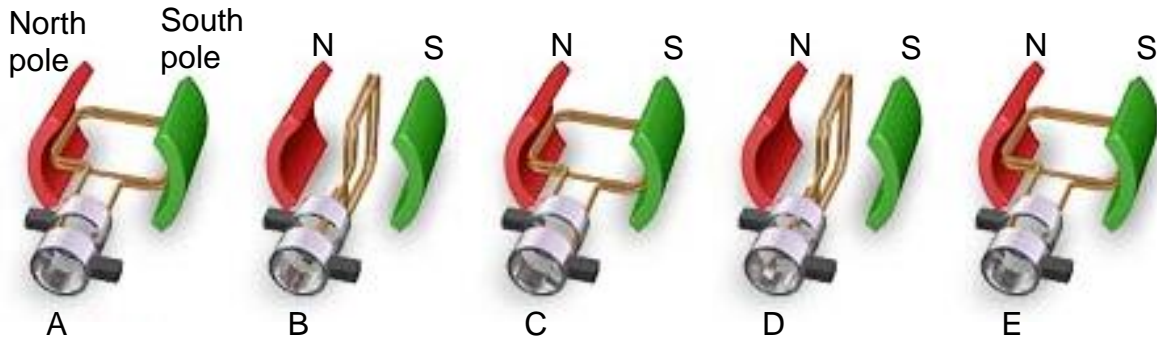
8.1 A loudspeaker operates as a force is exerted on a current carrying conductor in a magnetic field.

The diagram below illustrates a cross-section of a simple design of a loudspeaker. It consists of a permanent magnet with a coil of wire, called the voice coil, surrounding the north pole of the magnet. When an electrical signal is sent to the voice coil, a force is experienced by the voice coil. The speaker cone is connected to the voice coil and moves with the voice coil.



- 8.1.1 Use a sketch to show the direction of the magnetic field around a single current carrying conductor where the current is directed into the page. The direction of the current must also be shown. At least three field lines must be shown. (3)
- 8.1.2 In order for the speaker cone to move to the right in the diagram above, in which direction must the current in the coil be directed at position P? (2)
- 8.1.3 A loudspeaker needs the speaker cone to vibrate. How is this achieved? Briefly explain your answer in point form. (3)

8.2 The diagrams illustrate an electrical generator with a rotating coil shown in a number of different positions labelled A–E between magnetic poles.



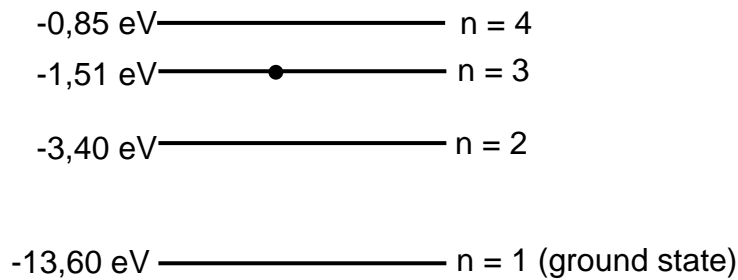
[Images from: <<http://micro.magnet.fsu.edu/electromag/electricity/generators/index.html>>]

- 8.2.1 State the energy conversion that takes place during the operation of the generator. (2)
- 8.2.2 A student states that the diagrams illustrate an a.c. generator. Is this statement correct? Give a reason for your answer. (2)
- 8.2.3 State *Faraday's Law of electromagnetic induction*. (2)
- 8.2.4 Draw a sketch graph of the emf output from this generator as a function of time. Position A occurs at 0 s. Label points A–E to correspond to the diagrams. (3)
- 8.2.5 Briefly explain why you labelled point C in the position shown in your answer to Question 8.2.4. (2)

**[19]**

**QUESTION 9      PHOTONS & ELECTRONS**

The energy levels for a hydrogen atom are represented on the diagram below.



An excited electron is in the 3rd energy level as indicated.

- 9.1 How many unique frequencies will be in the emission spectrum as the excited electron returns to the ground state? (2)
- 9.2 Calculate the frequency of the photon emitted when the electron transition is from the  $n = 2$  level to the ground state. (4)
- 9.3 Hydrogen gas in a discharge tube emits light of wavelength 655 nm.
- 9.3.1 Calculate the energy (in eV) that corresponds to this wavelength of light. (4)
- 9.3.2 On the diagram **on the answer sheet**, draw an arrow for the transition that will result in a wavelength of 655 nm. (2)
- 9.4 Why are the energy levels stated as negative values? (2)

**[14]**

**Total: 200 marks**