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.   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.   Number your answers as the questions are numbered.

7.   Show your working in all calculations.

8.   Units need not be included in the working of 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 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 unit listed below can be expressed as $kg \cdot m^2 \cdot s^{-2}$?

    A   newton per second
    B   newton
    C   joule
    D   watt

1.2   A trolley X with a mass m is travelling at velocity v. It is brought to rest by a braking force F over a distance d. An identical trolley Y, but with twice the mass of X, has the same initial velocity v and is brought to rest by the same force F. What will the stopping distance of Y be?

    A d
    B $2d$
    C $\frac{1}{2}d$
    D $4d$

1.3   An object moves 12 m south from its starting point in a time of 6 s, then 24 m north in a time of 10 s.

Which of the following correctly shows the magnitudes of its average speed and its average velocity?

	Average speed ($m \cdot s^{-1}$)	Average velocity ($m \cdot s^{-1}$)
A	2,25	0,75
B	2,25	2,20
C	2,20	2,20
D	2,20	0,75

1.4   A car has an ornament hanging from the inside mirror. The position of the ornament when the car is travelling at a very high constant speed is:
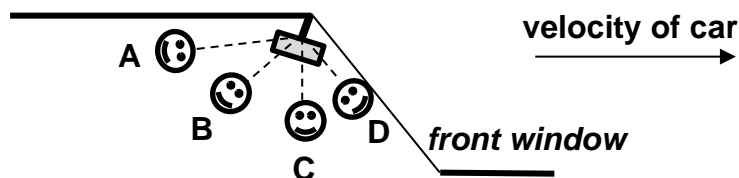
1.5 A child climbs a door frame using the friction between the inside of the frame and the child's hands and feet, as shown in the diagram below. The mass of the child is 50 kg and the friction between the frame and each hand and foot is identical.

The angle made by the child's arms and legs to the vertical is 60° when they are stationary.
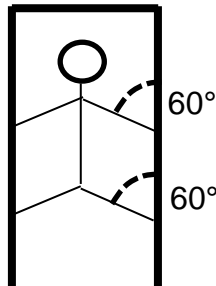
What is the friction between the door frame and each hand or foot?

A $\dfrac{245}{4}$

B $\dfrac{490}{4}$

C $\dfrac{849}{4}$

D $\dfrac{224}{4}$

1.6 Two insulated spheres carry charges of + 2Q and – 4Q. They are a distance **x** apart. Each sphere experiences a force **F**. They are brought together to touch and then separated to half the original distance. What will the new force experienced by the spheres be?
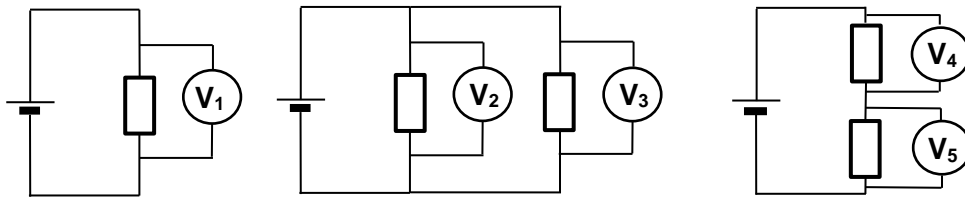
A   2 **F**

B   4 **F**

C $\dfrac{1}{2}$ **F**

D $\dfrac{1}{4}$ **F**

1.7 In the circuit shown alongside, the switch is open. The reading on the voltmeter is:

A   0 V
B   6 V
C   0,6 V
D   12 V
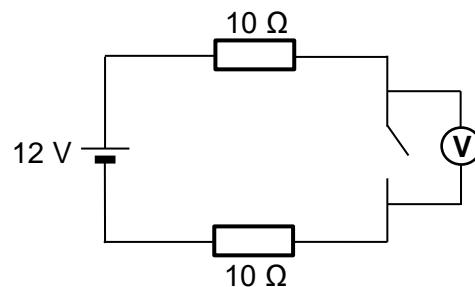
1.8   Three circuits with identical resistors are shown below. The cells connected to the circuits are identical and the internal resistance of these cells can be ignored. Rank the readings on the voltmeters shown from largest to smallest.

A $V_1 > V_2 = V_3 > V_4 = V_5$
B $V_2 > V_3 > V_1 > V_4 > V_5$
C $V_2 = V_3 > V_1 > V_4 = V_5$
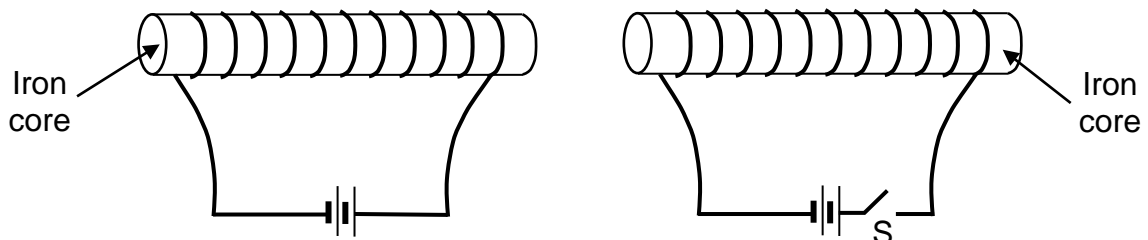D $V_1 = V_2 = V_3 > V_4 = V_5$

1.9   A current carrying conductor is placed into a magnetic field, as shown in the diagram below.
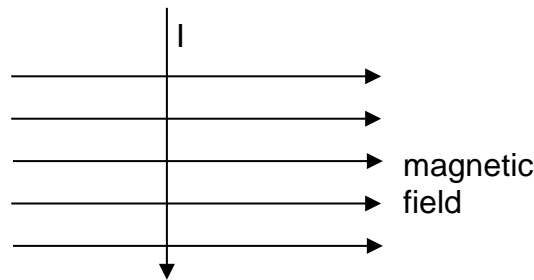
The conductor experiences a force:

A   to the right
B   to the left
C   out of the page
D   into the page

1.10   Two coils of wire, each wrapped on an iron core, are placed next to each other as shown. Switch S is open.

When the switch S is closed, the force between the coils will:

A   change direction (from attraction to repulsion <u>or</u> repulsion to attraction)
B   decrease
C   increase
D   no longer be zero

                                                                                            [20]
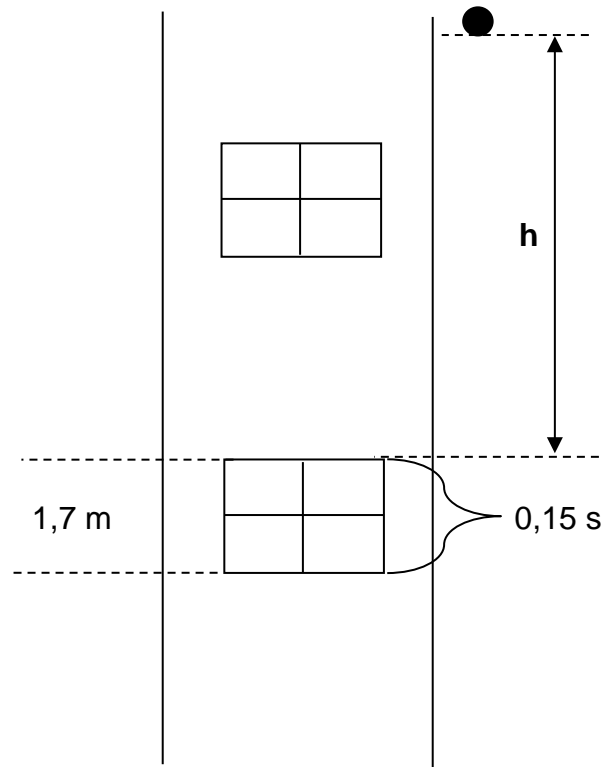
QUESTION 2   KINEMATICS

2.1   Car A accelerates uniformly from rest for 5 seconds. Car B begins to accelerate uniformly from rest at time t_1. Both cars travel at a constant velocity from 5 seconds after Car A began. The position-time graph showing the motion of Cars A and B is given below (not to scale):
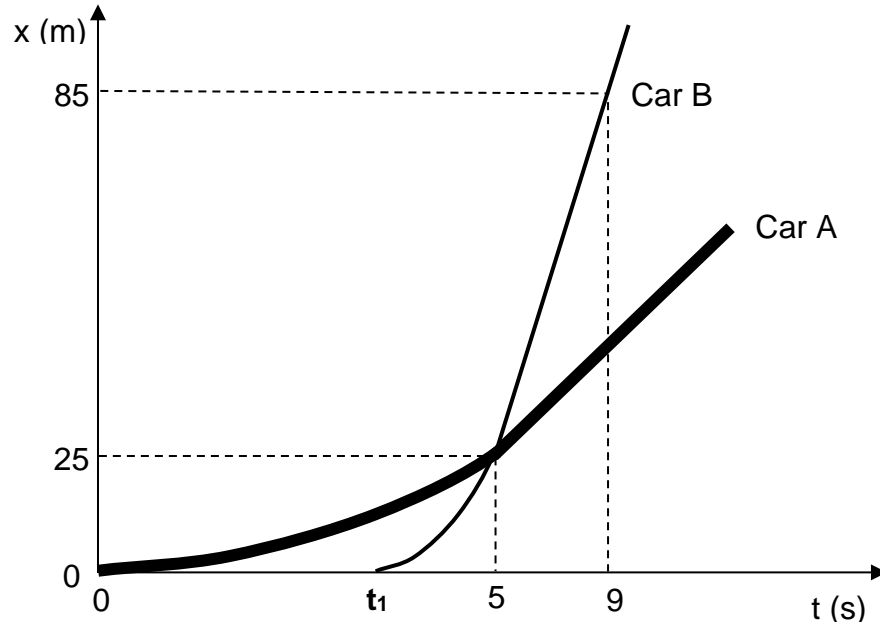
2.1.1   Define *velocity*.   (2)

2.1.2   Calculate the magnitude of the acceleration of Car A in the first 5 seconds.   (3)

2.1.3   Compare the positions of the cars at 5 seconds.   (2)

2.1.4   Calculate the speed that Car A reaches after 5 seconds.   (3)

2.1.5   Calculate the speed of Car B between 5 and 9 seconds.   (2)

2.1.6   Calculate t_1 when Car B begins to accelerate.   (3)

2.1.7   How far apart will the cars be 12 seconds after Car A began to move (at t = 12 seconds)?   (4)

2.2 A ball is dropped from a height **h** above the top of a window, as shown in the diagram below. The window is 1,7 m tall and the ball takes 0,15 s to fall past the window. *Air resistance can be ignored.*

Determine the height above the top of the window, **h**, from which the ball was dropped. (5)

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QUESTION 3   KINEMATICS

3.1   A picnic basket is being lifted up to a treehouse at a constant velocity of 2 m·s^{-1}.

As the basket is being lifted, a sandwich falls out of the basket. The sandwich takes 0,7 seconds to fall to the ground below. *Air resistance can be ignored.*

3.1.1   Define *displacement*.   (2)

3.1.2   Calculate the time that it will take the sandwich to reach its maximum height.   (3)

3.1.3   What was the height of the basket above the ground when the sandwich fell out?   (3)

3.1.4   Calculate the maximum height reached by the sandwich above the ground.   (4)

3.1.5   On the axes provided **on the Answer Sheet** sketch an acceleration vs time graph for the sandwich from the moment it leaves the basket to just before it hits the ground.   (2)

3.1.6   On the axes provided **on the Answer Sheet** sketch a velocity vs time graph for the sandwich from the moment it leaves the basket to just before it hits the ground.   (2)

3.2 Shopper **A** is pushing a trolley down the aisle of a grocery shop at a constant speed. Shopper **B** is in an enormous hurry and tries to push their trolley across Shopper **A**'s path without a collision.
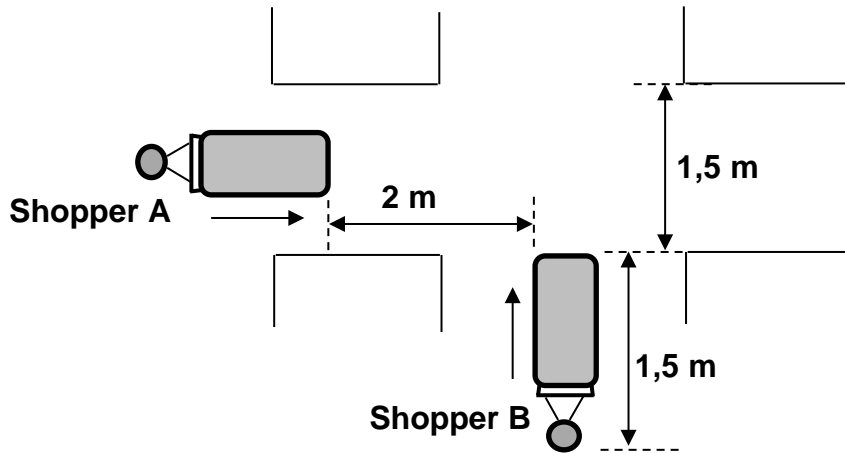
Shopper **A** travels at a constant speed of 0,8 m·s^{-1}. Shopper **A** is a distance of 2 m away when Shopper **B**'s trolley enters the aisle and **B** sees **A** (shown in the diagram above).

B immediately accelerates at 0,48 m·s^{-2} straight across the path of **A** to get out of the way, while **A** continues at a constant speed. **B** needs to be all the way across the 1,5 m aisle to be clear of **A**'s path and avoid a collision.

Calculate the minimum initial speed of Shopper **B** to safely cross in front of Shopper **A**.   (5)

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QUESTION 4   NEWTON

4.1   A hairdryer blows out air. The hairdryer shown has a mass of 600 g and is hung from its electrical cable. When the hairdryer is off, it hangs vertically downward (dashed line), but when it switches on and blows out air, it swings up to come to rest in the position shown while it is blowing air horizontally. The cable makes an angle of 8° to the vertical when it is stationary and blowing air.
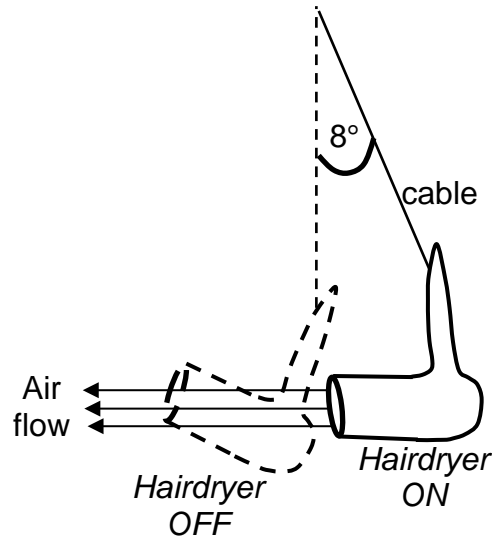
4.1.1 State *Newton's third law*.   (2)

4.1.2 Explain why the hairdryer cable is at an angle to the vertical when the hairdryer is blowing air.   (2)

4.1.3 Draw a labelled free body diagram of the forces acting on the stationary hairdryer when it is blowing air.   (3)

4.1.4 Determine the magnitude of the force that the hairdryer exerts on the air when the hairdryer is stationary.   (3)

4.2   A box (mass 10 kg) is at rest on a slope. The angle of the slope is 15° and the coefficient of static friction between the box and the surface is 0,6.
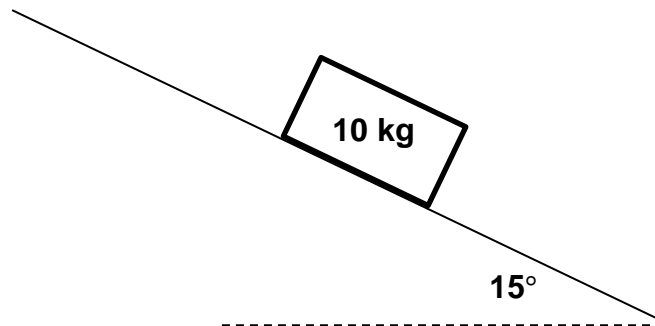

4.2.1 Draw a labelled free body diagram showing all the forces acting on the box while it is stationary.   (3)

4.2.2 Define *frictional force due to a surface.*   (2)

4.2.3 Calculate the magnitude of the maximum frictional force acting on the box.   (4)

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

4.2.5 Calculate the minimum force that would have to be applied to the box parallel to the slope to start the box sliding down the slope. Include the direction of the applied force in your answer.   (4)

4.2.6 The angle of the slope is increased. At what angle will the box begin to slide without an external applied force?   (4)

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QUESTION 5   MOMENTUM, WORK, ENERGY & POWER

5.1   A child is swinging on a swing suspended from a tree branch, shown below.
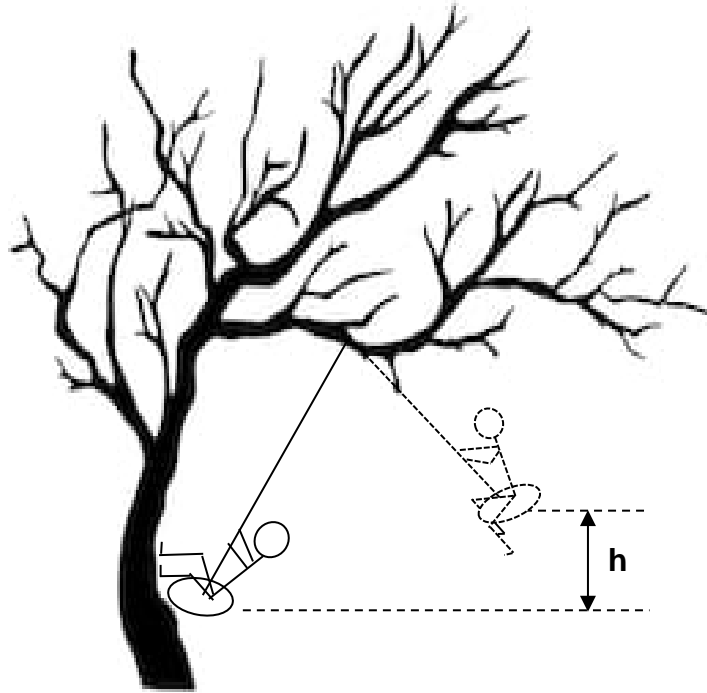
[Image of tree: <https://www.shutterstock.com/image-vector/vector-tree-187913555>]

As the child reaches the tree trunk, travelling horizontally at 1,5 m·s⁻¹, they bend their knees and push off the tree trunk at right angles over a period of 0,8 seconds. The child leaves the tree trunk with a speed of 3,5 m·s⁻¹ horizontally to swing up to a height, **h**. The mass of the child is 25 kg.

5.1.1 Define *impulse*.   (2)

5.1.2 Calculate the magnitude of the average force that the tree exerts on the child during the period of contact.   (3)

5.1.3 Will the magnitude of the force that the child exerts on the tree trunk during this period be GREATER THAN, THE SAME AS or LESS THAN the force that the child experiences, as calculated in Question 5.1.2?   (2)

5.1.4 State *the principle of conservation of mechanical energy*.   (2)

5.1.5 What will be the maximum height, **h**, that the child will reach?   (3)

5.2   An athlete (mass 65 kg) slides a distance of 2 m across a muddy field before coming to rest. The athlete's initial velocity is 2,5 m·s^{-1}.

    5.2.1   Calculate the initial kinetic energy of the athlete. (3)

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

    5.2.3   Calculate the magnitude of the frictional force that the athlete experiences while sliding. (3)

    5.2.4   Calculate the rate at which the frictional force dissipates the kinetic energy of the athlete. (5)

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QUESTION 6   FIELDS

Mercury is a relatively small planet with a radius of $2{,}44 \times 10^6$ m. The gravitational field strength at different distances from the centre of Mercury is recorded in the table.

r (x 10^6 m)	$\dfrac{1}{r^2}$ (x 10^{-13} m^{-2})	gravitational field strength (N·kg^{-1})
2,5	1,6	3,5
2,8	1,3	2,8
3,2	1,0	2,1
3,5	**missing value**	1,8
4,5	0,5	1,1
5,8	0,3	0,7

6.1   Calculate the value that is missing from the table.   (1)

6.2   Plot a graph of gravitational field strength (on *y*-axis) vs $\dfrac{1}{r^2}$ (on *x*-axis) on the graph paper provided **on the Answer Sheet**.   (6)

6.3   Use your graph to determine the magnitude of the gravitational field strength on the surface of Mercury. Show all necessary working.   (3)

6.4   Calculate the gradient of your graph. Show the values that you used on your graph. No unit is required in your answer.   (4)

6.5   Use an appropriate equation and your gradient calculated in Question 6.4 to determine the mass of Mercury.   (4)

6.6   A box with a mass of 5 kg is raised through a height of 2 m on the surface of Mercury. How much gravitational potential energy will the box gain?   (3)

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QUESTION 7   ELECTRIC CIRCUITS

7.1   A pump is connected to a water tank to pump rainwater into a house. The pump is rated 750 W and it is connected to the 240 V main supply.

7.1.1   What current will the pump draw when operating on the 240 V supply?   (3)

7.1.2   The cost of electricity is R1,20 per kilowatt hour. Calculate the cost of using the pump continuously for 20 minutes.   (3)

7.2   In the circuit represented below, the battery has an emf of 12 V and an internal resistance of 0,5 Ω. The battery is connected as shown to a light bulb and resistor R_X, both of unknown resistance. Ammeters have zero resistance and the voltmeter has infinite resistance.
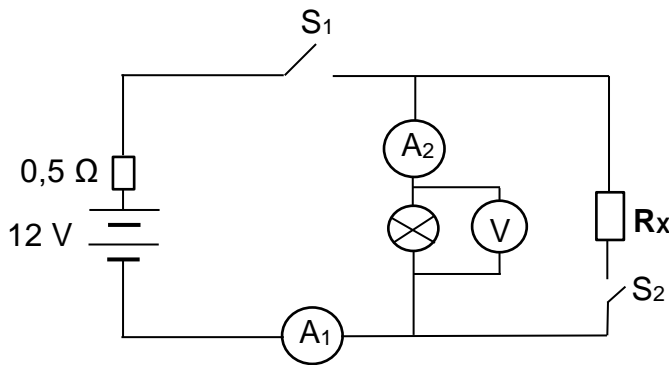
Switch S_1 and switch S_2 are initially both open.

7.2.1   Define *emf*.   (2)

7.2.2   What will be the reading on the voltmeter, V, when both switches are open?   (2)

Switch S_1 is now closed, while S_2 remains open. Ammeter A_1 reads 1,6 A.

7.2.3   Determine the resistance of the bulb.   (4)

7.2.4   Calculate the reading on the voltmeter, V.   (3)

7.2.5   Calculate the rate of energy dissipation in the battery.   (3)

7.2.6   Switch S_2 is now closed so that both switches are closed. When switch S_2 is closed, state whether the following will DECREASE, INCREASE or STAY THE SAME:

(a)   the reading on ammeter A_1. Explain your answer.   (2)
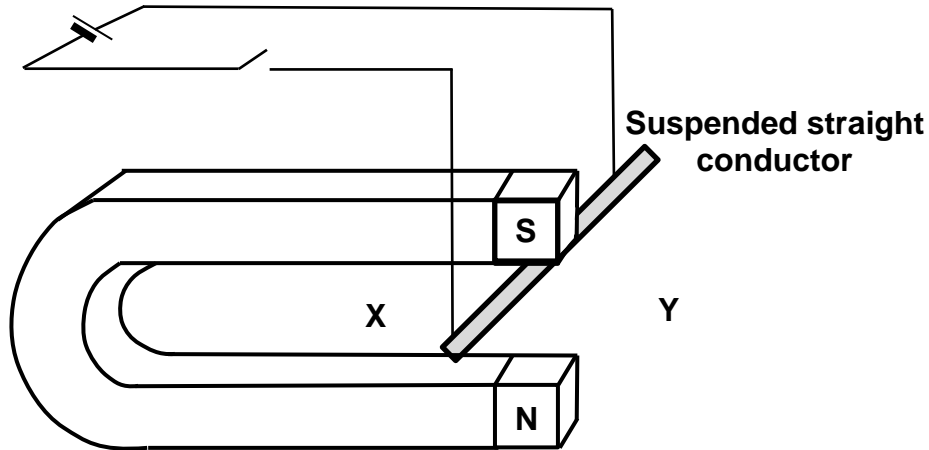
(b)   the rate of energy dissipation in the battery.   (2)

(c)   the reading on voltmeter V. Explain your answer.   (2)

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QUESTION 8   ELECTRODYNAMICS

The diagram below shows a straight conductor connected to a battery and suspended between the poles of a permanent magnet, so that it is perpendicular to the magnet. The conductor is free to move.

8.1   Will the conductor move towards the side marked **X** or **Y** when the switch is closed? Write only **X** or **Y**. (2)

8.2   Briefly explain why the conductor moves. (2)

8.3   Suggest two changes that could be made to the set up where either change would cause the conductor to move in the opposite direction. (2)

8.4   Identify two changes that could be made to increase the force that the conductor experiences. (2)

8.5   The conductor is rotated through 90 degrees so that it is suspended between the poles of the magnet, parallel to the magnet, as shown alongside.
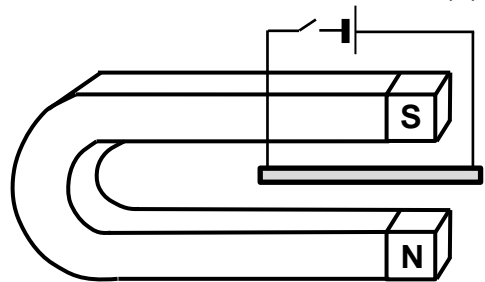
Would the conductor still experience a magnetic force when the switch is closed? (1)

A transformer is connected to the output of an AC generator.

8.6   Explain how the transformer changes the voltage output of the generator, referring to the basic operation of an ideal transformer. (3)

8.7   The generator produces 16 V. The transformer has 200 turns on the primary coil. How many turns must there be on the secondary coil for the transformer to produce 240 V? (3)

8.8   Explain why high voltages are used for the transmission of electrical energy through the national grid. Use an appropriate equation in your explanation. (3)

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QUESTION 9   PHOTONS AND ELECTRONS

9.1   The diagram below shows four transitions (A, B, C and D) in a hydrogen atom. *The diagram is not to scale.*

        0 eV

        -0,85 eV

        -1,51 eV

        -3,40 eV

        A   B

        -13,6 eV

        C   D
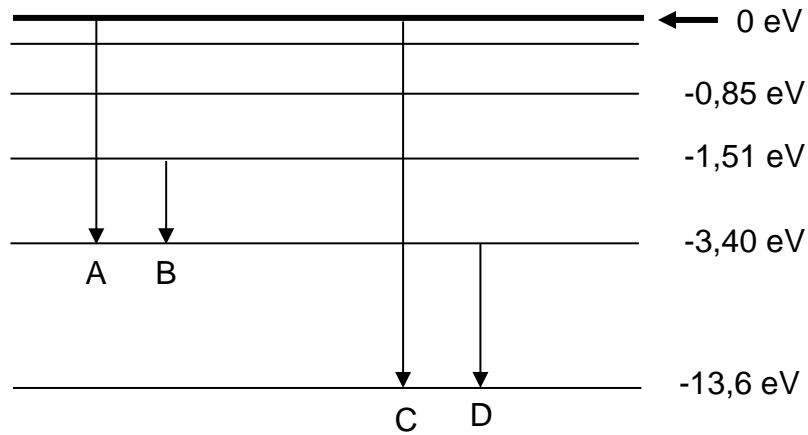
    9.1.1   Explain what the arrows A–D represent.   (2)

    9.1.2   Which arrow (A, B, C or D) corresponds to the greatest wavelength of light emitted? Give a reason for your answer.   (2)

    9.1.3   Calculate the frequency of light that would be emitted by transition D.   (4)

9.2   Caesium metal has a work function of $3,36 \times 10^{-19}$ J. Blue light with a wavelength of 470 nm is shone onto the surface of the caesium.

    9.2.1   Define *threshold frequency*.   (2)

    9.2.2   Calculate the threshold frequency of caesium.   (3)

    9.2.3   Will the blue light be able to eject an electron from caesium? Justify your answer with a calculation.   (3)

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Total: 200 marks