1. A cell of negligible internal resistance is connected in series with a microammeter of negligible resistance and two resistors of 10 kΩ and 15 kΩ. The current is 200 μA.

Draw a circuit diagram of the arrangement.

(1)

Calculate the e.m.f. of the cell.

.....

.....

e.m.f. = ...

(2)

Where a voltmeter is connected in parallel with the 15 kΩ resistor, the current in the microammeter increases to 250 μA. Sketch a diagram of the modified circuit.

(1)

Calculate the resistance of the voltmeter.

.....

.....

.....

.....

Resistance = ...

(3)

(Total 7 marks)

2. A copper wire is 2.0 m long and has a cross-sectional area of 1.00 mm^2. It has a p.d. of 0.12 V across it when the current in it is 3.5 A. Draw a circuit diagram to show how you would check these voltage and current values.

(3)

Calculate the rate at which the power supply does work on the wire.

.....

.....

Rate = ...

(2)

Copper has about 1.7×10^{29} electrons per metre cubed. Calculate the drift speed of the charge carriers in the wire.

.....

.....

.....

Drift speed = ...

(3)

The power from the supply connected to the wire is equal to the total force F_t on the electrons multiplied by the drift speed at which the electrons travel. Calculate F_t.

.....

.....

.....

F_t = ...

(3)
(Total 11 marks)

3. A light-dependent resistor may be used with additional components to make a light meter. Sketch a diagram for a suitable circuit.

(2)

Explain how your circuit works

.....

.....

.....

.....

(2)
(Total 4 marks)

4. Define the term *resistivity.*

.....

.....

.....

(2)

The resistivity of copper is 1.7×10^{-8} Ωm. A copper wire is 0.6 m long and has a cross-sectional area of $1 mm^2$. Calculate its resistance.

.....

.....

.....

Resistance = ...

(3)

Two such wires as used to connect a lamp to a power supply of negligible internal resistance. The potential difference across the lamp is 12 V and its power is 36 W. Calculate the potential difference across each wire.

.....

.....

.....

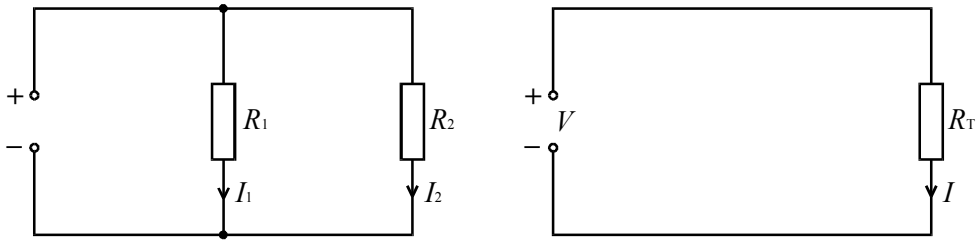
Potential difference = ...

(3)

Draw a circuit diagram of the above arrangement. Label the potential differences across the wires, lamp and power supply.

(3)
(Total 11 marks)

5. The power supplies in the two circuits shown below are identical.



Write down the relationship between I_1, I_2 and I which must hold if the combined resistance of the parallel pair, R_1, and R_2, is to equal R_r.

.....

.....

(1)

Hence derive the formula for the equivalent resistance of two resistors connected in parallel.

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(3)

Use your formula to show that the resistance between the terminals of a low-resistance component is hardly changed when a high-resistance voltmeter is connected in parallel with it.

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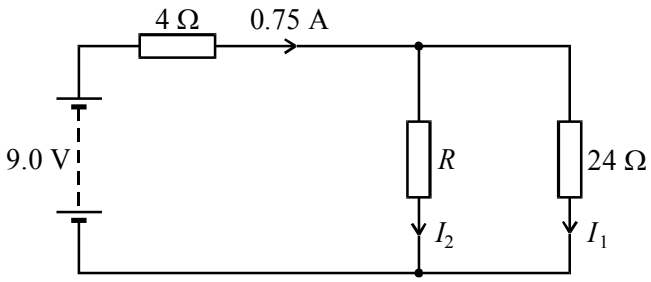
(2)
(Total 6 marks)

6. The circuit shows a battery of negligible internal resistance connected to three resistors.



Calculate current I_1.

.....

.....

.....

I_1 = ...

(3)

Calculate resistance *R*

.....

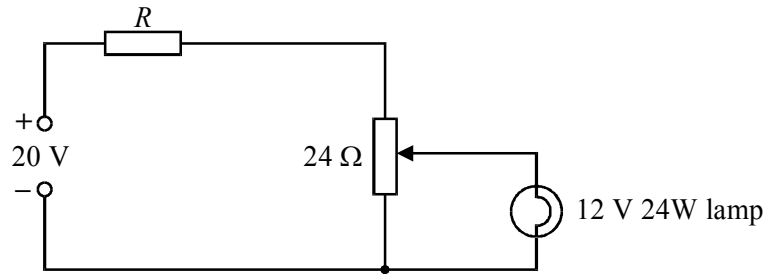
.....

R = ...

(2)

(Total 5 marks)

7. The circuit shown is used to produce a current-voltage graph for a 12 V, 24 W lamp.



Show on the diagram the correct position for a voltmeter and an ammeter.

(2)

Calculate the resistance of the lamp in normal operation.

.....

.....

.....

Resistance = ...

(3)

Calculate the value for *R* which would enable the voltage across the lamp to be varied between 0 V and 12V.

.....

.....

.....

.....

R = ...

(4)

(Total 9 marks)

8. A semiconducting strip, 6mm wide and 0.5 mm thick, carries a current of 8mA. The carrier density is 7×10^{-23} m^{-3}. Calculate the carrier drift speed.

.....

.....

.....

.....

Drift speed = ...

(3)

An approximate value for the drift speed in a copper wire of the same dimensions and carrying the same current would be about 10^{-7} ms $^{-1}$. Compare this figures with your calculated result and account for any difference in terms of the equation $I = nAqv$.

.....

.....

.....

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.....

.....

(3)

Explain why the resistance of a semiconducting strip decreases when its temperature rises.

.....

.....

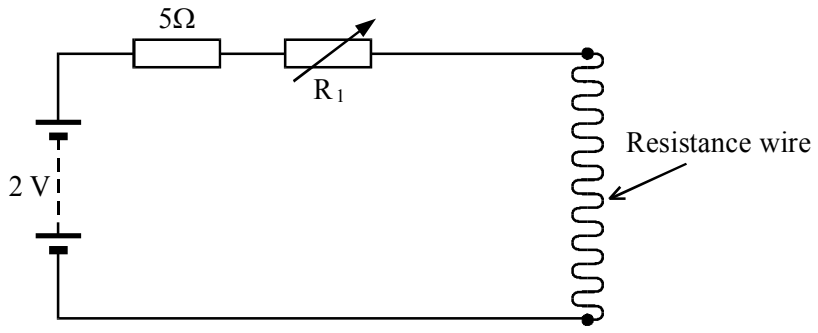
.....

.....

(2)
(Total 8 marks)

9. You are given a piece of resistance wire. It is between two and three metres long and has a resistance of about 15 Ω. You are asked to measure the resistivity of the metal alloy it is made from.

Make the necessary additions to the following circuit to enable it to be used for the experiment.



(2)

Describe briefly how you would use the circuit above to measure the resistance of the wire.

……

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(5)

Once the resistance of the wire is known, two more quantities must be measured before its resistivity can be calculated. What are they?

……

……

……

……

(2)

Is there any advantage in finding the resistance of the wire from a graph compared with calculating an average value from the measurements? Explain your answer.

……

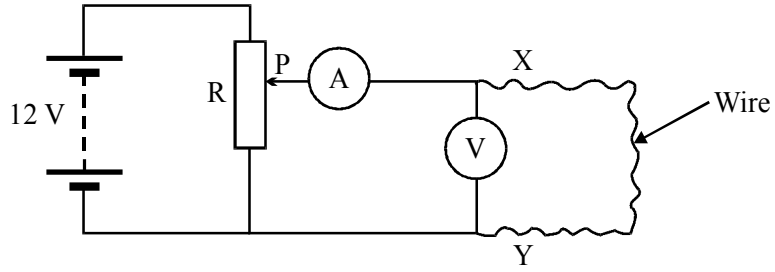
……

……

……

(2)
(Total 11 marks)

10. The circuit diagram shows a 12 V power supply connected across a potential divider R by the sliding contact P. The potential divider is linked to a resistance wire XY through an ammeter. A voltmeter is connected across the wire XY.



Explain, with reference to this circuit, the term *potential divider*.

……

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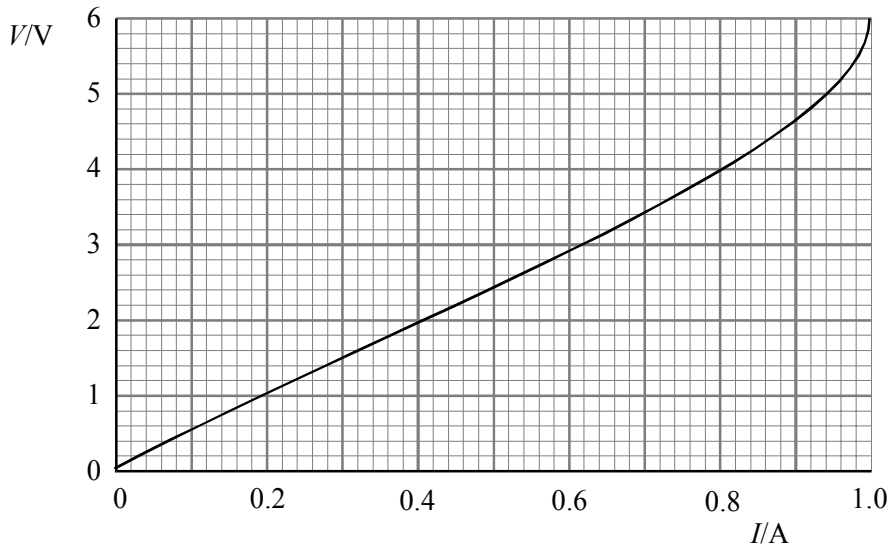
……

(2)

The circuit has been set up to measure the resistance of the wire XY. A set of voltage and current measurements is recorded and used to draw the following graph.



Explain why the curve deviates from a straight line at higher current values.

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(2)

Calculate the resistance of the wire for low current values.

……

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……

(2)

To determine the resistivity of the material of the wire, two more quantities would have to be measured. What are they?

……

……

(2)

Explain which of these two measurements you would expect to have the greater influence on the error in a calculated value for the resistivity? How would you minimise this error?

……

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……

……

(3)
(Total 11 marks)

11. A wire 6.00 m long has a resistivity of 1.72 ? 10^{-8} ? m and a cross-sectional area of 0.25 mm^2 Calculate the resistance of the wire.

.....….....…

.....….....…

.....….....…

Resistance = ...…

(3)

The wire is made from copper. Copper has 1.10 ? 10^{29} free electrons per metre cubed. Calculate the current through the wire when the drift speed of the electrons is 0.093^{-1} mm s^{-1}.

.....….....…

.....….....…

.....….....…

Current = ...…

(3)

The wire is cut in two and used to connect a lamp to a power supply. It takes 9 hours for an electron to travel from the power supply to the lamp. Explain why the lamp comes on almost as soon as the power supply is connected.

.....….....…

.....….....…

.....….....…

.....….....…

(3)
(Total 9 marks)

12. A 100 W tungsten filament lamp operates from the 230 V mains. Calculate its resistance.

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.....

Resistance =.....

(2)

The drift speed of the electrons in the filament is much higher than the drift speed of electrons in the rest of the circuit. Suggest and explain a reason for this.

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.....

.....

(4)
(Total 6 marks)

13. Define the term *resistivity.*

.....

.....

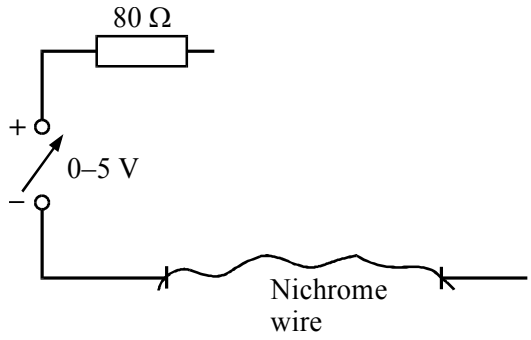
.....

.....

(2)

A student is asked to measure the resistivity of the alloy nichrome given a nichrome wire known to have a resistance of about two or three ohms. The wire is mounted between two copper clamps, X and Y, near the ends of the wire. The power supply is a variable power supply of output 0–5 V. The series resistor is 80 Ω.

Complete the following circuit diagram.



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(2)

The 80 Ω series resistor ensures that the current is kept small. Explain why this is important.

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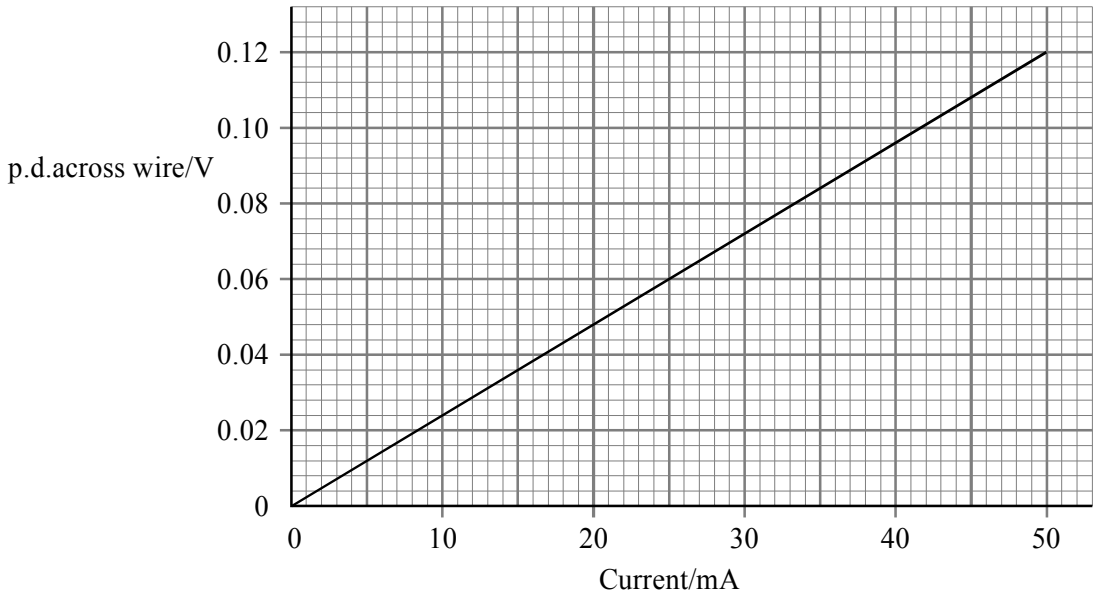
(2)

A number of measurements were made of the voltage across the wire for different values of the current flowing in it. The following graph was drawn.



Calculate the resistance of the nichrome wire.

.....

.....

.....

Resistance =

(3)

The length of wire between the clamps is 51 cm. The diameter of the nichrome wire is 0.59mm.Calculate the resistivity of the nichrome.

.....

.....

.....

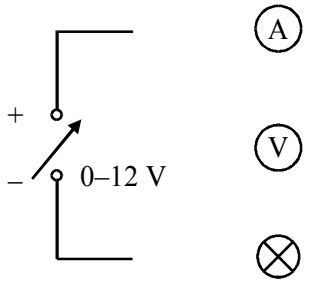
Resistance =

(3)

(Total 12 marks)

14. You are asked to set up a circuit to take some measurements and to draw a graph which shows how the current in a 12 V, 24 W electric filament lamp varies with the potential difference across it.

The diagram shows the electrical components you will need. Complete a suitable circuit diagram by drawing the connection wires.



(2)

What measurements would you make using this circuit?

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.....

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.....

.....

(3)

Sketch and label the graph you would expect to obtain.

(3)
(Total 8 marks)

15. A torch has three identical cells, each of e.m.f. 1.5 V, and a lamp which is labelled 3.5 V, 0.3 A. Draw a circuit diagram for the torch.

(2)

Assume that the lamp is lit to normal brightness and that the connections have negligible resistance. Mark on your diagram the voltage across each circuit component and the current flowing in the lamp.

(3)

Calculate the internal resistance of one of these cells.

Resistance = ...……

(3)
(Total 8 marks)

16. (a) Describe how you would determine by experiment approximate values for the e.m.f and internal resistance of a torch battery. Include a circuit diagram.

.....

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.....

.....

(4)

(b) (i) A battery has an e.m.f. of 12.0 V and an internal resistance of 3.0Ω.Calculate the p.d. across the battery when it is delivering a current of 3.0 A.

.....

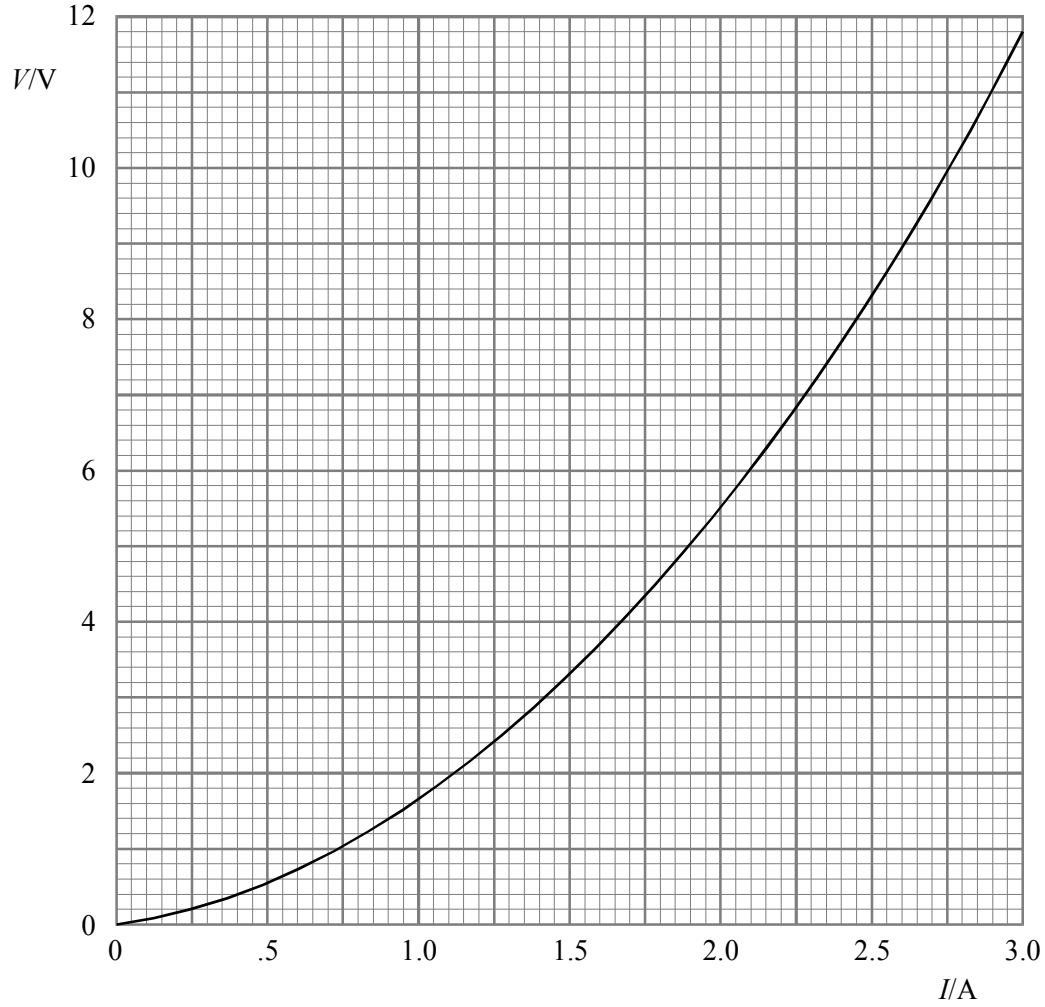
.....

.....

p.d. = ...

(2)

(ii) The same battery is now connected to a filament lamp. The graph shows how the p.d. across the lamp would depend on the current through it.



Use your answer to part (i) to help you draw, on the same axes, a line showing how the p.d. across the battery would depend on the current through it.

(1)

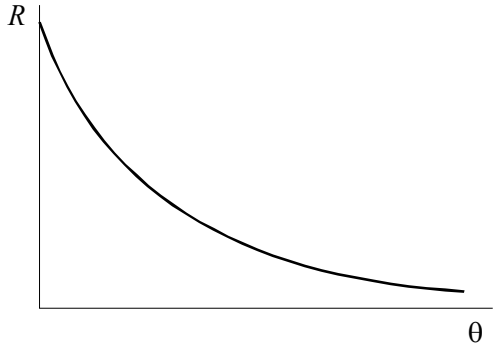
What current will the battery drive through the lamp?

.....

(1)

(Total 8 marks)

17. The graph shows how the resistance *R* of a thermistor depends on temperature θ.



In terms of the behaviour of the material of the thermistor, explain qualitatively the variation shown on the graph.

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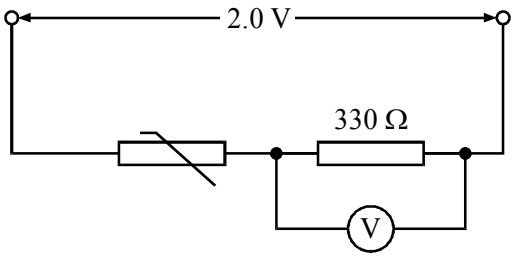
.....

(2)

A student connects the thermistor in series with a 330 Ω resistor and applies a potential difference of 2.0 V. A high resistance voltmeter connected in parallel with the resistor reads 0.80 V.



Calculate the resistance of the thermistor.

.....

.....

.....

Resistance = ...

(3)

The student now increases the applied p.d. from 2.0 V to 20 V. She expects the voltmeter reading to increase from 0.80 V to 8.0 V but is surprised to find that it is greater. Explain this.

.....

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.....

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.....

.....

(3)
(Total 8 marks)

18. The current I through a metal wire of cross-sectional area A is given by the formula

$$I = nA\upsilon e$$

where e is the electronic charge on the electron. Define the symbols n and υ.

.....

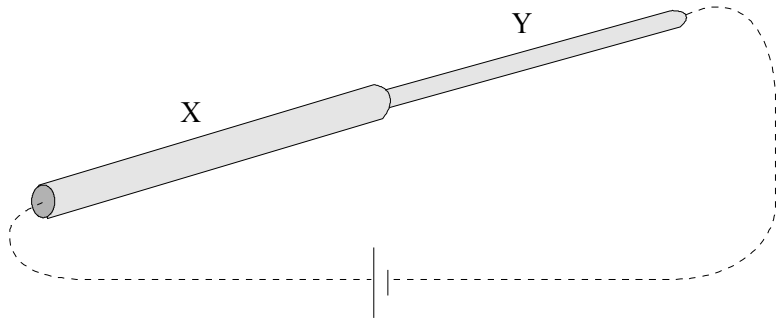
.....

.....

.....

(2)

Two pieces of copper wire, X and Y, are joined end-to-end and connected to a battery by wires which are shown as dotted lines in the diagram. The cross-sectional area of X is double that of Y.



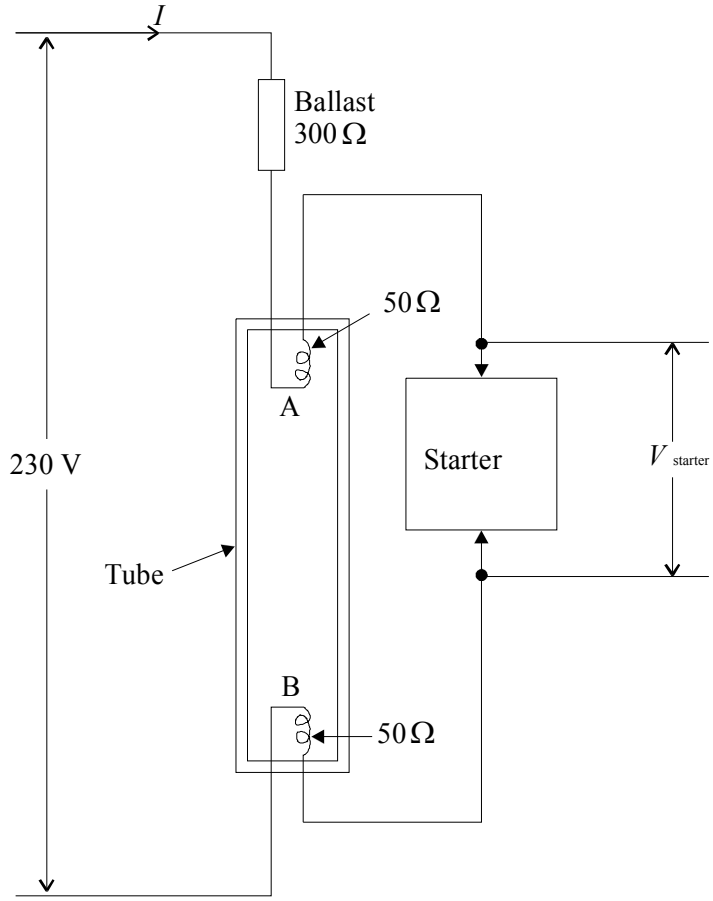
In the table below, n_x and n_y denote the values of n in X and Y, and similarly for the other quantities. Write in the table the value of each ratio, and alongside it explain your answer.

Ratio	Value	Explanation
$\frac{n_Y}{n_X}$		
$\frac{I_Y}{I_X}$		
$\frac{\upsilon_Y}{\upsilon_X}$		

(6)
(Total 8 marks)

19. The diagram shows the circuit of a fluorescent light fitting. It consists of a tube, a starter and a ballast resistance of 300 Ω.

The fluorescent tube is filled with gas. It contains two filaments at A and B of resistance 50 Ω that heat the gas.



When the light is first turned on, the tube does not conduct but the starter does, drawing a current of 0.50 A from the 230 V supply.

Calculate the voltages across the ballast resistor and each filament when this current flows.

.....

.....

.....

.....

.....

Voltage across ballast =.....

Voltage across each filament =.....

(3)

Mark these voltages on the diagram, and hence calculate the voltage across the starter when the starting current is flowing. Mark your answer on the diagram.

(2)

The starting current heats the filaments and the gas in the tube but the voltage across the tube is not large enough to make it conduct. However, after a few seconds the starter stops conducting. The voltage across the tube rises and the gas conducts. A current now flows from A to B and the tube lights up.

What fundamental change is necessary for a gas, which was an insulator, to be able to conduct?

.....

.....

(1)

Now that the tube is conducting, the voltage across AB is 110 V. Calculate the power dissipated in the whole circuit.

.....

.....

.....

Power dissipated =.....

(3)

In a faulty fluorescent lamp the filaments at both ends of the tube glow steadily but the tube does not light up. Identify, with a reason, the faulty component.

.....

.....

(1)
(Total 10 marks)

20. An electric shower is connected to the mains supply by a copper cable 20 m long. The two conductors inside the cable each have a cross-sectional area of 4.0 mm^2 **.** The resistivity of copper is $1.7 \times 10^{-8}\ \Omega$. Show that the resistance of each of the conductors is 0.085 Ω.

.....

.....

.....

.....

(2)

The operating current of the shower is 37 A. Calculate the total voltage drop caused by the cable supplying the shower.

.....

.....

.....

Voltage =.....

(2)

Explain why cable with 6.0 mm^2 conductors would have been more suitable for this shower installation.

.....

.....

.....

.....

(2)
(Total 6 marks)

21. A student connects a power supply to a block of lead. The block is thermally insulated from its surroundings. A voltage of 0.42 V drives a current of 23 A through the block. The temperature of the block rises 1.5 K above the room temperature in 30 s. Show that the energy given to the block is about 300 J.

.....

.....

.....

.....

.....

(2)

The equation $\Delta U = \Delta Q + \Delta W$ applies to the block during this process. For each of these three terms state, with a reason, its value.

ΔU .....

.....

ΔQ .....

.....

ΔW .....

.....

(6)

In a second experiment the student beats one side of the block a number of times with a hammer. He hits the same spot each time. During this process the block is indented by a distance of 2.4 mm and its temperature rises by 1.5 K. Calculate the average force applied by the hammer.

.....

.....

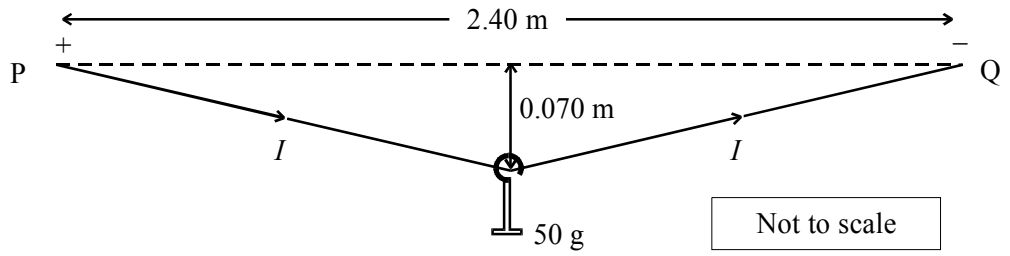
.....

Force =.....

(3)

(Total 11 marks)

22. A student devises a way of measuring electric current by hanging a mass of 50 g on a conducting wire stretched between two points P and Q which are 2.40 m apart. The sag at the centre of the wire varies with the current *I*, as the wire expands because of the heating effect of the current. The sag is 0.070 m when the current is 13 A d.c.



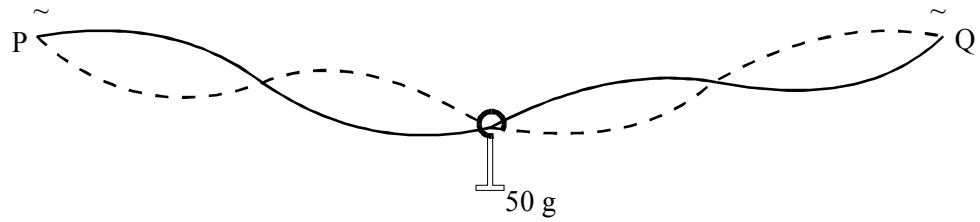
(a) Draw a free-body force diagram for the 50 g mass when the sag is 0.070 m. Hence, or otherwise, determine the tension *T* in the wire.

(5)

(b) Outline how the student could have measured the resistance of the conducting wire at different values of *I* before setting up this experiment.

(3)

(c) The student now connects P and Q to a 50 Hz a.c. supply. When the current is 13 A r.m.s. the wire is found to oscillate as shown.



The student measures the distance between adjacent nodes along the wire to be 606 mm.

(i) What is meant by a current of 13 A r.m.s.?

(ii) Deduce the speed c of transverse waves along the hot wire.

(iii) Suggest why the wire oscillates in this manner.

(6)

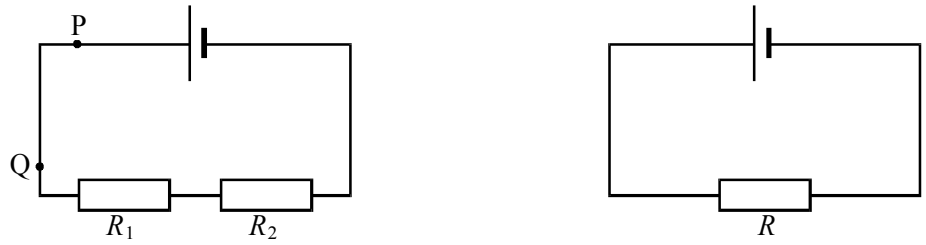
(d) The tension in the wire is related to c and the mass per unit length μ of the wire by the expression

$$T = \mu c^2$$

Show that the unit of μc^2 is N.

(2)
(Total 16 marks)

23. The resistors R_1 and R_2 in circuit (i) are equivalent to a single resistor R in circuit (ii).



(i) (ii)

Prove that $R = R_1 + R_2$

.....

.....

.....

.....

.....

.....

(3)

In a real circuit it is usually assumed that there is no potential difference between two points, such as P and Q in diagram (i), which are on the same connecting lead. Explain why this is usually a good approximation.

.....

.....

.....

(2)

In what circumstances might the approximation break down?

.....

.....

(1)

A laboratory lead consists of 16 strands of fine copper wire twisted together. Each strand is 30 cm long with a diameter of 0.15 mm. Calculate the potential difference across the lead when it is carrying a current of 2.0 A.

(The resistivity of copper = 1.7×10^{-8} Ωm**)**

.....

.....

.....

.....

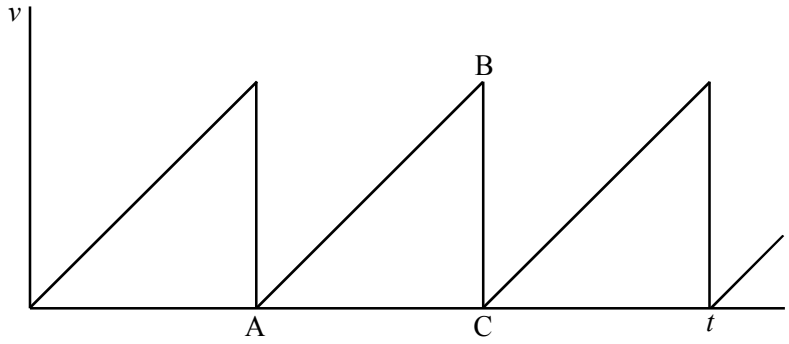
.....

Potential difference =.....

(4)

(Total 10 marks)

24. The diagram is a velocity-time graph for an electron.



Describe carefully the motion represented by lines AB and BC.

AB: .....

.....

BC: .....

.....

(2)

The graph is a much simplified model of how an electron moves along a wire carrying a current. Explain what causes the motion represented by AB and BC.

AB: .....

.....

BC: .....

.....

(2)

Explain the term *drift velocity* and indicate its value on the graph above.

.....

.....

(2)

With reference to the behaviour of the electron, explain why the wire gets warm.

.....

.....

(1)

(Total 7 marks)