Electricity

1 Nov01

7 (a) A student has been asked to make an electric heater. The heater is to be rated as 12 V 60W, and is to be constructed of wire of diameter 0.54 mm. The material of the wire has resistivity $4.9 \times 10^{-7}\Omega$m.

(i) Show that the resistance of the heater will be 2.4Ω. [2]

(ii) Calculate the length of wire required for the heater.[3]

(b) Two cells of e.m.f. E_1 and E_2 are connected to resistors of resistance R_1, R_2 and R_3 as shown in Fig. 7.1.

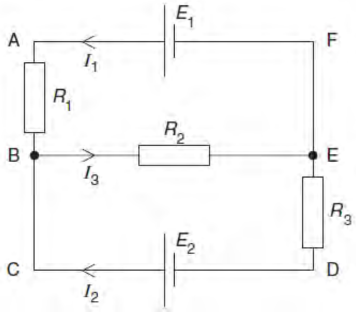


Fig. 7.1

The currents I_1, I_2 and I_3 in the various parts of the circuit are as shown.

(i) Write down an expression relating I_1, I_2 and I_3.[1]

(ii) Use Kirchhoff's second law to write down a relation between

1. E_1, R_1, R_2, I_1 and I_3 for loop ABEFA,
2. E_1, E_2, R_1, R_3, I_1 and I_2 for loop ABCDEFA. [2]

2. May 02

6 Two horizontal metal plates are situated 1.2 cm apart, as illustrated in Fig. 6.1.

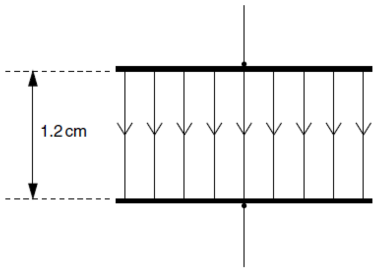


Fig. 6.1

The electric field between the plates is found to be 3.0×10^4NC^{-1} in the downward direction.

(a) (i) On Fig. 6.1, mark with a + the plate which is at the more positive potential.

(ii) Calculate the potential difference between the plates.[3]

(b) Determine the acceleration of an electron between the plates, assuming there is a vacuum between them. [3]

3. May 02

8 A student has available some resistors, each of resistance 100Ω.

(a) Draw circuit diagrams, one in each case, to show how a number of these resistors may be connected to produce a combined resistance of

(i) 200Ω, (ii) 50Ω, (iii) 40Ω. [4]

(b) The arrangement of resistors shown in Fig. 8.1 is connected to a battery.

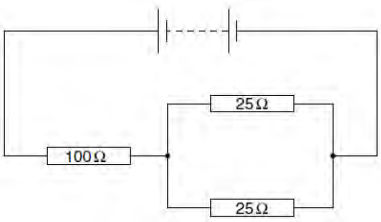


Fig. 8.1

The power dissipation in the 100 Ω resistor is 0.81W. Calculate

(i) the current in the circuit, current = ... A

(ii) the power dissipation in each of the 25 Ω resistors.[4]

4. Nov 02

6 An electron travelling horizontally in a vacuum enters the region between two horizontal metal plates, as shown in Fig. 6.1.

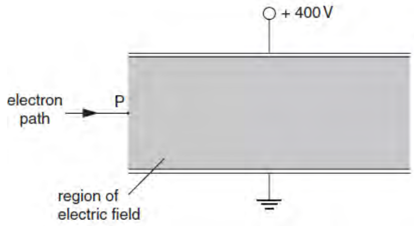


Fig. 6.1

The lower plate is earthed and the upper plate is at a potential of + 400V. The separation of the plates is 0.80 cm.

The electric field between the plates may be assumed to be uniform and outside the plates to be zero.

(a) On Fig. 6.1,

(i) draw an arrow at P to show the direction of the force on the electron due to the electric field between the plates,

(ii) sketch the path of the electron as it passes between the plates and beyond them. [3]

(b) Determine the electric field strength E between the plates.[2]

(c) Calculate, for the electron between the plates, the magnitude of

(i) the force on the electron, (ii) its acceleration. [4]

(d) State and explain the effect, if any, of this electric field on the horizontal component of the motion of the electron [2]

5. Nov 02

7 A student set up the circuit shown in Fig. 7.1.

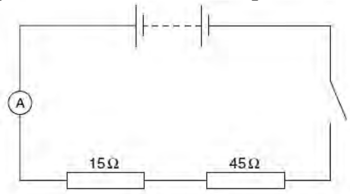


Fig. 7.1

The resistors are of resistance 15 Ω and 45 Ω. The battery is found to provide 1.6×10^5 J of electrical energy when a charge of 1.8×10^4 C passes through the ammeter in a time of 1.3×10^5 s.

(a) Determine

(i) the electromotive force (e.m.f.) of the battery,

(ii) the average current in the circuit.[4]

(b) During the time for which the charge is moving, 1.1×10^5 J of energy is dissipated in the 45 Ωresistor.

(i) Determine the energy dissipated in the 15 Ω resistor during the same time

(ii) Suggest why the total energy provided is greater than that dissipated in the two resistors. [4]

6. May 03

A filament lamp operates normally at a potential difference (p.d.) of 6 V. The variation with p.d. V of the current I in the lamp is shown in the Fig. 5.1.

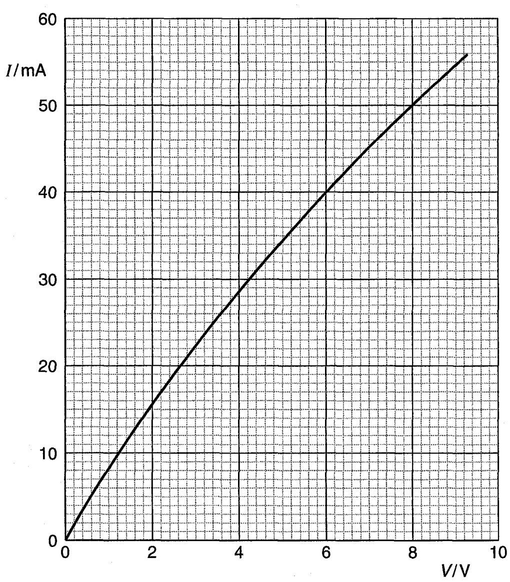


Fig. 5.1

(a) Use Fig. 5.1 to determine, the this lamp,
(i) the resistance when it is operating at a p.d. of 6.0 V,
(ii) the chang in resistance when the p.d. increases from 6.0 V to 8.0 V. [4]
(b) the lamp is connected into the circuit of Fig. 5.2.

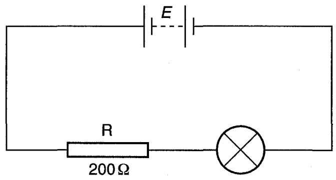


Fig. 5.2

R is a fixed resistor of resistance 200 Ω. The battery has e.m.f. E and negligible internal resistance.
(i) On Fig. 5.1, draw a line to show the variation with p.d. V of the current I in the resistor R.
(ii) Determine the e.m.f. of the battery for the lamp to operate normally. [4]

7. Nov 03

5 Two large flat metal plates A and B are placed 9.0 cm apart in vacuum as illustrated in Fig. 5.1.

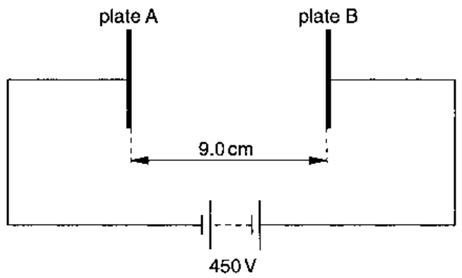
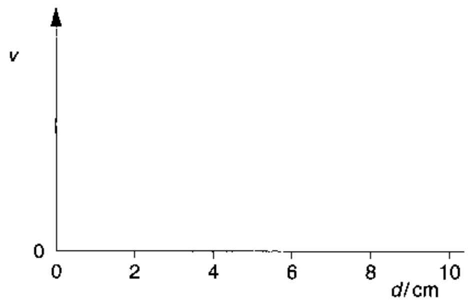


Fig. 5.1

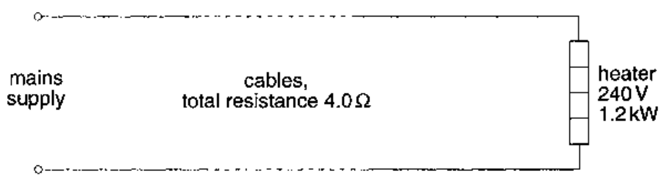
A potential difference of 450 V is maintained between the plates by means of a battery.
(a) (i) On Fig. 5.1, draw an arrow to indicate the direction of the electric field between plates A and B.
(ii) Calculate the electric field strength between A and B.
(b) An electron is released from rest at the surface of plate A.
(i) Show that the change in electric potential energy in moving from plate A to plate B is 7.2×10^{17} J.
(ii) Determine the speed of the electron on reaching plate B [4]
(c) On the axes of Fig. 5.2, sketch a graphic show the variation with distance d from plate A of the speed v of the electron. [1]



8 Nov 03

7 An electric heater is rated as 240 V, 1.2 kW and has constant resistance.
(a) For the heater operating at 240V,
(I) show that the current in the heater is 5.0 A,
(ii) calculate its resistance. resistance=……………..Ω

(b) The heater in (a) is connected to a mains supply by means of two long cables, , illustrated in Fig. 7.1.



The cables have a total resistance of 4.0 Ω. The voltage of the mains supply is adjusted so that the heater operates normally at 240V. Using your answers in
(a), where appropriate, calculate
(i) the potential difference across the cables,
(ii) the voltage of the mains supply,
(iii) the power dissipated in the cables. [3]
(c) Using information from (b), determine the efficiency e at which power is transferred from the supply to the heater. That is, calculate

$$\varepsilon = \frac{\text{power dissipated in heater}}{\text{power input from supply}}.$$ [2]

9. May 04

7 A household electric lamp is rated as 240 V, 60W. The filament of the lamp is made from tungsten and is a wire of constant radius 6.0×10^{-6} m. The resistivity of tungsten at the normal operating temperature of the lamp is 7.9×10^{-7} Ωm.
(a) For the lamp at its normal operating temperature,
(i) calculate the current in the lamp,
(ii) show that the resistance of the filament is 960Ω. [3]
(b) Calculate the length of the filament. [3]
(c) Comment on your answer to (b). [1]

10. May 04

8 A thermistor has resistance 3900Ω at 0 ℃ and resistance 1250 Ω at 30 ℃. The thermistor is connected into the circ uit of Fig. 8.1 in order to monitor temperature changes.

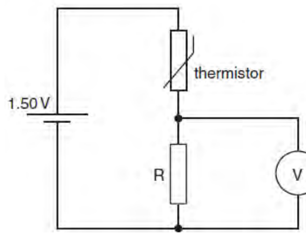


Fig. 8.1

The battery of e.m.f. 1.50V has negligible internal resistance and the voltmeter has infinite resistance.
(a) The voltmeter is to read 1.00V at 0 ℃. Show that the resistance of resistor R is 7800Ω. [2]
(b) The temperature of the thermistor is increased to 30 ℃. Determine the reading on the voltmeter. [2]
(c) The voltmeter in Fig. 8.1 is replaced with one having a resistance of 7800Ω. Calculate the reading on this voltmeter for the thermistor at a temperature of 0 ℃.

11-Nov 04

6 Fig. 6.1 shows the variation with applied potential difference V of the current I in an electrical component C.

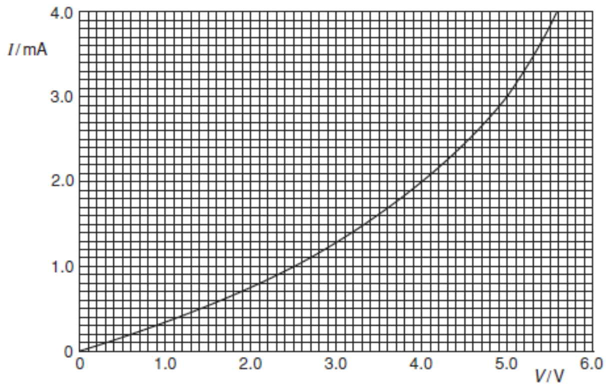


Fig. 6.1

(a) (i) State, with a reason, whether the resistance of component C increases or decreases with increasing potential difference. [2]
(ii) Determine the resistance of component C at a potential difference of 4.0 V. [2]

(b) Component C is connected in parallel with a resistor R of resistance 1500Ω and a battery of e.m.f. E and negligible internal resistance, as shown in Fig. 6.2.

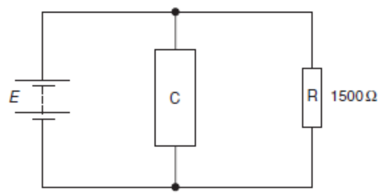


Fig. 6.2

(i) On Fig. 6.1, draw a line to show the variation with potential difference V of the current I in resistor R. [2]
(ii) Hence, or otherwise, use Fig. 6.1 to determine the current in the battery for an e.m.f. of 2.0 V. [2]
(c) The resistor R of resistance 1500 Ω and the component C are now connected in series across a supply of e.m.f. 7.0 V and negligible internal resistance. Using information from Fig. 6.1, state and explain which component, R or C, will dissipate thermal energy at a greater rate. [3]

12-May 05

6 Two parallel metal plates P and Q are situated 8.0 cm apart in air, as shown in Fig. 6.1.

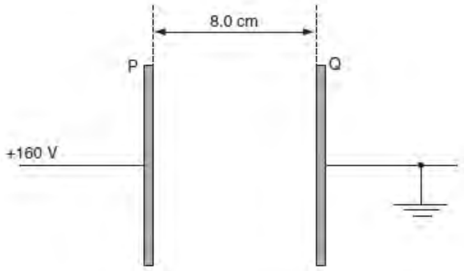


Fig. 6.1

Plate Q is earthed and plate P is maintained at a potential of +160 V.
(a) (i) On Fig. 6.1, draw lines to represent the electric field in the region between the plates. [2]
(ii) Show that the magnitude of the electric field between the plates is 2.0×10^3 Vm^{-1}. [1]
(b) A dust particle is suspended in the air between the plates. The particle has charges of $+1.2 \times 10^{-15}$C and -1.2×10^{-15} C near its ends. The charges may be considered to be point charges separated by a distance of 2.5 mm, as shown in Fig. 6.2.

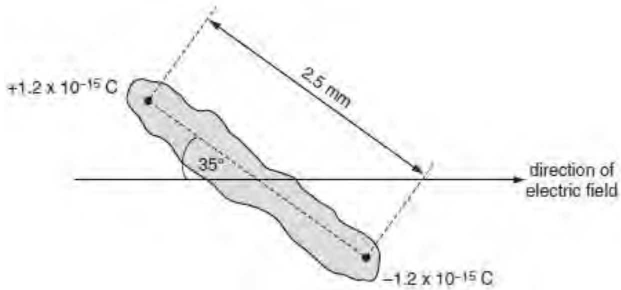


Fig. 6.2

The particle makes an angle of 35° with the directi on of the electric field.
(i) On Fig. 6.2, draw arrows to show the direction of the force on each charge due to the electric field. [1]
(ii) Calculate the magnitude of the force on each charge due to the electric field. [2]
(iii) Determine the magnitude of the couple acting on the particle.
couple = ... Nm [2]
(iv) Suggest the subsequent motion of the particle in the electric field. [2]

13-May 05

7 (a) Define the resistance of a resistor. [1]
(b) In the circuit of Fig. 7.1, the battery has an e.m.f. of 3.00 V and an internal resistance r. R is a variable resistor. The resistance of the ammeter is negligible and the voltmeter has an infinite resistance.

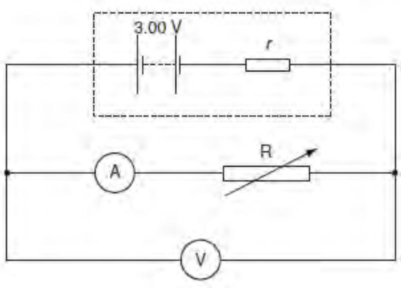


Fig. 7.1

The resistance of R is varied. Fig. 7.2 shows the variation of the power P dissipated in R with the potential difference V across R.

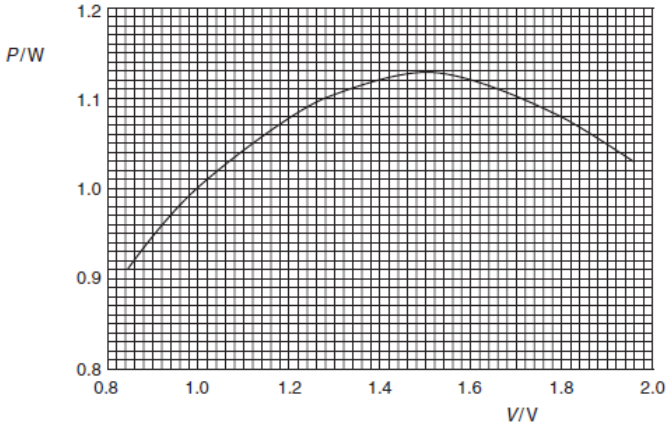


Fig. 7.2

(i) Use Fig. 7.2 to determine
1. the maximum power dissipation in R,
2. the potential difference across R when the maximum power is dissipated. [1]
(ii) Hence calculate the resistance of R when the maximum power is dissipated. [2]
(iii) Use your answers in (i) and (ii) to determine the internal resistance r of the battery. [3]
(c) By reference to Fig. 7 2, it can be seen that there are two values of potential difference V for which the power dissipation is 1.05W. State, with a reason, which value of V will result in less power being dissipated in the internal resistance. [3]

Nov 05

6 Two horizontal metal plates X and Y are at a distance 0.75 cm apart. A positively charged particle of mass 9.6 × 10–15 kg is situated in a vacuum between the plates, as illustrated in Fig. 6.1.

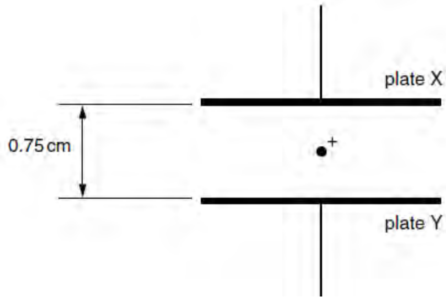


Fig. 6.1

The potential difference between the plates is adjusted until the particle remains stationary.
(a) State, with a reason, which plate, X or Y, is positively charged. [2]
(b) The potential difference required for the particle to be stationary between the plates is found to be 630 V. Calculate
(i) the electric field strength between the plates, [2]
(ii) the charge on the particle.

14-Nov 05

7 A battery of e.m.f. 4.50 V and negligible internal resistance is connected in series with a fixed resistor of resistance 1200Ω and a thermistor, as shown in Fig. 7.1.

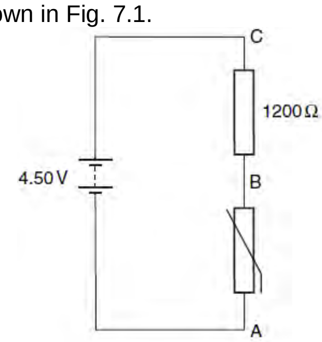


Fig. 7.1

(a) At room temperature, the thermistor has a resistance of 1800Ω. Deduce that the potential difference across the thermistor (across AB) is 2.70 V. [2]

(b) A uniform resistance wire PQ of length 1.00m is now connected in parallel with the resistor and the thermistor, as shown in Fig. 7.2.

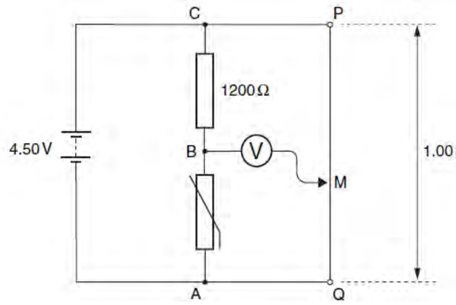


Fig. 7.2

A sensitive voltmeter is connected between point B and a moveable contact M on the wire.
(i) Explain why, for constant current in the wire, the potential difference between any two points on the wire is proportional to the distance between the points.[2]
(ii) The contact M is moved along PQ until the voltmeter shows zero reading.
1. State the potential difference between the contact at M and the point Q.
2. Calculate the length of wire between M and Q. [2]
(iii) The thermistor is warmed slightly. State and explain the effect on the length of wire between M and Q for the voltmeter to remain at zero deflection.[2]

15-May 06
7 A circuit contains three similar lamps A, B and C. The circuit also contains three switches, S1, S2 and S3, as shown in Fig. 7.1.

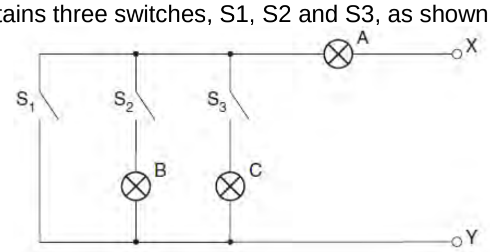


Fig. 7.1

One of the lamps is faulty. In order to detect the fault, an ohm-meter (a meter that measures resistance) is connected between terminals X and Y. When measuring resistance, the ohmmeter causes negligible current in the circuit.
Fig. 7.2 shows the readings of the ohm-meter for different switch positions.

switch S_1	switch S_2	switch S_3	meter reading / Ω
open	open	open	∞
closed	open	open	15 Ω
open	closed	open	30 Ω
open	closed	closed	15 Ω

Fig. 7.2

(a) Identify the faulty lamp, and the nature of the fault.
faulty lamp: ………… nature of fault: …………………… [2]
(b) Suggest why it is advisable to test the circuit using an ohm-meter that causes negligible current rather than with a power supply. [1]
(c) Determine the resistance of one of the non-faulty lamps, as measured using the ohmmeter. [1]
(d) Each lamp is marked 6.0 V, 0.20 A. Calculate, for one of the lamps operating at normal brightness,
(i) its resistance,[2] **(ii)** its power dissipation. [2]
(e) Comment on your answers to **(c)** and **(d)(i)**. [2]

16-Nov 06
6 A straight wire of unstretched length L has an electrical resistance R. When it is stretched by a force F, the wire extends by an amount ΔL and the resistance increases by ΔR. The area of cross-section A of the wire may be assumed to remain constant.
(a) (i) State the relation between R, L, A and the resistivity ρ of the material of the wire. [1]
(ii) Show that the fractional change in resistance is equal to the strain in the wire. [2]
(b) A steel wire has area of cross-section 1.20×10^{-7}m^2 and a resistance of 4.17Ω.
The Young modulus of steel is 2.10×10^{11}Pa. The tension in the wire is increased from zero to 72.0 N. The wire obeys Hooke's law at these values of tension
Determine the strain in the wire and hence its change in resistance. Express your answer to an appropriate number of significant figures. change = ……………………… Ω [5]

17-Nov 06
7 (a) Distinguish between the electromotive force (e.m.f.) of a cell and the potential difference (p.d.) across a resistor [3]
(b) Fig. 7.1. is an electrical circuit containing two cells of e.m.f. E_1 and E_2.

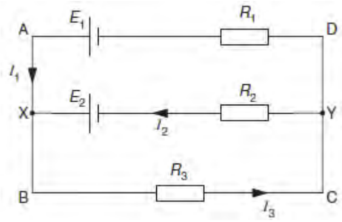


Fig. 7.1

The cells are connected to resistors of resistance R1, R2 and R3 and the currents in the branches of the circuit are I_1, I_2 and I_3, as shown.
(i) Use Kirchhoff's first law to write down an expression relating I_1, I_2 and I_3. [1]
(ii) Use Kirchhoff's second law to write down an expression relating
1. E_2, R_2, R_3, I_2 and I_3 in the loop XBCYX, [1]
2. E_1, E_2, R_1, R_2, I_1 and I_2 in the loop AXYDA. [1]

18-May 07
2 (a) Define electric field strength. [1]
(b) Two flat parallel metal plates, each of length 12.0 cm, are separated by a distance of 1.5 cm, as shown in Fig. 2.1.

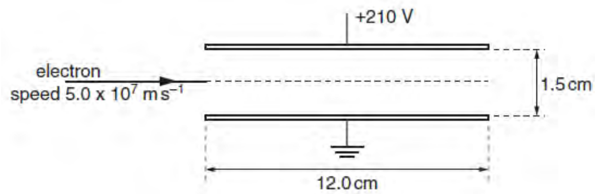


Fig. 2.1

The space between the plates is a vacuum.
The potential difference between the plates is 210 V. The electric field may be assumed to be uniform in the region between the plates and zero outside this region.
Calculate the magnitude of the electric field strength between the plates. field strength = ...N C^{-1} [1]

(c) An electron initially travels parallel to the plates along a line mid-way between the plates, as shown in Fig. 2.1. The speed of the electron is 5.0×10^7 m s^{-1}.
For the electron between the plates,
(i) determine the magnitude and direction of its acceleration, [4]
(ii) calculate the time for the electron to travel a horizontal distance equal to the length of the plates. [1]
(d) Use your answers in **(c)** to determine whether the electron will hit one of the plates or emerge from between the plates. [3]

19-May 07
6 A car battery has an internal resistance of 0.060 Ω. It is re-charged using a battery charger having an e.m.f. of 14 V and an internal resistance of 0.10 Ω, as shown in Fig. 6.1.

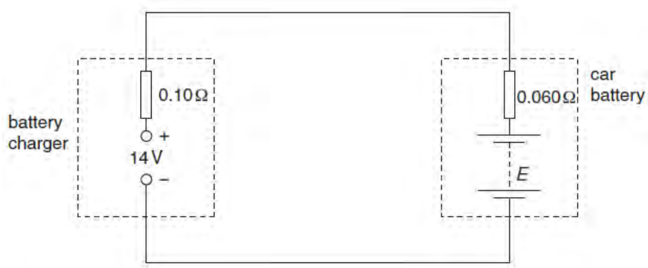


Fig. 6.1

(a) At the beginning of the re-charging process, the current in the circuit is 42 A and the e.m.f. of the battery is E (measured in volts). **(i)** For the circuit of Fig. 6.1, state
1. the magnitude of the total resistance,
2. the total e.m.f. in the circuit. Give your answer in terms of E. [2]
(ii) Use your answers to **(i)** and data from the question to determine the e.m.f. of the car battery at the beginning of the re-charging process. e.m.f. = ...V [2]

(b) For the majority of the charging time of the car battery, the e.m.f. of the car battery is 12 V and the charging current is 12.5 A. The battery is charged at this current for 4.0 hours.
Calculate, for this charging time,
(i) the charge that passes through the battery, [2]
(ii) the energy supplied from the battery charger, [2]
(iii) the total energy dissipated in the internal resistance of the battery charger and the car battery. [2]
(c) Use your answers in **(b)** to calculate the percentage efficiency of transfer of energy from the battery charger to stored energy in the car battery. efficiency = ...% [2]

20-Nov 07
6 An electric shower unit is to be fitted in a house. The shower is rated as 10.5 kW, 230 V. The shower unit is connected to the 230 V mains supply by a cable of length 16 m, as shown in

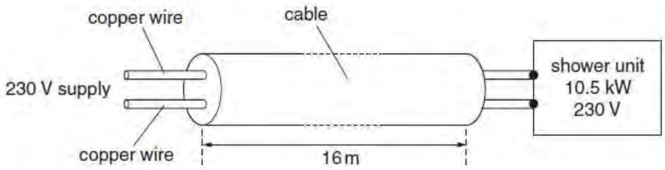


Fig. 6.1
(a) Show that, for normal operation of the shower unit, the current is approximately 46 A. [2]
(b) The resistance of the two wires in the cable causes the potential difference across the shower unit to be reduced. The potential difference across the shower unit must not be less than 225 V.
The wire in the cable are made of copper of resistivity 1.8×10^{-8} Ωm.
Assuming that the current in the wires is 46 A, calculate
(i) the maximum resistance of the cable, [3]
(ii) the minimum area of cross-section of each wire in the cable. [3]
(c) Connecting the shower unit to the mains supply by means of a cable having wires with too small a cross-sectional area would significantly reduce the power output of the shower unit.
(i) Assuming that the shower is operating at 210 V, rather than 230 V, and that its resistance is unchanged, determine the ratio

power dissipated by shower unit at 210 V
power dissipated by shower unit at 230 V [2]
(ii) Suggest and explain one further disadvantage of using wires of small cross-sectional area in the cable. [2]

21-May 08
6 An electric heater consists of three similar heating elements A, B and C, connected as shown in Fig. 6.1.

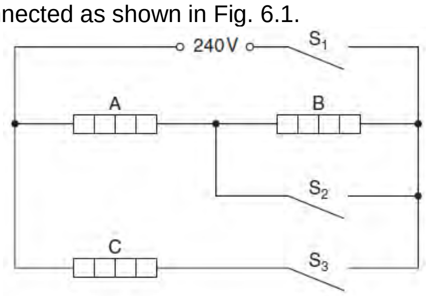


Fig. 6.1
Each heating element is rated as 1.5 kW, 240 V and may be assumed to have constant resistance.
The circuit is connected to a 240 V supply.
(a) Calculate the resistance of one heating element. [2]

(b) The switches S_1, S_2 and S_3 may be either open or closed. Complete Fig. 6.2 to show the total power dissipation of the heater for the switches in the positions indicated.

S_1	S_2	S_3	total power / kW
open	closed	closed	....
closed	closed	open	....
closed	closed	closed	....
closed	open	open	....
closed	open	closed	....

22-Nov 08
4 Two parallel plates P and Q are separated by a distance of 7.6 mm in a vacuum. There is a potential difference of 250 V between the plates, as illustrated in Fig. 4.1

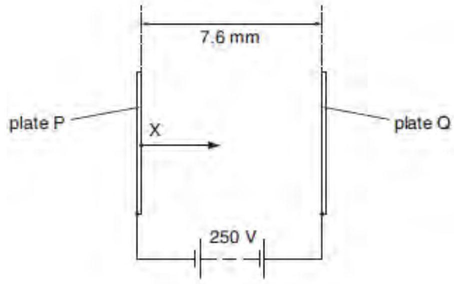


Fig. 4.1
Electrons are produced at X on plate P. These electrons accelerate from rest and travel to plate Q.
The electric field between the plates may be assumed to be uniform.
(a) (i) Determine the force on an electron due to the electric field [3]
(ii) Show that the change in kinetic energy of an electron as it moves from plate P to plate Q is 4.0×10^{-17} J. [2]
(iii) Determine the speed of an electron as it reaches plate Q. [2]
(b) The positions of the plates are adjusted so that the electric field between them is not uniform. The potential difference remains unchanged. State and explain the effect, if any, of this adjustment on the speed of an electron as it reaches plate Q. [3]

23-Nov 08
7 A potential divider circuit consists of two resistors of resistances P and Q, as shown in Fig. 7.1.

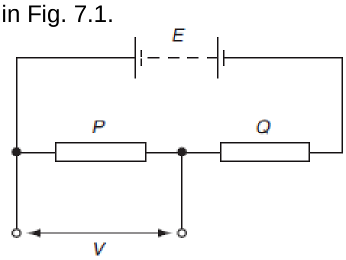


Fig. 7.1
The battery has e.m.f. E and negligible internal resistance.
(a) Deduce that the potential difference V across the resistor of resistance P is given by the expression

$$V = \frac{P}{P+Q} E.$$

(b) The resistances P and Q are 2000 Ω and 5000 Ω respectively. A voltmeter is connected in parallel with the 2000 Ω resistor and a thermistor is connected in parallel with the 5000 Ω resistor, as shown in Fig. 7.2.

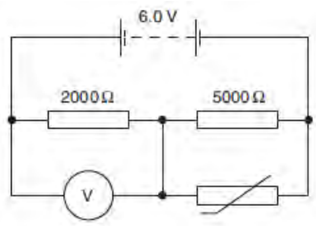


Fig. 7.2
The battery has e.m.f. 6.0 V. The voltmeter has infinite resistance.
(i) State and explain qualitatively the change in the reading of the voltmeter as the temperature of the thermistor is raised. [3]

(ii) The voltmeter reads 3.6 V when the temperature of the thermistor is 19 °C. Calculate the resistance of the thermistor at 19 °C. resistance = ……………………… Ω [4]

24-May 09

6 Two vertical parallel metal plates are situated 2.50 cm apart in a vacuum. The potential difference between the plates is 350 V, as shown in Fig. 6.1.

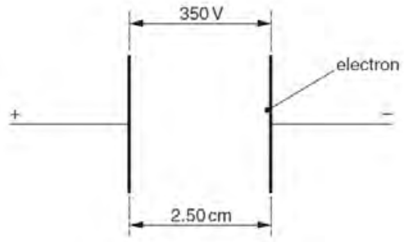


Fig. 6.1

An electron is initially at rest close to the negative plate and in the uniform electric field between the plates.

(a) (i) Calculate the magnitude of the electric field between the plates. electric field strength = ... N C^{-1} [2]

(ii) Show that the force on the electron due to the electric field is 2.24×10^{-15} N. [2]

(b) The electron accelerates horizontally across the space between the plates. Determine

(i) the horizontal acceleration of the electron,[2]

(ii) the time to travel the horizontal distance of 2.50 cm between the plates.[2]

(c) Explain why gravitational effects on the electron need not be taken into consideration in your calculation in **(b)**. [2]

25-May 09

7 A network of resistors each of resistance R, is shown in Fig 7.1.

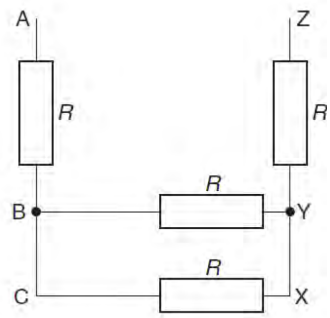


Fig. 7.1

(a) Calculate the total resistance, in terms of R, between points

(i) A and C,

resistance = ... [1]

(ii) B and X,

resistance = ... [1]

(iii) A and Z.

resistance = ... [1]

(b) Two cells of e.m.f. E_1 and E_2 and negligible internal resistance are connected into the network in **(a)**, as shown in Fig. 7.2.

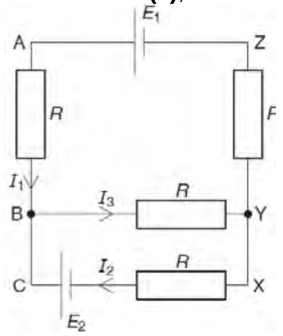


Fig. 7.2

The currents in the network are as indicated in Fig. 7.2.

Use Kirchhoff's laws to state the relation

(i) between currents I_1, I_2 and I_3, [1]

(ii) between E_2, R, I_2 and I_3 in loop BCXYB, [1]

(iii) between E_1, E_2, R, I_1 and I_2 in loop ABCXYZA. [1]