TOPIC 17 Current Electricity

1 Which statement describes the electric potential difference between two points in a wire that carries a current?

A the force required to move a unit positive charge between the points

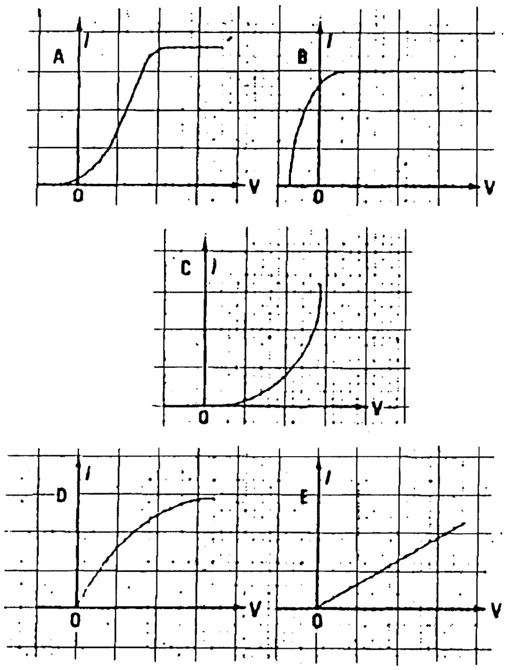
B the ratio of the energy dissipated between the points to the current

C the ratio of the power dissipated between the points to the current

D the ratio of the power dissipated between the points to the charge moved

J76/II/17; N84/II/17; J97/I/13; J2000/I/16

2 Which one of the following graphs best represents the relation between current I and applied p.d. V for the forward characteristic of a germanium diode?



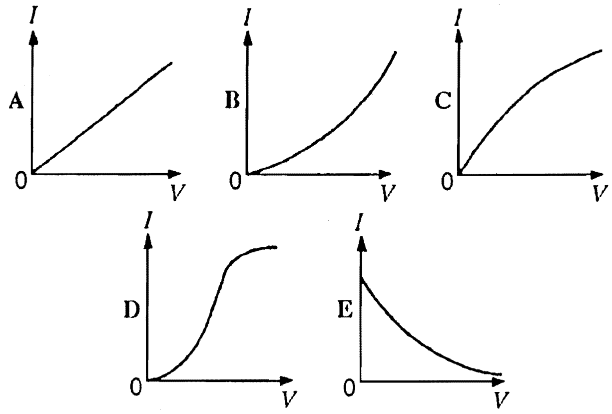
J76/II/24

3 A resistor of resistance 1.0 kΩ has a thermal capacity of 5.0 J K^{-1}. A p.d. of 4.0 V is applied across it for 120 s. If the resistor is thermally insulated, the final rise in temperature is

A 8.0×10^{-4} K
B 3.2×10^{-3} K
C 9.6×10^{-2} K
D 0.38 K
E 9.6 K

J77/II/18

4 The resistance of tungsten increases with increasing temperature. As a result, the relation between the current, I, flowing in the tungsten filament of an electric lamp and the potential difference, V, between its ends is of the form



N77/II/17

5 A surge of current flows through a filament lamp when it is first switched on. The reason for the surge is that

A when the lamp is switched on, the filament is cold and its resistance is much less than at its working temperature.

B the mains voltage may be at its peak value when the lamp is switched on and the current will then be greater than its r.m.s value.

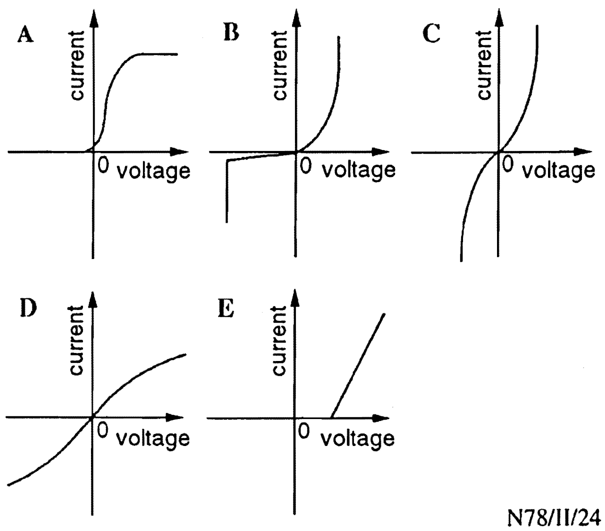
C mains switches are spring-loaded and make sudden contact, not allowing time for the current to increase gradually.

D the parallel conductors in the mains cable act as a capacitor and this capacitor discharges itself through the filament.

E the filament is a coil and this acts as an inductance which produces a large e.m.f.

J78/II/19

6 Which of the following graphs best represents the current-voltage characteristics of a semiconductor diode?

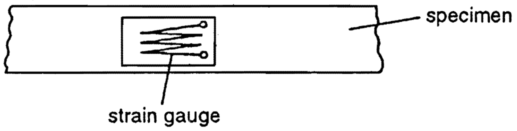


N78/II/24

7 A high potential is applied between the electrodes of a hydrogen discharge tube so that the gas is ionised. Electrons then move towards the positive electrode and protons towards the negative electrode. In each second, 5×10^{18} electrons (each of charge -1.6×10^{-19} C) and 2×10^{18} protons pass a cross-section of the tube. The current flowing in the discharge tube is

A 0.16 A
B 0.48 A
C 0.80 A
D 1.12 A
E 1.44 A J80/II/23

8 Tensile strain may be measured by the change in electrical resistance of a *strain gauge*. A strain gauge consists of folded fine metal wire mounted on a flexible insulating backing sheet, firmly attached to the specimen, so that the strain in the metal wire is always identical to that in the specimen.



When the strain in the specimen is increased, the resistance of the wire

A decreases, because the length increases and the cross-sectional area decreases.

B decreases, because the length decreases and the cross-sectional area increases.

C increases or decreases depending upon the relative magnitude of the changes in length and cross-sectional area.

D increases, because the length decreases and the cross-sectional area increases.

E increases, because the length increases and the cross-sectional area decreases. N80/II/19; J91/I/13

9 A generator produces 100 kW of power at a potential difference of 10 kV. The power is transmitted through cables of total resistance 5 Ω.

How much power is dissipated in the cables?

A 50 W
B 250 W
C 500 W
D 50 000 W J81/II/17; J87/I/20; J93/I/14; J96/I/13

10 A sample of resistive material is prepared in the form of a thin square slab of side x.

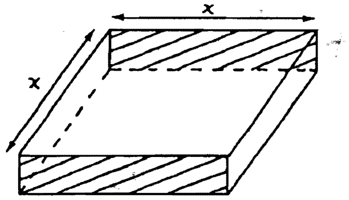


Fig. 1

For a given thickness, the resistance between opposite edge faces of the sample (shown shaded in Fig. 1) is

A proportional to x^2.
B proportional to x.
C independent of x.
D inversely proportional to x.
E inversely proportional to x^2. N81/II/21

11 A battery is connected in series with a 2 Ω resistor and a switch as shown in Fig. 2 below. A voltmeter connected across the battery reads 12 V when the switch is open but 8 V when it is closed.

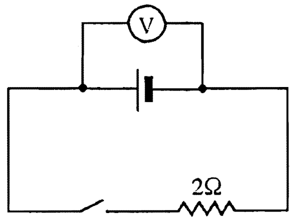


Fig. 2

What is the internal resistance of the battery?

A $^2/_3$ Ω
B 1 Ω
C $^4/_3$ Ω
D 4 Ω
E 6 Ω J82/II/17

12 In the circuit shown in Fig. 3 below, the resistance of the tungsten filament lamp L increases with temperature. The current can be varied by means of the rheostat.

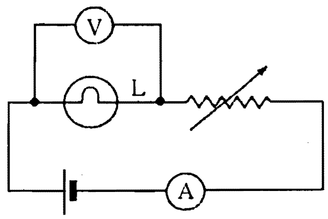
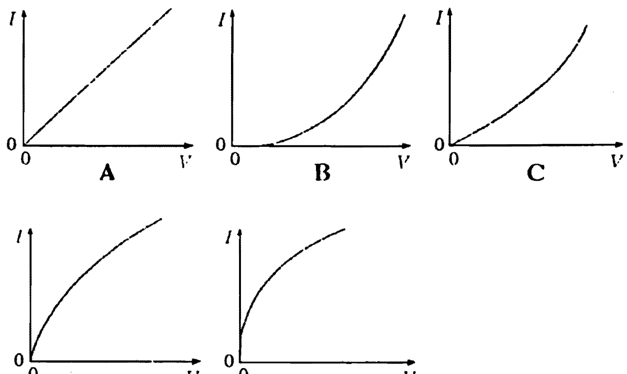


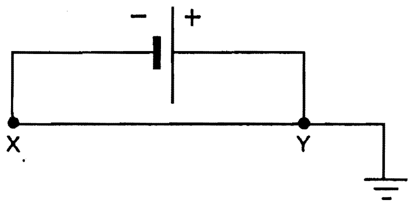
Fig. 3

Which one of the following graphs best shows how the ammeter reading I varies with the voltmeter reading V?

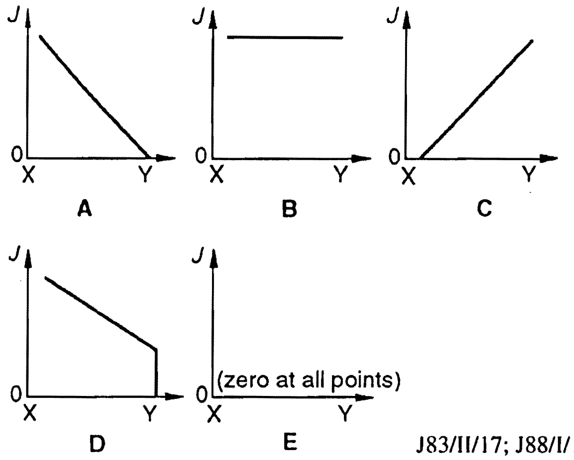


N82/II/17

13 A battery is connected to a uniform resistance wire XY, and the end Y of the wire is earthed as shown in the circuit diagram below.



Which one of the following graphs shows how the current density J varies along XY?



J83/II/17; J88/I/13

14 What is the conductance of a wire of length l and uniform cross-sectional area A made of material of resistivity ρ?

A $\frac{A}{\rho l}$ **B** $\frac{\rho}{l}$ **C** $\frac{\rho A}{l}$ **D** $\frac{1}{\rho}$ **E** $\frac{\rho l}{A}$

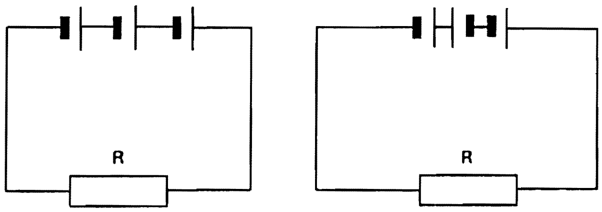
J83/II/18; N84/II/18

15 A circular plastic disc of diameter d has n metal studs uniformly spaced around its circumference. Each stud carries a charge q. The disc is made to rotate about its axis at p revolutions per second. What is the equivalent current of the rotating charges?

A nq/p
B nq
C npq
D $npq/\pi d$
E $\pi dnpq$

J85/I/14

16 Three identical cells each having an e.m.f. of 1.5 V and a constant internal resistance of 2.0 Ω are connected in series with a 4.0 Ω resistor R, firstly as in circuit (i), and secondly as in circuit (ii).



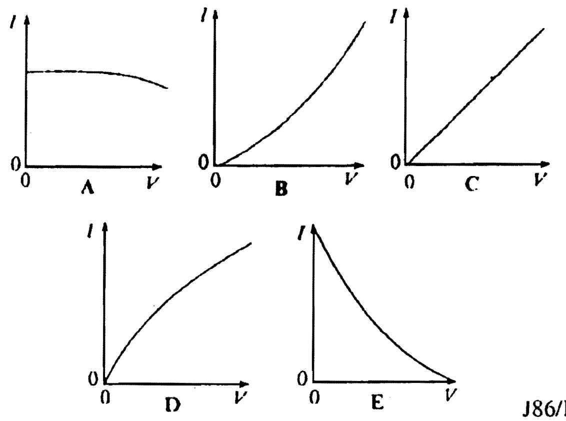
Circuit (i) Circuit (ii)

What is the ratio $\frac{\text{power in R in circuit (i)}}{\text{power in R in circuit (ii)}}$?

A 9.0
B 7.2
C 5.4
D 3.0
E 1.8

J85/I/17

17 Some early electric light bulbs used carbon filaments, the resistances of which decreased as their temperature increased. Which of the following graphs best represents the way in which I, the current through such a bulb, would depend upon V, the potential difference across it?



J86/I/14

18 The resistance of a certain circuit element is directly proportional to the current passing through it. When the current is 1.0 A the power dissipated in the element is 6.0 W. What is the power dissipated when the current is raised to 2.0 A?

A 3.0 W
B 6.0 W
C 12 W
D 24 W
E 48 W

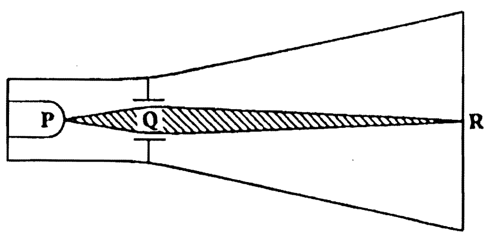
N87/I/13

19 A wire 3.00 m long, of uniform cross-sectional area 2.00 mm², has a conductance of 1.25 S. What is the resistivity of the material of the wire? [1 S = 1Ω^{-1}]

A 5.3×10^{-7} S
B 8.3×10^{-7} S
C 0.80 S
D 2.4 S
E 1.9×10^{6} S

N87/I/14

20 In the diagram of an oscilloscope below, the shaded area represents a section through the electron beam which is generated near **P**, deflected and accelerated at Q, and focused at **R**. The tube contains no gas.



How does the electric current of the beam vary along **PQR**?

A It has the same value at **P**, **Q** and **R**.

B It decreases from **P** to **Q** but becomes very large at the point **R**.

C It decreases from **P** to **Q**, then increases to reach the same value at **R** as at **P**.

D It increases between **P** and **Q**, then remains constant from **Q** to **R**.

E It increases from **P** to **Q** then decreases to reach the same value at **R** as at **P**. N87/I/6

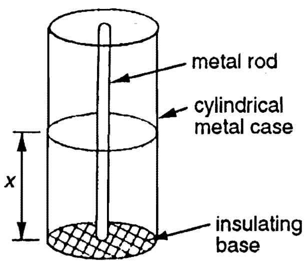
21 A cylindrical metal wire, of length l and cross-sectional area S, has resistance R, conductance G, resistivity ρ and conductivity σ. Which one of the following expressions for σ is valid?

A $\frac{GR}{\rho}$ D $\frac{\rho l G}{SR}$

B $\frac{Rl}{S}$ E $\frac{GS}{l}$

C $\frac{\rho R}{G}$ J88/I/15

22 A conducting liquid fills a cylindrical metal case to a depth x as shown in the diagram.



The resistance between the case and the metal rod is

A proportional to x^2.

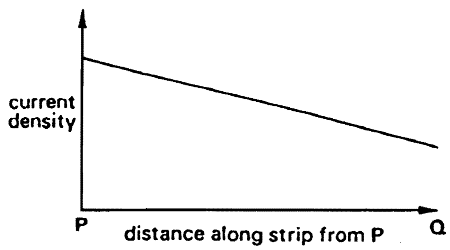
B proportional to x.

C independent of x.

D inversely proportional to x.

E inversely proportional to x^2. N88/I/13

23 An electric current flows along an insulated strip **PQ** of metallic conductor. The current density in the strip varies as shown in the graph.



Which one of the following statements could explain this variation?

A The strip is narrower at **P** than at **Q**.

B The strip is narrower at **Q** than at **P**.

C The potential gradient along the strip in uniform.

D The current at **P** is greater than the current at **Q**.

E The resistance per unit length of the strip is constant. N88/I/14

***24** In an electrostatic machine, a belt of width w, having surface charge density σ, travels with velocity v. As the belt passes a certain point, all the charge is removed and is carried away as an electric current. What is the magnitude of this current?

A $wv\sigma$ D $wv^2\sigma$

B $\frac{w\sigma}{v}$ E $\frac{1}{2}wv^2\sigma$

C $\frac{v\sigma}{w}$ J89/I/13

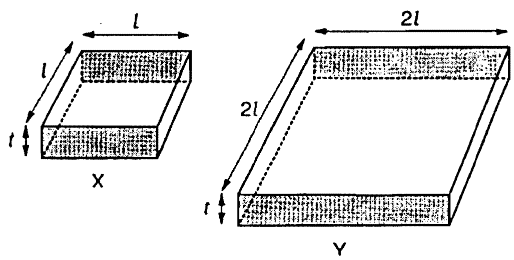
25 An electrical source with internal resistance r is used to operate a lamp of resistance R. What fraction of the total power is delivered to the lamp?

A $\frac{R+r}{R}$ D $\frac{R}{r}$

B $\frac{R-r}{R}$ E $\frac{r}{R}$

C $\frac{R}{R+r}$ J89/I/14

26 Two squares, X and Y are cut from the same sheet of metal of thickness t. The lengths of the sides of X and Y are l and $2l$ respectively.



What is the ratio $\frac{R_X}{R_Y}$ of the resistances between the opposite shaded faces of X and of Y?

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

N89/I/10; J2000/I/14

27 A thermocouple is connected across a galvanometer of resistance 30 Ω. One junction is immersed in water at 373 K and the other in ice at 273 K. The e.m.f. of the thermocouple is 90 μV for each 1 K difference in temperature between the junctions, and the thermocouple resistance is 6 Ω.

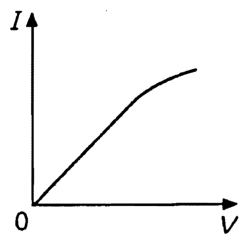
What current will flow in the galvanometer?

A 1.8 μA D 1.5 mA

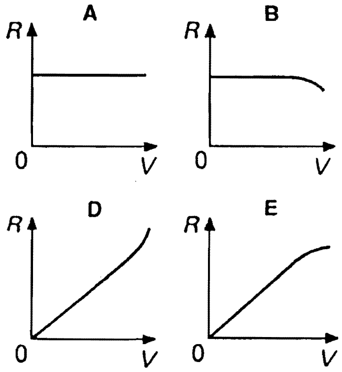
B 250 μA E 1.8 mA

C 300 μA N89/I/13; J92/I/16

28 The current I flowing through a component varies with the potential difference V across it as shown.

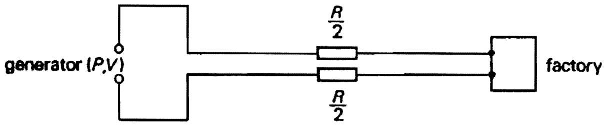


Which graph best represents how the resistance R varies with V?



N91/I/16

29 A generator, with output power P and output voltage V, is connected to a factory by cables of total resistance R.



What is the power input to the factory?

A P

B $P - \left(\frac{P}{V}\right)\frac{R}{2}$

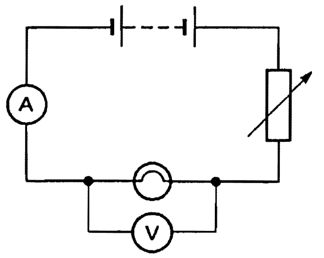
C $P - \left(\frac{P}{V}\right) R$

D $P - \left(\frac{P}{V}\right)^2 \frac{R}{2}$

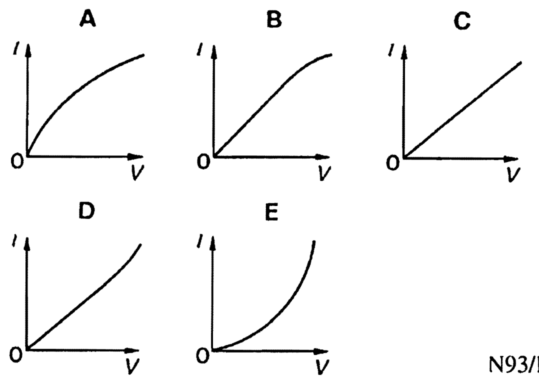
E $P - \left(\frac{P}{V}\right)^2 R$

N92/I/14

30 The diagram shows a metal filament lamp connected in series with an ammeter, battery and a variable resistor. A high resistance voltmeter is connected across the lamp.



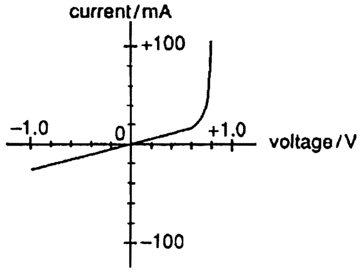
Which graph represents the variation of I, the current through the lamp, with the potential difference V across it?



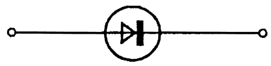
N93/I/12

31 A student is given a sealed box containing a concealed electrical circuit.

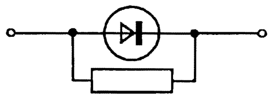
Having taken a series of current and voltage readings, the student plots the current-voltage characteristic below.

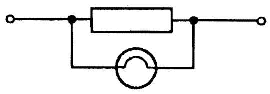


Which circuit is most likely to be enclosed within the box?

A 

B 

C 

D 

N94/I/15

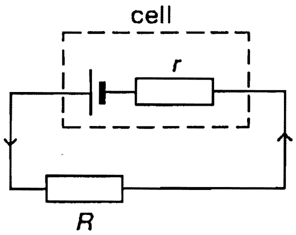
32 Two wires **P** and **Q**, each of the same length and the same material, are connected in parallel to a battery. The diameter of **P** is half that of **Q**.

What fraction of the total current passes through **P**?

A	0.20	**C**	0.33
B	0.25	**D**	0.50

N94/I/16

33 A cell of internal resistance r is connected to a load of resistance R.



Energy is dissipated in the load, but some thermal energy is also wasted in the cell. The efficiency of such an arrangement is found from the expression

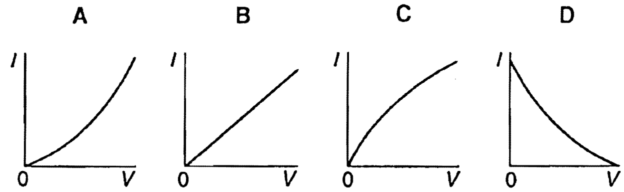
$$\frac{\text{energy dissipated in the load}}{\text{energy dissipated in the complete circuit}}.$$

Which of the following gives the efficiency in this case?

A $\frac{r}{R}$ **B** $\frac{R}{r}$ **C** $\frac{r}{R+r}$ **D** $\frac{R}{R+r}$

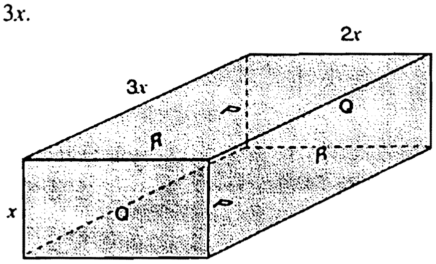
J95/I/14

34 Which graph best represents the way in which the current I through a thermistor depends upon the potential difference V across it?



N95/I/14

35 The diagram shows a rectangular block with dimensions x, $2x$ and $3x$.



Electrical contact can be made to the block between opposite pairs of faces (for example, between the faces labelled **P**).

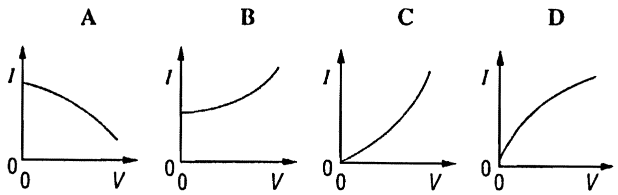
Between which two faces would the maximum electrical resistance be obtained?

A the faces labelled **P**
B the faces labelled **Q**
C the faces labelled **R**
D the resistance is the same, whichever pair of faces is used

J96/I/14

36 The resistance of a thermistor decreases significantly as its temperature increases.

Which graph best represents the way in which the current I in the thermistor depends upon the potential difference V across it?



J97/I/14; N2000/I/13

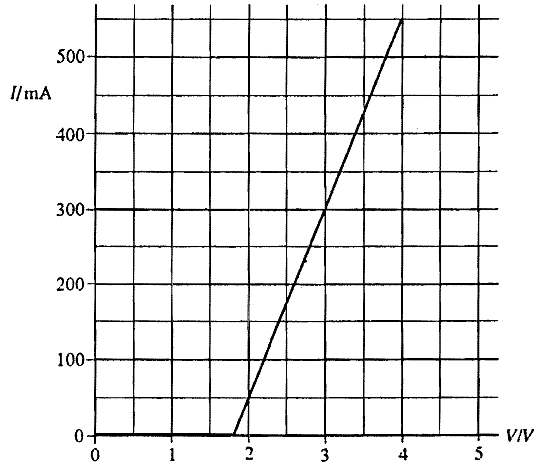
37 Protons in a parallel beam each move at a uniform velocity v, thus forming a current I. The charge on each proton is e.

Which expression represents the number of protons present in unit length of the beam? (You may wish to consider the units of the quantities involved.)

A $\frac{I}{e}$ **B** $\frac{I}{ev}$ **C** $\frac{Iv}{e}$ **D** $\frac{I}{v}$

N97/I/14

38 The diagram shows the relation between the direct current I in a certain conductor and the potential difference V across it. When $V < 1.8$ V, the current is negligible.

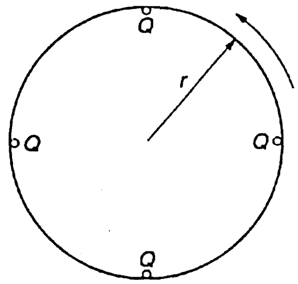


Which statement about the conductor is correct?

A It does not obey Ohm's law but when $V > 1.8$ V its resistance is 4 Ω.
B It does not obey Ohm's law but when $V = 3$ V its resistance is 10 Ω.
C It obeys Ohm's law when $V > 1.8$ V and when $V = 3$ V its resistance is 10 Ω.
D It obeys Ohm's law when $V > 1.8$ V but its resistance is not constant.

J98/I/14

39 Four small conductors, on the edge of an insulating disc of radius r, are each given a charge of Q. The frequency of rotation of the disc is f.

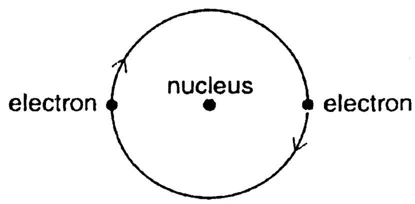


What is the equivalent electric current at the edge of the disc?

A $4Qf$ **B** $\frac{4Q}{f}$ **C** $8\pi rQf$ **D** $\frac{2Qf}{\pi r}$

N98/I/14

40 The diagram shows a model of an atom in which two electrons move round a nucleus in a circular orbit. The electrons complete one full orbit in 1.0×10^{-15} s.



What is the current caused by the motion of the electrons in the orbit?

A 1.6×10^{-34} A
B 3.2×10^{-34} A
C 1.6×10^{-4} A
D 3.2×10^{-4} A

J99/I/15

41 A cell of e.m.f. E delivers a charge Q to an external circuit Which statement is correct?

A The energy dissipation in the external circuit is EQ

B The energy dissipation within the cell is EQ.

C The external resistance is EQ.

D The total energy dissipation in the cell and the external circuit is EQ. N99/I/13

42 A thin film resistor in a solid-state circuit has a thickness 1 μm and is made of nichrome of resistivity 10^{-6} Ωm. Calculate the resistances available between opposite edges of a 1 mm^2 area of film

(a) if it is square shaped.

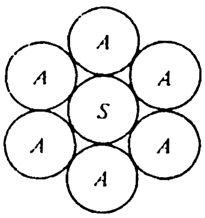
(b) if it is rectangular, 20 times as long as it is wide.

J76/I/5

43 A generator supplies a fixed power to an electrical installation by power lines of finite resistance. Show that the power lost as heat in the cables is proportional to $1/V^2$, where V is the potential difference at the generator output.

This result suggests that losses can be reduced indefinitely by a suitable choice of generator p.d. Discuss briefly whether this is practicable. N81/I/7

***44**



A = aluminium

S = steel

Fig. 4

An electricity supply cable consists of a steel core of area of cross-section 50 mm^2 with six other conductors of aluminium of the same cross-sectional area arranged around it (Fig. 4). Find the resistance of a 120 m length of the cable.

[Resistivities: steel, 9.0×10^{-8} Ωm, aluminium, 2.5×10^{-8} Ωm.]

J82/I/6

45 Using an electric drill, it takes 150 s to make a hole in a piece of brass of mass 0.45 kg. During this process, the average power delivered to the drill from the electricity mains is 300 W. How much electrical energy is used in drilling the hole?

If 70% of the energy supplied to the drill appears as heat in the brass, what is the initial rate of rise of temperature of the metal?

(Specific heat capacity of brass = 390 J kg^{-1} K^{-1}.) J84/I/11

46 A cell has e.m.f. 1.5 V and internal resistance 0.5 Ω. Calculate the power delivered when the cell is connected to an external 2.5 Ω resistor. What is the value of the external resistance if the power delivered is to have a maximum value? [6]

J88/III/4

47 *(a)* Define *power*.

(b) Why is it that, in the SI system of units, power **cannot** be defined using the equation

power = potential difference × current? [2]

N88/II/1

48 A potential difference V drives a current I through

(i) the filament of a torch bulb,

(ii) a piece of intrinsic semiconductor.

Sketch graphs, one for each case, to show how I depends on V as V is increased from zero to a value which causes significant heating.

Why do the graphs differ in shape? [6]

N89/III/5

49 An electric kettle is rated at 2.0 kW when operating on a 240 V supply. What power will the kettle absorb if the supply is reduced to 220 V? [3]

N89/III/7

50 *(a)* A filament lamp is marked 240 V 60 W. Calculate

(i) the current through the lamp when it is working normally, [1]

(ii) the resistance of the lamp when it is working normally. [1]

(iii) The resistance of the lamp is found to be less when it is not lit than when it is working normally. Sketch the current-voltage characteristic of the filament lamp on the axes in Fig. 5.

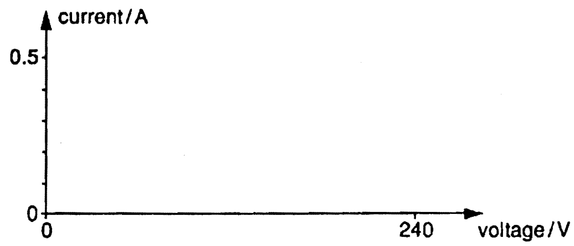


Fig. 5 J94/II/3 (part)

51 *(a)* State the equation linking charge Q, current I and time t. [1]

(b) Calculate the charge which passes each point in a circuit in a time of 60 s when there is a current of 0.76 mA. [2]

N95/II/4 (part)

52 An electric light bulb is marked 120 V, 40 W.

(a) Calculate the current in this bulb when operating on a 120 V supply.

current = ... A [2] *(b)* Describe **three** different ways in which energy can be transferred from the filament when it is operating normally. [6]

(c) If the light bulb is now connected to a 240 V supply it will work for perhaps an hour as a 160 W bulb before its filament breaks.

(i) How will the relative importance of the answers you have given to *(b)* change when the bulb is run on this increased voltage?

(ii) Suggest a reason why the bulb can operate for so long a time before its filament breaks. [3]

N97/II/5

53 *(a)* Describe, in terms of a simple electron model, the difference between an electrical conductor and an electrical insulator. [2]

(b) State

(i) two metals which are conductors,

(ii) one non-metal which is a conductor,

(iii) one solid which is an insulator. [3]

(c) Air is normally an insulator. However, it can be made to conduct under certain conditions.

(i) Suggest one condition that could cause air to conduct electricity.

(ii) Suggest one hazard which might be associated with the conduction of electricity in air. [2]

(d) In a cathode-ray tube, there is a current of 150 μA in the vacuum between the cathode and the anode. Calculate

(i) the time taken for a charge of 3.0 C to be transferred,

time taken = ... s

(ii) the number of electrons emitted per second from the cathode.

number per second =.............................. s^{-1} [4]

J98/II/4

Long Questions

54 Distinguish between the terms *potential difference* and *electromotive force*. Define the units in which they are usually measured. [4]

Give three examples of systems in which current is not directly proportional to applied potential difference. Give sketch graphs showing the form of each *I–V* relationship and give some explanation of the form of each graph. [6]

The current *I* through a certain device is related to the p.d. *V* across it by the equation

$$I = a\,(e^{bV} - 1)$$

where $a = 10^{-4}$ A and $b = 40\ V^{-1}$. When the device is connected to a battery of e.m.f. 1.5 V, a current of 0.1 A flows. Calculate the internal resistance of the battery. [lg e ≈ 0.43.] [8]

N77/III/3

55 What do you understand by

(a) resistance,

(b) resistivity,

(c) conductivity. N81/III/5 (part)

56 *(a)* (i) Define the *coulomb*, the *joule* and the *watt*.

(ii) Show that defining the volt as a joule per coulomb is equivalent to defining it as a watt per ampere. [5]

N89/III/10 (part); N82/III/3 (part)

57 Define the *volt*, and distinguish between *electromotive force* and *potential difference*. N82/III/3 (part)

58 Deduce from first principles an express for the rate at which heat is generated in a circuit of resistance *R* in which a current *I* passes. State clearly the basic definitions you employ.

A voltmeter is connected across a variable resistance *R*, which itself is in series with an ammeter and a battery. For one value of *R*, the readings are 1.00 V and 0.25 A. For another value of *R*, they are 0.90 V and 0.30 A. Calculate the e.m.f. of the battery, its internal resistance, and the two values of *R*.

State any assumptions you make concerning the meters.

The value of *R* is now adjusted so that it equals the internal resistance of the battery. Calculate the rate at which heat is generated.

(a) in the battery,

(b) in the whole system. N84/III/3

59 What do you understand by the terms *potential difference* and *electromotive force*?

Describe how the internal resistance of a cell may be determined. Give the theory of your method.

The various electrical circuits in operation in a car may be considered to have a combined resistance *R*. They are supplied by a battery of e.m.f. *E* and internal resistance *r*.

(a) If the efficiency η of the circuits may be defined as the ratio of the power delivered to the circuits to the total power dissipated, show that

$$\eta = R\,/\,(R + r).$$

(b) Sketch labelled graphs on the same axis for *R* to show how η and the power output vary with *R*. Mark the axis with the value of *r*.

(c) Hence, or otherwise, determine η when there is maximum power output from the battery.

If the starter motor of a car is operated when the head-lights are switched on, they are seen to dim. Explain this observation. N85/III/11

60 Define resistance and resistivity.

(a) Calculate the resistance of a nichrome wire of length 500 mm and diameter 1.0 mm given that the resistivity of nichrome is $1.1 \times 10^{-6}\ \Omega$ m.

(i) Describe how you would use a potentiometer to make an accurate determination of the resistance of this wire.

(ii) Explain why problems might arise in trying to determine the resistance of this wire by measuring the current through it and the potential difference across it using moving-coil meters.

(b) State and explain one additional precaution which would be needed to obtain an accurate value for the resistance of a wire of the same dimensions as above, but made of copper.

(Resistivity of copper = $1.7 \times 10^{-8}\ \Omega$ m) N86/III/11

61 Define *potential difference* and *resistance*. Derive an expression for the rate at which thermal energy is generated in a circuit of resistance R in which the current is I. [4]

Describe how a voltmeter may be calibrated at one particular reading by an electrical heating method. By reference to the theory of your method, explain why voltmeters calibrated in this way cannot be said to have been calibrated in terms of the base units only. [7]

A certain voltmeter has a resistance of 1500 Ω. When connected to a battery, the voltmeter reads 2.90 V. When a resistor of resistance 1000 Ω is then connected in parallel with the voltmeter, the reading drops to 2.76 V. Explain why the reading changes and calculate all you can about the battery. [6] N87/III/11

62 *(a)* (i) Define *resistance.*

(ii) Write down an equation which relates *resistance* and *resistivity.* Identify all the symbols in the equation. [3]

(b) Calculate the resistance per metre of a copper wire of diameter 0.050 mm and resistivity $1.7 \times 10^{-8}\ \Omega$ m. [2]

J90/III/2 (part)

63 *(a)* (i) Distinguish between the electromotive force of a cell and the potential difference between its terminals.

(ii) A cell of e.m.f. E and internal resistance r is connected to a resistor of resistance R as shown in Fig. 6.

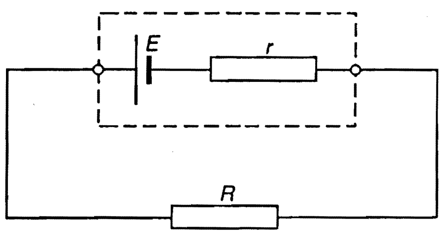


Fig. 6

Show that V, the terminal potential difference of the cell, is given by

$$V = \frac{ER}{R + r}$$ [6]

N91/III/4 (part)

64 *(a)* (i) Define *electric potential difference* and state the SI unit in which it is measured.

(ii) Use your definition in (i) to show that P, the power dissipation in a resistor of resistance R is given by

$$P = \frac{V^2}{R}$$

where V is the potential difference across the resistor. [5]

(b) A battery of e.m.f. E and internal resistance r is connected in series with a resistor of resistance R, as shown in **Fig. 7**.

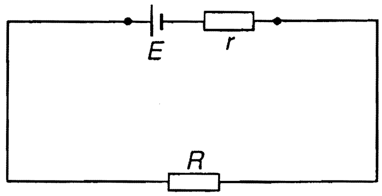


Fig. 7

(i) Give expressions, in terms of E, r and R for

(1) the current I in the circuit,

(2) the power P_R dissipated in the external resistor.

(ii) The battery generates total power P_T. Show that the fraction $\frac{P_R}{P_T}$ is given by

$$\frac{P_R}{P_T} = \frac{R}{R + r}$$ [6]

(c) A car battery of e.m.f. 12 V and internal resistance 0.014 Ω delivers a current of 110 A when first connected to the starter motor.

(i) Calculate

(1) the resistance of the starter motor,

(2) the fraction of the total power which is dissipated in the battery. [5]

(ii) After prolonged use, the internal resistance of the battery may increase. State and explain how the performance of the battery is affected by an increase in the internal resistance. [4]

J93/III/3

65 *(a)* A potential difference of 9.0 V is causing electrons to flow through a steel wire so that 1.0×10^{20} electrons pass a point in the wire in 60 s. Calculate

(i) the charge which passes the point in 60 s,

(ii) the electric current in the wire,

(iii) the resistance of the wire. [6]

(b) Sketch graphs with labelled axes to show how the current through the wire will vary with the p.d. across it if the temperature of the wire

(i) is kept constant,

(ii) increases as the current increases. [4]

(c) A copper wire of area of cross-section 3.8×10^{-9} m^2 has length 0.67 m.

(i) Calculate the resistance of the wire. (Resistivity of copper = 1.7×10^{-8} Ω m.) [3]

(ii) When the copper wire is subjected to a particular stress, a strain of 0.012 is produced in the wire.

(1) State what is meant by *stress* and by *strain*. [2]

(2) Show that the fractional change in the area of cross-section of the wire is –0.012. Assume that the total volume remains unaltered. [2]

(3) Calculate the resistance of the wire when it has this strain of 0.012. [3]

N94/III/3

66 *(a)* Define potential difference. [1]

(b) If the equation $V = IR$ is used to define resistance, why is it not then possible to use the same equation to define potential difference? [2]

(c) One element of an electric cooker has an I – V characteristic as shown in Fig. 8.

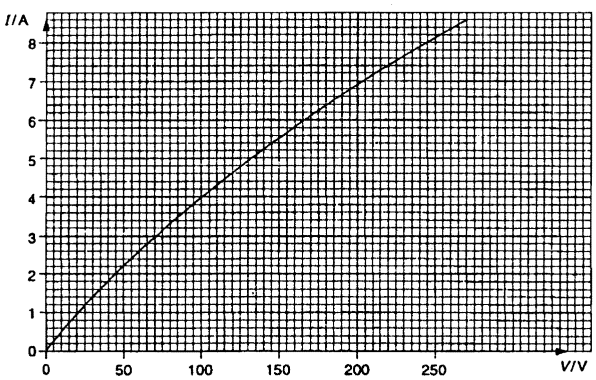


Fig. 8

(i) Explain how the characteristic shows that the resistance of the element increases with potential difference. [3]

(ii) Explain in terms of the movement of charged particles why the resistance increases with potential difference. [3]

(iii) Use the graph to estimate the potential difference which should be applied to the element if it is to have a resistance of 30 Ω. [3]

(iv) What will be the current in the element when it has a resistance of 30 Ω? [1]

(v) What will be the power of the element when it has a resistance of 30 Ω? [1]

(d) Why is it *not* sensible to control the power to a heating element, such as the one for the electric cooker in *(c)*, by the use of either of the circuits in Fig. 9? [4]

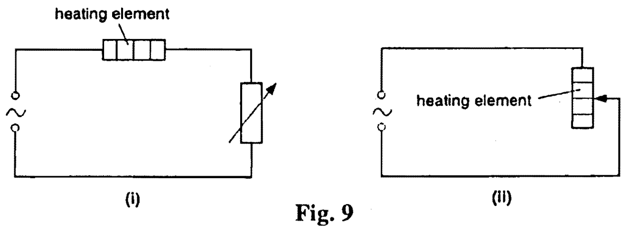


Fig. 9

(e) Suggest a more suitable means of controlling the average power output of the heating element over a period of time. [2] J95/III/4

67 *(a)* Use energy considerations to distinguish between electromotive force (e.m.f.) and potential difference (p.d.). [3]

(b) A cell of e.m.f. E and internal resistance r is connected to a resistor of resistance R, as shown in Fig. 10.

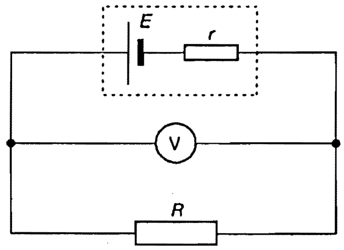


Fig. 10

A voltmeter of infinite resistance is connected in parallel with the resistor.

(i) Copy Fig. 10 and include in the circuit a switch so that the voltmeter may be used to measure either the e.m.f. E of the cell or the terminal potential difference V.

(ii) State whether the switch should be open or closed when measuring

1. the e.m.f,
2. the terminal p.d.

(iii) Derive a relation between E, V, r and the current I in the circuit. [5]

J96/III/4 (part)

68 *(a)* Define *potential difference* and the *volt*. [2]

(b) A battery of e.m.f. 9.00 V and internal resistance 0.50 Ω is connected to a resistor of resistance 8.36 Ω. Determine

(i) the current in the circuit,

(ii) the potential difference across the 8.36 Ω resistor,

(iii) the power supplied to the 8.36 Ω resistor. [6]

(c) Explain why the potential difference across the terminals of a battery is normally lower than the battery's e.m.f. Under what condition is the potential difference across a battery's terminals equal to its e.m.f.? [3]

N96/III/3 (part)

69 *(a)* (i) Explain what is meant by the *resistivity* of a material.

(ii) Show that the unit in which resistivity is measured is Ω m. [3]

N97/III/4 (part)

70 *(a)* (i) What is meant by an *electric current*?

(ii) Explain why power is required to maintain an electric current in a metallic conductor. [4]

(c) (i) A metal of resistivity ρ is used to make an electric cable of cross-sectional area A. Show that the resistance r per unit length of the cable is given by the expression

$$r = \rho / A.$$

(ii) Some electrical appliances are used with long cables to connect them to the electrical supply. State and explain two reasons why the connecting cable should have a low value for r. [6]

J98/III/2 (part)

71 *(a)* Define

(i) *potential difference*,

(ii) the *volt*. [2]

(b) State the equation relating the resistance R of a wire to its area of cross-section A, its length l and the resistivity ρ of the material of which it is made. [1]

(c) The overhead wire used to supply power to the engine of a train has area of cross-section 5.00×10^{-5} m^2 and is made of copper of resistivity 1.72×10^{-8} Ωm. Calculate the resistance of one kilometre length of the wire. [2]

(d) Fig. 11 shows the arrangement for supplying power to an engine. A 25 kV supply is used and the return current from the engine returns through the track. The resistance per kilometre of the overhead wire is as calculated in *(c)* and the resistance of the track can be neglected.

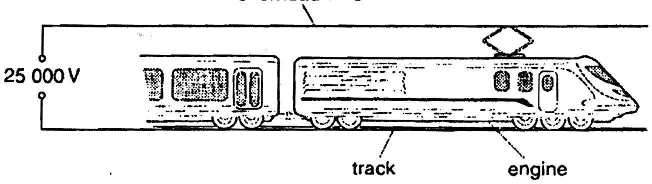


Fig. 11

(i) Consider first when the engine is close to the power supply and requires 6700 kW of power. Calculate the current which is needed. [2]

(ii) When the engine is 30 km from the power supply, it is supplied with a current of 180 A. Calculate

1. the resistance of the overhead wire between the power supply and the engine,
2. the potential difference across the engine,
3. the power supplied to the engine,
4. the fraction of the power supplied which is used by the engine. [7]

(e) Explain the following facts about the supply to the engine.

(i) A railway employee who touches the track through which there is a current of 180 A does not get an electric shock.

(ii) A high voltage supply is essential for a railway system such as this.

(iii) A different current is needed when the train is climbing a hill from that required when travelling at the same speed on the flat. [6]

N98/III/4

72 *(a)* State what is meant by

(i) the *resistance* of a sample of a metal,

(ii) the *resistivity* of the metal. [4]

J99/III/5 (part)

73 *(a)* (i) Explain what is meant by an *electric current*.

(ii) Explain why some solids are electrical conductors and some are insulators.

(iii) Describe electrical conduction in a metal. [3]

(b) Explain why it is difficult to quote a value for the resistance of a filament lamp. [1]

(c) In a gas, conduction occurs as a result of negative particles flowing one way and positive particles flowing in the opposite direction, as illustrated in Fig. 12.

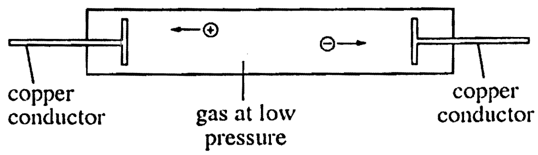


Fig. 12

In this case, the copper conductors to the gas carry a current of 0.28 mA. The number of negative particles passing any point in the gas per unit time is 1.56×10^{15} s^{-1} and the charge on each negative particle is -1.60×10^{-19} C.

Calculate

(i) the negative charge flowing past any point in the gas per second,

(ii) the positive charge flowing past any point in the gas per second,

(iii) the number of positively charged particles passing any point in the gas per second, given that the charge on each positive particle is $+3.20 \times 10^{-19}$ C. [6]

(d) By considering the significant figures available, explain why your answers to *(c)*(ii) and (iii) are unreliable. [2]

**(e)* In one practical example of electrical conduction of particles through a gas, a magnetic field is applied across the gas. Instead of travelling directly along the tube the positive and negative charges travel along different paths, as shown in Fig. 13.

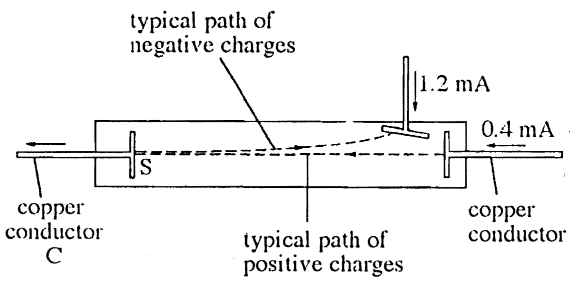


Fig. 13

(i) State the direction of the applied magnetic field. Explain how you obtained your answer.

(ii) How is it possible for the positive particles still to travel in an apparently straight line?

(iii) State Kirchhoff's first law and use it to find the current in conductor C.

(iv) Suggest what is happening to the particles at surface S of the copper conductor C. [8]

N99/III/5

74 *(a)* State the equation linking charge Q, current I and time t. [1]

(b) Calculate the charge which flows past any point in a circuit when a current of 6.2 mA exists in the circuit for one hour. Why should you not give your answer to 4 significant figures? [2]

(c) Define *potential difference.* [1]

(d) A water heater is marked 230 V, 3000 W. It is switched on for 5000 seconds. For this heater, calculate

(i) the current through the heater,

(ii) the resistance of the heater,

(iii) the energy supplied by the heater during this time. [7]

(e) The resistivity of the human body is low compared with the resistivity of skin, which is about 3×10^4 Ω m for dry skin.

(i) For a layer of dry skin 1 mm thick, determine the resistance of a 1 cm^2 area of skin. [3]

(ii) A person, who is well earthed, accidentally grabs a wire of diameter 0.4 cm at a potential of 50 V. His hand makes contact with the whole circumference of the wire over a distance of 9 cm as shown in Fig. 14.

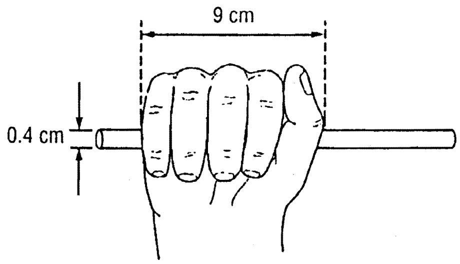


Fig. 14

The average thickness of the skin of his hand is 1 mm. Estimate the current through the person. [2]

(iii) Discuss **two** factors, referred to above, which affect the magnitude of the current and hence affect the possible danger from electric shock. One obvious safety precaution is to keep live wires well insulated. What other safety precautions do you suggest? [4]

N2000/III/4