TOPIC 18 D.C. Circuits

1 A resistor and three similar cells, each of e.m.f. 1.5 V and internal resistance 6 Ω, are connected as shown in Fig. 1.

The current I through the resistor is

A 0.075 A
B 0.083 A
C 0.24 A
D 0.36 A
E 0.45 A

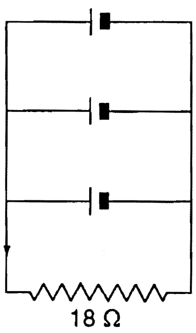


Fig. 1

N76/II/18

2 In the continuous flow method for determining the specific heat capacity of a liquid, the liquid flows at a constant rate through a tube containing a coil of resistance wire as shown (Fig. 2) and an electric current passes through the coil.

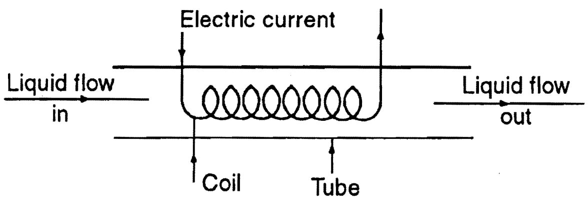
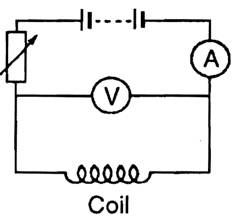


Fig. 2

Which one of the following circuits is most suitable for setting and measuring the energy supplied to the coil?

A



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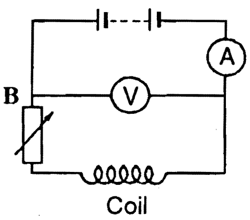

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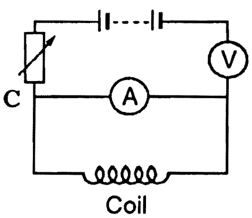
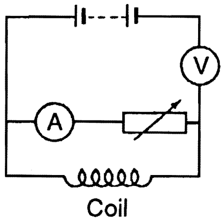
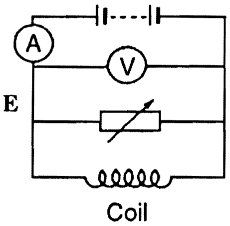


D



E



J79/II/26

3 The meter in the circuit shown below (Fig. 3) has an uncalibrated linear scale. With the circuit as shown, the scale reading is 20.

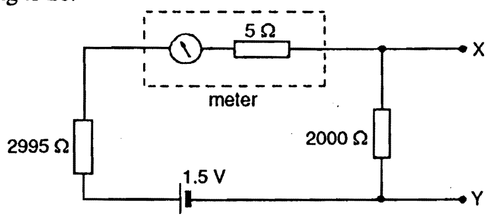


Fig. 3

When another 2000 Ω resistor is connected across XY, the scale reading is

A 10 **B** 16 **C** 25 **D** 28 **E** 40

J80/II/17

4 The current that passes through a certain diode varies with the potential difference across it as shown in Fig. 4*(a)* below. PQ is a straight line. Two such diodes are connected in parallel with a milliammeter of resistance 100 Ω, as shown in Fig, 4*(b)*.

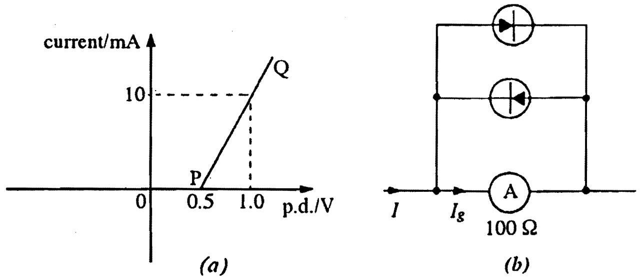


Fig. 4

What is the value of the direct current I when the current I_g through the milliammeter is 8 mA?

A 8 mA
B 14 mA
C 20 mA
D 24 mA
E 40 mA

J82/II/25

5 The potential difference between the points P and Q in the network shown in the diagram below (Fig. 5) is 10 V.

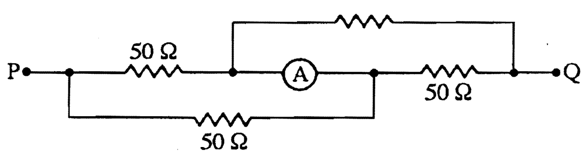


Fig. 5

The current registered by the meter (which is of negligible resistance) is

A 0 mA
B 50 mA
C 100 mA
D 200 mA
E 500 mA

N82/II/19

6 Three resistors are connected as shown in Fig. 6 below and the points X and Y are connected to a source of direct current.

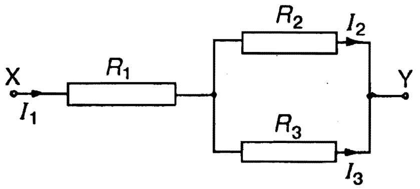


Fig. 6

The ratio I_1 / I_3 is

A $\dfrac{R_3 + R_1}{R_1}$

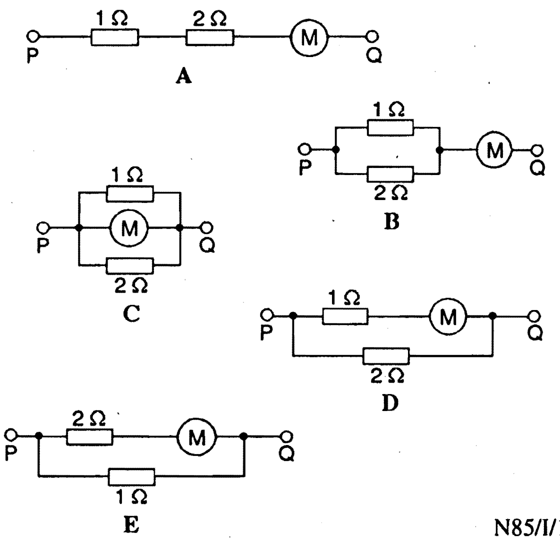
B $\dfrac{R_2 + R_1}{R_1}$

C $\dfrac{R_2 R_3}{R_1 (R_2 + R_3)}$

D dependent on the internal resistance of the source.

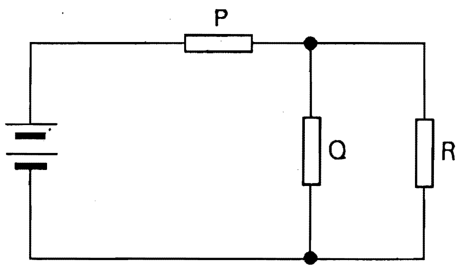
E independent of R_1. N84/II/20

7 In which one of the following arrangements of resistors does the meter M, which has a resistance of 2 Ω, give the largest reading when the same potential difference is applied between points P and Q?



N85/I/15

8 The resistors P, Q and R in the circuit have equal resistance.



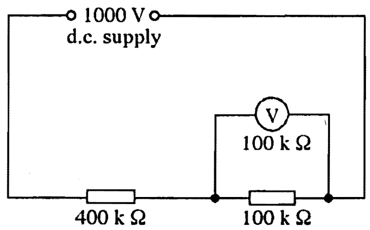
The battery, of negligible internal resistance, supplies a total power of 12 W.

What is the power dissipated by heating in resistor R?

A 2 W B 3 W C 4 W D 6 W

N86/I/14; J94/I/14

9 A constant voltage d.c. source is connected, as shown in the diagram below, across two resistors of resistance 400 kΩ and 100 kΩ.



What is the reading of the voltmeter, also of resistance 100 kΩ, when connected across the second resistor as shown?

A 111 V

B 125 V

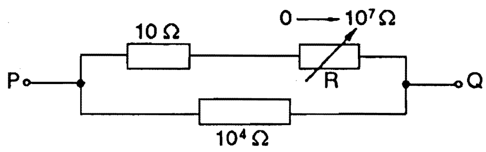
C 200 V

D 250 V

E 333 V

N86/I/15

10 In the diagram, the variable resistor **R** can be adjusted over its full range from zero to 10^7 Ω.



What are the approximate limits for the resistance between **P** and **Q**?

A zero and 10^4 Ω

B 10 Ω and 10^4 Ω

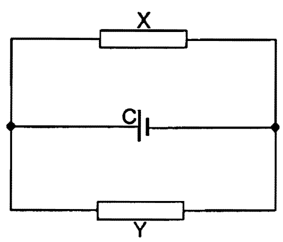
C 10 Ω and 10^7 Ω

D 10 Ω and 10^{11} Ω

E 10^4 Ω and 10^7 Ω

N88/I/15

11 In the circuit shown, each of the resistors **X** and **Y** has resistance 6 Ω. The cell **C** has e.m.f. 12 V and internal resistance 3 Ω.



What is the current in **Y**?

A 0.5 A

B 1.0 A

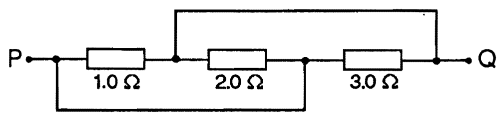
C 2.0 A

D 4.0 A

E 8.0 A

N88/I/16

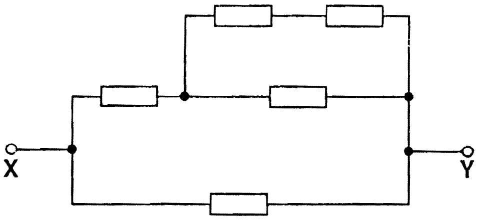
12 Three, resistors are connected as shown in the diagram using connecting wires of negligible resistance.



What is the approximate resistance between points P and Q?

A	0.5 Ω	C	2.0 Ω	E	3.6 Ω
B	0.8 Ω	D	2.2 Ω		J89/I/15

13 The circuit diagram shows a network of resistors each of resistance R.

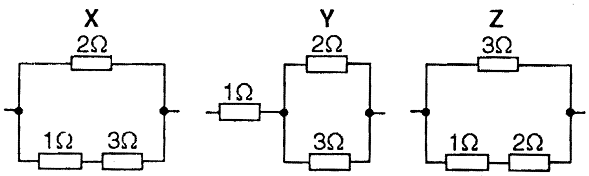


What is the effective resistance between the points **X** and **Y**?

A $\frac{2R}{7}$ C $\frac{5R}{8}$ E $\frac{3R}{4}$

B $\frac{R}{2}$ D $\frac{2R}{3}$ N89/I/14

14 Three resistors of resistance 1 Ω, 2 Ω and 3 Ω respectively are used to make the combinations **X, Y** and **Z** shown in the diagrams.



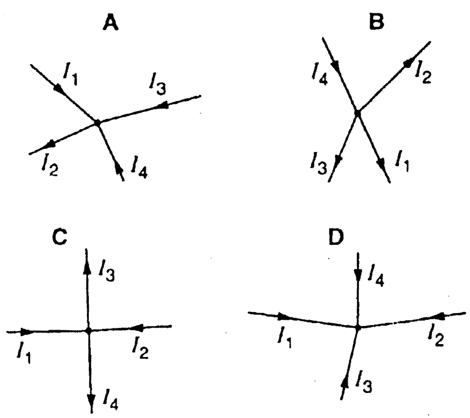
Which of the following gives the combinations in order of increasing resistance?

A	XYZ	D	ZXY
B	XZY	E	ZYX
C	YXZ		J90/I/16

15 The diagrams show connected wires which carry currents I_1, I_2, I_3 and I_4.

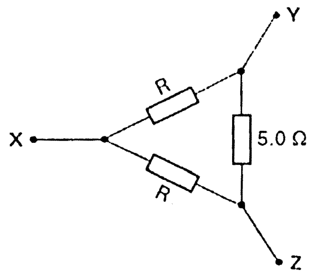
The currents are related by the equation $I_1 + I_2 = I_3 + I_4$.

To which diagram does this equation apply?



N90/I/16; N98/I/16

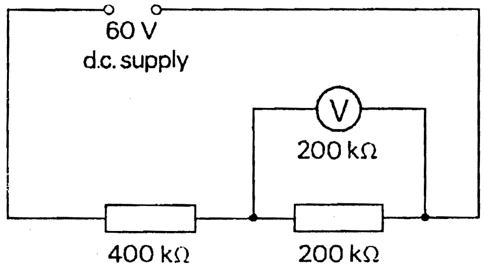
16 The diagram shows a network of three resistors. Two of these, marked R, are identical. The other one has a resistance of 5.0 Ω.



The resistance between **Y** and **Z** is found to be 2.5 Ω. What is the resistance between **X** and **Y**?

A	0.21 Ω	D	4.8 Ω
B	0.53 Ω	E	6.0 Ω
C	1.9 Ω		J91/I/14

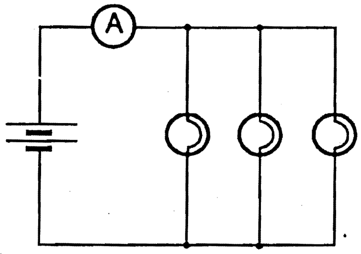
17 A constant 60 V d.c. supply is connected across two resistors of resistance 400 kΩ and 200 kΩ.



What is the reading of the voltmeter, also of resistance 200 kΩ when connected across the second resistor as shown in the diagram?

A	12 V	D	30 V
B	15 V	E	40 V
C	20 V		J92/I/15

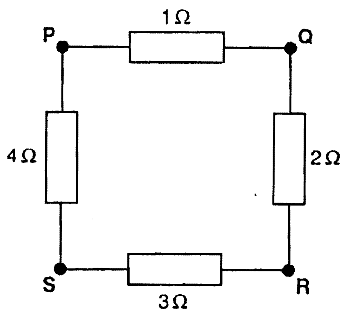
18 Three similar light bulbs are connected to a constant-voltage d.c. supply as shown in the diagram. Each bulb operates at normal brightness and the ammeter (of negligible resistance) registers a steady current.



The filament of one of the bulbs breaks. What happens to the ammeter reading and to the brightness of the remaining bulbs?

	ammeter reading	*bulb brightness*	
A	increases	increases	
B	increases	unchanged	
C	unchanged	unchanged	
D	decreases	unchanged	
E	decreases	decreases	J93/I/13

19 Four resistors are connected as shown.

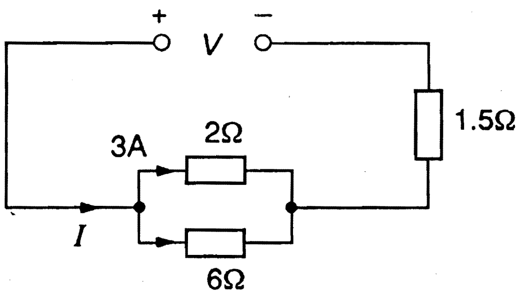


Between which two points is the resistance of the combination a **maximum**?

A	P and Q	C	R and S
B	Q and S	D	S and P

N95/I/15; J2000/I/15

20 In the circuit shown, there is a current of 3 A in the 2 Ω resistor.

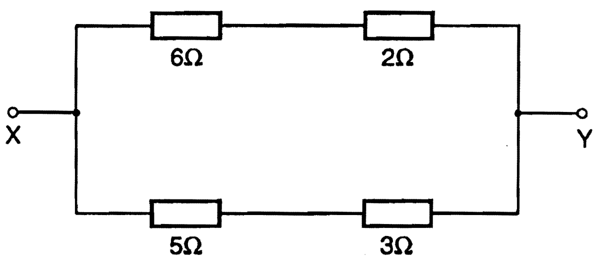


What are the values of the current I delivered by, and the voltage V across, the power supply?

	I/A	V/V
A	3	10.5
B	4	9
C	4	12
D	12	18

J97/I/15

21 In the circuit shown, a potential difference of 3 V is applied across XY.



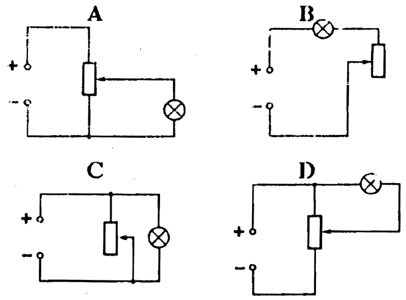
What is the current through the 5 Ω resistor?

A $\frac{15}{8}$ A **B** $\frac{3}{4}$ A **C** $\frac{3}{5}$ A **D** $\frac{3}{8}$ A

N97/I/15

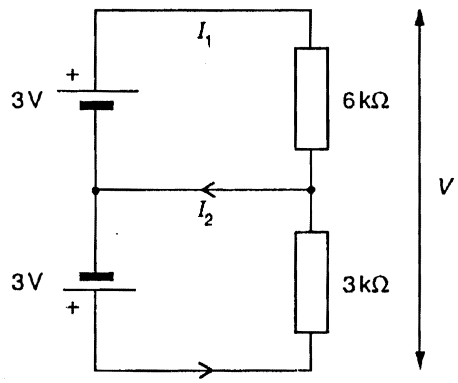
22 A lamp is connected to a power supply of negligible internal resistance.

Which circuit could **not** be used as a practical means to vary the voltage across the lamp?



J98/I/15

23 In the circuit, two 3 V cells are connected to resistors of resistance 3 kΩ and 6 kΩ.

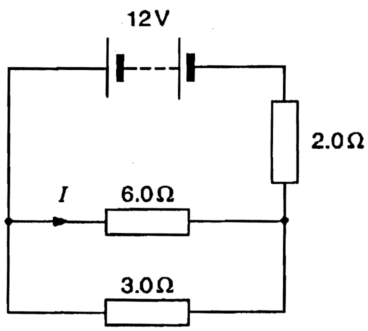


What are the correct values for the currents I_1, and I_2, and the total potential difference V across the pair of resistors?

	I_1/mA	I_2/mA	V/V
A	0.5	0.5	6
B	0.5	0.5	0
C	0.5	1.5	0
D	0.5	1.5	6

J99/I/16

24 The diagram shows a circuit in which the battery has negligible internal resistance.



What is the value of the current I?

A	1.0A	C	2.0A
B	1.6A	D	3.0A

N99/I/14

25 A row of 25 decorative lights, connected in series, is connected to a mains transformer. When the supply is switched on, the lights do not work. The owner uses a voltmeter to test the circuit. When the voltmeter is connected across the third bulb in the row, a reading of zero is obtained.

Which of the following **cannot** be the only fault in the circuit?

A The filament of one of the other bulbs has broken.
B The filament of the third bulb has broken.
C The fuse in the mains transformer has blown.
D There is a break in the wire from the supply to the transformer. N99/I/15

26 Fig. 7 shows the circuit of a simple ohm-meter. A milliammeter of resistance *r*, which gives full-scale deflection when a current of 5 mA flows through it, is connected to a 1.5 V cell of negligible internal resistance and a 297 Ω resistor, as shown. The resistors to be measured are connected between the terminals A and B. When A and B are short-circuited, the meter gives full-scale deflection.

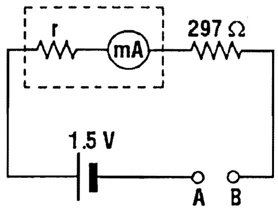


Fig. 7

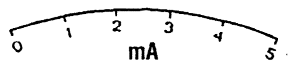


Fig. 8

(a) Find the resistance *r* of the meter.

(b) What resistance connected between A and B would cause a deflection of half full-scale?

(c) Fig. 8 shows the scale of the meter in mA. Sketch this diagram on your answer paper and mark on the diagram the resistance graduations corresponding to 0 Ω, 300 Ω, 900 Ω and 1200 Ω. N81/I/6

27

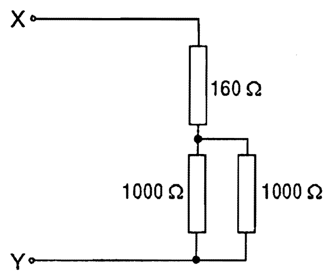


Fig. 9

The circuit shown in Fig. 9 is constructed of resistors, each of which has a maximum safe power rating of 0.40 W.

(a) Find the maximum potential difference that can be applied between X and Y without damage to any of the resistors.

(b) If this potential difference were exceeded, which resistor would be most likely to fail? N84/I/6

28 Deduce the value of the current *I* as shown in the circuit of Fig. 10.

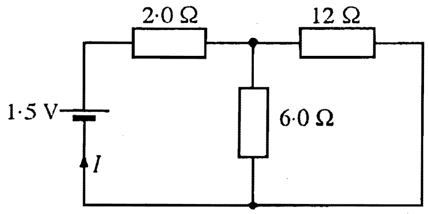


Fig. 10 N86/III/4

29 Fig. 11 shows an arrangement by which the resistance between A and B may be varied.

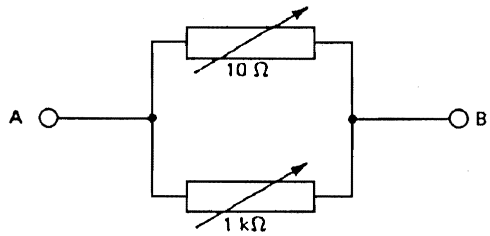


Fig. 11

Explain briefly why the 1 kΩ variable resistor may be used as a means of making fine adjustments to the total resistance of the combination. J87/III/5

30 Draw a diagram to show how you could connect together four 560 Ω resistors so that their combined resistance is 560 Ω. If each resistor has a maximum power rating of 0.5 W, explain briefly why the maximum power rating of this arrangement is 2 W. [2]
N87/III/2

31 A manufacturer of electric cookers makes the heater of the grill out of ten identical coils of wire. These coils are connected to one another and to the mains by way of two switches as shown in Fig. 12. The two switches are ganged together. This means that if one is off, both are off: if one is at **X**, both are at **X**: if one is at **Y**, both are at **Y**.

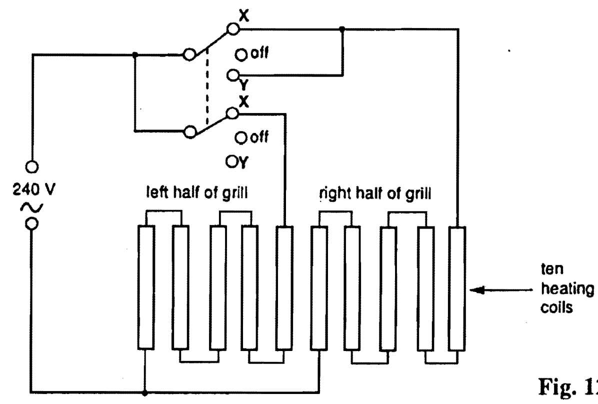


Fig. 12

(a) For the position of the switches at **X** as shown, describe, in terms of series and parallel, how the ten coils are connected. [2]

(b) Both switches are at **X**.

*(i) What is the r.m.s. potential difference across each of the ten coils? [1]

(ii) Calculate the resistance of each of the ten coils if each coil is to have a power output of 160W. [3]

(c) Describe what will happen to the grill if both switches are moved to **Y**. Suggest **one** advantage of this switching arrangement. [3]

N93/II/4

32 (b) A lighting circuit includes four lamps connected as shown in Fig. 13. The resistance of each lamp *should* be 120 Ω when it is not lit.

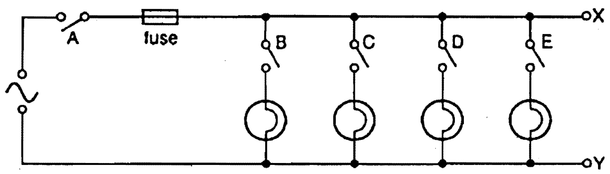


Fig. 13

A fault is discovered in the circuit, so switch A is turned off and the fuse is removed for safety. A resistance meter is connected between the points X and Y and the following readings are obtained for different switch positions.

Switches A	B	C	D	E	Resistance meter reading/Ω
off	off	off	off	off	14 600 000
off	off	off	off	on	120
off	off	off	on	on	60
off	off	on	on	on	40
off	on	on	on	on	0.2

(i) If there were no fault in the circuit, what would the resistance meter read when switches B, C, D and E are on and A is off?

(ii) Why does the resistance meter not read infinity when all the switches are off?

(iii) Suggest what the fault in the circuit may be. [5]

J94/II/3 (part)

33 Fig. 14 shows an electrical circuit in which the internal resistance of the battery is negligible.

Complete Fig. 15 by giving the electrical quantities for each of the components in the circuit. You are advised to start by completing the column for component A.

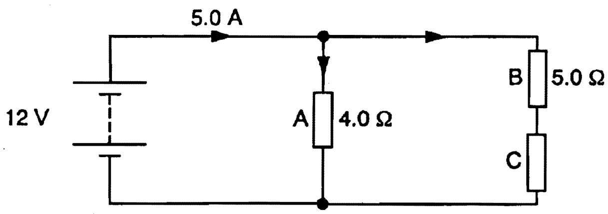


Fig. 14 [9]

circuit component	A	B	C	whole circuit
potential difference/V				12
current/A				5.0
power/W				
resistance/Ω	4.0	5.0		

Fig. 15 J2000/II/2

Long Questions

34

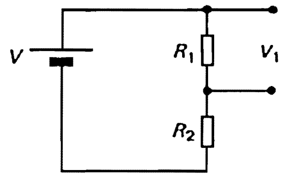


Fig. 16

State Ohm's law.

For the circuit shown in Fig. 16 derive an expression for the potential difference V_1 in terms of R_1, R_2, and V, where the symbols have their customary meanings and the cell has negligible internal resistance.

Deduce expressions for the potential differences indicated by a moving-coil voltmeter of resistance R when it is connected (a) across R_1, (b) across R_2.

Calculate the readings on the meter if $V = 2$ V, $R_1 = R_2 = 1 \times 10^3\ \Omega$ and $R = 500\ \Omega$.

Comment on the fact that your calculated values do not add to 2 V. Hence, discuss the factors that affect the choice of voltmeters for practical purposes. J81/III/5

35 Define *resistance* and state *Ohm's law.*

Describe how you would measure a resistance of the order of $10^{-2}\ \Omega$, making use of a standard resistor of known low resistance.

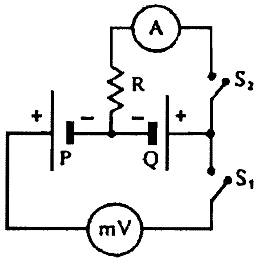


Fig. 17

Two almost identical lead-acid accumulator batteries, P and Q, are connected with opposing polarities in a circuit which includes an ammeter, a millivoltmeter and a resistor R as shown in Fig. 17. Describe and explain in general terms why the meter readings may change when

(a) switch S_1 is closed with S_2 left open,

(b) switch S_2 is closed with S_1 remaining closed.

With S_1 closed, the reading of the millivoltmeter changes by 20 m V and the ammeter reads 5.0 A when S_2 is closed as in *(b)*. Calculate the internal resistance of battery Q, assuming the resistance of the millivoltmeter to be much larger than R.

Why is this assumption (i) reasonable, (ii) necessary?

Why is this two-battery method capable of giving the internal resistance of an accumulator to greater accuracy than the one-battery, ammeter, resistor and voltmeter technique?

J82/III/3

36 State *Kirchhoff's laws.* Explain how each is based on a fundamental physical principle.

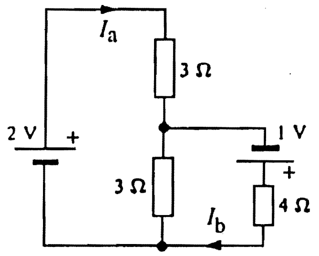


Fig. 18

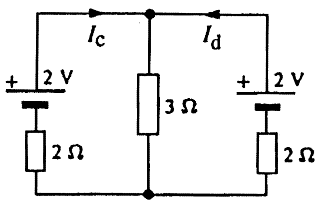


Fig. 19

Use the laws to deduce values of the currents I_a, I_b, I_c and I_d as shown in the circuits (Figs. 18 & 19). J83/III/3 (part)

37 *(a)* State *Kirchhoff's laws* for electrical circuits. Explain how each law is based on a fundamental physical principle. Describe experiments, one in each case, which may be used to test the laws. [9]

(b) A galvanometer may be used as a voltmeter when connected to a suitable resistor. How, in principle, is this achieved? [3]

(c) A 2.0 V cell of negligible internal resistance is connected in series with two resistors of resistances 750 Ω and 500 Ω respectively (see Fig. 20).

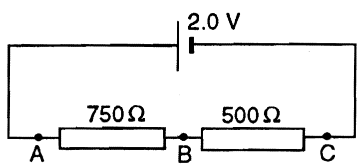


Fig. 20

What is the reading of an accurately calibrated voltmeter of resistance 1500 Ω when connected between the points

(i) A and C,

(ii) A and B,

(iii) B and C? [6]

By making reference to your answers, discuss the significance of the resistance of a voltmeter which is to be used to obtain reliable readings for potential differences in a circuit. [4] J88/III/10

38 *(a)* What do you understand by the *internal resistance* of a cell? [4]

(b) In the circuit of Fig. 21 the voltmeter may be assumed to have infinite resistance, but the resistance of the ammeter is NOT negligible. Readings V and I from the voltmeter and ammeter respectively are shown in the table for different values of R.

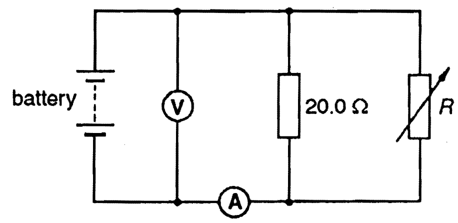


Fig. 21

R/Ω	V/V	I/A
1.00	2.86	1.40
2.00	3.59	1.23
3.00	4.12	1.11
4.00	4.54	1.03
5.00	4.80	0.95
7.00	5.29	0.84
9.00	5.62	0.77

(i) Explain why the voltmeter reading decreases as the current increases. [4]

(ii) Plot a graph of V against I and use it to determine a value for the internal resistance of the battery. [7]

(iii) For which value of R in the table is the power output from the battery greatest? [2]

(iv) Use your answer to (iii) to estimate the resistance of the ammeter. [5] J89/III/10

39 *(a)* Define the terms *potential difference* and *resistance.* [2]

(b) Two sets of coloured lamps are designed for use with a 240V supply. Both sets have 12 lamps. In one set the lamps are arranged in series; in the other they are arranged in parallel. In each case the total power is 60W.

For a single lamp in the set connected in series, calculate

(i) the current,

(ii) the potential difference,

(iii) the resistance.

Calculate the same three quantities for a lamp in the set which is connected in parallel. [7]

(c) The circuit for the set connected in series is shown in Fig. 22.

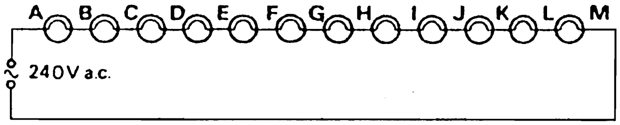


Fig. 22

The lamps do not light up when the set is plugged in so a voltmeter is used to test the circuit. For each of the following observations identify the fault.

(i) The potential difference between **A** and **M** is zero.

(ii) The potential difference is zero across every lamp except **EF**, across which the potential difference is 240 V.

(iii) The potential difference between **A** and **M** is 240V but the potential difference is zero across every single lamp. [4]

(d) (i) Some lamps are designed so that when the filament fails the resistance of the lamp drops to zero. If this happens to one of the lamps in the set connected in series calculate the fractional increase in the power dissipated in each of the remaining lamps, assuming that the resistance of these lamps does not change.

(ii) What is likely to happen if failed lamps are not replaced? [7]

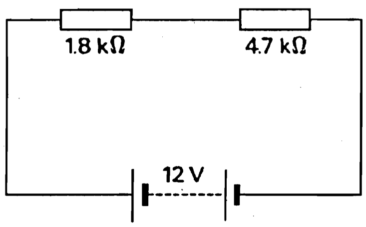
N90/III/4

40 (a) Define (i) *potential difference* and the *volt*;

(ii) *resistance* and the *ohm*. [4]

(b) Two resistors having resistances of 1.8 kΩ and 4.7 kΩ are connected in series with a battery of e.m.f. 12 V and negligible internal resistance as shown in Fig. 23.

Fig. 23



(i) What is meant by the expression an *e.m.f. of 12 V?* [2]

(ii) What is the potential difference across each of the resistors? [3]

(c) When a particular voltmeter of fixed resistance *R*, which is known to be accurately calibrated, is placed across the 1.8 kΩ resistor in Fig. 23 it reads 2.95 V. When placed across the 4.7 kΩ resistor it reads 7.70 V.

(i) Why do these two readings not add up to 12 V?[3]

(ii) Calculate the resistance *R* of the voltmeter. [4]

(d) A second, identical, voltmeter is used so that a voltmeter is placed across each resistor. What will each voltmeter read? [4] J91/III/3

41 (b) The two lamps on a bicycle are powered by a small dynamo. The dynamo resistance is 20 Ω and at one particular speed, the dynamo generates an e.m.f. of 6.0 V. Each lamp may be considered to have a constant resistance of 5.0 Ω. Calculate the current in each lamp if the lamps are connected

(i) in series, (ii) in parallel. [5]

(c) By reference to your answers in *(b)*, draw a circuit diagram to show how the lamps should be connected to the dynamo so that the greater light output is achieved. Justify your choice of circuit. [4]

(d) The dynamo is replaced by one having an internal resistance of less than 5 Ω. In this case, which combination of lamps, series or parallel, will give the greater light output? Justify your answer. [5]

N91/III/4 (part)

42 (a) Give an expression for *P*, the power dissipated in a resistor of resistance *R*, in terms of *V*, the potential difference across the resistor, and *I*, the current through the resistor. Hence show that *P* is given by the expression

$$P = \frac{V^2}{R}.$$ [3]

A certain electric hotplate, designed to operate on a 250 V supply, has two coils of nichrome wire of resistivity 9.8×10^{-7} Ω m. Each coil consists of 16 m of wire of cross-sectional area 0.20 mm^2.

(b) For one of the coils calculate

(i) its resistance,

(ii) the power dissipation when a 250 V supply is connected across the coil, assuming its resistance does not change with temperature. [4]

(c) Show, by means of diagrams, how these coils may be arranged so that the hotplate may be made to operate at three different powers. In each case, calculate the power rating. [5]

(d) The hotplate is connected to the 250 V supply by means of cable of total resistance 3.0 Ω.

(i) Calculate the power loss in the connecting cable when the hotplate is being used on its middle power rating.

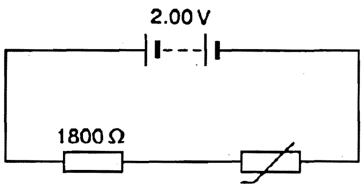
(ii) Comment qualitatively on any change in power loss in the cable when the hotplate is operating at each of its other power ratings. [6]

(e) Different connecting cables are available for use with the hotplate. The maximum safe current which can be used in any one of the cables is 1 A or 3 A or 6 A or 12 A. State which is the most appropriate cable to use and briefly explain one possible danger of using cable with a lower maximum safe current. [2]

J92/III/3

43 *(c)* The temperature change on expansion of the gas is to be detected using a small thermistor. The thermistor is connected in series with a fixed resistor of resistance 1800 Ω and a 2.00 V battery of negligible internal resistance, as shown in Fig. 24.

Fig. 24



Initially, the thermistor has resistance 1800 Ω and after the gas expands, its resistance is 1910 Ω. Calculate the potential difference across the thermistor

(i) before the expansion,

(ii) after the gas has expanded. [3]

N95/III/5 (part)

44 *(d)* An *I-V* characteristic for a thermistor is shown in Fig. 25. Draw a diagram of a circuit which you could use to take measurements to obtain this characteristic. [2]

(e) The thermistor, the characteristic of which is given in Fig. 25, is used in the circuit shown in Fig. 26.

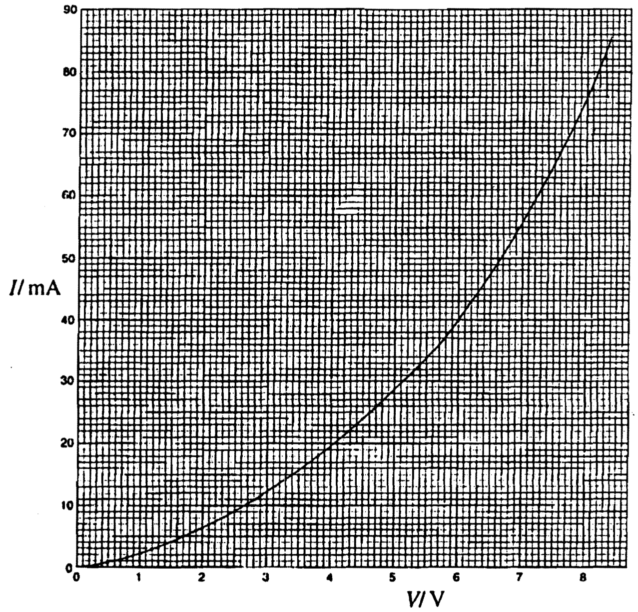


Fig. 25

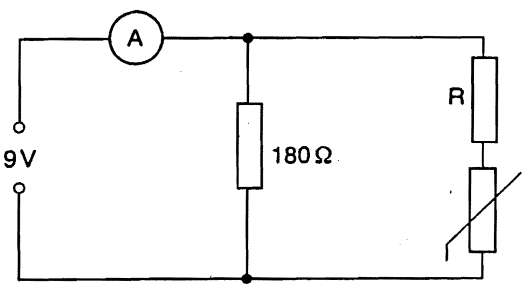


Fig. 26

It is found that there is a current of 90 mA from the supply. Calculate

(i) the current through the 180 Ω resistor,

(ii) the p.d. across the thermistor,

(iii) the value of the resistance of resistor R. [5]

(f) When the temperature of the thermistor in the circuit in *(e)* is kept at 0 °C by immersing it in a mixture of ice and water, it is found that the current from the supply becomes 60 mA. The resulting values of *V* and *I* for the thermistor no longer lie on the graph of Fig. 25. Suggest why the point corresponding to these values is not on the characteristic. [2]

N96/III/3 (part)

45 *(a)* Name a material commonly used as (i) the conductor, (ii) the insulator, in household electrical wiring. [2]

(b) A metal, such as silver, conducts electricity approximately 10^{20} times more readily than an insulator of the same dimensions, such as sulphur. Explain this qualitatively using a simple electron model. [3]

(c) A car headlamp is marked 12 V, 72 W. It is switched on for a 20 minute journey. Calculate

(i) the current in the lamp,

(ii) the charge which passes through the lamp during the journey,

(iii) the energy supplied to the lamp during the journey,

(iv) the working resistance of the lamp. [6]

(d) Two of the headlamps referred to in part *(c)* are connected into the circuit shown in Fig. 27, in which one source of e.m.f. (the generator of the car) is placed in parallel with the car battery and the two lamps. Both lamps are on and are working normally.

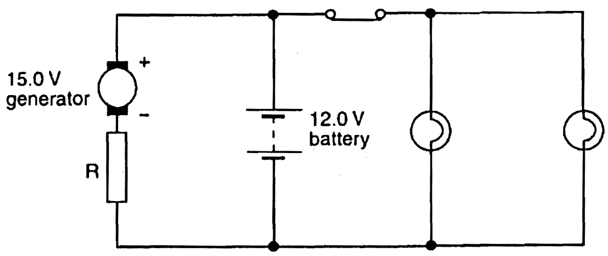


Fig. 27

The battery has an e.m.f. of 12.0 V and negligible internal resistance: the generator has an e.m.f. of 15.0 V and negligible internal resistance. The generator is in series with a variable resistor R.

(i) The value of R is adjusted so that there is no current in the battery when the lamps are on.

Calculate

1. the current in the generator,

2. the value of the resistance of R. [5]

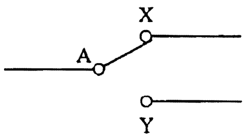
(ii) Calculate the current in the battery when both lamps are switched off, the value of R remaining the same as in (i). [2]

(e) Suggest two advantages which the circuit, as shown in Fig. 27, has over a single power source. [2]

J97/III/4

46 *(b)* Fig. 28 illustrates a two-way switch.

Fig. 28



Such a switch enables electrical contact to be made between A and X or between A and Y.

It is required to design a circuit such that a lamp may be switched on or off independently at two different locations. Fig. 29 illustrates part of the circuit.

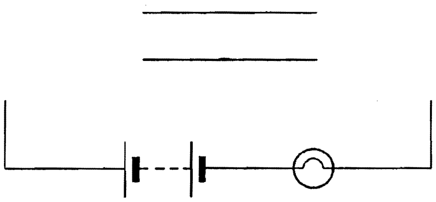


Fig. 29

Copy Fig. 29 and complete the circuit diagram using two two-way switches. [2]

(d) An electrical component Z has the current/voltage *(I/V)* characteristic shown in Fig. 30.

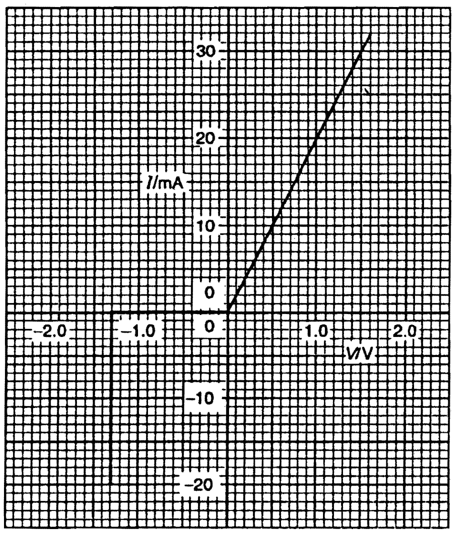


Fig. 30

The component is said to be forward-biassed for positive values of voltage and reverse-biassed when the voltage is negative.

(i) Determine the resistance of Z when Z is

1. forward-biassed,

2. reverse-biassed ($V = -1.0$ V).

(ii) Comment on the possible values of the resistance of Z when $V = -1.3$ V.

(iii) The component Z is connected in parallel with a resistor of resistance 50 Ω. A d.c. supply of e.m.f. 1.5 V and negligible internal resistance is connected across the parallel combination, as shown in Fig. 31.

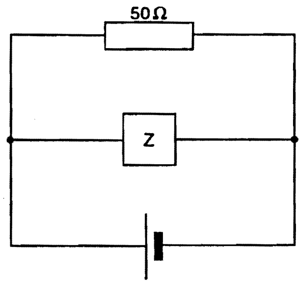


Fig. 31

1. Calculate the current from the supply when the component Z is forward-biassed.

2. State why it would be ill-advised to attempt to reverse the polarity of the supply so that the component Z is reverse-biassed. [8]

J98/III/2 (part)

47 *(c)* The circuit of Fig. 32 was designed by a student.

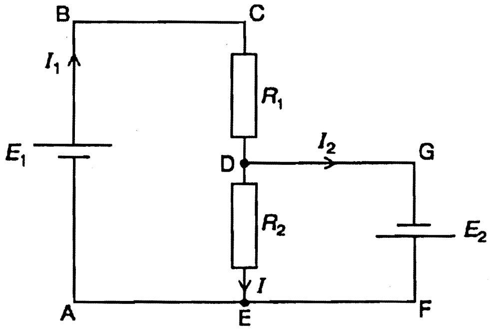


Fig. 32

The cells have e.m.f.'s E_1 and E_2 and the currents in the cells are I_1 and I_2 respectively. The resistors have resistances R_1 and R_2 and the current in the resistor of resistance R_2 is I.

Use Kirchhoff's laws to write down expressions in terms of E_1, E_2, R_1, R_2, I, I_1, and I_2 (where appropriate) for

(i) the currents at junction D,

(ii) the circuit loop ABCDEA,

(iii) the circuit loop GFEDG. [3]

J2000/III/4 (part)

Potential Divider

48

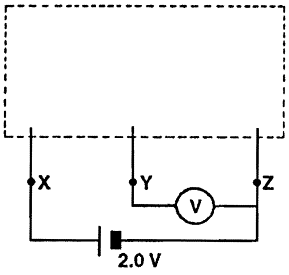
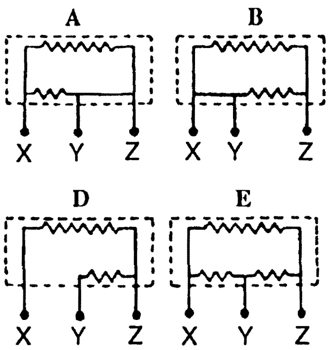


Fig. 33

A network of resistors is connected by terminals X, Y, Z in the circuit shown in Fig. 33. If the e.m.f. of the cell (which has negligible internal resistance) is 2.0 V and the voltmeter reading is 1.4 V, which one of the following circuits is possible for the network? (The resistance of the voltmeter V is very much greater than those of the resistors in the network.)



N76/II/20

49 Six 5 Ω resistors are connected to a 2 V cell of negligible internal resistance as shown in Fig. 34. The potential difference between X and Y is

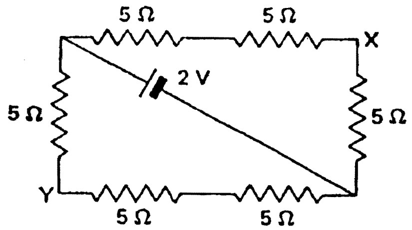


Fig. 34

A	2/3 V	**D**	2 V
B	8/9 V	**E**	8/3 V
C	4/3 V		

J77/II/19

50 A battery of e.m.f. *V* and negligible internal resistance is connected to a resistor of resistance *R*, as shown in Fig. 35.

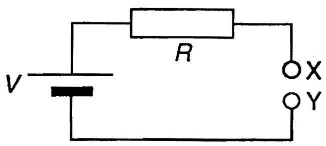


Fig. 35

Two voltmeters are used, one at a time, to measure the potential difference across the terminals X and Y. One voltmeter has a resistance *R*. The other voltmeter has a resistance 10 *R*. Which one of the following correctly gives the readings of the two voltmeters?

	Reading of voltmeter of resistance R	*Reading of voltmeter of resistance 10R*
A	nearly *V*	nearly *V*
B	*V*/2	nearly *V*
C	nearly *V*	*V*/2
D	*V*/2	*V*/2
E	*V*/10	nearly *V*

J78/II/23

51 A p-n junction diode with the forward characteristic shown in Fig. 36 *(a)* is connected in series with a variable, low voltage d.c. power supply, a meter of negligible internal resistance and a 50 Ω resistor as shown in Fig. 36 *(b)*.

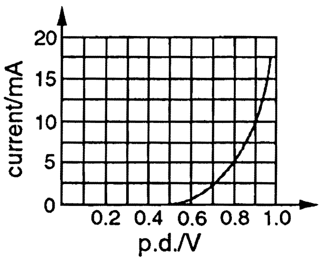


Fig. 36 *(a)*

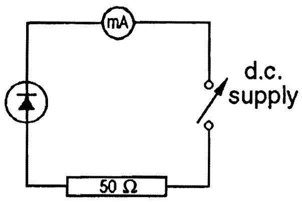


Fig. 36 *(b)*

When the meter reads 5 mA, the potential difference across the supply is about

A 0.25 V
B 0.75 V
C 1.05 V
D 1.25 V
E 2.75 V

J79/II/24

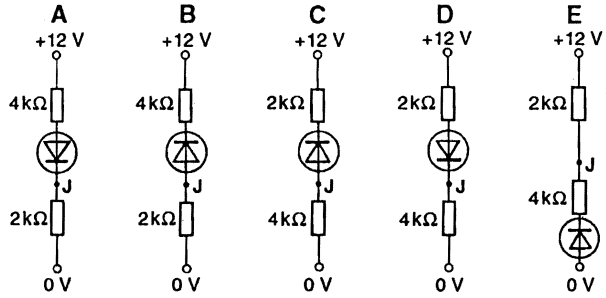
52 A two-range d.c. voltmeter has a common negative terminal and two positive terminals, one to give a full scale deflection for 10 V and the other to give a full scale deflection for 3 V. The resistance of the voltmeter between the negative terminal and the +3 V terminal is 1000 Ω. The resistance between the negative terminal and the +10 V terminal is

A 300 Ω
B 333 Ω
C 1000 Ω
D 3000 Ω
E 3333 Ω

J81/II/22

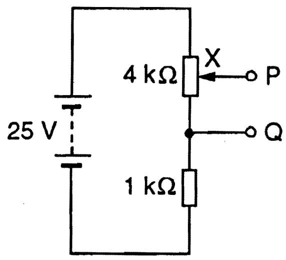
53 Assume the diodes shown in the diagrams are ideal (i.e. they have zero resistance in the forward direction and infinite resistance in the reverse direction).

In which of the component arrangements is the potential at J equal to 8 V?



N92/I/13; J85/I/15

54 The diagram below shows a potential divider circuit which, by adjustment of the position of the contact X, can be used to provide a variable potential difference between the terminals P and Q.

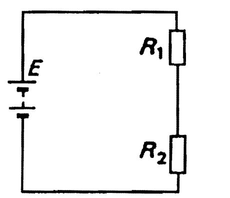


What are the limits of this potential difference?

- **A** 0 and 20 mV
- **B** 5 mV and 25 mV
- **C** 0 and 20 V
- **D** 0 and 25 V
- **E** 5 V and 25 V

J86/I/15

55 A battery of e.m.f. E and negligible internal resistance is connected to two resistors of resistances R_1 and R_2 as shown in the circuit diagram.

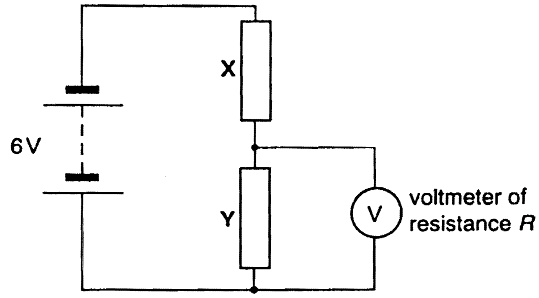


What is the potential difference across the resistor of resistance R_2?

- **A** $\dfrac{E(R_1 + R_2)}{R_1}$
- **B** $\dfrac{E(R_1 + R_2)}{R_2}$
- **C** $\dfrac{ER_1}{(R_1 + R_2)}$
- **D** $\dfrac{ER_2}{(R_1 + R_2)}$
- **E** $\dfrac{ER_2}{R_1}$

N89/I/15

56 In the circuit shown, resistors **X** and **Y**, each of resistance R, are connected to a 6V battery of negligible internal resistance. A voltmeter, also of resistance R, is connected across **Y**.

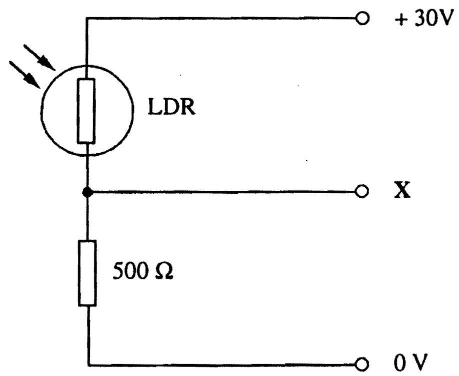


What is the reading of the voltmeter?

- **A** between zero and 3 V
- **B** 3V
- **C** between 3V and 6V
- **D** 6V

J90/I/15; N96/I/14

57 The light dependent resistor (LDR) and a 500 Ω resistor form a potential divider between voltage lines held at +30 V and 0 V as shown in the diagram.

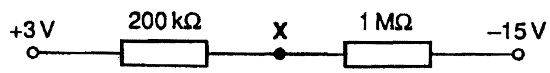


The resistance of the LDR is 1 000 Ω in the dark but then drops to 100 Ω in bright light. What is the corresponding change in the potential at **X**?

- **A** a fall of 25 V
- **B** a fall of 15V
- **C** a rise of 10 V
- **D** a rise of 15 V
- **E** a rise of 25 V

N91/I/15

58 Two resistors, of resistance 200 kΩ and 1 MΩ respectively, form a potential divider with outer junctions maintained at potentials of +3 V and −15 V.

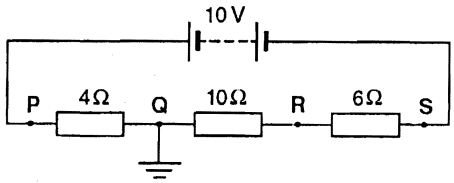


What is the potential at the junction **X** between the resistors?

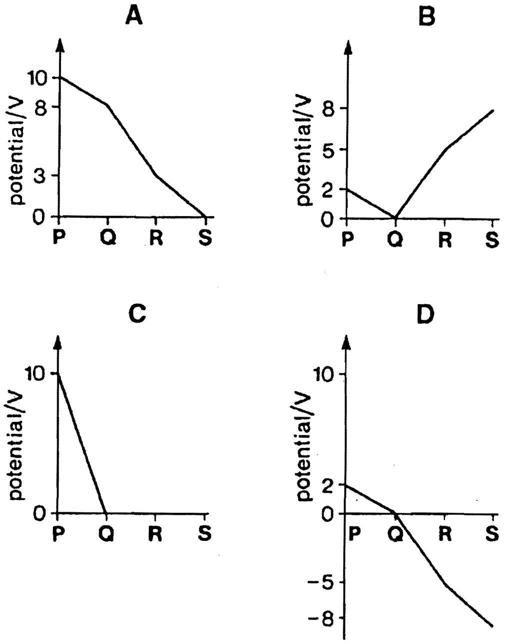
A +1 V **B** 0 V **C** −0.6 V **D** −12 V

N94/I/14

59 The diagram shows three resistors of resistances 4Ω, 10Ω and 6Ω connected in series. A potential difference of 10 V is maintained across them, with point Q being earthed.

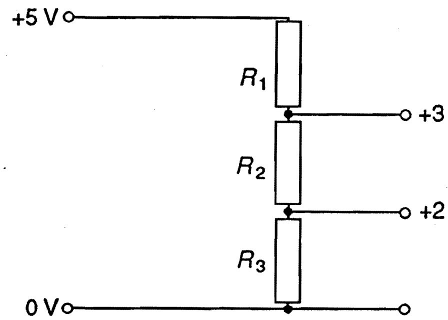


Which graph represents the change in potential along the resistor network?



J95/I/15

60 A potential divider is used to give outputs of 2 V and 3 V from a 5 V source, as shown.



Which combination of resistances, R_1, R_2, R_3, gives the correct voltages?

	R_1/kΩ	R_2/kΩ	R_3/kΩ
A	1	1	2
B	2	1	2
C	3	2	2
D	3	2	3

J96/I/15

Long Questions

61 Define *resistance*. Write down a relationship between *resistance* and *resistivity*.

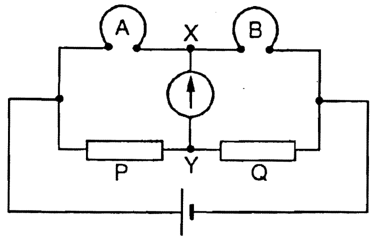


Fig. 37

In the circuit of Fig. 37, A and B are lengths of different resistance wire and P and Q are two identical resistors. If the resistance of A is equal to that of B, explain why no current flows through the galvanometer.

The material of wire A has a resistivity of 4.0×10^{-7} Ωm and the diameter of A is 1.6 times that of B. In order that the galvanometer should show zero deflection, the length of A is three times that of B. What is the resistivity of the material of wire B?

When the cell is replaced by one with a larger e.m.f. but similar internal resistance, the galvanometer indicates a small current. Suggest an explanation as to why this occurs.

If the direction of the current is from X to Y, deduce whether the resistance of A is greater or less than that of B.

J87/III/11

62 *(c)* A student decided to build a temperature probe and set up the circuit shown in Fig. 38. The battery has e.m.f. 9.0 V and negligible internal resistance

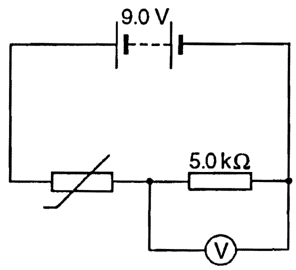


Fig. 38

The voltmeter has infinite resistance. The calibration curve for the thermistor is shown in Fig. 39.

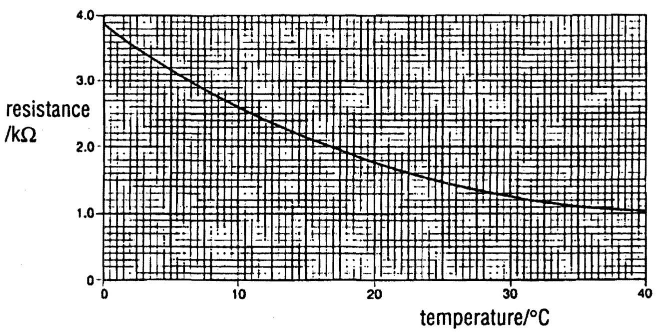


Fig. 39

(i) Suggest why it is necessary to include a fixed resistor in the circuit of Fig. 38.

(ii) The probe is to be used to measure temperature in the range 0 °C to 30 °C.

1. Use Fig. 39 to find the resistance of the thermistor when the probe is at 30 °C.
2. Hence calculate the reading on the voltmeter for the temperature of 30 °C.

(iii) When the temperature of the thermistor is 2.5 °C, the voltmeter reads 5.30 V. The voltmeter has a range 0 – 10 V. Suggest one disadvantage of using this voltmeter in the circuit of Fig. 38 for temperature measurement. [7]

*(d) During laboratory testing of the circuit in *(c)*, the battery became 'flat'. In order to proceed with his work, the student modified the circuit as shown in Fig. 40.

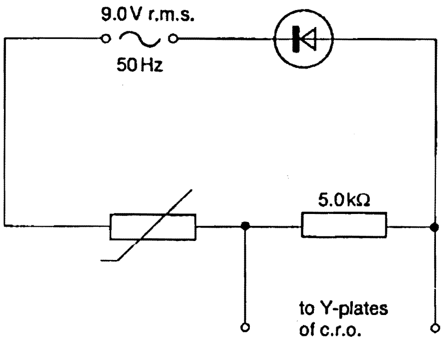


Fig. 40

The screen of the c.r.o. was marked with a grid of squares of side 1.0 cm and the settings on the c.r.o. were as follows:

time base: 5.0 ms cm^{-1}

Y-plate sensitivity: 5.0 V cm^{-1}

By reference to *(c)*(iii), and assuming that the diode is ideal, draw to scale a sketch of the trace as seen on the screen of the c.r.o. when the temperature of the probe is 2.5 °C. [5]

J96/III/4 (part)

63 *(b)* A strain gauge consists of a thin metal foil firmly bonded to a flexible plastic backing sheet, as illustrated in Fig. 41.

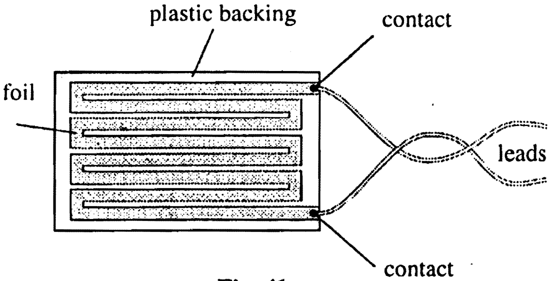


Fig. 41

The foil has total length l and total resistance R between the contacts. When the foil is extended by an amount Δl, the resistance changes by an amount ΔR, such that

$$\Delta R/R = 0.485\,(\Delta l/l).$$

(i) Suggest why the device illustrated in Fig. 41 is referred to as a *strain* gauge.

(ii) Explain, by reference to the definition of resistivity, why the resistance of the metal foil changes when it is extended. [4]

(c) In one particular application, the strain gauge S is connected in series with a fixed resistor F of resistance 400 Ω and a battery of e.m.f. 4.50 V and negligible internal resistance, as illustrated in Fig. 42.

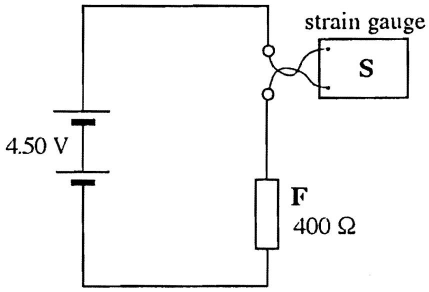


Fig. 42

(i) Show that there is a potential difference of 2.40 V across the resistor F when the strain gauge has a resistance of 350 Ω. Explain your working carefully. [3]

(ii) The gauge is given a strain of 1.18%. Using the expression given in *(b)*, calculate the *change* in

1. the resistance of the strain gauge,
2. the potential difference across the resistor F.

[5]

(e) In practice, the method outlined in *(b)* and *(c)* may not give a reliable result for the stress. Suggest two factors, other than a change in strain, which might give rise to a change in the potential difference across the resistor F. [2]

J99/III/5 (part)

Potentiometer

64 A potentiometer circuit is set up as in Fig. 43.

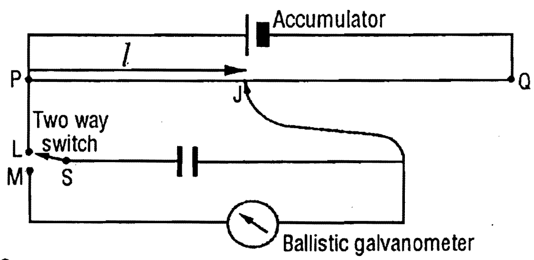


Fig. 43

An experiment is performed as follows: S is connected to L and the movable contact J is then allowed to touch PQ momentarily at a known distance l from P. S is now connected to M and the throw θ of the galvanometer is recorded. This procedure is repeated for a number of different values of l. The student wishes to plot his observations as a straight-line graph. He should plot

A θ against l.
B θ against $1/l$.
C $l\theta$ against θ.
D lg θ against l.
E θ against lg l.

N76/II/21

65 A potentiometer has a wire XY of length l and resistance R. It is powered by a battery of e.m.f. E and internal resistance r in series with a resistor of resistance r. With a cell in the branch circuit, the null point is found to be $l/3$ from X, as shown in Fig. 44.

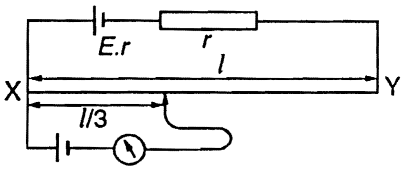


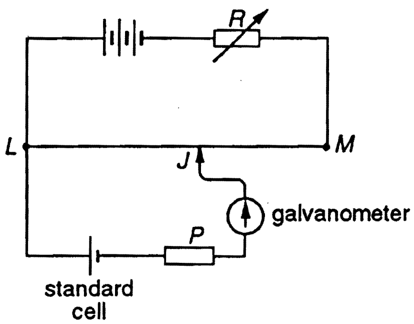
Fig. 44

The e.m.f. of the cell is

A $E/3$
B $ER/3(R + r)$
C $Er/3(R + 2r)$
D $ER/3(R + 2r)$
E $E(R + 2r)/3R$

J79/II/18

66 A potentiometer is to be calibrated with a standard cell using the circuit shown in the diagram below.



The balance point is found to be near L. To improve accuracy the balance point should be nearer M. This may be achieved by

A replacing the galvanometer with one of lower resistance.
B replacing the potentiometer wire with one of higher resistance per unit length.
C putting a shunt resistance in parallel with the galvanometer.
D increasing the resistance R.
E reducing the resistance R.

J87/I/17; N80/II/20

67

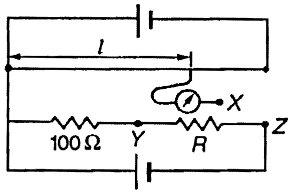


Fig. 45

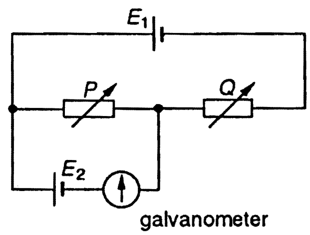
The diagram (Fig. 45) shows a circuit which may be used to compare the resistance R of an unknown resistor with a 100 Ω standard. The distances l from one end of the potentiometer slide-wire to the balance point are 400 mm and 588 mm when X is connected to Y and to Z respectively. The length of the slide-wire is 1.00 m.

What is the value of resistance R?

A 32 Ω
B 47 Ω
C 68 Ω
D 147 Ω
E 150 Ω

J81/II/23

68 Two cells of e.m.f.'s E_1 and E_2 and of negligible internal resistances are connected with two variable resistors as shown in the diagram below. When the galvanometer shows no deflection, the values of the resistances are P and Q.

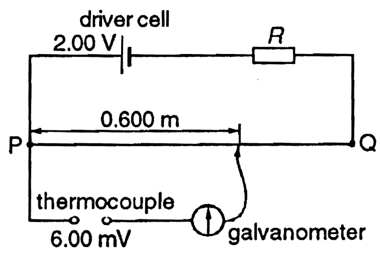


What is the value of the ratio E_2/E_1?

A $\frac{P}{Q}$
B $\frac{P}{(P + Q)}$
C $\frac{Q}{(P + Q)}$
D $\frac{(P + Q)}{P}$
E $\frac{(P + Q)}{Q}$

J87/I/16; N93/I/13

69 The diagram below shows a simple potentiometer circuit for measuring a small e.m.f. produced by a thermocouple.

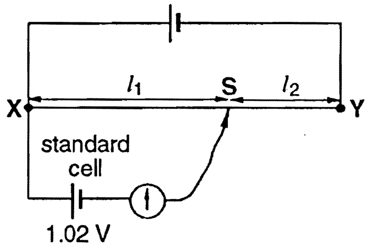


The meter wire PQ has a resistance of 5 Ω and the driver cell has an e.m.f. of 2.00 V. If a balance point is obtained 0.600 m along PQ when measuring an e.m.f. of 6.00 mV, what is the value of the resistance R?

A 95 Ω
B 195 Ω
C 495 Ω
D 995 Ω
E 1995 Ω

N87/I/17

70 A standard cell of e.m.f. 1.02 V is used to find the potential difference across the wire **XY** as shown in the diagram. It is found that there is no current in the galvanometer when the sliding contact is at **S**, l_1 from **X** and l_2 from Y.



What is the potential difference across XY?

A 1.02 V

B $1.02\left(\frac{l_2}{l_1}\right)$ V

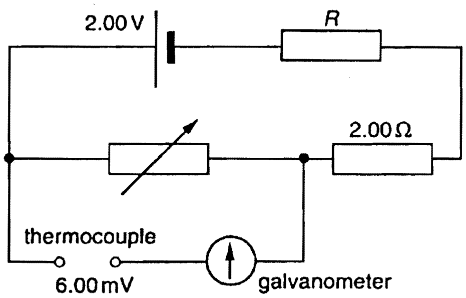
C $1.02\left(\frac{l_1}{l_2}\right)$ V

D $1.02\left(\frac{l_1 + l_2}{l_2}\right)$ V

E $1.02\left(\frac{l_1 + l_2}{l_1}\right)$ V

N88/I/17

71 The diagram shows a circuit for measuring a small e.m.f. produced by a thermocouple.



There is zero current in the galvanometer when the variable resistor is set at 3.00 Ω.

What is the value of the resistance *R*?

A 195 Ω **C** 995 Ω
B 495 Ω **D** 1995 Ω

N98/I/15

72 The slide-wire of a simple potentiometer has a resistance of 5.0 Ω. The current source for the potentiometer is a cell of e.m.f. 2.0 V and of negligible internal resistance. Draw a labelled circuit-diagram showing how the potentiometer might be used to measure an e.m.f. of up to about 2.5 mV from a copper-constantan thermocouple. Calculate a suitable value for the resistor which should be placed in series with the slide-wire. N83/I/8

73 In using a simple slide-wire potentiometer circuit, a large protective resistance is sometimes connected in series with the galvanometer. Why is this done? Explain how (if at all) the presence of this resistance affects *(a)* the position of the balance point, *(b)* the precision with which it may be found.

J84/I/7

Long Questions

74 Draw circuit diagrams and give the relevant equations to show how a potentiometer may be used with a standard cell and a standard resistor

(a) to calibrate an ammeter at one particular reading,

(b) to determine the internal resistance of a cell, which may be assumed to be constant.

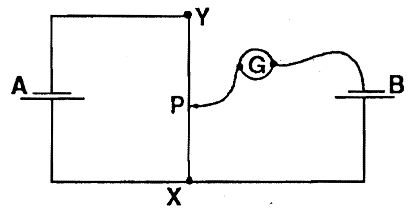


Fig. 46

In the circuit shown in Fig. 46, cell **A** has a constant e.m.f. of 2.0 V and negligible internal resistance. Wire **XY** is 100 cm long with a resistance of 5.0 Ω. Cell **B** has an e.m.f. of 1.5 V and an internal resistance of 0.80 Ω. Calculate the length **XP** required to produce zero current in the galvanometer **G**

(i) in the circuit as shown in Fig. 46,

(ii) when a 1.0 Ω resistor is placed in series with **A**,

(iii) when this resistor is removed from **A** and placed in series with **B**,

(iv) when this resistor is placed in parallel with **B**.

Explain your calculations carefully. J75/II/7(part)

75 Draw a circuit diagram to show how a simple slide-wire potentiometer may be used to compare the e.m.f.'s of two batteries. Show clearly what readings are taken and how the result is calculated. Explain how it is that this method compares e.m.f.'s rather than p.d.'s.

A potentiometer measurement shows the e.m.f. of a battery to be 2.80 V but a moving-coil voltmeter indicates 2.50 V. The voltmeter consists of a moving-coil galvanometer of resistance 50 Ω in series with a larger resistor *X*. This voltmeter reads 3.00 V when the current through it is 10 mA. Calculate the resistance of (i) the battery, (ii) the resistor *X*.

N82/III/3(part)

76 *(b)* With the aid of a circuit diagram, explain how a slide-wire potentiometer may be used to compare the e.m.f.'s of two cells. Give the theory of the method, indicating clearly what assumption is made regarding the slide wire. [5]

(c)

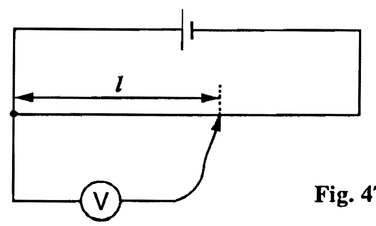


Fig. 47

A potentiometer wire is suspected of having been damaged at some point along its length. To test this, the circuit of Fig. 47 is set up.

The table shows readings of the potential difference V, taken using a voltmeter of infinite resistance, for lengths of wire l.

l/m	0.10	0.25	0.40	0.55	0.70	0.85	1.00
V/V	0. 17	0.42	0.67	0.93	1.49	1.75	2.00

Plot a graph of V against l. Explain the shape of your graph and hence determine the region of the wire in which the damage has occurred. [6]

(d) The wire in *(c)* has a resistance per unit length of 8.0 Ωm^{-1} when undamaged. Calculate

(i) the potential difference per unit length of undamaged wire,

(ii) the current in the wire,

(iii) the increase in resistance produced by the damage. [6]

N89/III/10 (part)