D.C. CIRCUITS

10 D.C. circuits

10.1 Practical circuits

Candidates should be able to:

1 recall and use the circuit symbols shown in section 6 of this syllabus

2 draw and interpret circuit diagrams containing the circuit symbols shown in section 6 of this syllabus

3 define and use the electromotive force (e.m.f.) of a source as energy transferred per unit charge in driving charge around a complete circuit

4 distinguish between e.m.f. and potential difference (p.d.) in terms of energy considerations

5 understand the effects of the internal resistance of a source of e.m.f. on the terminal potential difference

10.2 Kirchhoff's laws

Candidates should be able to:

1 recall Kirchhoff's first law and understand that it is a consequence of conservation of charge

2 recall Kirchhoff's second law and understand that it is a consequence of conservation of energy

3 derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in series

4 use the formula for the combined resistance of two or more resistors in series

5 derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in parallel

6 use the formula for the combined resistance of two or more resistors in parallel

7 use Kirchhoff's laws to solve simple circuit problems

10.3 Potential dividers

Candidates should be able to:

1 understand the principle of a potential divider circuit

2 recall and use the principle of the potentiometer as a means of comparing potential differences

3 understand the use of a galvanometer in null methods

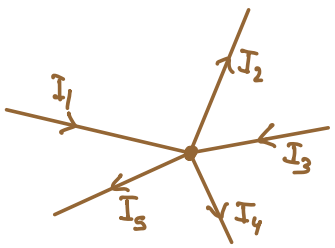
4 explain the use of thermistors and light-dependent resistors in potential dividers to provide a potential difference that is dependent on temperature and light intensity

KIRCHHOFF'S LAWS:-

(a) Kirchhoff's first law:-

Statement: The algebraic sum of all the currents entering a junction is equal to the algebraic sum of currents leaving that junction or node.

Mathematical form:-



$$\Sigma I_{enter} = \Sigma I_{leave}$$

$$I_1 + I_3 = I_2 + I_4 + I_5$$

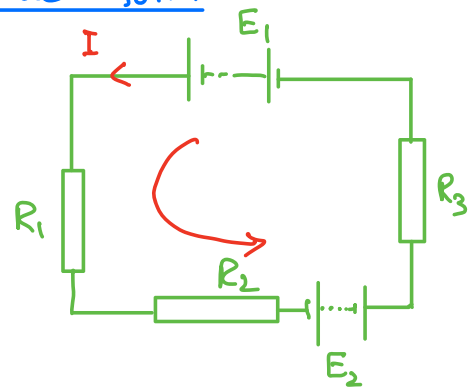
Note: Since current is the flow of charge carriers, so total charge carriers which flow to a junction must be equal to the charge carriers leaving the junction. Hence K 1st law is based upon conservation of charge.

(b) Kirchhoff's second law:-

Statement: In a closed loop / circuit, the algebraic sum of all the emfs of sources must be equal to sum of potential differences

across components in that loop.

Mathematical form:



$$\Sigma \text{ e.m.f} = \Sigma \text{ p.d.}$$

$$E_1 + E_2 = IR_1 + IR_2 + IR_3$$

$$E_1 + E_2 = V_1 + V_2 + V_3$$

Note: K 2nd law is based upon the principle of conservation of energy.

Loop Analysis:

Hint:

(1) e.m.fs of source are
(a) added if they draw current in one direction along the loop and
(b) subtracted if currents drawn by them are against the assumed loop.

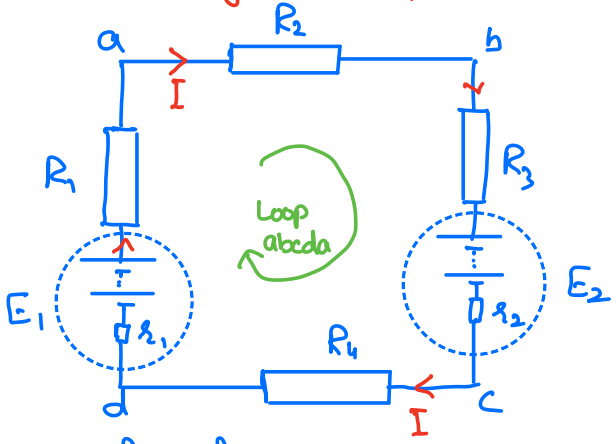
(2) Put +ve sign with current if along the loop and -ve if against the loop.

(3) Mark any direction of current by following Kirchhoff's first law and these directions of

current must be independent of polarity of an e.m.f source.

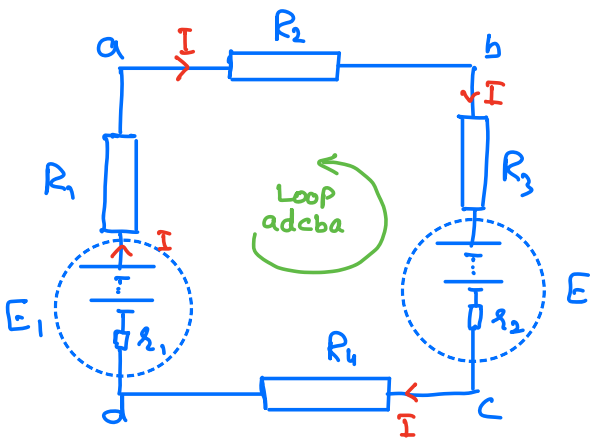
(4) The direction of current once marked must not be changed through out analysis.

(a) Single loop Analysis:



Eq. for loop abcda:

$E_1 - E_2 = IR_1 + IR_2 + IR_3 + Ir_2 + IR_4 + Ir_1$ —— (1)



Voltage equation for loop adcba

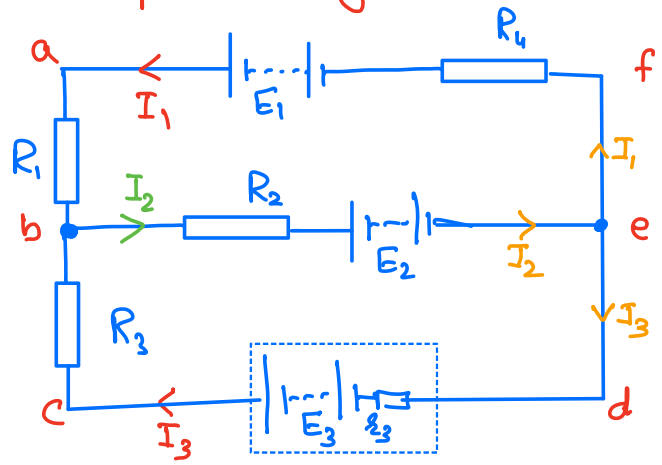
$-E_1 + E_2 = -IR_1 - Ir_1 - IR_4 - Ir_2 - IR_3 - IR_2$

$E_1 - E_2 = IR_1 + Ir_1 + IR_4 + Ir_2 + IR_3 + IR_2$ —— (2)

Eq. (1) = Eq. (2)

(b) Multiple loop Analysis:-

Q. 1)



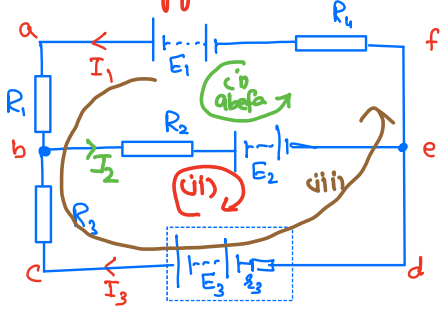
(a) Mark the direction of current I_2 in branch be.

(b) Using Kirchhoff's first law, write current eq.

i) for junction b $\quad I_1 + I_3 = I_2$

ii) for junction e $\quad I_2 = I_1 + I_3$

(c) Write voltage eq. using Kirchhoff's second law for loop



i) abefa

$$E_1 - E_2 = I_1 R_1 + I_2 R_2 + I_1 R_4$$

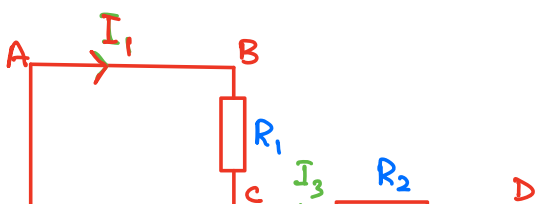
ii) cbedc

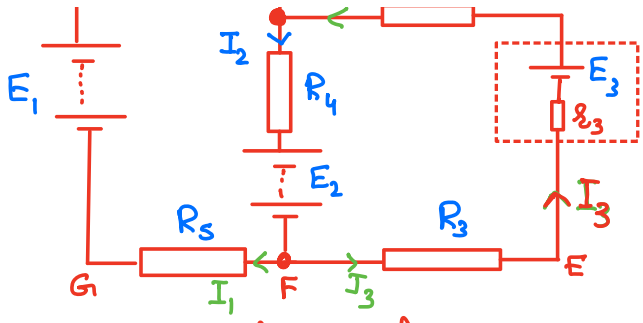
$$E_3 - E_2 = I_3 R_3 + I_2 R_2 + I_3 r_3$$

iii) abcdefa

$$E_1 - E_3 = I_1 R_1 - I_3 R_3 - I_3 r_3 + I_1 R_4$$

Q. 2)





(a) Mark the direction of current I_2 in branch CF.

(b) Identify the old e.m.f. source in above circuit.

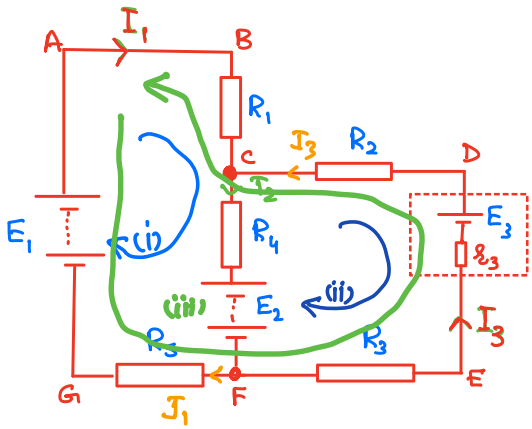
E_3 due to internal resistance shown in it.

(c) Write current equation for junction

(i) C $\quad I_1 + I_3 = I_2$

(ii) F $\quad I_2 = I_1 + I_3$

(d) Write voltage eq. for loop



(i) ABCFGA

$E_1 - E_2 = I_1R_1 + I_2R_4 + I_1R_5$

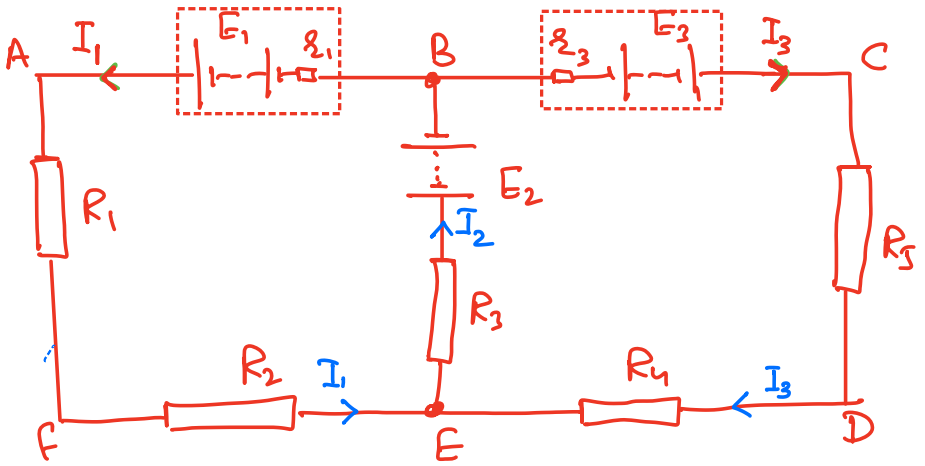
(ii) CDEFC

$E_2 - E_3 = -I_3R_2 - I_3\varepsilon_3 - I_3R_3 - I_2R_4$

(iii) AGFEDCBA

$-E_1 + E_3 = -I_1R_5 - I_3R_3 + I_3\varepsilon_3 + I_3R_2 - I_1R_1$

Q.3)



(a) Mark and label direction of current in branch

(i) ED I_3 from D to E

(ii) BE I_2 from E to B by Kirchhoff's first law

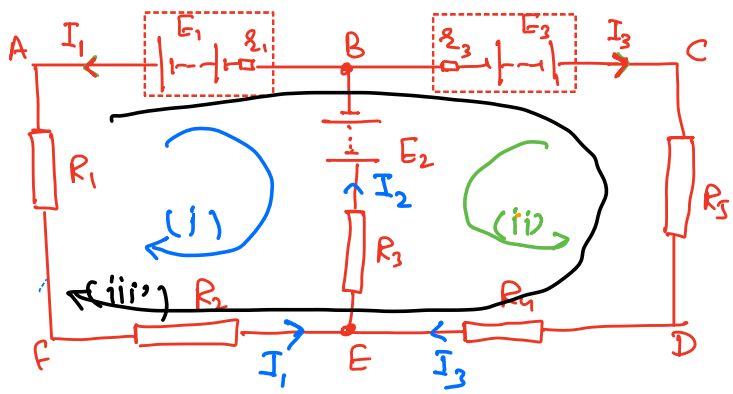
(b) Identify the new e.m.f source.

E_2 because no internal resistance is shown

(c) Write current equation for junction

(i) B $I_2 = I_1 + I_3$

(ii) E $I_1 + I_3 = I_2$



(d) Write voltage equation for loop in ABEFA

$$-E_1 + E_2 = -I_2 R_3 - I_1 R_2 - I_1 R_1 - I_1 \mathcal{R}_1$$

(ii) CBEDC

$$E_2 - E_3 = -I_2R_3 - I_3R_4 - I_3R_5 - I_3\mathcal{E}_3$$

(iii) ABCDEFA

$$E_3 - E_1 = I_3\mathcal{E}_3 + I_3R_5 + I_3R_4 - I_1R_2 - I_1R_1 - I_1\mathcal{E}_1$$

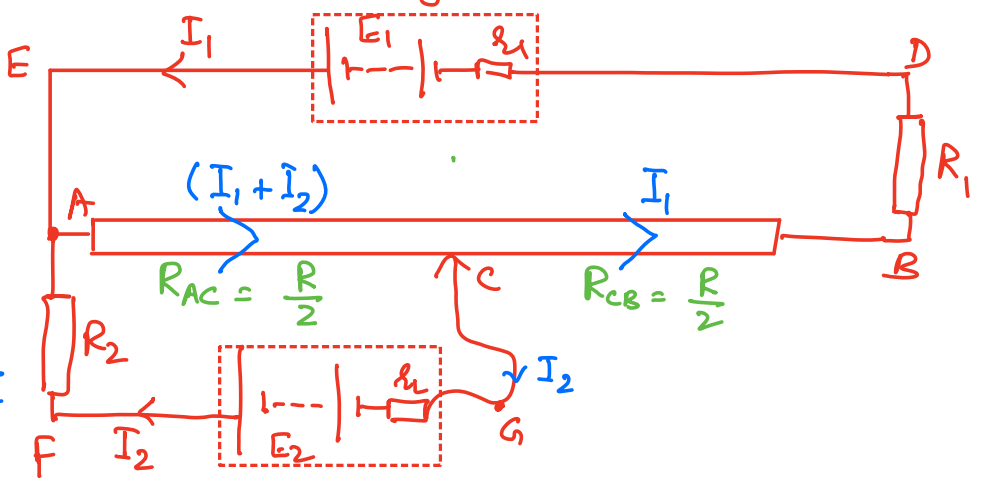
Q4) AB is a uniform wire of resistance R. C is the mid-point of AB as shown.

$R = \rho\frac{L}{A}$

$R \propto L$

$\frac{R}{2} = \frac{L}{2}$

$R_{AC} = R_{CB} = \frac{R}{2}$



(a) Mark and label interms of I_1 and I_2, the direction of current in branch

i) AC $(I_1 + I_2)$ from A to C

ii) CB I_1 from C to B

(b) Write voltage equation interms of I_1 and I_2 for loop

(i) EACBDE

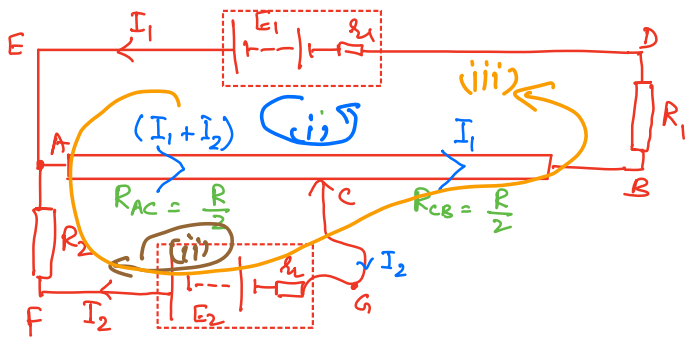
$$E_1 = (I_1 + I_2)\frac{R}{2} + I_1\frac{R}{2} + I_1 R_1 + I_1 \xi_1$$

(ii) FACGF

$$E_2 = I_2 R_2 + (I_1 + I_2)\frac{R}{2} + I_2 \xi_2$$

(iii) EAFGCBDE

$$E_1 - E_2 = -I_2 R_2 - I_2 \xi_2 + I_1\frac{R}{2} + I_1 R_1 + I_1 \xi_1$$



Difference between Electromotive Force (*e.m.f*) & Potential Difference (*p.d.*):

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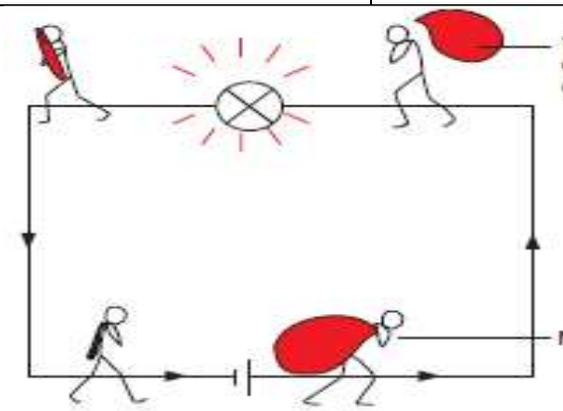
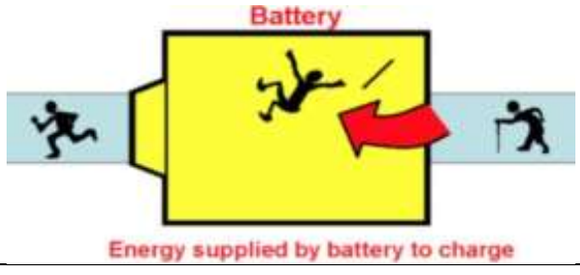
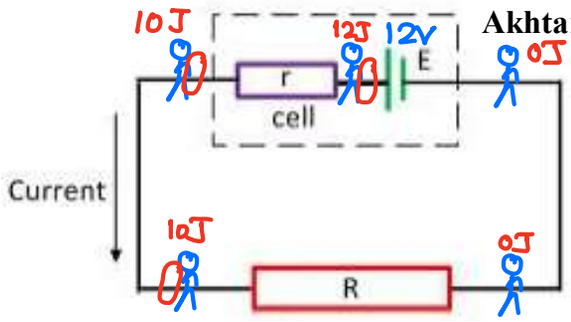
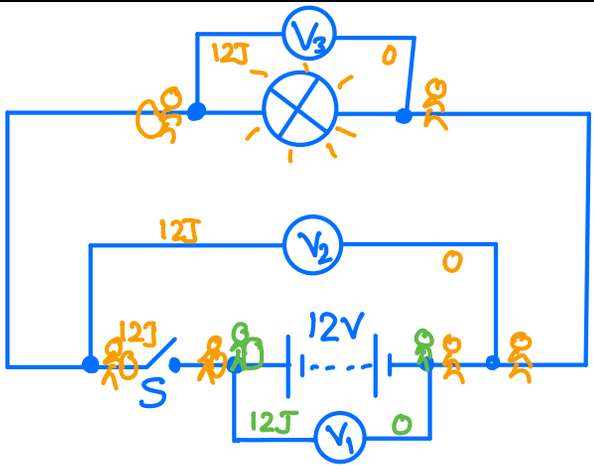
	e.m.f (E)	*p.d. (V)*
Definition 1	Any form of energy converted into electrical energy per unit charge is e.m.f.	Electrical energy converted into any other form of energy per unit charge is p.d. or voltage
	 $V = \frac{W}{Q}$ $12V = \frac{12J}{1C}$	
	$E = \frac{\text{Any form to electrical energy}}{\text{charge}}$ $V = \frac{W}{Q}$	$\text{p.d} = \frac{\text{Electrical to any other form}}{\text{charge}}$
	e.m.f is always of a source e.g cell, battery, thermocouple, Solar cell, generator etc  Energy supplied by battery to charge	p.d. is always across a component or appliance eg, electrical heater, fridge, vacuum cleaner, filament lamp etc.



Definition 2	It is the amount of energy dissipated per unit charge to move in a complete circuit or loop $E = I(R + r)$ $E = IR + Ir$ $E = IR + V$	It is the amount of energy dissipated per unit charge to move in an external load/ circuit / appliance $V = IR$



	If switch S is opened $V_1 = 12V$ and measure e.m.f of source while $V_2 = V_3 = 0$	If switch S is closed $V_1 = V_2 = V_3 = 12V$ and all measure p.d. across filament lamp
	A voltmeter connected across a source measures its emf if it does not draw any current to external circuit.	A voltmeter connected anywhere measures p.d. across a component if current flows through that circuit.

Q.1 An electrical quantity is defined as 'the energy Converted by a source in driving unit charge round a complete circuit. What is this quantity called?

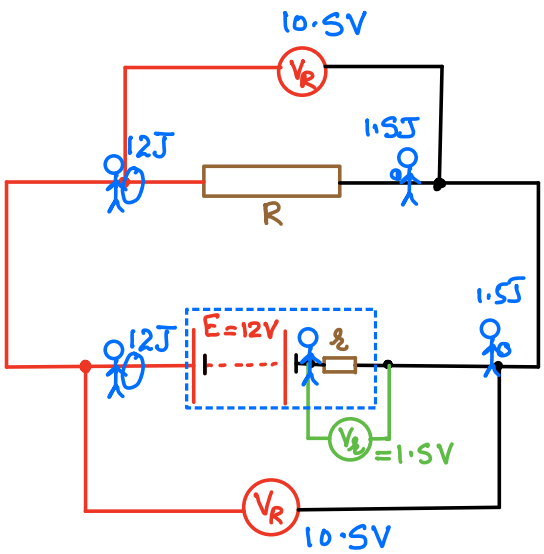
A current **B** potential difference **C** electromotive force **D** power

[redacted]

Terminal p.d. :- It is the p.d. between terminals of a cell / battery when a current is being delivered.

Lost voltage :- It is the p.d. across internal resistance of source.

Concept :-



V_R – Terminal p.d.

V_r – Lost voltage

By Kirchhoff's second law i.e conservation of energy principle

$$E = V_R + V_r$$

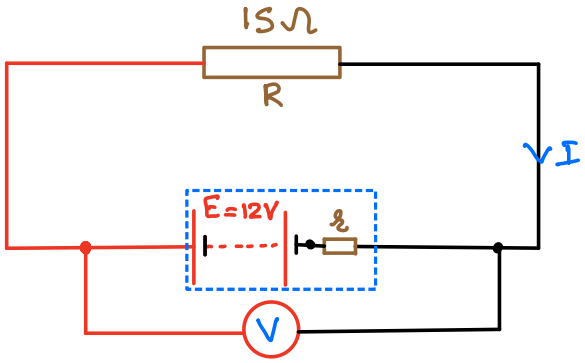
Note :-

1- The terminal p.d. (V_R) is always less than the e.m.f (E) of source when power supply delivers a current. This is because of the p.d. across the internal resistance as Lost voltage.

2- Lost voltage = current x Internal resistance

$$V_r = Ir$$

Q) If voltmeter connected records 9.0V. Calculate



i) current (I) in the circuit

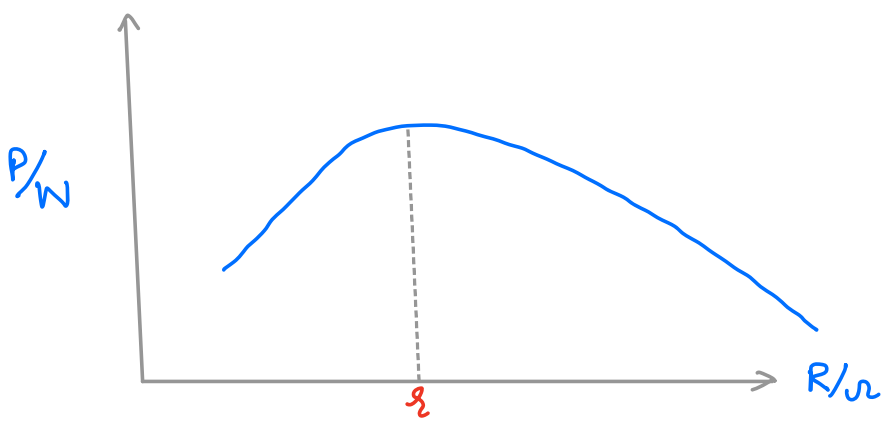
$$V = IR$$
$$9.0 = I(15) \Rightarrow I = 0.60\,A$$

ii) internal resistance of the source

$$E = V_r + V_R$$
$$E = Ir + V_R$$
$$12 = (0.60)r + 9.0$$
$$r = \frac{12 - 9.0}{0.60} \Rightarrow \boxed{r = 5\Omega}$$

(3) Power dissipated in a circuit is maximum if

internal resistance of source = External resistance of load



Circuit Symbols:

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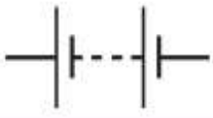
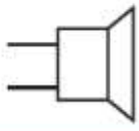
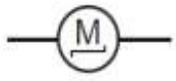
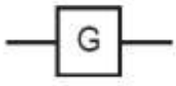
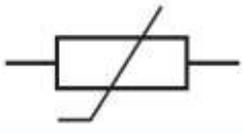
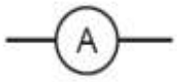
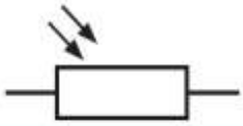
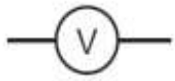
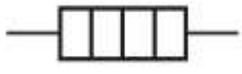
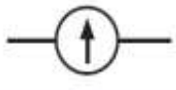
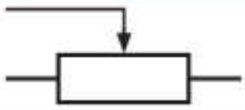
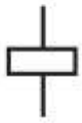
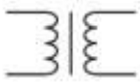
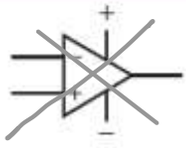
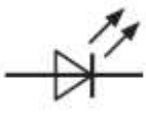
cell		switch	
battery of cells	or 	earth	
power supply		electric bell	
a.c. power supply		buzzer	
junction of conductors		microphone	
lamp		loudspeaker	
fixed resistor		motor	
variable resistor		generator	
thermistor		ammeter	
light-dependent resistor		voltmeter	
heater		galvanometer	

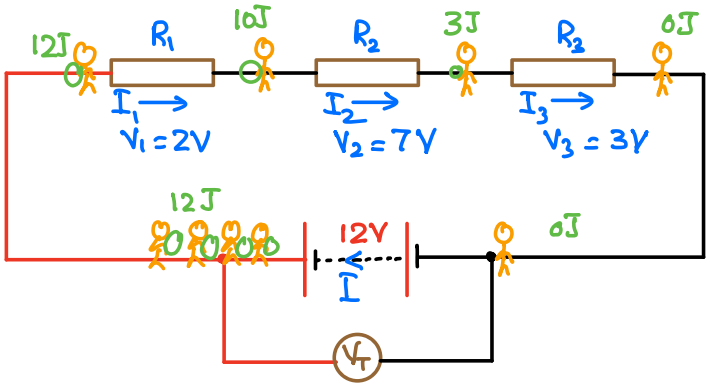
potentiometer		oscilloscope	
relay coil		antenna	
transformer		capacitor	
diode		~~operational amplifier~~	
light-emitting diode			

Combination of Resistors:-

(a) Resistances in series:-

Identification:- Single path for the flow of current i.e. one way traffic for flow of charge carriers.

Suppose $R_1 < R_3 < R_2$



Properties:

1- **Current:** Same current through each resistor

$$I = I_1 = I_2 = I_3$$

2- **P.d / voltage:-** P.d vary depending upon resistance of resistor i.e $(P.d)\uparrow$ if $(R/\Omega)\uparrow$ or vice versa

But by Kirchhoff's voltage law

$$V = V_1 + V_2 + V_3$$

3- **Total resistance:-**

$$V = V_1 + V_2 + V_3$$

But $V = IR$

$$IR = I_1R_1 + I_2R_2 + I_3R_3$$

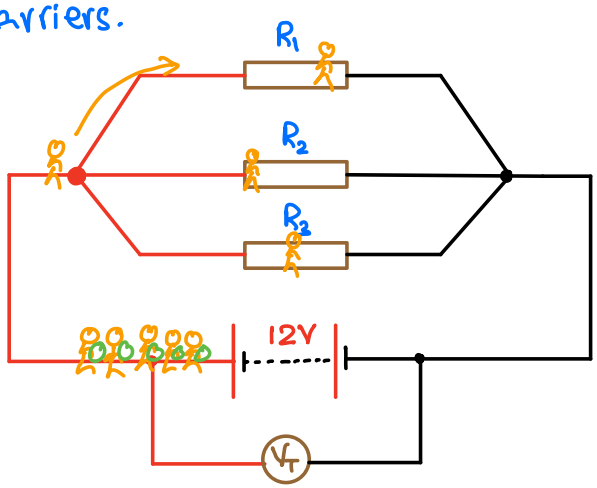
$$IR = IR_1 + IR_2 + IR_3 \quad \{I = I_1 = I_2 = I_3\}$$

$$\boxed{R = R_1 + R_2 + R_3}$$

(b) Resistances in parallel:-

Identification:- Several / multiple paths for the flow of charge carriers.

Suppose $R_1 < R_3 < R_2$



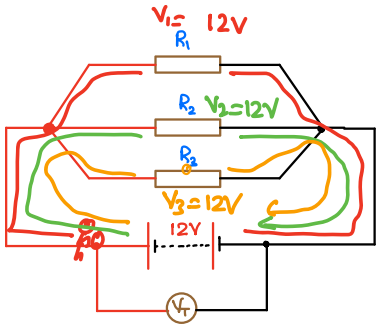
$I = \frac{ne}{t}$

Properties:

i) Current: Different current flows through each resistor what ever its resistance is ie I↓ if R↑ or vice versa, but by Kirchhoff's first law

$$I = I_1 + I_2 + I_3$$

ii) Voltage / P.d.:-



P.d. across each resistor is same and is independent of value of resistance. This is due to the availability of single e.m.f source and a resistor with in a loop.

$$V = V_1 = V_2 = V_3$$

(iii) **Total Resistance :-**

Since, $I = I_1 + I_2 + I_3$

But $I = \frac{V}{R}$

$$\frac{V}{R_T} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$$

Since in parallel, $V = V_1 = V_2 = V_3$

$$\frac{V}{R_T} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\boxed{\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Therefore, total resistance in parallel is always less than least resistance of a resistor connected in the combination.

Total Resistance of two resistors in parallel:-

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_T} = \frac{R_2 + R_1}{R_1 R_2} \Rightarrow R_T = \frac{R_1 R_2}{R_1 + R_2}$$

$$\boxed{\text{Total resistance} = \frac{\text{Product of resistances}}{\text{Sum of resistances}}}$$

For n - identical resistors, each of resistance R

(i) In series, $R_T = nR$

(ii) In parallel, $R_T = \frac{R}{n}$

Measuring Devices:

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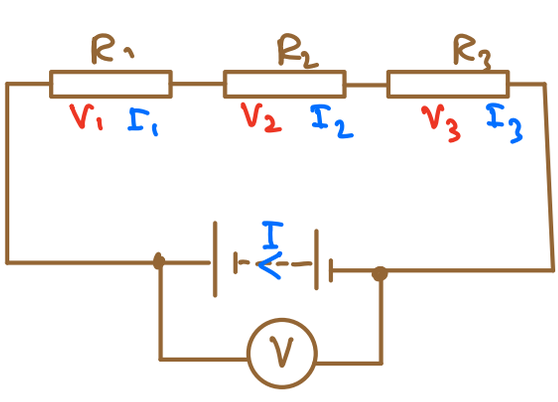
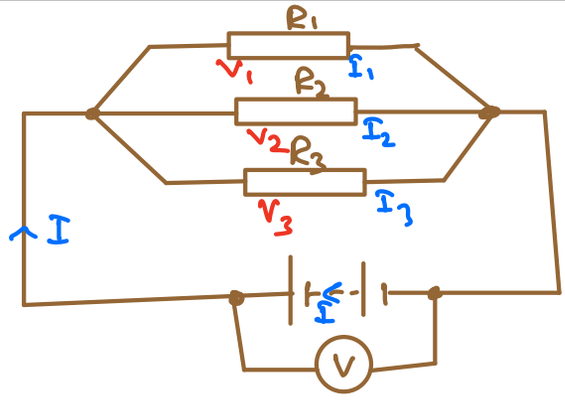
	Ammeter	Voltmeter
Purpose	Measure current in a component or in a circuit	Measure e.m.f of a source or p.d. across an appliance
Symbol	—(A)—	—(V)—
Connectivity	Series combination	Parallel combination
Note	Internal Resistance of an Ammeter is zero/negligible. So circuit is shorted if it is connected in parallel combination	Internal Resistance of voltmeter is infinite. Hence circuit becomes opened if it is connected in series combination

Combination of Resistors:

Combination	Series combination	Parallel combination
Circiut		
Identification	Single path for the flow of current	Several paths for the flow of current
Current	Same amount of current flows through each resistor $I = I_1 = I_2 = I_3$	Current which flows through each resistor is different as per its resistance ie $I \downarrow R \uparrow$ but by Kirchhoff's first law $I = I_1 + I_2 + I_3$
Voltage (pd)	P.d. across each resistor is diffelent depending upon its resistance ie $V \uparrow$ if $R \uparrow$. By Kirchhoff's second law	P.d across each resistor is same due to availability of single emf source and a load in a loop. By Kirchhoff's second law

	$V = V_1 + V_2 + V_3$	$V = V_1 = V_2 = V_3$
Total Resistance	$V = V_1 + V_2 + V_3$ $IR_T = I_1R_1 + I_2R_2 + I_3R_3$ $IR_T = IR_1 + IR_2 + IR_3$ $R_T = R_1 + R_2 + R_3$	$I = I_1 + I_2 + I_3$ $\frac{V}{R_T} = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}$ $\frac{V}{R_T} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$ $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

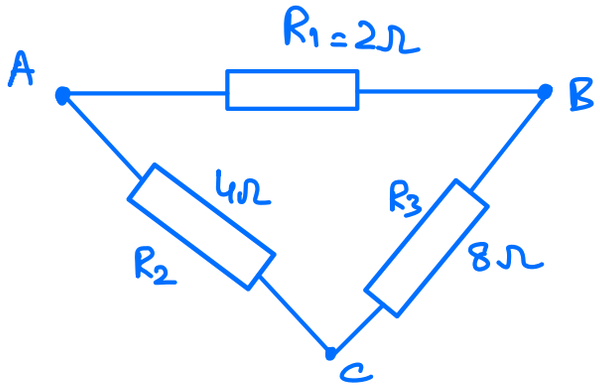
Total Resistance of two resistors in parallel:

$$\text{Total resistance} = \frac{\text{Product of resistances}}{\text{Sum of resistances}}$$

Hint to attempt questions:

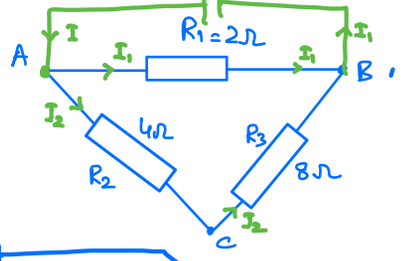
Always assume that an e.m.f source (battery) is connected across terminals between which an effective resistance is to be calculated.

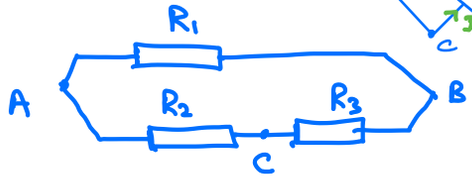
Q1)



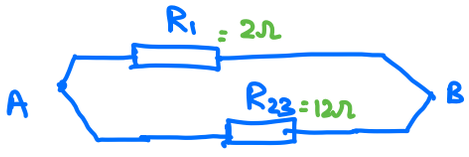
Calculate total resistance b/w

(i) AB



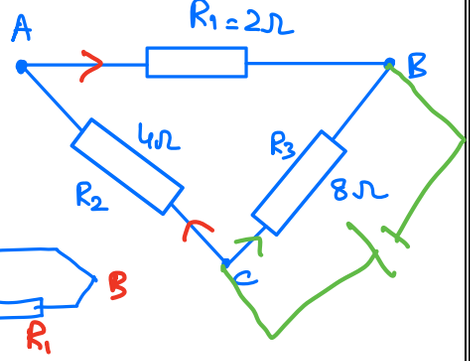


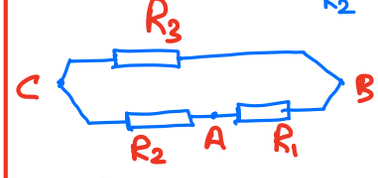
$R_{23} = R_2 + R_3 = 4 + 8 = 12\Omega$



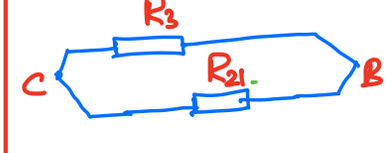
$$R_{AB} = \frac{R_1 R_{23}}{R_1 + R_{23}} = \frac{(2)(12)}{2+12} = 1.7\Omega$$

(ii) BC





$R_{21} = 4 + 2 = 6\Omega$



$$R_{CB} = \frac{(R_3)(R_{21})}{R_3 + R_{21}}$$

$$R_{CB} = \frac{(8)(6)}{8+6} = 3.43\Omega$$

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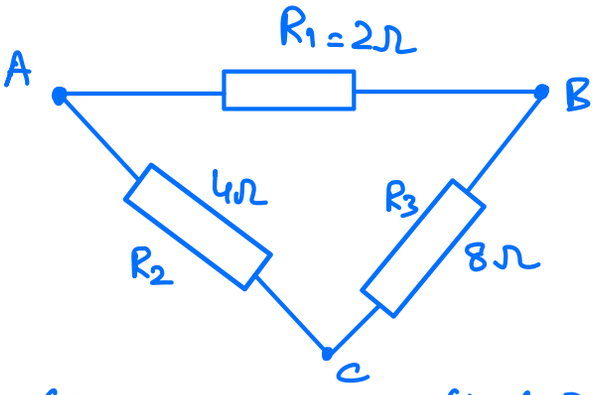
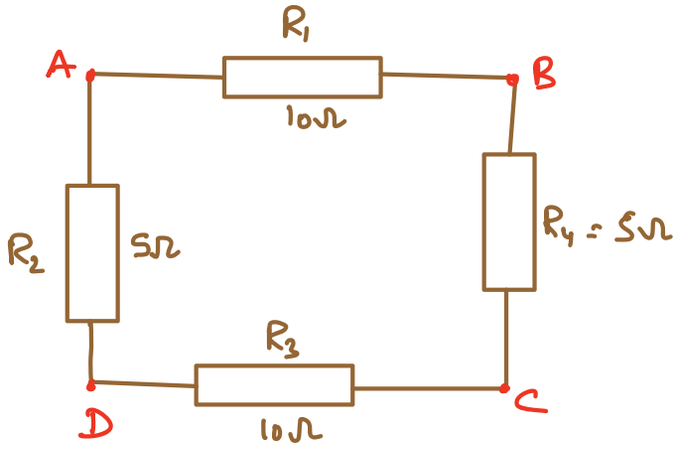
(iii)

$R_{AC} = ?$



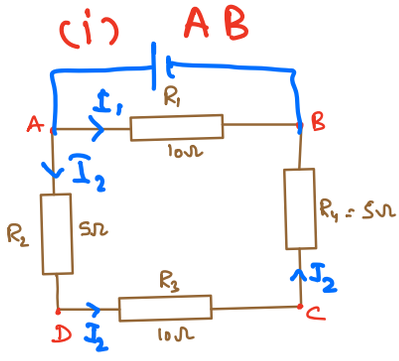
$$R_{AC} = \frac{(R_2)(R_{13})}{R_2 + R_{13}} = \frac{(4)(10)}{4+10} = \frac{40}{14} = 2.86\Omega$$

Q)



Calculate total resistance b/w

(i) AB

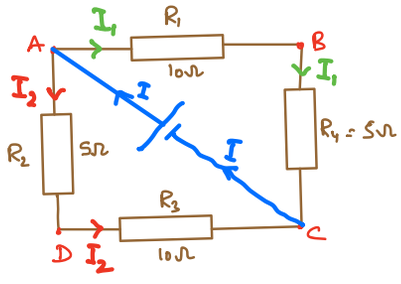


$$R_{234} = 5+10+5 = 20\Omega$$

$$R_{AB} = \frac{(R_1)(R_{234})}{R_1 + R_{234}} = \frac{(10)(20)}{10+20}$$

$$= \frac{200}{30} = 6.67\Omega$$

(ii) AC



$$R_{14} = 10+5 = 15\Omega$$

$$R_{23} = 5+10 = 15\Omega$$

$$R_{AC} = \frac{(R_{14})(R_{23})}{R_{14} + R_{23}} = \frac{(15)(15)}{15+15}$$

$$= \frac{225}{30} = 7.5$$

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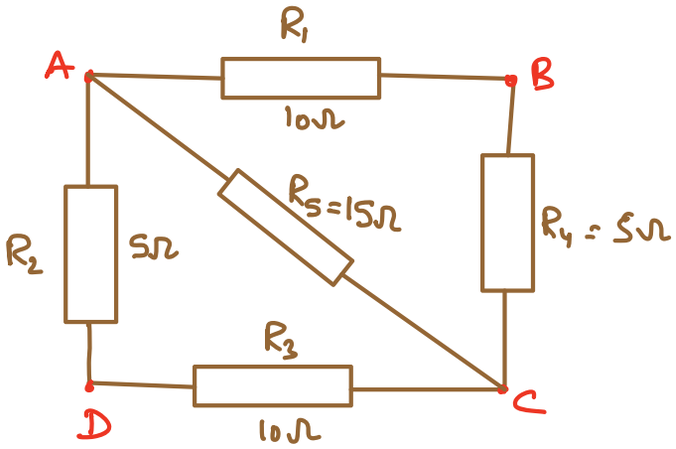
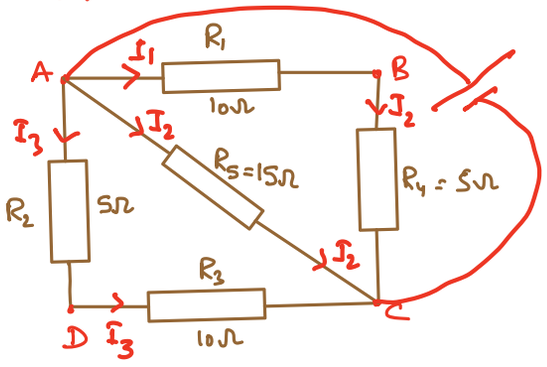
Q)



Calculate total resistance between

(i) AC [1]



$R_{14} = 10 + 5 = 15Ω$

$R_{23} = 5 + 10 = 15Ω$

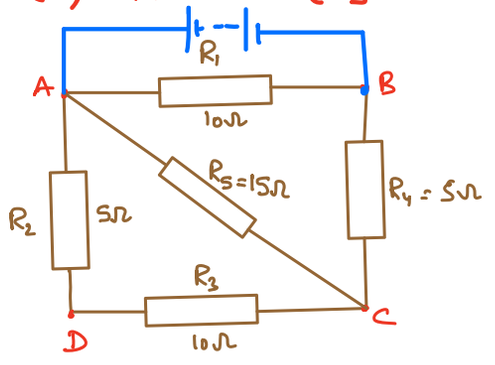
$R_5 = 15Ω$

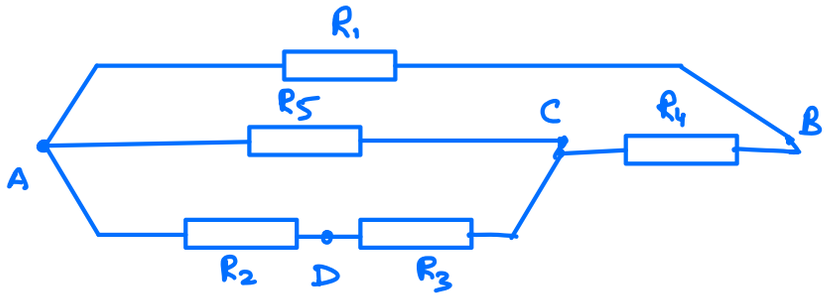
$$\frac{1}{R_{AC}} = \frac{1}{R_{14}} + \frac{1}{R_5} + \frac{1}{R_{23}}$$

$$\frac{1}{R_{AC}} = \frac{1}{15} + \frac{1}{15} + \frac{1}{15} = \frac{3}{15} = \frac{1}{5}$$

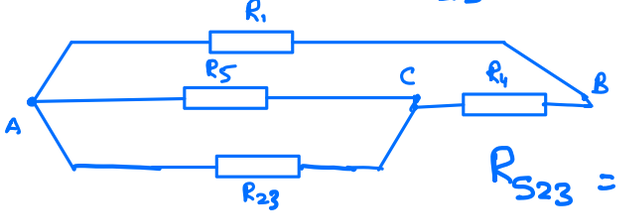
$$R_{AC} = \frac{5}{1} \Rightarrow \boxed{R_A = 5.0Ω}$$

(ii) AB [2]

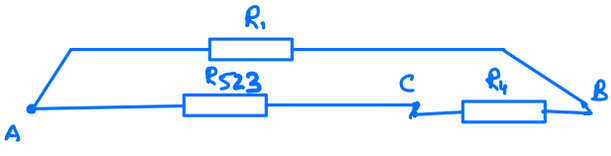




$R_{23} = R_2 + R_3 = 5 + 10 = 15Ω$



$$R_{523} = \frac{(15)(15)}{15+15} = \frac{225}{30} = 7.5Ω$$

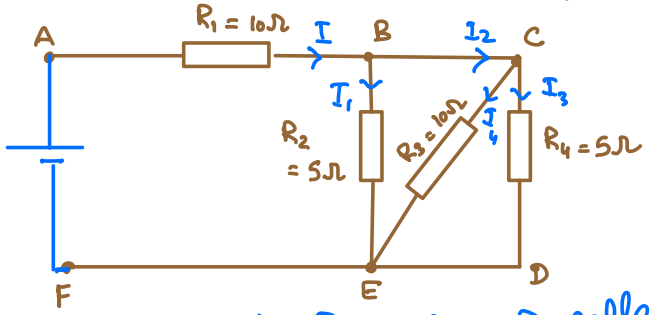


$R_{4523} = R_{523} + R_4 = 7.5 + 5 = 12.5Ω$

$$R_{AB} = \frac{(R_1)(R_{4523})}{R_1 + R_{4523}} = \frac{(10)(12.5)}{10+12.5} = 5.56\,Ω$$

Q) Calculate the total resistance of following circuits.

(i)



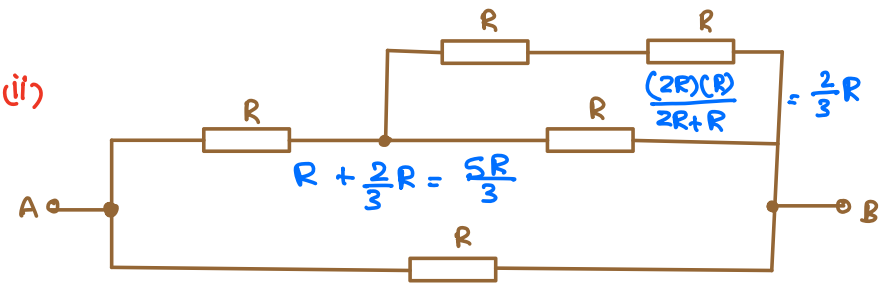
R_2, R_3 and R_4 are parallel to each other

$$\frac{1}{R_{234}} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} \Rightarrow \frac{1}{R_{AF}} = \frac{1}{5} + \frac{1}{10} + \frac{1}{5} = \frac{2+1+2}{10}$$

$$R_{234} = \frac{10}{5} = 2\Omega$$

$$R_{AF} = R_1 + R_{234} = 10 + 2 = 12\Omega$$

(ii)



$$R_{AB} = \frac{(R)\left(\frac{5R}{3}\right)}{R + \frac{5R}{3}} = \frac{\frac{5R^2}{3}}{\frac{8R}{3}} = \frac{5R}{8}$$

Types of Circuit:

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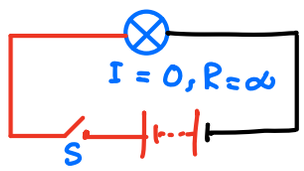
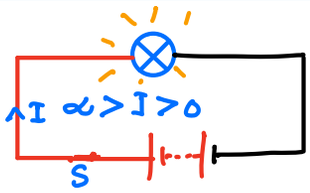
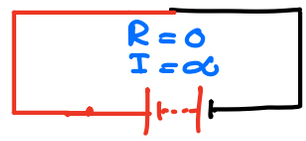
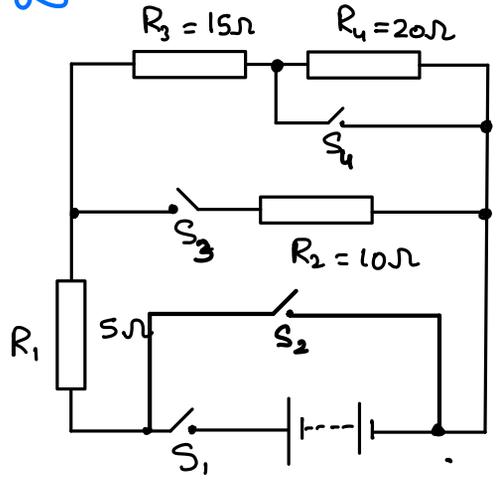
Type	Open Circuit	Closed Circuit	Short Circuit
Arrangemet			
Current/A	No current flows through circuit $I = 0$	current flows through circuit $\infty > I > 0$	Infinite current flows $I = \infty$
Resistance/Ω	$R = \infty$	$\infty > R > 0$	$R = 0$
	Energy of the source is not converted into any other form	Energy of the source is converted into other form in the load.	Circuit with out any load. very high current flows which dissipate heat energy and may lead to fire.

Q) Identify the circuit



Switch	S_1	S_2	S_3	S_4	Circuit
	open	open	open	open	opened
	open	closed	closed	closed	opened
	closed	open	closed	open	closed
	closed	closed	open	closed	shorted
	closed	closed	closed	open	shorted
	closed	closed	closed	closed	shorted

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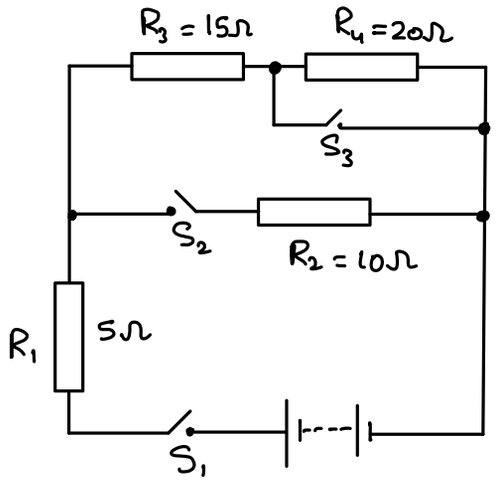
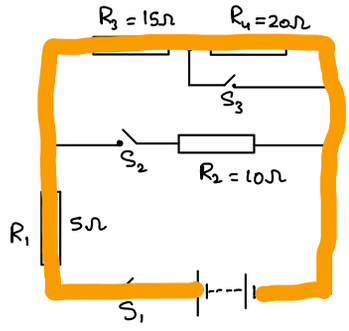
Q)



Calculate the total resistance if

(i) switch S_1 is closed, S_2 and S_3 are opened.

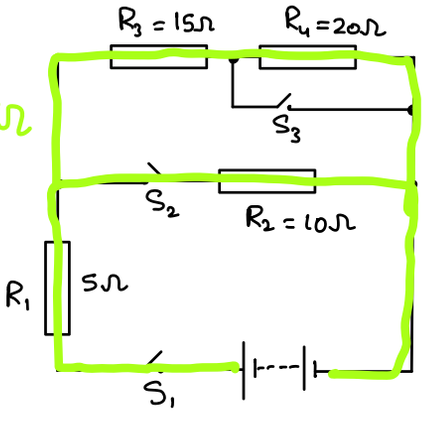
$$R = R_1 + R_3 + R_4$$
$$= 5 + 15 + 20$$
$$= 40\,\Omega$$



(ii) switch S_1 and S_2 are closed while S_3 is opened.

$$R_{34} = 15 + 20 = 35\,\Omega$$
$$R_{234} = \frac{(R_2)(R_{34})}{R_2 + R_{34}} = \frac{(10)(35)}{10+35} = 7.78\,\Omega$$

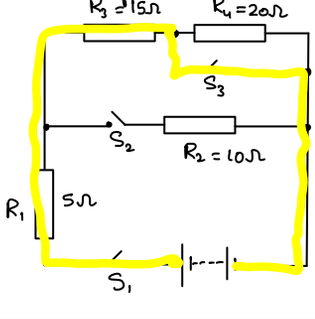
$$R_{1234} = R_1 + R_{234}$$
$$= 5 + 7.78 = 12.8\,\Omega$$



(iii) Switch S_1 and S_3 are closed while S_2 is opened.

Switch S_3 shorted Resistor R_4. So no current flows through R_4

$$R = R_1 + R_3 = 5 + 15 = 20\,\Omega$$



For Examiner's Use

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

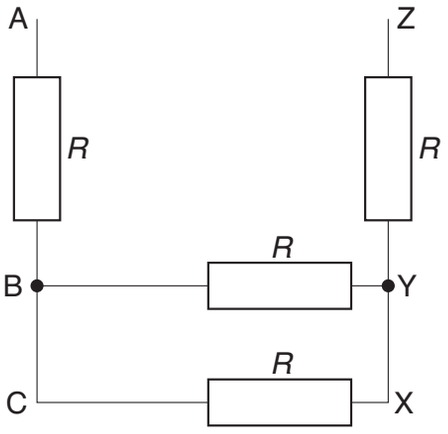
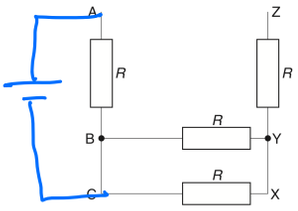


Fig. 7.1

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

(i) A and C,

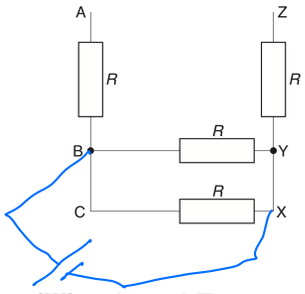


Path BC shorted branches BY and XC

$R_{AC} = R$

resistance = ... R ..... [1]

(ii) B and X,

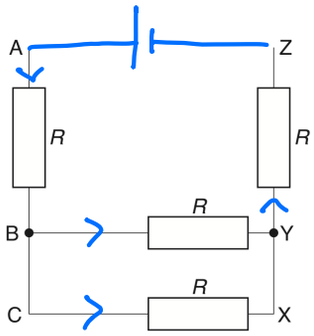


Both resistors in branches BY and CX are parallel to each other.

$\frac{(R)(R)}{R+R} = \frac{R^2}{2R}$

resistance = ... $\frac{R}{2}$ ..... [1]

(iii) A and Z.



$R_{AZ} = R + \frac{R}{2} + R$

$= \frac{5R}{2}$

resistance = ... $\frac{5R}{2}$ ..... [1]

7 **(a)** A network of resistors, each of resistance R, is shown in Fig. 7.1.

For Examiner's Use

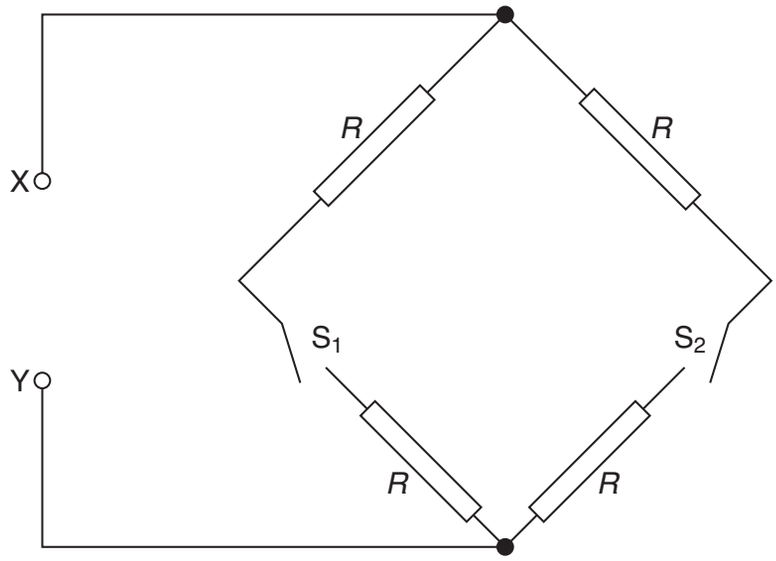


Fig. 7.1

Switches S_1 and S_2 may be 'open' or 'closed'.

Complete Fig. 7.2 by calculating the resistance, in terms of R, between points X and Y for the switches in the positions shown.

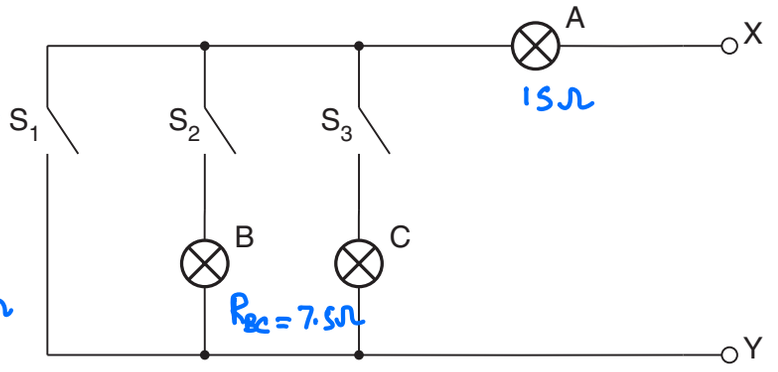
switch S_1	switch S_2	resistance between points X and Y
open	open	∞ (Infinite)
open	closed	$R + R = 2R$
closed	closed	$\frac{(2R)(2R)}{2R+2R} = R$

Fig. 7.2

[3]

For Examiner's Use

7 A circuit contains three similar lamps A, B and C. The circuit also contains three switches, S_1, S_2 and S_3, as shown in Fig. 7.1.



Identical resistor in parallel
$R_T = \frac{R}{n}$
$R_{BC} = \frac{15}{2} = 7.5\Omega$
$\frac{1}{R_{BC}} = \frac{1}{R_B} + \frac{1}{R_C}$ $R_{BC} = 7.5$
or $R_{BC} = \frac{R_B R_C}{R_B + R_C}$
$= \frac{(15)(15)}{15+15} = 7.5\Omega$

Fig. 7.1

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

Fig. 7.2 shows the readings of the ohm-meter for different switch positions.

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

$R_A = 15\Omega$
$R_A + R_B = 30\Omega \Rightarrow 15+15=30\Omega$
X but red answer should be $= 7.5 + 15 = 22.5\Omega$

Fig. 7.2

(a) Identify the faulty lamp, and the nature of the fault.

faulty lamp: C

nature of fault: lamp C is shorted [meter reading of 15Ω only provides resistance of lamp A. NO current flows through filament B] [2]

(b) Suggest why it is advisable to test the circuit using an ohm-meter that causes negligible current rather than with a power supply.

High current flows through the circuit which blows up the fuse of power supply unit. [1]

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For Examiner's Use

(c) Determine the resistance of one of the non-faulty lamps, as measured using the ohm-meter.

resistance = ... 15 ..... Ω [1]

(d) Each lamp is marked 6.0 V, 0.20 A.

Calculate, for one of the lamps operating at normal brightness,

(i) its resistance,

$$R = \frac{V}{I} = \frac{6.0}{0.20}$$

resistance = ... 30 ..... Ω [2]

(ii) its power dissipation.

$$P = I^2R$$

$$= (0.20)^2(30)$$

$$= 1.2\ W$$

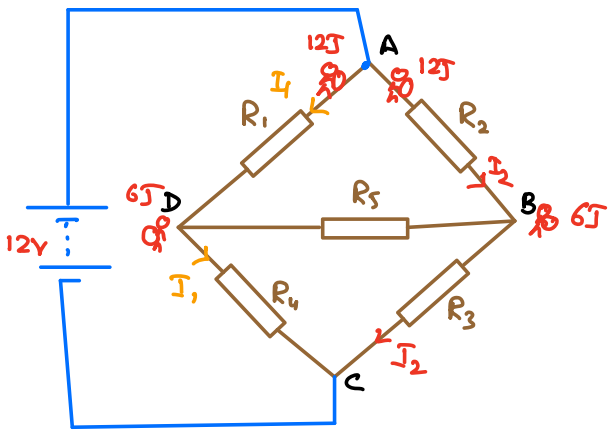
power = ... W [2]

(e) Comment on your answers to **(c)** and **(d)(i)**.

Filament of lamp is cold when measuring with ohm-meter and becomes warm due to supply current through it during calculation for normal brightness. [2]

Hint: No current flows through a resistor if p.d. across it is zero and therefore, its resistance is not taken into calculation.

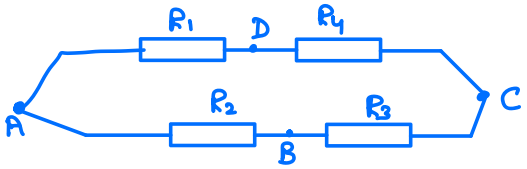
Q) If $R_1 = R_2 = R_3 = R_4 = R_5 = 5\Omega$, Calculate total resistance b/w AC.



Since potential at B = potential at D

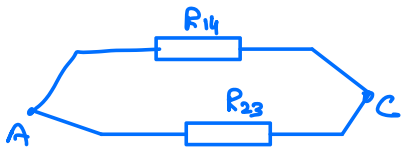
So p.d across BD = 0

Hence, no current flows through R_5 and its resistance is not considered.



$R_{14} = R_1 + R_4 = 5+5 = 10\Omega$

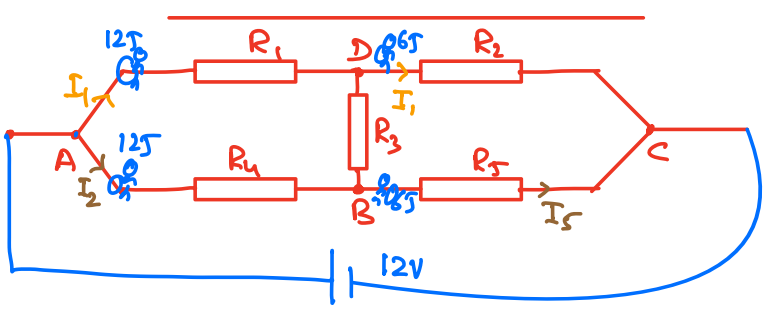
$R_{23} = R_2 + R_3 = 5+5 = 10\Omega$



$$R_{AC} = \frac{(R_{14})(R_{23})}{R_{14}+R_{23}} = \frac{(10)(10)}{10+10}$$

$$= \frac{100}{20} = 5\Omega$$

Q)



If $R_1 = R_2 = R_3 = R_4 = R_5 = 10\Omega$, Calculate R_{AC}

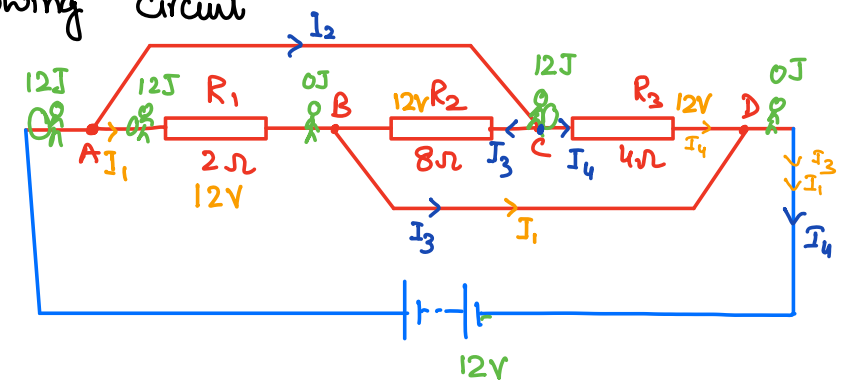
$$R_{12} = R_1 + R_2 = 10 + 10 = 20\Omega$$

$$R_{45} = R_4 + R_5 = 10 + 10 = 20\,\Omega$$

$$R_{AC} = \frac{(R_{12})(R_{45})}{R_{12} + R_{45}} = \frac{(20)(20)}{20+20} = \frac{400}{40} = 10\Omega$$

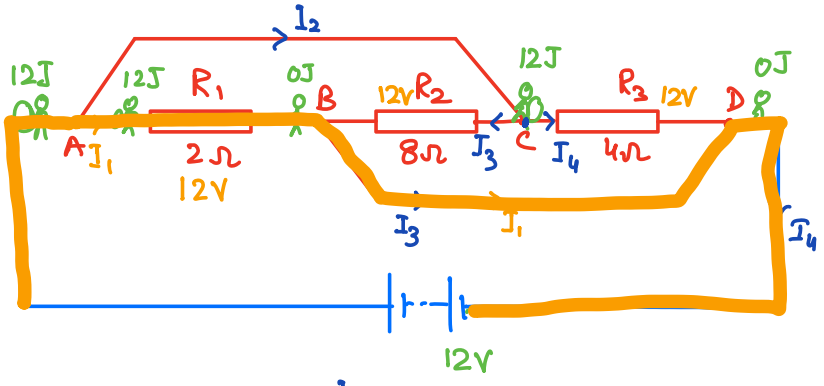
*A grade

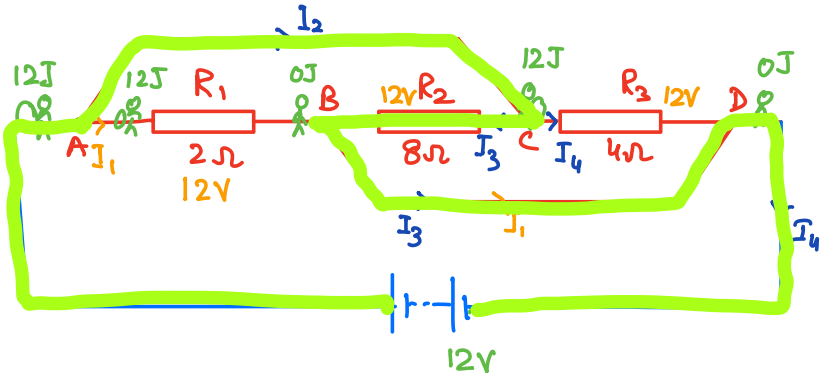
Q) Calculate the total resistance between AD of the following circuit

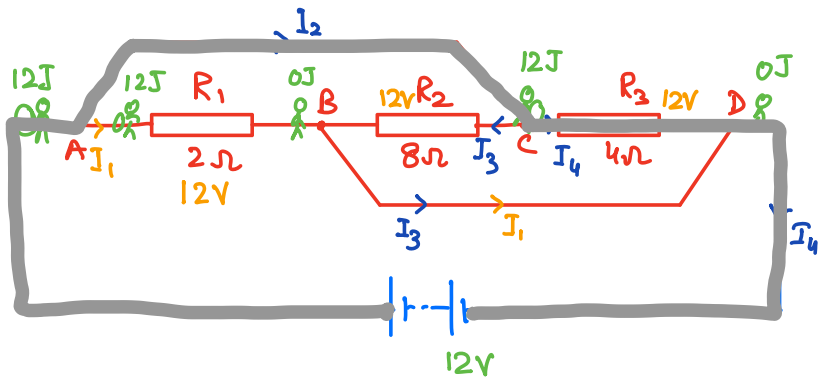


$$V = \frac{W}{Q}$$

$$12V = \frac{12J}{1C}$$







All given resistors are connected parallel to each other

$$\frac{1}{R_{AD}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{2} + \frac{1}{8} + \frac{1}{4}$$

$$\frac{1}{R_{AD}} = \frac{4 + 1 + 2}{8} = \frac{7}{8}$$

$$R_{AD} = \frac{8}{7} = 1.14\,\Omega$$

10.3 Potential dividers

Candidates should be able to:

1 understand the principle of a potential divider circuit

2 recall and use the principle of the potentiometer as a means of comparing potential differences

3 understand the use of a galvanometer in null methods

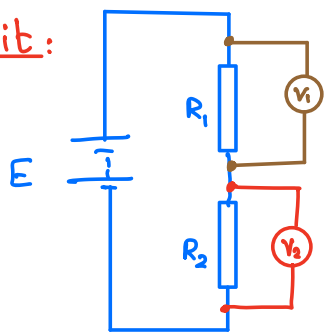
4 explain the use of thermistors and light-dependent resistors in potential dividers to provide a potential difference that is dependent on temperature and light intensity

Potential divider:-

Combination :- Series combination

Symbol :-

Circuit:



By Kirchhoff's second law

$$E = I(R_1 + R_2)$$

$$I = \frac{E}{R_1 + R_2}$$

Current through each resistor and emf source

$$I = \frac{E}{R_1 + R_2}$$

P.d. across R_1:

$$V_1 = I R_1$$

$$V_1 = \left(\frac{E}{R_1 + R_2}\right) R_1 \Rightarrow V_1 = \left(\frac{R_1}{R_1 + R_2}\right) E$$

P.d. across R_2:

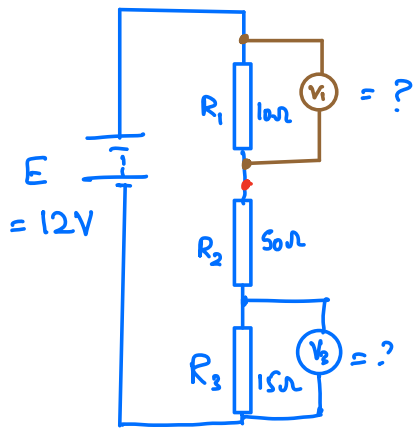
$$V_2 = I R_2$$

$$V_2 = \left(\frac{E}{R_1 + R_2}\right) R_2 \Rightarrow V_2 = \left(\frac{R_2}{R_1 + R_2}\right) E$$

Formula:

$$\text{output p.d} = \left(\frac{\text{Given resistance}}{\text{Total resistance}}\right)(\text{e.m.f of source})$$

Q)



$$V_1 = \left(\frac{R_1}{R_1 + R_2 + R_3}\right) E$$

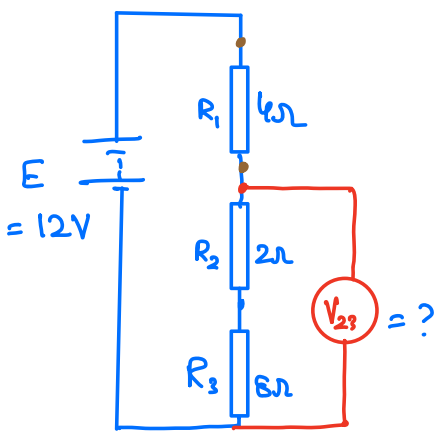
$$V_1 = \left(\frac{10}{10+50+15}\right)(12) = \frac{120}{75}$$

$$\boxed{V_1 = 1.6\,V}$$

$$V_3 = \left(\frac{R_3}{R_1 + R_2 + R_3}\right)(E)$$

$$= \left(\frac{15}{75}\right)(12) = 2.4V$$

Q)

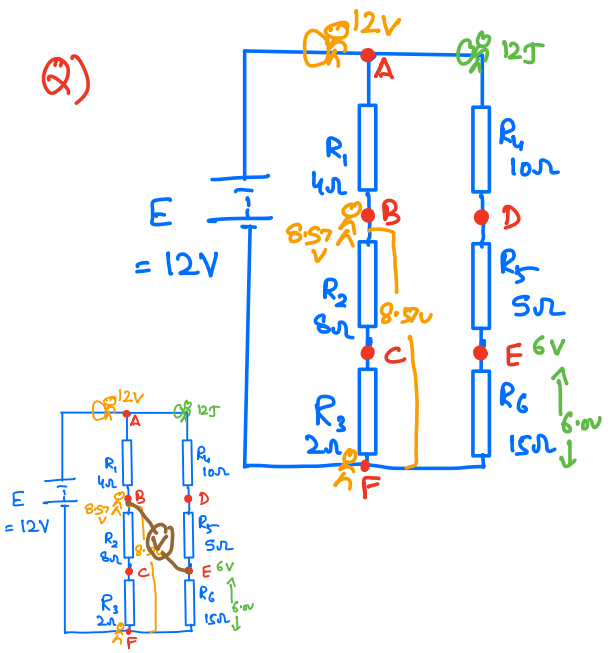


$$V_{23} = \left(\frac{R_{23}}{R_1 + R_2 + R_3}\right) E$$

$$= \left(\frac{10}{4+2+8}\right)(12)$$

$$= 8.57\,V$$

Q)



Calculate

(i) $$V_{BF} = \left(\frac{R_{23}}{R_1 + R_2 + R_3}\right) E$$

$$= \left(\frac{10}{4+8+2}\right)(12) = 8.57\,V$$

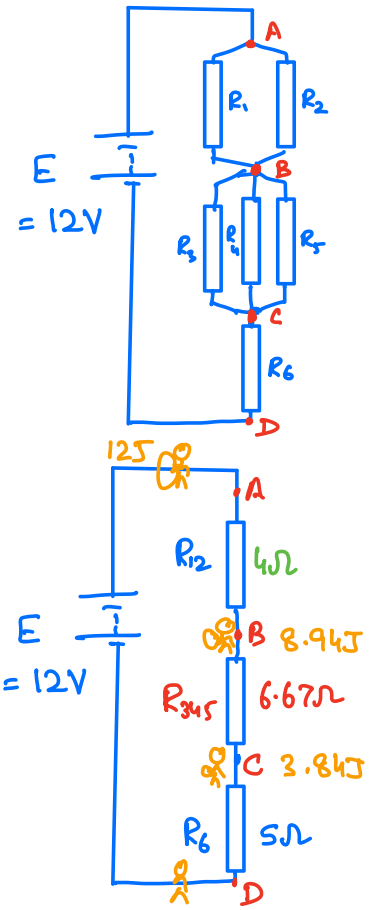
(ii) $$V_{EF} = \left(\frac{R_6}{R_4 + R_5 + R_6}\right)(E)$$

$$= \left(\frac{15}{10+5+15}\right)(12) = 6.0\,V$$

(iii) $$V_{BE} = V_{BF} - V_{EF}$$

$$= 8.57 - 6.0 = 2.57V$$

Q)



If $R_1 = R_2 = 8\Omega$

$R_3 = R_4 = R_5 = 20\Omega$

$R_6 = 5\Omega$

$R_T = \frac{R}{n}$

$R_{12} = \frac{8}{2} = 4\Omega$

$R_{345} = \frac{20}{3} = 6.67\Omega$

(a) Calculate p.d. across

(i) $V_{AB} = \left(\frac{R_{12}}{R_{12} + R_{345} + R_6}\right) E$

$= \left(\frac{4}{4 + 6.67 + 5}\right)(12) = 3.06V$

(ii) $V_{BC} = \left(\frac{R_{345}}{R_{12} + R_{345} + R_6}\right) E$

$= \left(\frac{6.67}{4 + 6.67 + 5}\right)(12) = 5.1V$

$V_{CD} = \left(\frac{R_6}{R_{12} + R_{345} + R_6}\right) E$

$= 3.84V$

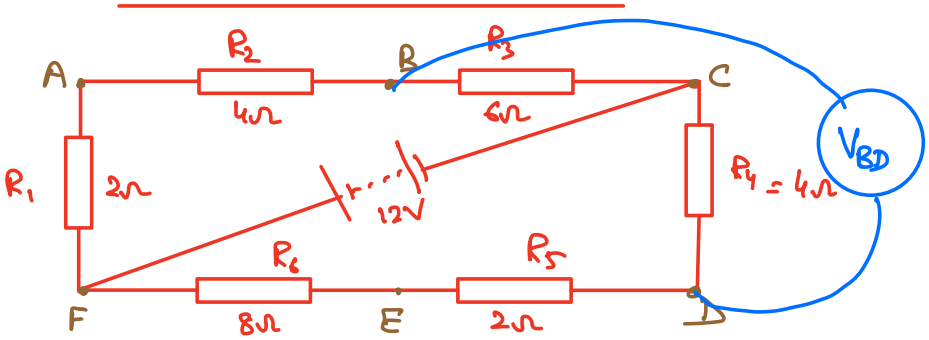
(b) State V_{CD}

$E = V_{AB} + V_{BC} + V_{CD}$

$12 = 3.06 + 5.1 + V_{CD}$

$V_{CD} = 3.84V$

Q)

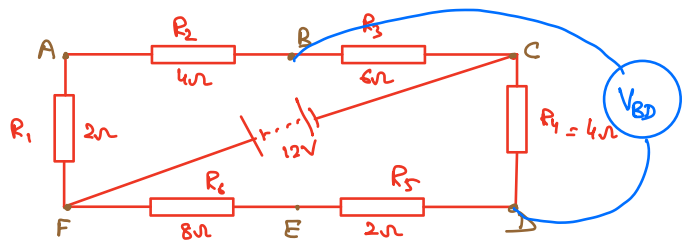


Calculate

(i) $V_{AC} = \left(\frac{R_{23}}{R_1 + R_2 + R_3}\right) E \Rightarrow V_{AC} = \left(\frac{10}{2+4+6}\right)(12) = 10V$

(ii) $V_{DC} = \left(\frac{R_4}{R_6 + R_5 + R_4}\right)(E) = \left(\frac{4}{8+2+4}\right)(12) = 3.4\,V$

(iii) V_{BD}



If C is the common reference point

$V_{BD} = V_{BC} - V_{DC}$

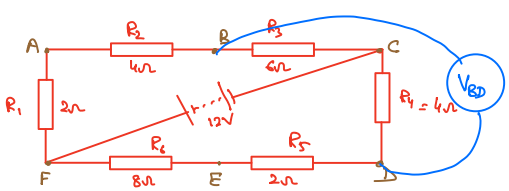
$V_{BD} = \left(\frac{R_3}{R_1+R_2+R_3}\right)E - \left(\frac{R_4}{R_6+R_5+R_4}\right)E$

$V_{BD} = \left(\frac{6}{12}\right)(12) - \left(\frac{4}{14}\right)(12)$

$= 6 - 3.4$

$V_{BD} = 2.6\,V$

OR



If junction F is the common reference point

$V_{BD} = V_{FB} - V_{FD}$

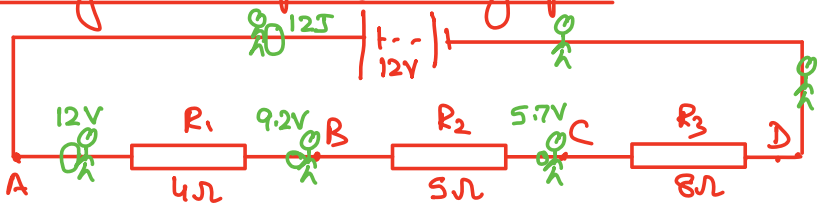
$V_{BD} = \left(\frac{R_{12}}{R_1+R_2+R_3}\right)E - \left(\frac{R_{6S}}{R_6+R_5+R_4}\right)E$

$V_{BD} = \left(\frac{6}{12}\right)(12) - \left(\frac{10}{14}\right)(12)$

$= 6 - 8.57$

$= -2.57 = -2.6\,V \Rightarrow V_{BD} = 2.6\,V$

Potential against position graph :-



(a) Calculate p.d across

(i) AB

$$V_{AB} = \left(\frac{R_1}{R_1+R_2+R_3}\right) E$$

$$V_{AB} = \left(\frac{4}{4+5+8}\right)(12)$$

$$= 2.8\,V$$

(ii) BC

$$V_{BC} = \left(\frac{R_2}{R_1+R_2+R_3}\right) E$$

$$V_{BC} = \left(\frac{5}{4+5+8}\right)(12)$$

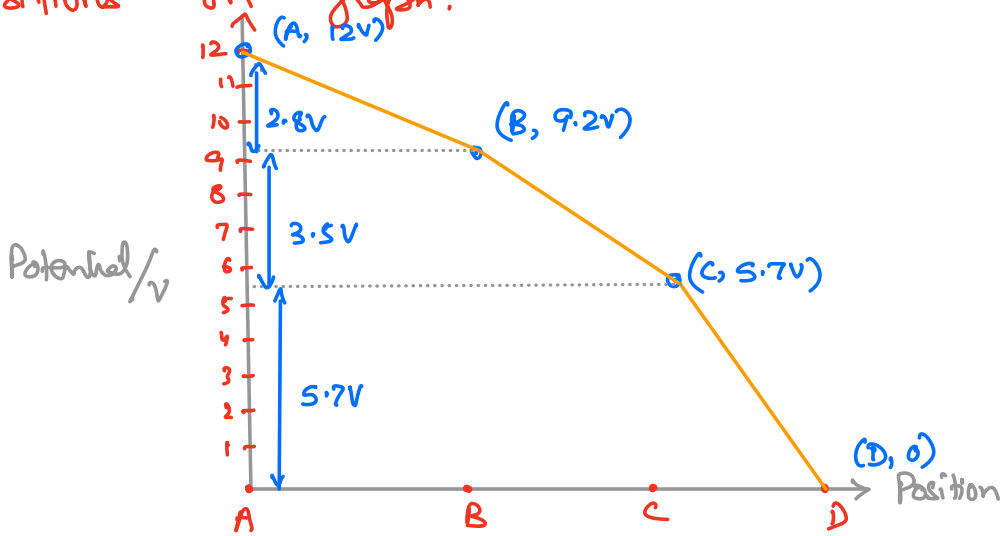
$$= 3.5\,V$$

(iii) CD

$$V_{CD} = 12-(2.8+3.5)$$

$$V_{CD} = 5.7\,V$$

(b) Sketch the potential against different positions on graph.

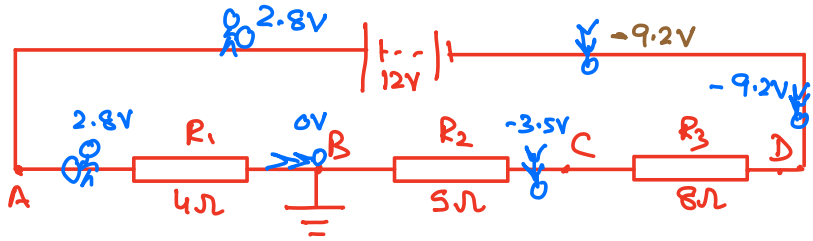


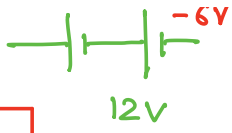
(c) If junction B is connected to Earth as shown in the diagram.

6V

$V = \frac{W}{Q}$

$v = \frac{\Delta I}{IC}$





$6-(-6)=12V$

$2.8-(-9.2)$

$= 12V$

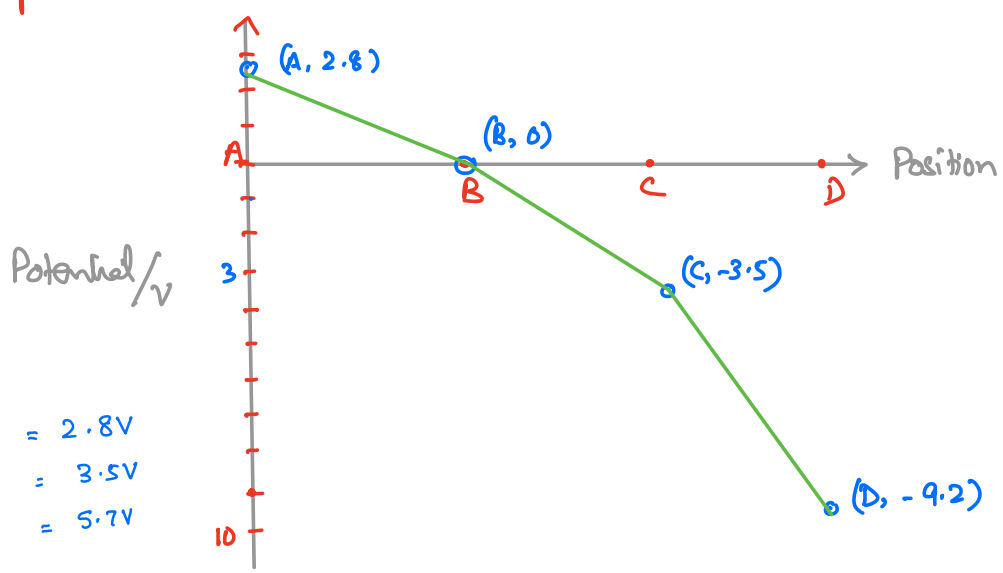
(i) State p.d. across

AB : $V_{AB} = 2.8V$

BC : $V_{BC} = 3.5V$

CD : $V_{CD} = 5.7V$

(b) Sketch the new potential against position graph



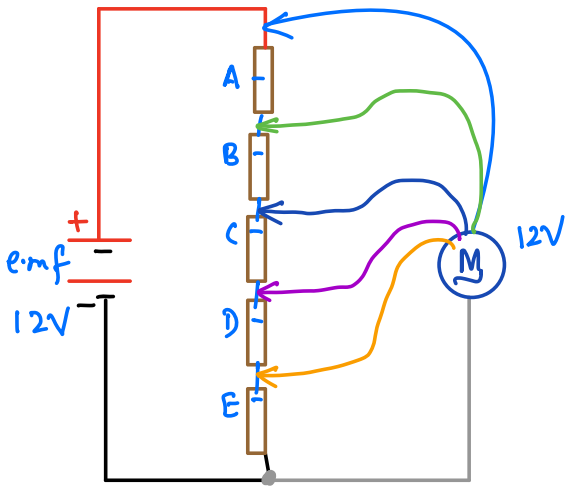
$V_{AB} = 2.8V$

$V_{BC} = 3.5V$

$V_{CD} = 5.7V$

Use of potentiometer to control speed of motor/fan:-

Concept :



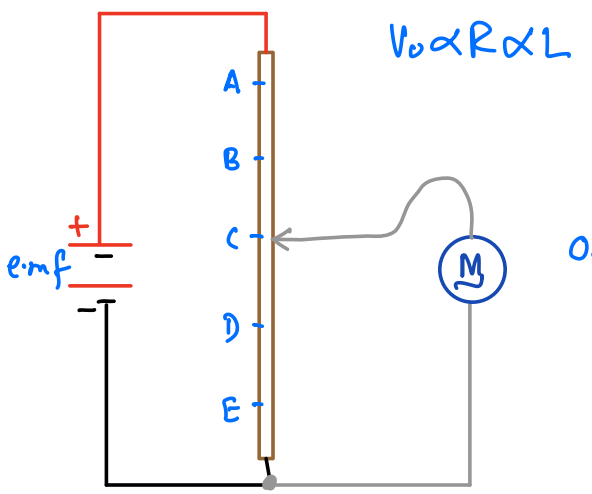
$$V_A = \left(\frac{R_{ABCDE}}{R_A+R_B+R_C+R_D+R_E}\right)(emf)$$

$$V_B = \left(\frac{R_{BCDE}}{R_A+R_B+R_C+R_D+R_E}\right)(emf)$$

$$V_C = \left(\frac{R_{CDE}}{R_A+R_B+R_C+R_D+R_E}\right)(emf)$$

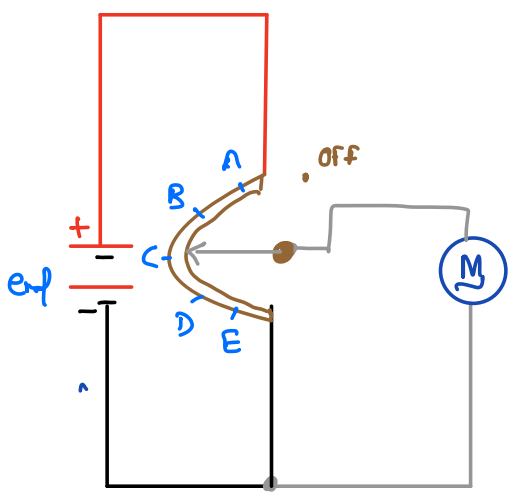
$$V_D = \left(\frac{R_{DE}}{R_A+R_B+R_C+R_D+R_E}\right)(emf)$$

$$V_E = \left(\frac{R_E}{R_A+R_B+R_C+R_D+R_E}\right)(emf)$$



$V_0 \propto R \propto L$

OR



Relative order of speed of motor/fan at different positions:-

$$V_A > V_B > V_C > V_D > V_E$$

because

Relative order of length and hence resistance across motor:-

$$L_A > L_B > L_C > L_D > L_E$$

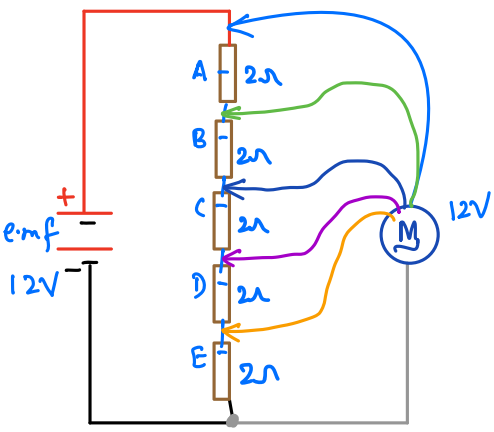
But $R = \rho \frac{L}{A} \Rightarrow R \propto L$

$$R_A > R_B > R_C > R_D > R_E$$

By potential divider relationship i.e $V_{out} \propto R$.
So p.d. across motor at different positions.

$$V_A > V_B > V_C > V_D > V_E$$

Illustration:



$$V_A = \left(\frac{R_{ABCDE}}{R_A + R_B + R_C + R_D + R_E}\right)(emf) \Rightarrow V_A = \left(\frac{10}{10}\right)(12) = 12V$$

$$V_B = \left(\frac{R_{BCDE}}{R_A + R_B + R_C + R_D + R_E}\right)(emf) \Rightarrow V_B = \left(\frac{8}{10}\right)(12) = 9.6V$$

$$V_C = \left(\frac{R_{CDE}}{R_A + R_B + R_C + R_D + R_E}\right)(emf) \Rightarrow V_C = \left(\frac{6}{10}\right)(12) = 7.2V$$

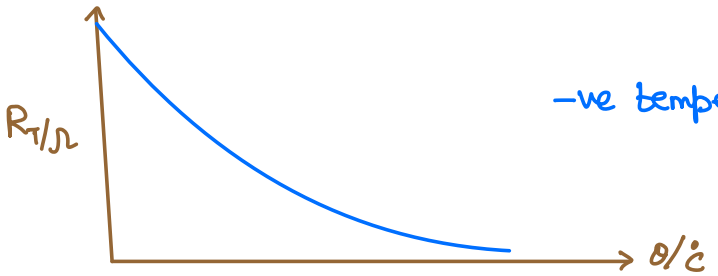
$$V_D = \left(\frac{R_{DE}}{R_A + R_B + R_C + R_D + R_E}\right)(emf) \Rightarrow V_D = \left(\frac{4}{10}\right)(12) = 4.8V$$

$$V_E = \left(\frac{R_E}{R_A + R_B + R_C + R_D + R_E}\right)(emf) \Rightarrow V_E = \left(\frac{2}{10}\right)(12) = 2.4V$$

Use of thermistor as potential divider:-

Thermistor:- An input transducer (which can convert non-electrical energy to electrical energy) whose resistance decreases with the increase of temperature or vice versa.

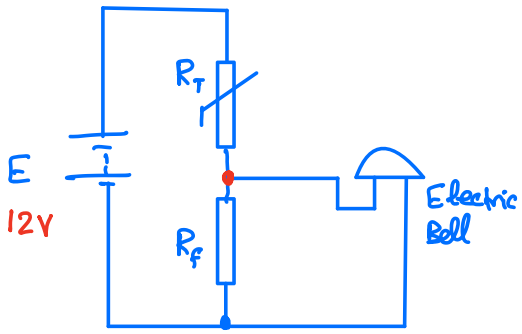
Graph:



-ve temperature coefficient

Symbol:

Thermistor as potential divider in fire alarm circuit:



At low temperature: ($\theta/^\circ C$) ↓

* (R_T) ↑ and (R_f) remain fixed.
* By comparism, ($R_T > R_f$)
* By potential divider relationship i.e ($V_{out} \propto R$)

So p.d. across ($R_T > R_f$)

* This lesser p.d. across R_f is even lesser than the operating voltage of electric bell, so it will not produce any sound.

At high temperature due to fire: ($\theta/^\circ C$) ↑

* (R_T) ↓ and (R_f) remain fixed.
* By comparism, ($R_T < R_f$)
* By potential divider relationship i.e ($V_{out} \propto R$)

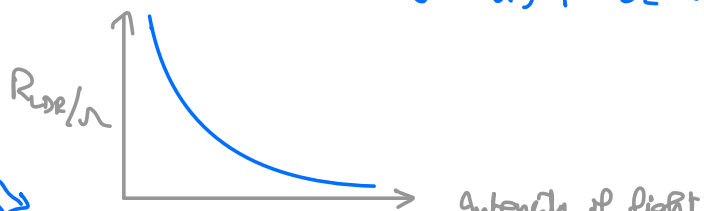
So p.d. across ($R_T < R_f$)

* This increase of p.d. across R_f is now equal to the operating voltage of electric bell and it will produce sound.

Note: The above circuit can be used in deep frost if electric bell is connected across thermistor.

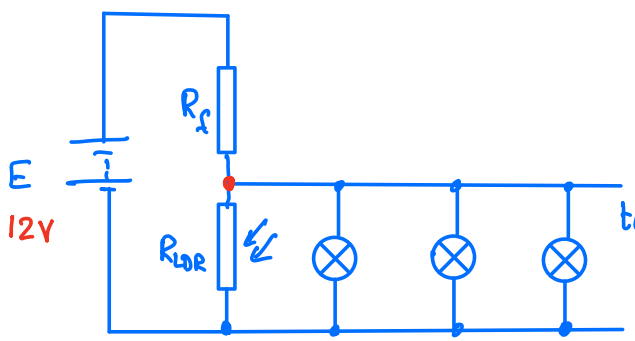
Use of Light Dependent resistor as potential divider in street light circuit :-

Characteristics :- $(R_{LDR}) \downarrow$ if (Intensity of light incident on it) $\uparrow$ or vice versa.



Symbol :

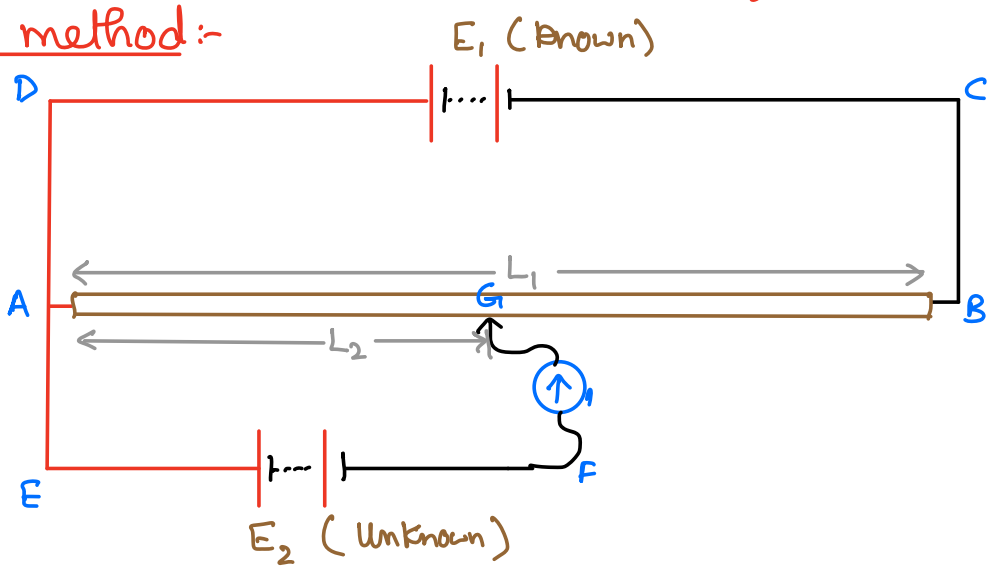
Circuit :



to other filament lamps in parallel.

S.No	Property	Sunlight (Day time)	Moon light (Night time)
1	Resistance of LDR	Decrease	Increase
2	Comparison of Resistance	$R_{LDR} < R_f$	$R_{LDR} > R_f$
3	Comparison of P.d. ($V_{out} \propto R$)	$V_{LDR} < V_f$	$V_{LDR} > R_f$
4	Filament lamps connected in parallel.	Filament lamps remain off due to lesser p.d across them	All filaments emit light with same brightness due to same p.d across them.

Determination of unknown emf of a source by Null method:-



Move the sliding contact / jockey along the resistor AB and locate a position where reading of Galvanometer becomes zero. This point / position is called Null point.

At Null point

potential at A = Potential at E

Also, potential at G = Potential at F

So

P.d. across AG = P.d. across EF

$$\left(\frac{R_{AG}}{R_{AG}+R_{GB}}\right) E_1 = E_2$$

$$\left(\frac{R_{AG}}{R_{AB}}\right) E_1 = E_2$$

But $R = \rho \frac{L}{A} \Rightarrow R \propto L$

Therefore,

$$\left(\frac{L_2}{L_1}\right) E_1 = E_2$$

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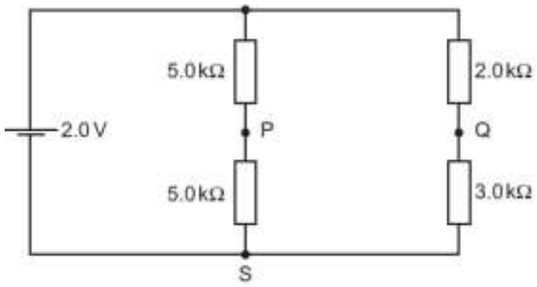
DC CIRCUITS

1. A cell of e.m.f. 2.0 V and negligible internal resistance is connected to the network of resistors shown.

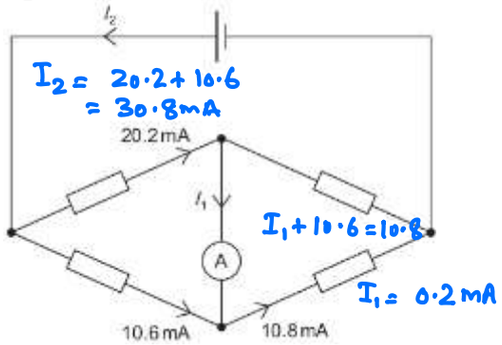


V_1 is the potential difference between S and P. V_2 is the potential difference between S and Q. What is the value of $V_1 - V_2$?

A +0.50 V **B** +0.20 V
C –0.20 V **D** –0.50 V

{Q.33/P1/June 2007, Q.14/P1/9243-Nov. 2000}

2. The diagram represents a circuit.



Some currents have been shown on the diagram. What are the currents I_1 and I_2?

	I_1	I_2
A	0.2 mA	10.8 mA
B	0.2 mA	30.8 mA
C	-0.2 mA	20.0 mA
D	-0.2 mA	30.8 mA

{Q.36/P1/Nov. 2006}

3. When four identical lamps P, Q, R and S are connected as shown in diagram 1, they have normal brightness.

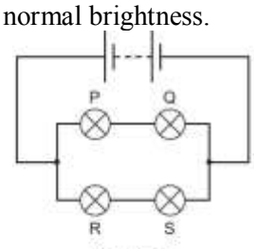


diagram 1

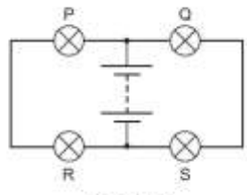
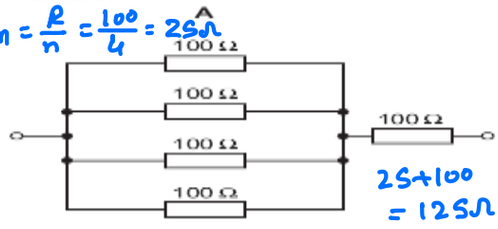


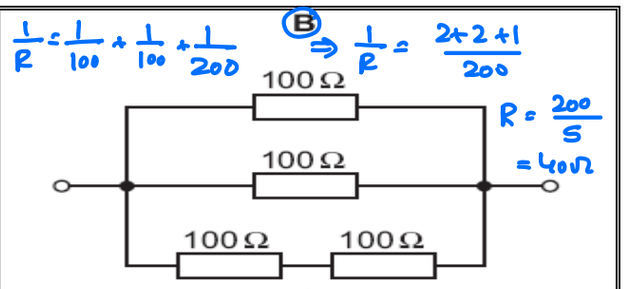
diagram 2

The four lamps and the battery are then connected as shown in diagram 2.
Which statement is correct?
A The lamps do not light.
B The lamps are less bright than normal.
C The lamps have normal brightness.
D The lamps are brighter than normal.

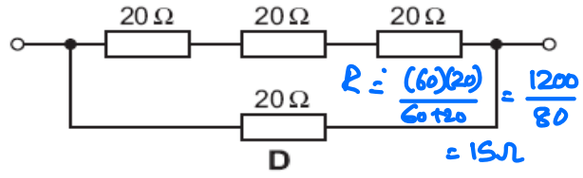
{Q.36/P1/June 2006}

4. Which circuit has a resistance of 40 Ω between the terminals?

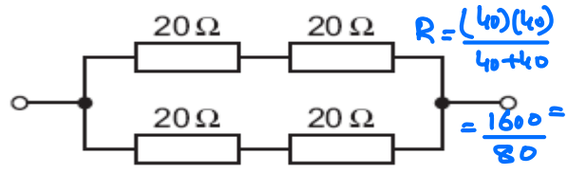




C

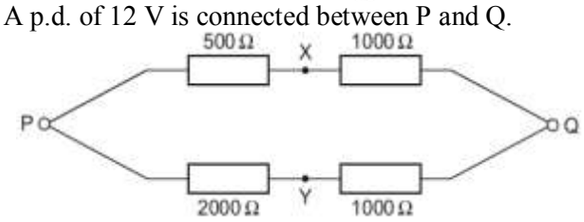


D



{Q.37/P1/ Nov. 2006}

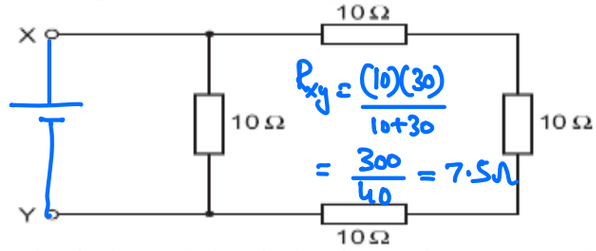
5. A p.d. of 12 V is connected between P and Q.



What is the p.d. between X and Y?
A 0 V **B** 4 V **C** 6 V **D** 8 V

{Q.33/P1/June 2006}

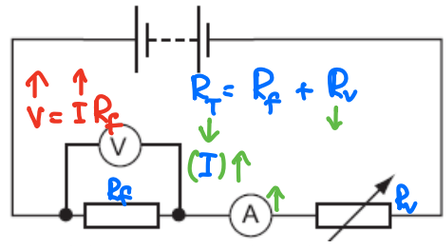
6. The diagram shows an arrangement of resistors.



What is the total electrical resistance between X and Y?
A less than 1 Ω **B** between 1 Ω and 10 Ω
C between 10 Ω and 30 Ω **D** 40 Ω

{Q.35/P1/June 2006}

7. The diagram shows a battery, a fixed resistor, an ammeter and a variable resistor connected in series. A voltmeter is connected across the fixed resistor.



The value of the variable resistor is reduced. Which correctly describes the changes in the readings of the ammeter and of the voltmeter?

	ammeter	voltmeter
A	decrease	decrease
B	decrease	increase
C	increase	decrease
D	increase	increase

{Q. 35/P1/June 2004}

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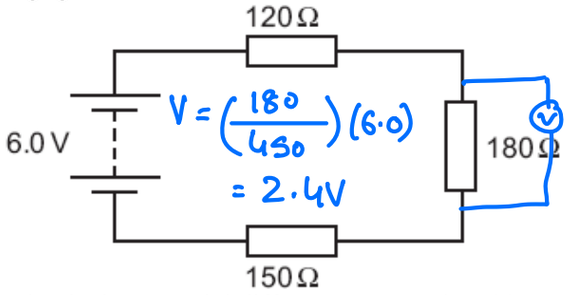
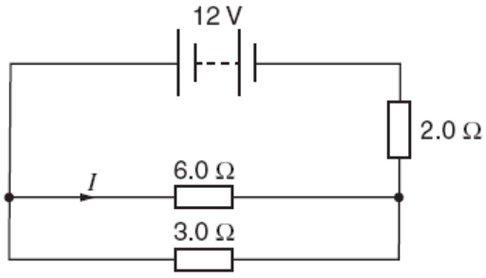
DC CIRCUITS

8. Three resistors are connected in series with a battery as shown in the diagram. The battery has negligible internal resistance.



What is the potential difference across the 180 Ω resistor?
A 1.6 V **B** 2.4 V **C** 3.6 V **D** 6.0 V
{Q.36/P1/Nov. 2005}

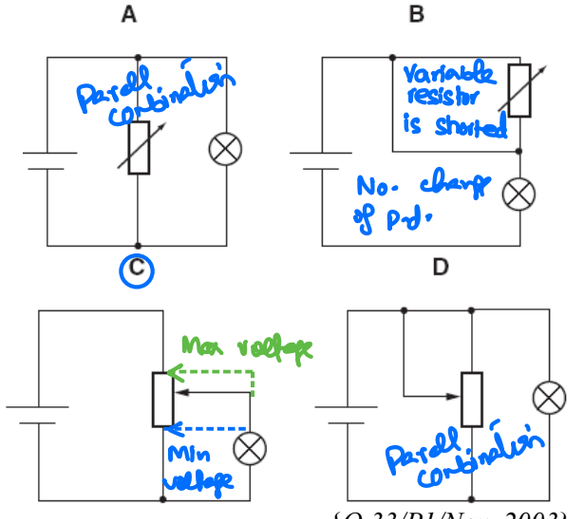
9. The diagram shows a circuit in which the battery has negligible internal resistance.



next page.

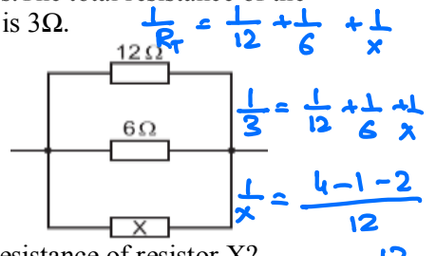
What is the value of the current *I* ?
A 1.0A **B** 1.6A **C** 2.0A **D** 3.0A
{Q.31/P1/Nov. 2003,Q.14/P1/9243-Nov. 1999}

10. Which diagram shows a potential divider circuit that can vary the voltage across the lamp?



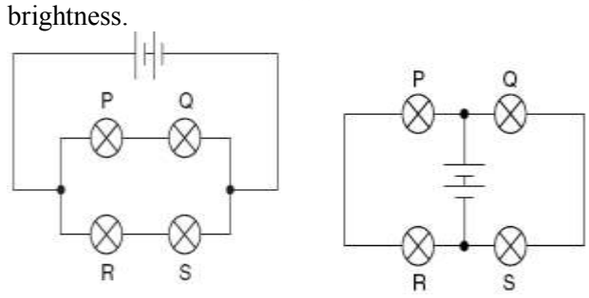
{Q.33/P1/Nov. 2003}

11. The diagram shows a parallel combination of three resistors.The total resistance of the combination is 3Ω.



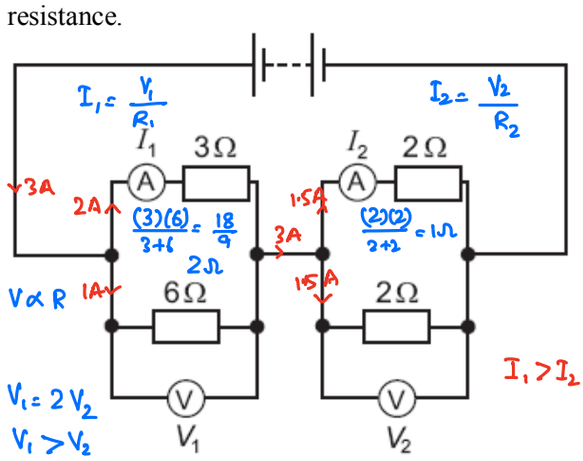
What is the resistance of resistor X?
A 2 Ω **B** 3 Ω
C 6 Ω **D** 12 Ω
{ Q. 37/P1/June 2004}

12. When four identical lamps P, Q, R and S are connected as shown in diagram 1, they have normal brightness.



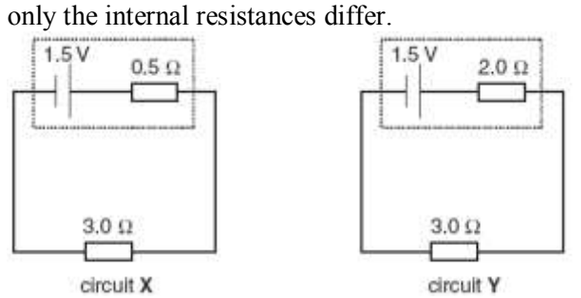
When the four lamps are connected as shown in diagram 2, which statement is correct?
A The lamps do not light.
B The lamps are less bright than normal.
C The lamps have normal brightness.
D The lamps are brighter than normal.
{Q.32/P1/June 2002}

13. In the circuit shown, the ammeters have negligible resistance and the voltmeters have infinite resistance.



The readings on the meters are I_1, I_2, V_1 and V_2, as labelled on the diagram. Which is correct?
A $I_1 > I_2$ and $V_1 > V_2$ **B** $I_1 > I_2$ and $V_1 < V_2$
C $I_1 < I_2$ and $V_1 > V_2$ **D** $I_1 < I_2$ and $V_1 < V_2$
{Q.37/P1/Nov. 2004}

14. The diagram shows two circuits. In these circuits, only the internal resistances differ.



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Which line in the table is correct?

	potential difference across 3.0Ω resistor	power dissipated in 3.0Ω resistor
A	greater in X than in Y	less in X than in Y
B	greater in X than in Y	greater in X than in Y
C	less in X than in Y	less in X than in Y
D	less in X than in Y	greater in X than in Y

{Q.34/P1/Nov. 2003}

15 The diagram shows an arrangement of four resistors.

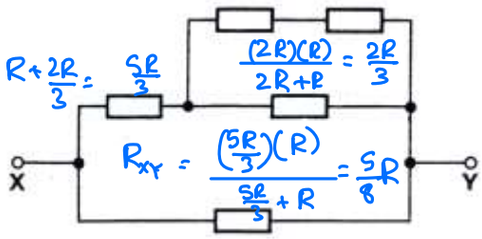
$R_{xy} = \frac{(16)(16)}{16+16} = 8\,k\Omega$ = 16 kΩ; 16 kΩ

What is the resistance between X and Y?

A 4kΩ **B** 8kΩ **C** 16 kΩ **D** 32 kΩ

{Q.33/P1/June 2003}

16. The circuit diagram shows a network of resistors, each of resistance ***R***.



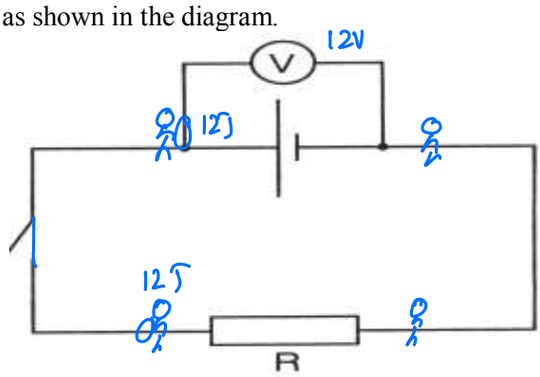
$R + \frac{2R}{3} = \frac{5R}{3}$; $\frac{(2R)(R)}{2R+R} = \frac{2R}{3}$; $R_{XY} = \frac{(\frac{5R}{3})(R)}{\frac{5R}{3}+R} = \frac{5R}{8}$

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

A 2R / 7 **B** R / 2

C 2R / 3 **D** 5R / 8

17. A cell has internal resistance. It is connected to a resistor *R*, a switch and a high resistance voltmeter as shown in the diagram.



12V; 12V; 12V

When the switch is closed, what does the reading on the voltmeter represent?

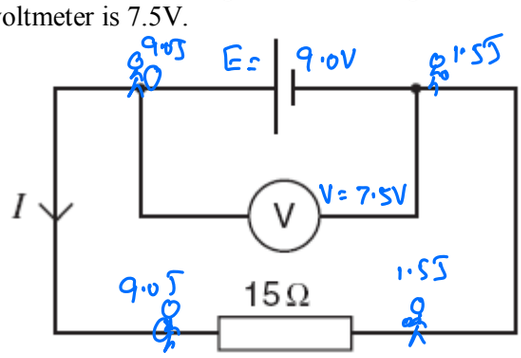
A the electromotive force of the cell if switch is open

B the potential difference across R

C the potential difference across the cell's internal resistance

D the sum of the potential difference across R and the cell's internal resistance

18. The e.m.f. of the cell in the following circuit is 9.0V. The reading on the high-resistance voltmeter is 7.5V.



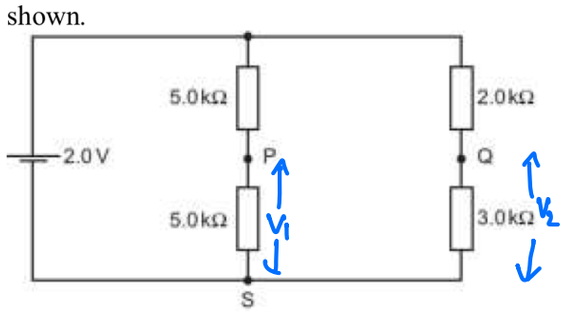
9.0V; 1.5V; 9.0V; 1.5V

What is the current *I* ?

A 0.1A $I = \frac{V}{R} = \frac{7.5}{15}$ **B** 0.5A

C 0.6A **D** 2.0A

Q1) A cell of e.m.f. 2.0 V and negligible internal resistance is connected to the network of resistors shown.



V_1; V_2

V_1 is the potential difference between S and P. V_2 is the potential difference between S and Q. What is the value of $V_1 - V_2$?

A +0.50 V **B** +0.20 V

C –0.20 V **D** –0.50 V

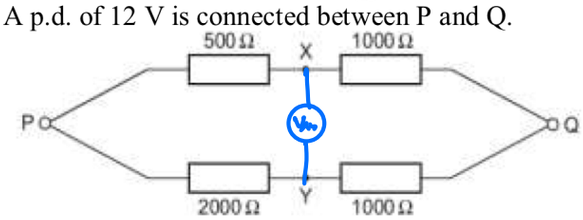
$\Delta V = V_1 - V_2$

$= \left(\frac{5}{5+5}\right)(2.0) - \left(\frac{3.0}{2.0+3.0}\right)(2.0)$

$= 1 - \frac{6}{5} = -\frac{1}{5}$

$= -0.20\,V$

A p.d. of 12 V is connected between P and Q.



What is the p.d. between X and Y?

A 0 V **B** 4 V **C** 6 V **D** 8 V

$V_{XY} = V_{XQ} - V_{YQ}$

$= \left(\frac{1000}{500+1000}\right)(12) - \left(\frac{1000}{2000+1000}\right)(12)$

$= \frac{12000}{1500} - \frac{12000}{3000}$

$= 8 - 4 = 4V$

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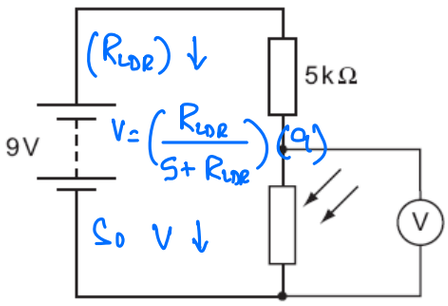
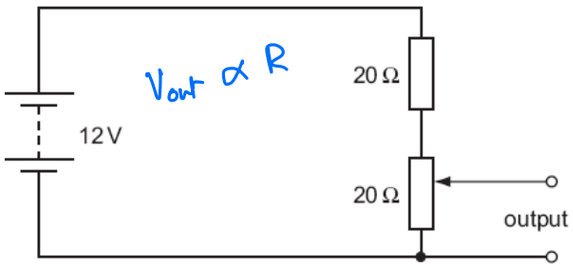
1. A circuit is set up with an LDR and a fixed resistor as shown.



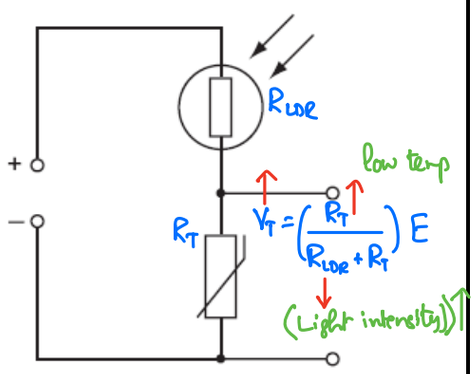
The voltmeter reads 4 V.
The light intensity is increased.
What is a possible voltmeter reading?
A 3V **B** 4V **C** 6V **D** 8 V
{Q.34/P1/June 2007}

2. The diagram shows a potentiometer and a fixed resistor connected across a 12 V battery of negligible internal resistance.



The fixed resistor and the potentiometer each have resistance 20 Ω. The circuit is designed to provide a variable output voltage.
What is the range of output voltages?
A 0 – 6 V **B** 0 – 12 V
C 6 – 12 V **D** 12 – 20 V
{Q.34/P1/ Nov. 2006}

3. The diagram shows a light-dependent resistor (LDR) and a thermistor forming a potential divider.

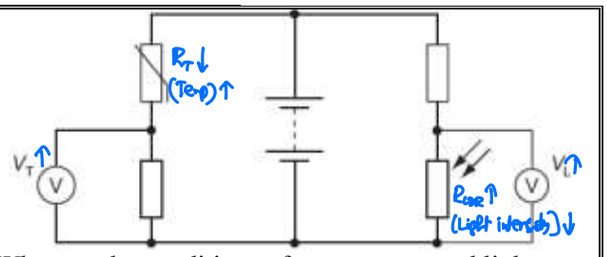


Under which set of conditions will the potential difference across the thermistor have the greatest value?

	illumination	temperature
A	low	low
B	high	low
C	low	high
D	high	high

{Q.37/P1/June 2006}

4. In the circuit shown on next column, the reading V_T on the voltmeter changes from high to low as the temperature of the thermistor changes. The reading V_L on the voltmeter changes from high to low as the level of light on the light-dependent resistor (LDR) changes.The readings on V_T and V_L are both high.

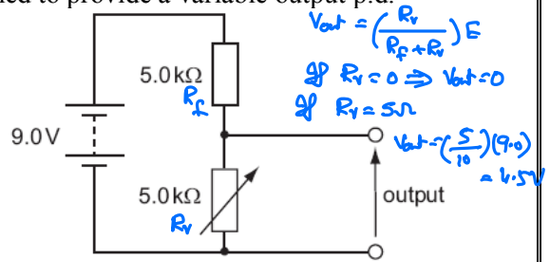


What are the conditions of temperature and light level?

	temperature	light level
A	low	low
B	low	high
C	high	low
D	high	high

{Q.37P1/Nov. 2005}

5. The diagram shows a potential divider circuit designed to provide a variable output p.d.

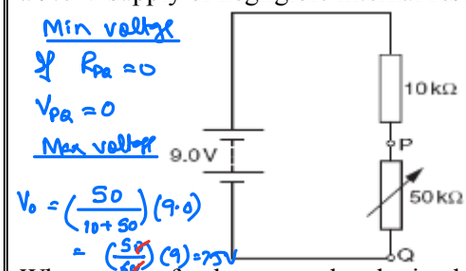


Which gives the available range of output p.d?

	Maximum output	Minimum output
A	3.0 V	0
B	4.5 V	0
C	9.0 V	0
D	9.0 V	4.5 V

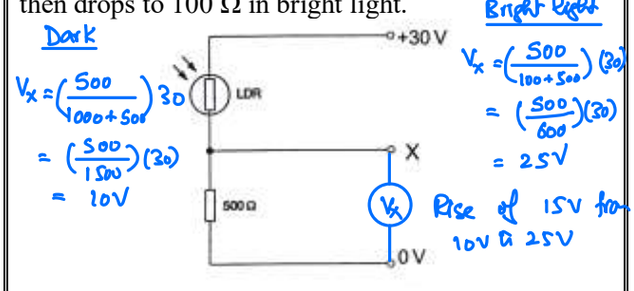
{Q. 36/P1/Nov. 2004}

6. The diagram shows a potential divider connected to a 9.0 V supply of negligible internal resistance.



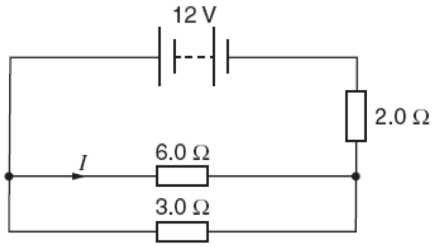
What range of voltages can be obtained between P and Q?
A zero to 1.5V **B** zero to 7.5V
C 1.5 V to 7.5V **D** 1.5 V to 9.0V
{Q.34/P1/June 2003}

7. A light-dependent resistor (LDR) and a resistor of resistance 500 Ω are connected between voltage lines held at +30 V and 0 V as shown.
The resistance of the LDR is 1000 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 rise of 15 V **B** a fall of 15 V
C a fall of 25 V **D** a rise of 25 V
{Q.36/P1/Specimen paper June 2001}

Q.9) The diagram shows a circuit in which the battery has negligible internal resistance.



What is the value of the current I?

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

Total resistance of parallel combination of 6.0Ω and 3.0Ω resistor:

$$R = \frac{(6)(3)}{6+3} = 2.0\,\Omega$$

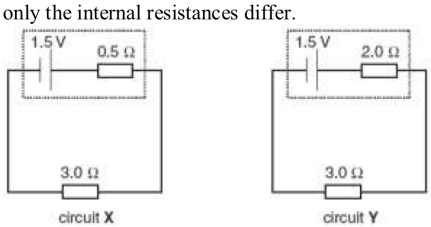
P.d. across 6.0Ω and 3.0Ω resistor

$$V = \left(\frac{2}{2+2}\right)(12) = 6.0\,V$$

Current in 6.0Ω resistor:

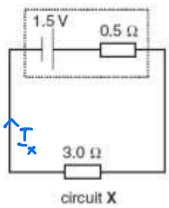
$$I = \frac{V}{R} = \frac{6.0}{6.0} = 1.0\,A$$

Q.14) The diagram shows two circuits. In these circuits, only the internal resistances differ.



Which line in the table is correct?

	potential difference across 3.0Ω resistor	power dissipated in 3.0Ω resistor
A	greater in X than in Y	less in X than in Y
(B)	greater in X than in Y	greater in X than in Y
C	less in X than in Y	less in X than in Y
D	less in X than in Y	greater in X than in Y



$1.5 = I_x(0.5+3.0)$

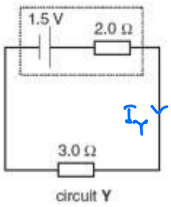
$I_x = \frac{1.5}{3.5} = 0.43\,A$

$V_x = I_x R$

$= (0.43)(3.0) = 1.29\,V$

$P_x = (I_x^2)(R)$

$= (0.43)^2(3.0) = 0.55\,W$



$1.5 = I_Y(2.0+3.0)$

$I_Y = 0.30\,A$

$V_Y = I_Y R = (0.30)(3)$

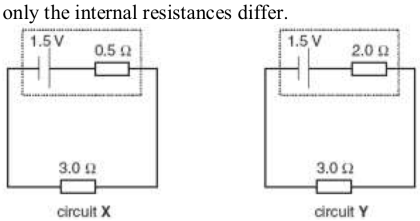
$= 0.90\,V$

$P_Y = I_Y^2 R = (0.30)^2(3)$

$= 0.27\,W$

$V_x > V_Y$ and $P_x > P_Y$

The diagram shows two circuits. In these circuits, only the internal resistances differ.



Which line in the table is correct?

	potential difference across 3.0Ω resistor	power dissipated in 3.0Ω resistor
A	greater in X than in Y	less in X than in Y
(B)	greater in X than in Y	greater in X than in Y
C	less in X than in Y	less in X than in Y
D	less in X than in Y	greater in X than in Y

$$V_x = \left(\frac{3.0}{0.5+3.0}\right)(1.5)$$

$V_x = 1.29\,V$

$$P_x = \frac{V_x^2}{R} = \frac{(1.29)^2}{3.0}$$

$P_x = 0.55\,W$

$$V_Y = \left(\frac{3.0}{2.0+3.0}\right)(1.5)$$

$V_Y = 0.90\,V$

$$P_Y = \frac{V_Y^2}{R} = \frac{(0.90)^2}{3.0}$$

$= 0.27\,W$

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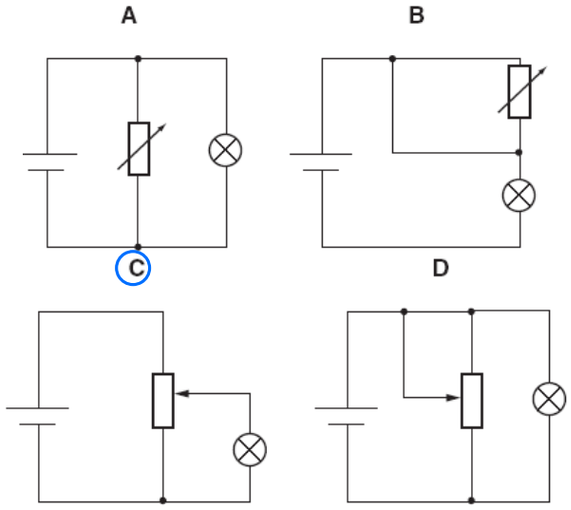
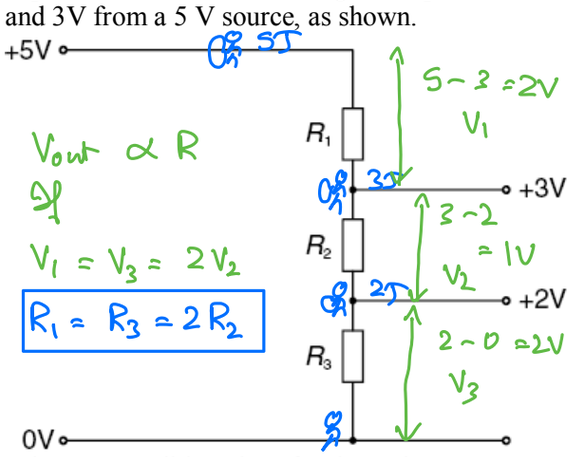
MIS, DCE, D AS/400e(IBM), OCP(PITB)
teacher_786@hotmail.com

8. Which diagram shows a potential divider circuit that can vary the voltage across the lamp?



{*Q.33/P1/Nov. 2003*}

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

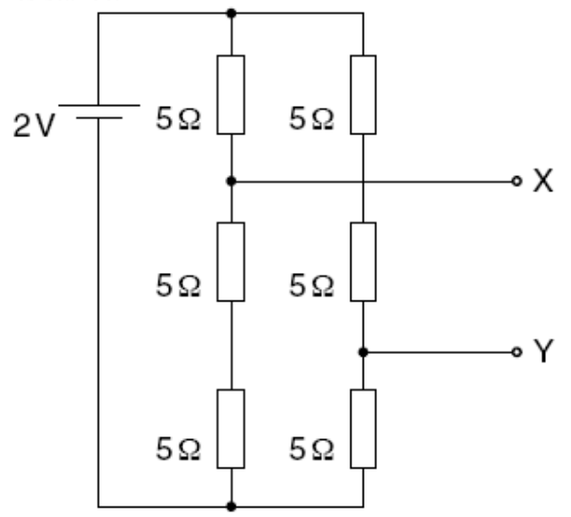


What are possible values for the resistances R_1, R_2 and R_3?

	R_1 / kΩ	R_2 / kΩ	R_3 / kΩ
A	2	1	5
B	3	2	2
C	4	2	4
D	4	6	10

{*Q.35/P1/June 2002, Q.35/P1/June 2001*}

10. Six resistors, each of resistance 5 Ω, are connected to a 2 V cell of negligible internal resistance.



What is the potential difference between terminals X and Y?

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

{*Q.36/P1/Nov. 2002*}

Theory question:

Figure 1 shows a linear variable resistor of resistance 500Ω in use as a potential divider to supply a variable potential difference across a circuit.

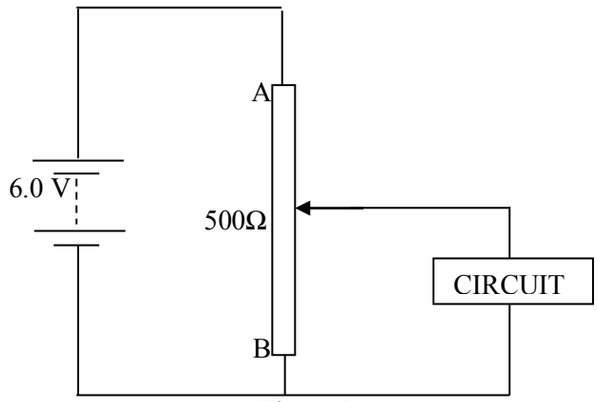


Figure 1

(a) Determine the potential difference across the circuit when the slider is

(i) at A

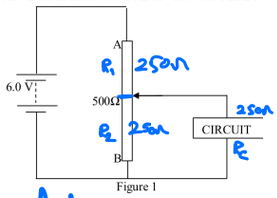
……6.0…… V

(ii) at B

……0…… V

[2]

(b) The circuit has resistance 250Ω. Calculate the potential difference across the circuit when th slider is half-way between A and E



Effective resistance of two 250Ω resistors.

$R_{2c} = \frac{250}{2} = 125\Omega$

$V_{out} = \left(\frac{R_{2c}}{R_1 + R_{2c}}\right) E$

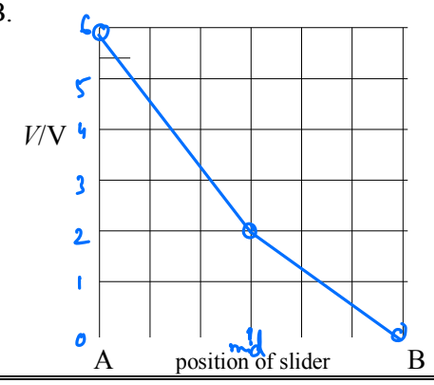
$= \left(\frac{125}{250 + 125}\right)(6.0)$

$= 2.0\text{V}$

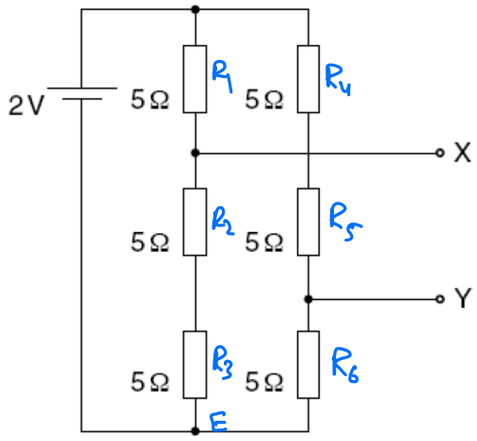
Potential difference with slider at half-way position

= ……2.0…… V [3]

(c) On Figure 2, sketch how the potential difference across the circuit varies as the slider is moved from A to B. [2]



Six resistors, each of resistance 5 Ω, are connected to a 2 V cell of negligible internal resistance.



What is the potential difference between terminals X and Y?

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

$$V_{XY} = V_{XE} - V_{YE}$$

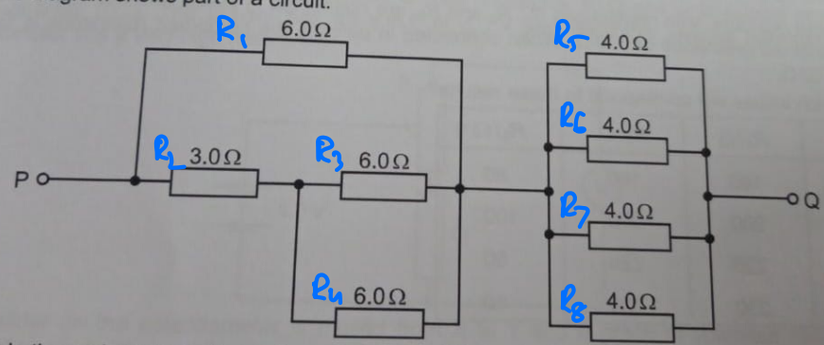
$$= \left(\frac{R_{23}}{R_1+R_2+R_3}\right)E - \left(\frac{R_6}{R_4+R_5+R_6}\right)E$$

$$= \left(\frac{10}{15}\right)(2) - \left(\frac{5}{15}\right)(2)$$

$$= \frac{20-10}{15} = \frac{10^{2}}{15_{3}}$$

Q35/P12/O/N/10

4 The diagram shows part of a circuit.



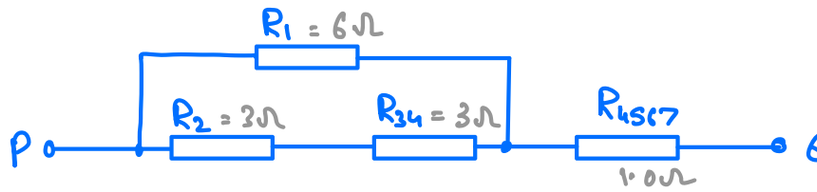
What is the resistance between the points P and Q due to the resistance network?

A 1.3Ω **B** 4.0Ω **C** 10Ω **D** 37Ω

Identical resistors in parallel: $R_n = \frac{R}{n}$

$$R_{5678} = \frac{4.0}{4} = 1.0\,\Omega$$

$$R_{34} = \frac{(6.0)(6.0)}{6.0+6.0} = 3.0\,\Omega$$



$$R_{234} = R_2 + R_{34} = 3+3 = 6\,\Omega$$

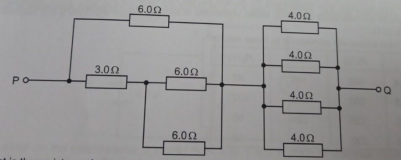
$$R_{1234} = \frac{6}{2} = 3.0\,\Omega$$

$$R_{PQ} = R_{1234} + R_{5678}$$

$$= 3.0 + 1.0 = 4.0\,\Omega$$

Q35/P12/O/N/10

4 The diagram shows part of a circuit.



What is the resistance between the points P and Q due to the resistance network?

A 1.3Ω B 4.0Ω C 10Ω D 37Ω