9749 H2 Physics Topic 15

DUNMAN HIGH SCHOOL

D.C. Circuits

Year 5 (2024)

Guiding Questions

- How are symbols and diagrams used to represent real circuits?
- How are the principles of charge and energy conservation applied to analyse circuits?

Content

- Circuit symbols and diagrams
- Series and parallel arrangements
- Potential divider
- Balanced potentials

Learning Outcomes

Candidates should be able to:

(a) recall and use appropriate circuit symbols as set out in the ASE publication Signs, symbols and systematics: the ASE companion to 16-19 science (2000)

(b) draw and interpret circuit diagrams containing sources, switches, resistors, ammeters, voltmeters, and/or any other type of component referred to in the syllabus

(c) solve problems using the formula for the combined resistance of two or more resistors in series

(d) solve problems using the formula for the combined resistance of two or more resistors in parallel

(e) solve problems involving series and parallel circuits for one source of e.m.f.

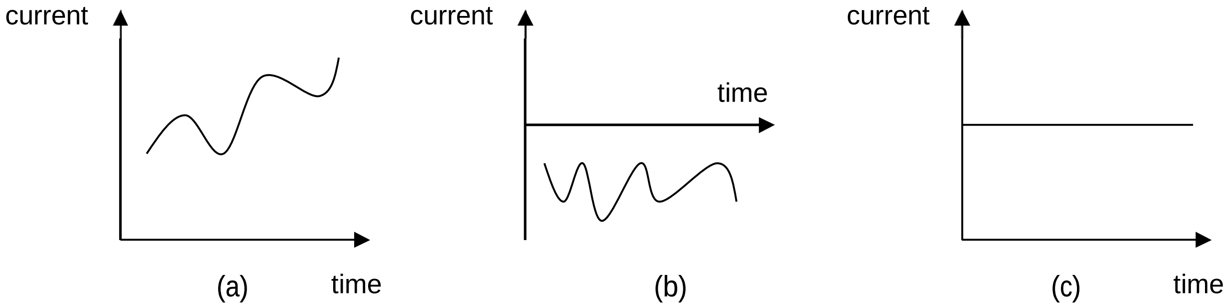
(f) show an understanding of the use of a potential divider circuit as a source of variable p.d.

(g) explain the use of thermistors and light-dependent resistors in potential divider circuits to provide a potential difference which is dependent on temperature and illumination respectively

(h) recall and solve problems by using the principle of the potentiometer as a means of comparing potential differences.

Introduction

D.C. stands for direct current. It means current flowing only in <u>one direction</u> in a closed circuit. The magnitude of the current, however, may vary from time to time. The following are some examples of graphs representing the variation of direct current with time.



In (a) and (b), the magnitudes of the current change with time. The currents in (a) and (b) flow in the opposite direction. In (c), the current flows with constant magnitude. We say, the current is a steady D.C. This chapter focuses mainly on the type of current shown in (c) – steady D.C.

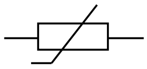
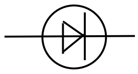
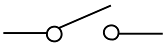
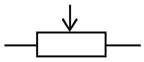
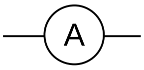
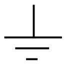
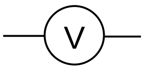
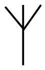
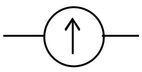
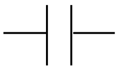
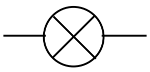
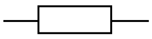
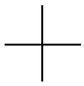
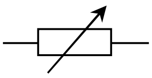
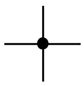
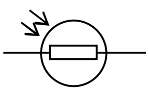
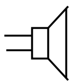
A simple D.C. circuit will usually comprise:

a) source (s), e.g. batteries, cells
b) switches
c) resistors (or other components such as capacitors)
d) measuring instruments such as voltmeter, ammeter, etc.

(a) recall and use appropriate circuit symbols as set out in the ASE publication Signs, symbols and systematics: the ASE companion to 16-19 science (2000)

(b) draw and interpret circuit diagrams containing sources, switches, resistors, ammeters, voltmeters, and/or any other type of component referred to in the syllabus

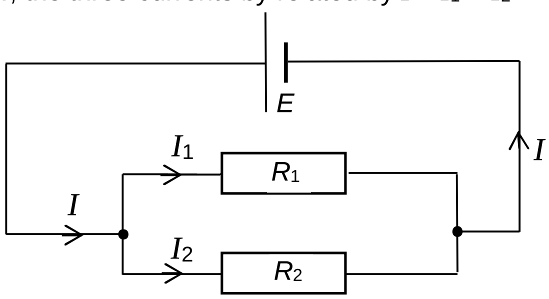
Standard circuit symbols are used to simplify circuit diagrams. Each circuit symbol represents an electrical device. The table below shows some common circuit symbols.

Symbol	Meaning	Symbol	Meaning
	cell / battery		thermistor
	power supply		diode
	switch		potential divider
	ammeter		earth
	voltmeter		aerial/antenna
	galvanometer		capacitor
	filament lamp		inductor
	resistor		wires crossing with no connection
	variable resistor		wires crossing with connection
	light dependent resistor		loudspeaker

Application of Charge and Energy Conservation Principles in Circuit Analysis

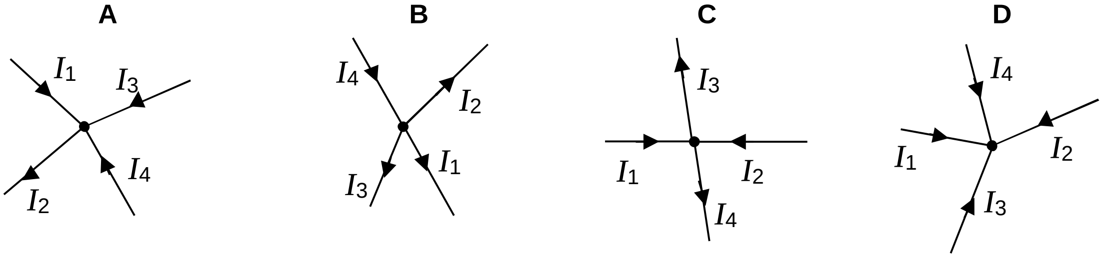
Charges cannot be created nor destroyed. This is the law of <u>Conservation of Charge</u>. Hence, the total charge that enters a junction per unit time (i.e. current entering) must be equal to the total charge that leaves the same junction per unit time (i.e. current leaving).

<u>Current Law</u>: The sum of currents entering any junction in an electric circuit is always equal to the sum of currents leaving that junction (otherwise charge would build up at the junction).
In the circuit below, the three currents by related by $I = I_1 + I_2$.



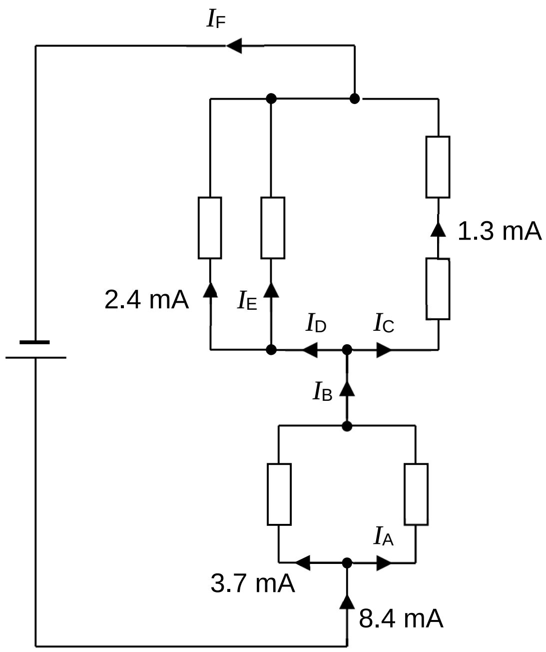
Example 1
The diagrams show connected wires which carry currents I_1, I_2, I_3 and I_4. The currents are related by the equation $I_1 + I_2 = I_3 + I_4$.

To which diagram does this equation apply? [N98/P1/Q16]



Answer: ______

Example 2
Calculate the currents I_A, I_B, I_C, I_D, I_E, and I_F as shown in the diagram below.



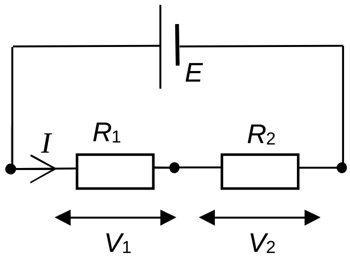
Answer:

I_A = ________________ I_B = ________________ I_C = ________________

I_D = ________________ I_E = ________________ I_F = ________________

The principle of Conservation of Energy states that energy cannot be created nor destroyed. Therefore, the electrical energy produced by the source should be equal to the sum of electrical energy consumed by all the components.

Consider a closed circuit of electromotive force (e.m.f.) E and resistance R_1 and R_2.



From the conservation of energy,

Energy supplied by the source = Energy dissipated by the resistors

$$(I\,E)\,t = (I^2 R_1)\,t + (I^2 R_2)\,t$$

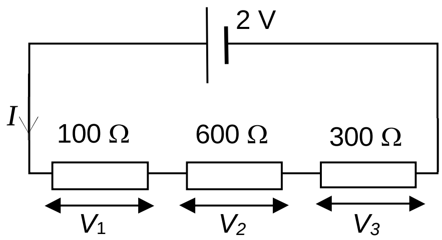
$$E = I R_1 + I R_2$$

i.e. $$E = V_1 + V_2$$

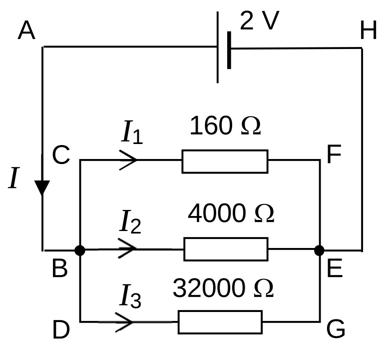
Voltage Law: In any closed loop in an electric circuit, the total e.m.f. E supplied equals to the total potential difference in that loop.

In the circuit above, $E = V_1 + V_2$

Example 3
Referring to the circuit drawn, determine the value of the current I and the potential difference across each resistor.

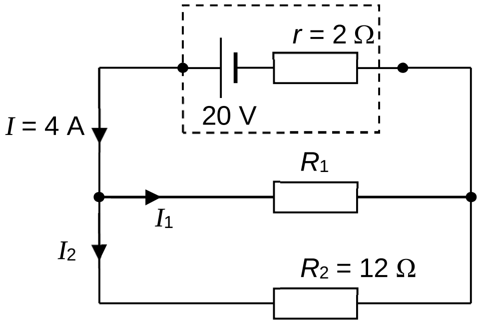


Example 4
Referring to the circuit drawn, determine the value of I and R, the combined resistance in the circuit.



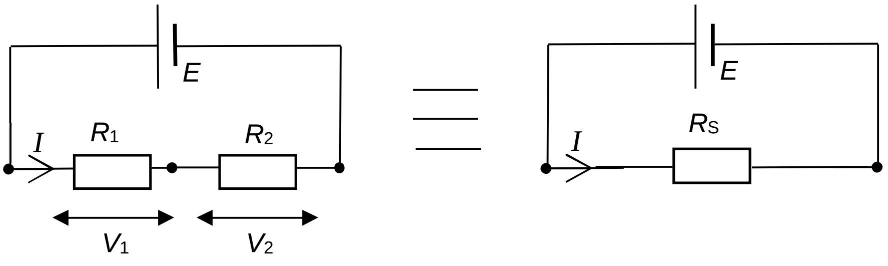
Example 5

A battery with an e.m.f. of 20 V and an internal resistance of 2.0 Ω is connected to resistors R_1 and R_2 as shown in the diagram. A total current of 4.0 A is supplied by the battery and R_2 has a resistance of 12 Ω. Calculate the resistance of R_1 and the power supplied to each circuit component.



(c) solve problems using the formula for the combined resistance of two or more resistors in series

In the circuit, the resistors R_1 and R_2 are said to be in series because the same current flows through both R_1 and R_2.



From conservation of energy,

$E = V_1 + V_2$

$I R_S = I_1 R_1 + I_2 R_2$

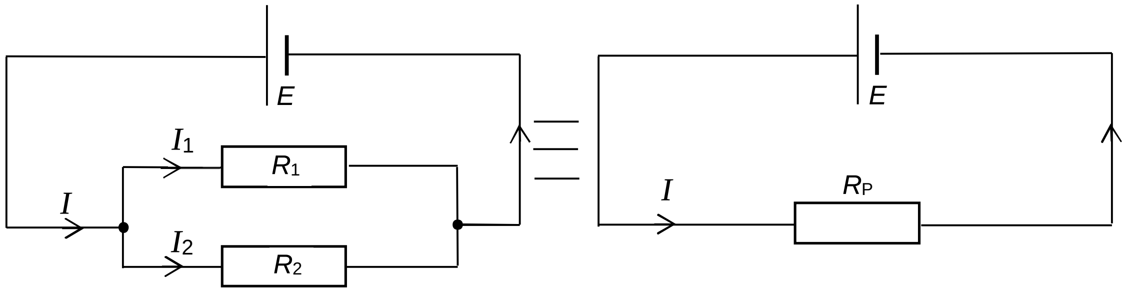
Since the resistors are in series $I_1 = I_2 = I$

Thus $\boxed{R_S = R_1 + R_2}$

Note: The combined resistance, R_S of resistors in series is always larger than the *largest* resistance in the network.

(d) solve problems using the formula for the combined resistance of two or more resistors in parallel

In the circuit, the resistors R_1 and R_2 are said to be in parallel because the potential difference across R_1 and R_2 is the same.



From conservation of charge,

$$I = I_1 + I_2$$

$$\frac{E}{R_P} = \frac{E_1}{R_1} + \frac{E_2}{R_2}$$

Since the resistors are in parallel, $E_1 = E_2 = E$,

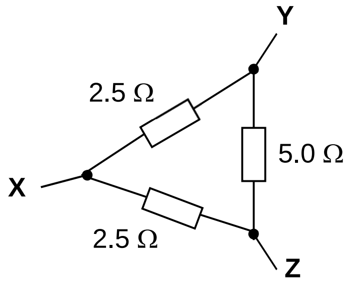
Thus, $\boxed{\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}}$

Note: The combined resistance, R_P of resistors in parallel is always smaller than the *smallest* resistance in the network.

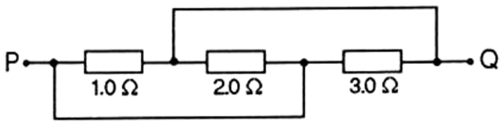
(e) solve problems involving series and parallel circuits for one source of e.m.f.

Example 6

The diagram shows a network of three resistors. Two of which have a resistance of 2.5 Ω and one of which has a resistance of 5.0 Ω, as shown. Determine the resistance between **X** and **Y**. [J91/P1/Q14]

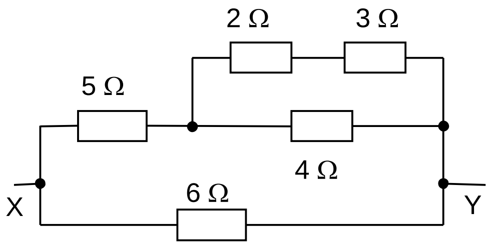


Example 7
Three resistors are connected as shown in the diagram using connecting wires of negligible resistance.



Calculate the resistance between the points P and Q. [6/11 Ω] [J89/P1/15]

Example 8
Calculate the resistance across XY for the network shown.

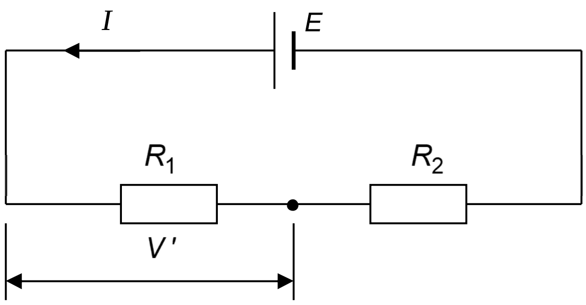


(f) **show an understanding of the use of a potential divider circuit as a source of variable p.d.**

A **potential divider** is an arrangement of resistors which is used to obtain a fraction of the potential difference provided by a voltage supply.

The circuit below shows a simple divider which consists of two known resistors of resistances R_1 and R_2 connected in series to a voltage supply of e.m.f. E.

The potential difference V' is then connected to a load, such as a lamp.



Current $I = \dfrac{E}{R_1 + R_2}$

The p.d. across R_1,

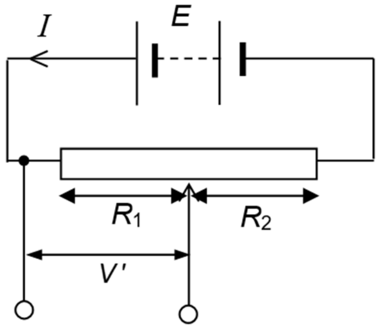
$$V' = IR_1 = \left(\frac{E}{R_1 + R_2}\right)R_1$$

$$V' = \left(\frac{R_1}{R_1 + R_2}\right)E$$

Note: V' is a fraction of the voltage of the supply.

$$\boxed{.\,V' = \left(\frac{R_1}{R_1 + R_2}\right)E \quad \text{or} \quad \frac{V'}{E} = \left(\frac{R_1}{R_1 + R_2}\right)}$$

To supply a continuously variable potential difference from zero to the full voltage of the supply E, a resistor with a sliding contact may be used.

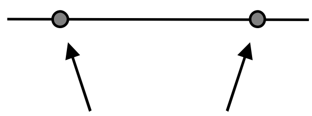


$$V' = \left(\frac{R_1}{R_1 + R_2}\right)E$$

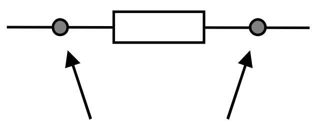
Potential and Potential Difference

Each point in a circuit has a potential. Two points have the same potential if they are connected directly by a wire of zero resistance, and there is no potential difference between them.

If the two points are separated by a *gap, a resistor, a battery or some other device with resistance*, the potential on either point can be *different*. The difference in potential between the two points is called the potential difference.



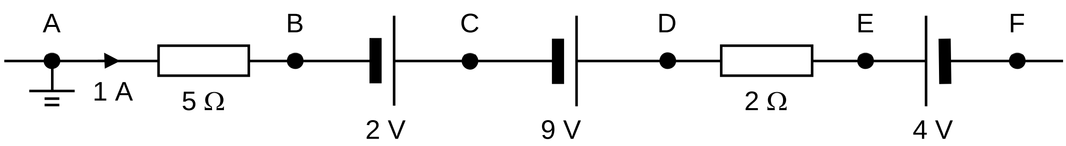
These two points have the *same* potential, the p.d. between them is zero.



These two points have *different* potential unless the current is zero in which case the p.d. across the resistor will be zero.

Hence, for potential difference (p.d.) to exist, the component must either be an e.m.f source (e.g., batteries, solar cells or thermocouples) or have resistance, and *current must be flowing* through the component.

Consider the following diagram showing part of a circuit:



As point A is connected to the earth, the potential at A is zero.

From point A to B:

The p.d. across the 5 Ω resistor, $V = IR = 1 \times 5 = 5$ V

As current flows from higher to lower potential, B is at a lower potential

Hence, potential at B is 0 – 5 V = –5 V

From point B to C:

The p.d. between B and C is 2 V (provided by the cell)
C is at higher potential as it is connected to the positive terminal of the battery
Hence, potential at C is –5 + 2 = –3 V

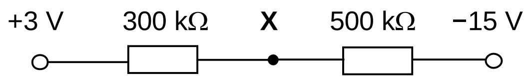
<u>From point C to D:</u>
The p.d. between C and D is 9 V (provided by the cell)
D is at higher potential as it is connected to the positive terminal of the battery
Hence, potential at D is –3 + 9 = 6 V

<u>From point D to E:</u>
The p.d. across the 2 Ω resistor, $V = IR = 1 \times 2 = 2$ V
As current flows from higher to lower potential, E is at a lower potential
Hence, potential at E is 6 – 2 = 4 V

<u>From point E to F:</u>
The p.d. between E and F is 4 V.
F is at lower potential as it is connected to the negative terminal of the battery.
Hence, potential at F is 4 – 4 = 0 V

Example 9

Two resistors, of resistance 300 kΩ and 500 kΩ respectively, form a potential divider with outer junctions maintained at potentials of +3 V and –15 V.

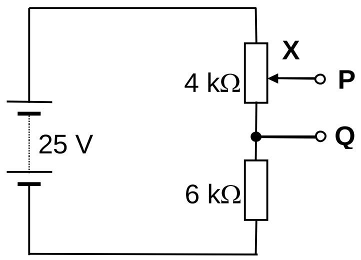


Determine the potential at the junction **X** between the resistors.

Example 10

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**.

Determine the limits of this potential difference.



Example 11

A 20 V battery with an internal resistance of 2.5 kΩ is connected to a 50 kΩ device. A voltmeter with an internal resistance of 120 kΩ and an ammeter with negligible internal resistance are used to measure the potential difference across the device and the current passing through it respectively.

(a) Sketch the circuit diagram for this setup.

(b) Determine the reading on the voltmeter and the ammeter.

Answer:

(a)

(b)

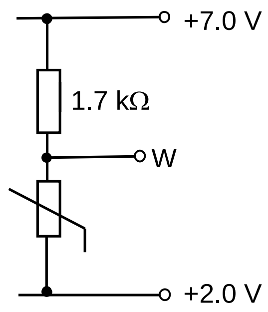
	Ideal	Practical	Connections
Voltmeter	- infinite internal resistance - does not draw current from circuit - reads the theoretical p.d. value across the points connected	- has a finite internal resistance - draws a small current from circuit - reads a p.d. that is smaller than the theoretical value	- always connected ***in parallel***, across the component whose p.d. is to be measured
Ammeter	- zero internal resistance - zero p.d. across its ends - reads the theoretical current value in the path	- has a small internal resistance - has a finite p.d. across its ends - reads a current that is smaller than the theoretical value	- always connected ***in series*** along the circuit path where the current is to be measured

(g) explain the use of thermistors and light-dependent resistors in potential dividers to provide a potential difference which is dependent on temperature and illumination respectively

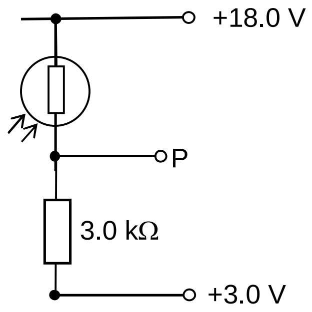
A thermistor is a resistor whose resistance varies greatly with temperature. Its resistance *decreases* with *increasing temperature*. When used in a potential divider circuit, it can provide a potential difference that depends on temperature. This makes thermistors ideal for monitoring and controlling temperatures.

An LDR is a resistor whose resistance varies with the intensity of light falling on it. Its resistance *decreases with increasing light intensity*. It can be used in a potential divider circuit to monitor light intensity, providing a potential difference dependent on the illumination. This makes LDRs ideal for applications where light levels need to be measured or controlled.

Example 12
In the figure below, the thermistor has a resistance of 800 Ω when hot, and a resistance of 5000 Ω when cold. Determine the potential at W when the temperature is hot.



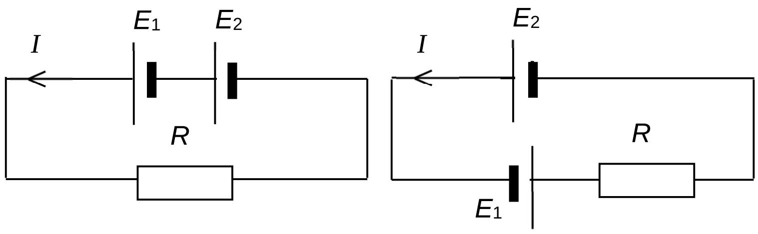
Example 13
In the figure below, the resistance of the LDR is 6.0 MΩ in the dark but then drops to 2.0 kΩ in the light. Determine the potential at point P when the LDR is in the light.



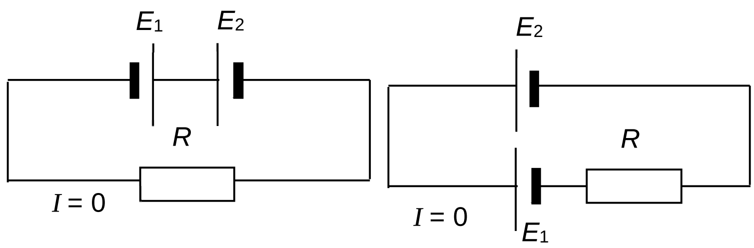
(h) recall and solve problems by using the principle of the potentiometer as a means of comparing potential differences

Potentiometer Principle

Before we look at the potentiometer, let us take a look at the two circuits below.

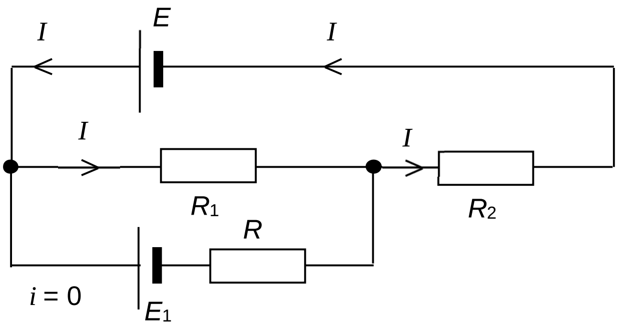


$$I = \frac{E_1 + E_2}{R}$$

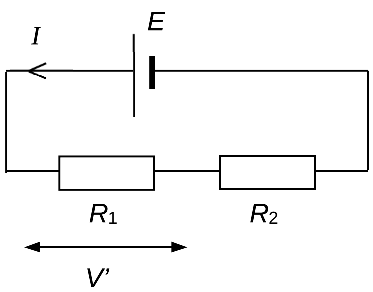


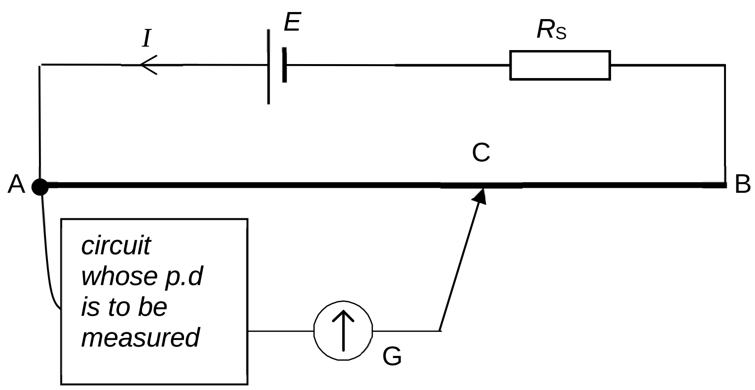
If $E_1 = E_2$, there is no current in the circuit.

We can replace the e.m.f. E_2 supplied by the battery with a potential divider circuit with an e.m.f. E and resistors R_1 and R_2.



By changing the values of the resistors, R_1 and R_2, we can change the p.d. across resistor R_1. When the p.d. across the resistor R_1 is equal to E_1, no current will flow through E_1. We have now constructed a potentiometer, which is an arrangement which measures p.d. accurately.





For a potentiometer found in our Physics laboratory, a length of resistance wire AB is used in place of the two resistors, R_1 and R_2. An additional resistor R_S connected in series with the wire serves to limit the current that flows through the circuit. The resistance of R_S will affect the p.d across the resistance wire AB.

A sliding contact is connected to a galvanometer G as shown, and is moved along the wire until a point, C is found on the wire such that there is *no current* in the galvanometer (null reading). This point is known as the null point or balance point and the length AC is known as the **balance length**. At the null point, the p.d. across the length AC is equal to the p.d. across the circuit to be measured. Hence, no current will flow through the galvanometer.

Assumptions

(i) wire has uniform cross-sectional area

(ii) potential difference across wire remains constant with time

(iii) length of wire remains constant with time

For a uniform wire of length L,

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

Since the same current flows through the entire wire,

$$V_{AC} = \frac{R_{AC}}{R_{AB}} \times V_{AB}$$

$$V_{AC} = \frac{L_{AC}}{L_{AB}} \times V_{AB} = \left(\frac{V_{AB}}{L_{AB}}\right) L_{AC} = kL_{AC}$$

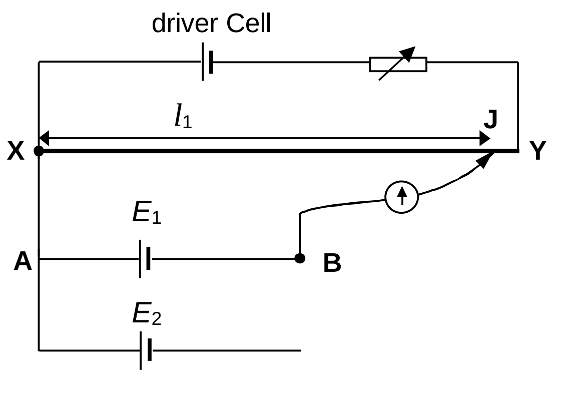
where k is the potential per unit length of the wire AB.

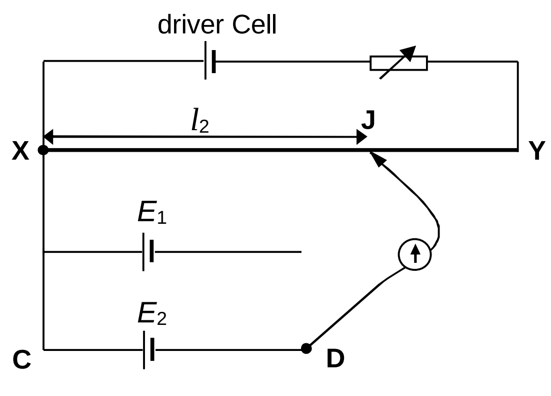
Comparing e.m.f.s

In practical circuitry, $V_{XY} \neq$ e.m.f. of *driver cell* as practical sources have *internal resistance*.

Hence in order to find the unknown e.m.f. (E_1) of a cell, we can compare it with a standard e.m.f. cell (E_2) using the circuit below.

The setting of the variable resistor must be the *same* for the two cells so that the *potential difference across XY is the same*. The variable resistor is used to *control* the potential difference across XY such that the balance length XJ is large enough to be accurately measured.





At the balance length (null deflection of galvanometer)

$$E_1 = kl_1 \text{ ---- (1)}$$

$$E_2 = kl_2 \text{ ---- (2)}$$

where k is the potential gradient of the wire **XY**.

(1) ÷ (2) ⇒

$$\frac{E_1}{E_2} = \frac{l_1}{l_2} \quad \Rightarrow \quad \boxed{E_1 = \frac{l_1}{l_2} E_2}$$

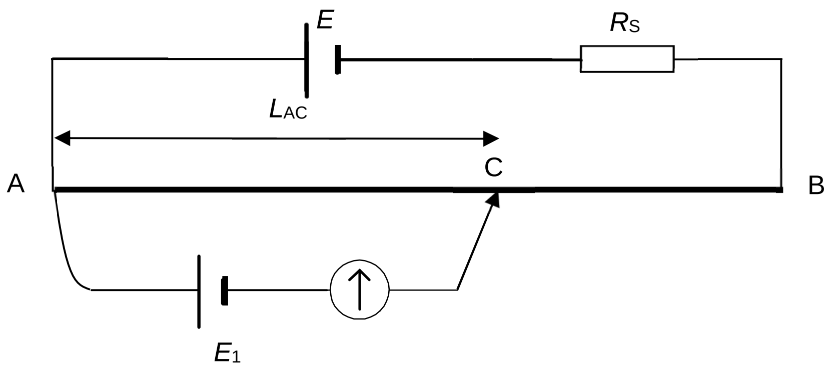
Note: E_1 and E_2 *need not* both be connected to the lower circuit *simultaneously*. They can be connected to the lower circuit one at a time, but their e.m.f.s can still be compared as above.

Example 14

A potentiometer is used to measure the e.m.f of Cell A. The potentiometer consists of a non-ideal driver cell of e.m.f. 20 V and one metre resistance wire. The balance length is 66.0 cm when Cell A is connected to the lower circuit. The balance length is 90.0 cm when a standard cell of e.m.f. 15 V is connected to the lower circuit. Find the e.m.f. of Cell A.

Measurement of e.m.f. of a battery

A potentiometer has a wire AB of length L and resistance R. It is powered by a battery of e.m.f. E and negligible internal resistance in series with a resistor of resistance R_S. With an unknown e.m.f. E_1 in the branch circuit, the balance point is found to be at C.



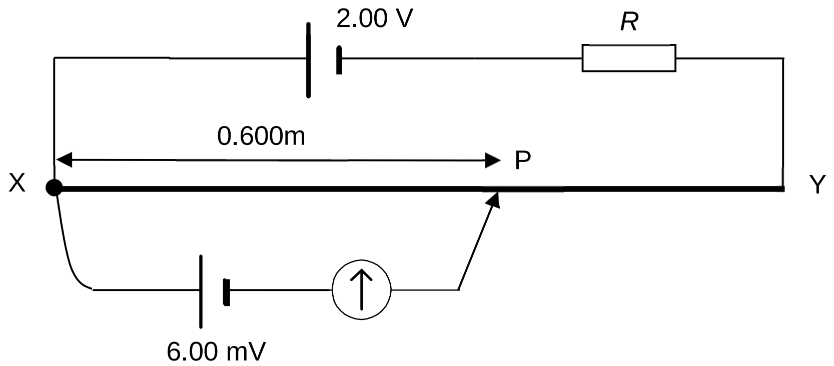
To find the unknown e.m.f. E_1, we need to first find the p.d. across wire AB:

$$V_{AB} = \frac{R}{R + R_S} \times E = \frac{RE}{R + R_S}$$

Using the potentiometer principle,

Example 15

The diagram below shows a simple potentiometer circuit for measuring a small e.m.f. source.



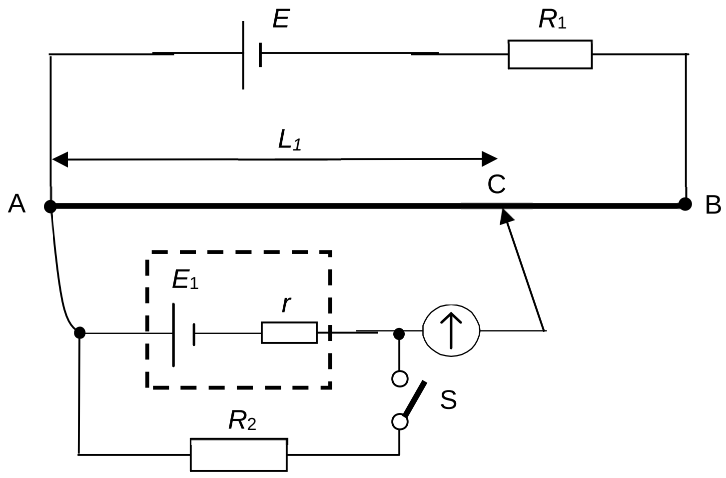
The wire XY has a length of 1.000 m and a resistance of 5.0 Ω. The driver cell has an e.m.f. of 2.00 V. If a balance point, P is obtained 0.600 m along XY when measuring an e.m.f. of 6.00 mV, what is the value of the resistance *R*?

Using the potentiometer principle,

Using the potential divider rule,

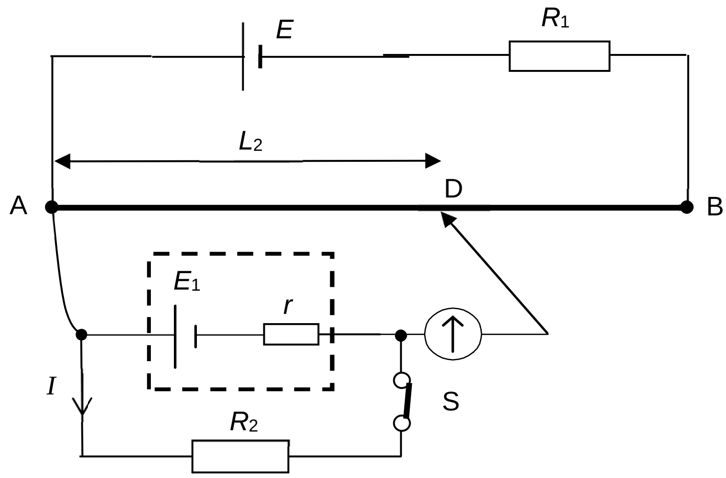
Determination of the internal resistance of a cell

To determine the internal resistance of a cell, the potentiometer circuit is to be set up as shown below.



With switch S opened, no current passes through the loop containing the resistor of resistance R_2. The balance point is at point C and the balance length is L_1.

With switch S closed, current passes through the loop containing the resistor of resistance R_2. The new balance point is now at point D and the balance length is L_2.



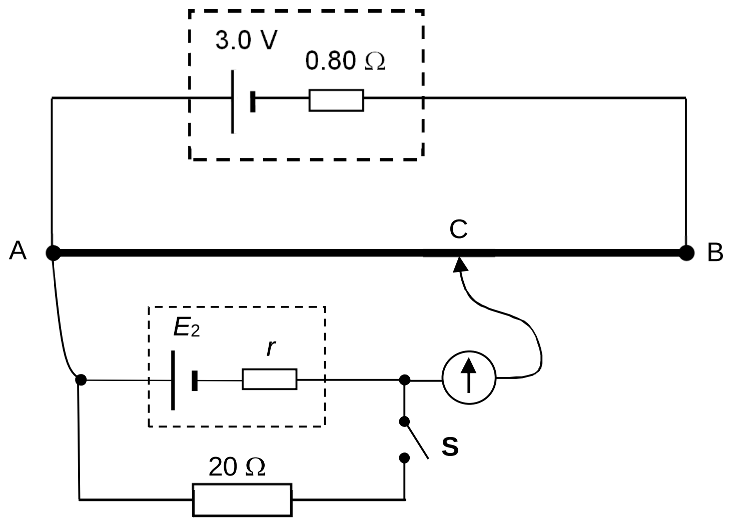
a) Using the balance length L_1, we can find the e.m.f. E_1.

b) Using the balance length L_2, we can find the terminal p.d. V across E_1 when there is a current flowing though E_1.

c) The terminal p.d. V across E_1 will also be equal to the p.d. across resistor R_2. Using $V = IR$, we can find the current I flowing through R_2.

d) Using the equation $V = E - Ir$, we can find the internal resistance r.

Example 16 A potentiometer circuit for measuring the internal resistance of a cell is shown below. The uniform wire AB has a length of 100.0 cm and a resistance of 1.6 Ω. The driver cell is of e.m.f. 3.0 V and internal resistance 0.80 Ω. A cell of unknown e.m.f. E_2 and internal resistance r and a resistor of 20 Ω is connected to the circuit.



The movable contact C can be connected to any point along the wire AB. When switch S is opened, a balance length of 61.0 cm is obtained. When switch S is closed, a balance length of 49.5 cm is obtained. Find the internal resistance, r.

V_{AB} =

When switch S is opened,

E_2 =

When switch S is closed, terminal p.d. across E_2

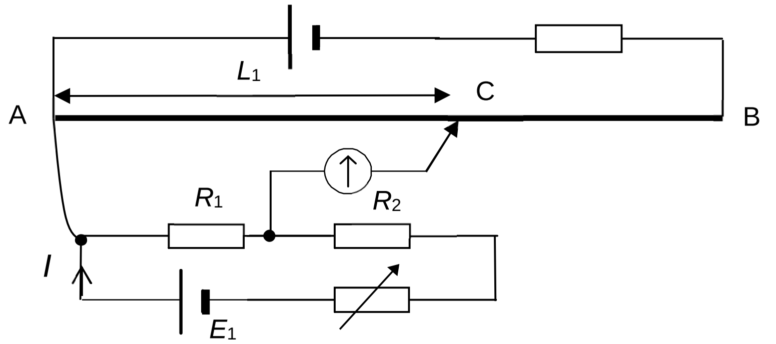
= $V_{20\,\Omega}$ =

$$I = \frac{V}{R} = \frac{0.99}{20} = 0.0495 \text{ A}$$

$V = E - I r \Rightarrow 0.99 = 1.22 - 0.0495\, r \Rightarrow r = 4.65\ \Omega$

Comparison of the resistances of two resistors

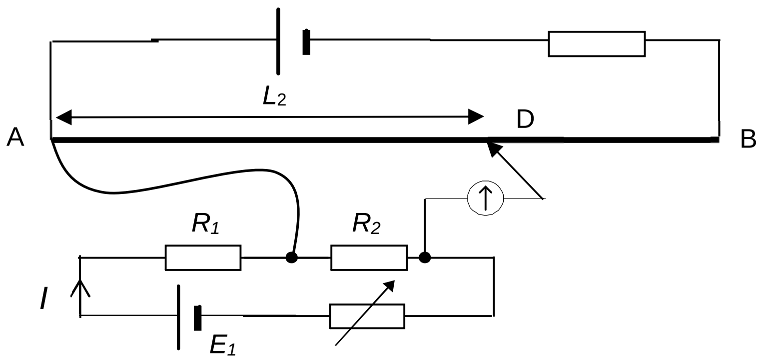
To measure the p.d. across R_1,



The balance length is found to be L_1.

The potential difference across R_1, $V_1 = \dfrac{L_1}{L_{AB}} \times V_{AB}$

To measure the p.d. across R_2.



The balance length is found to be L_2.

The potential difference across R_2, $V_2 = \dfrac{L_2}{L_{AB}} \times V_{AB}$

Since the same current I flows through R_1 and R_2 in the two configurations, we can conclude that

$$V_1 = \frac{L_1}{L_{AB}} \times V_{AB} \quad \& \quad V_2 = \frac{L_2}{L_{AB}} \times V_{AB}$$

$$IR_1 = \frac{L_1}{L_{AB}} \times V_{AB} \quad \& \quad IR_2 = \frac{L_2}{L_{AB}} \times V_{AB}$$

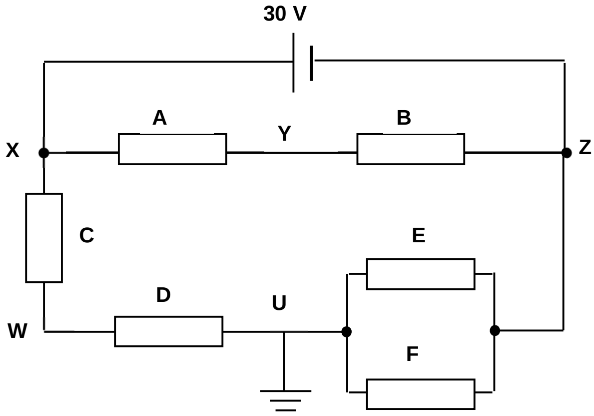
Hence,

If the resistance of either R_1 or R_2 is known, we can then find out the resistance of the other unknown resistor.

D. C. Circuits - Tutorial Questions

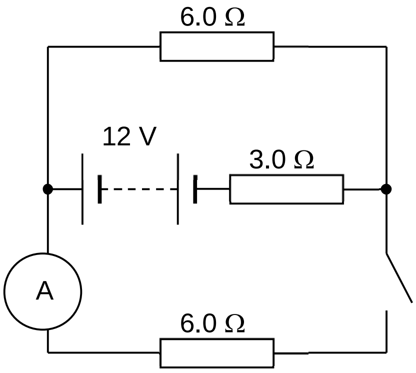
1. (a) The figure on the right shows a circuit containing a 30 V battery and 6 resistors. The potential differences across A, C and D are 22 V, 8 V and 12 V respectively. Find the potential difference across each of the components B, E and F and also the potential at the points U, W, X, Y and Z.

[Answer: 8 V, 10 V, 10 V, 0 V, 12 V, 20 V, −2 V, −10 V]



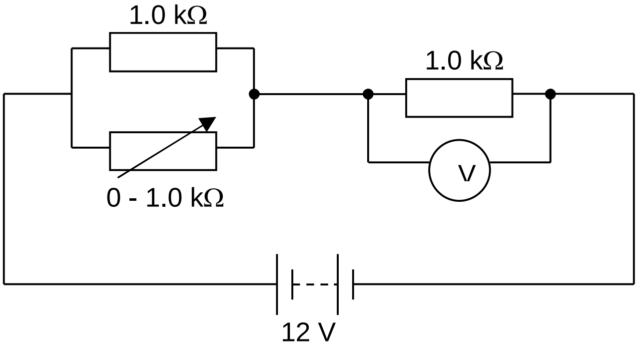
(b) Sketch a graph to show how the potential varies along the line XZ. Label the graph with appropriate values.

2. In the circuit, the battery has an e.m.f. of 12 V and an internal resistance of 3.0 Ω. The ammeter has negligible resistance.



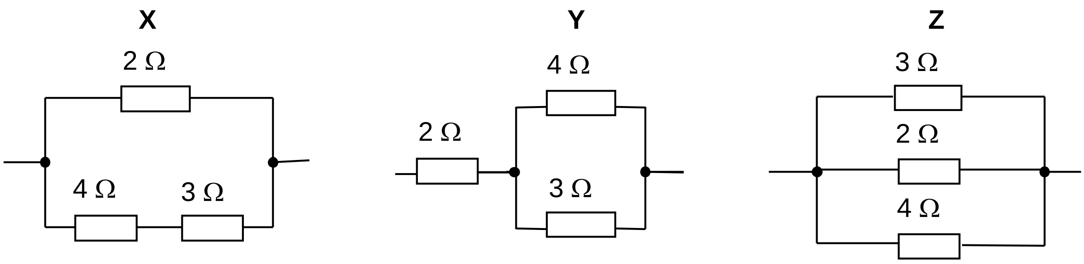
The switch is closed.
Calculate the reading on the ammeter. [Answer: 1 A] [N07/P1/28]

3. The diagram shows a resistor network connected to a 12 V battery of negligible internal resistance. The variable resistor has the range indicated, and the voltmeter has infinite resistance.

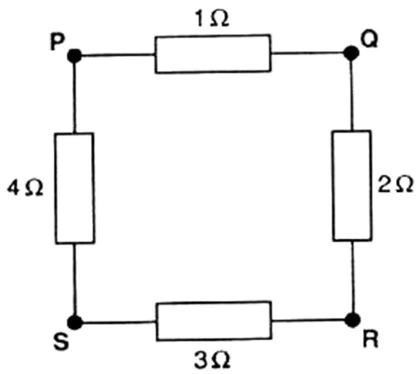


Calculate the maximum and minimum possible values of the voltmeter reading as the variable resistor is altered. [Answer: 12 V, 8 V] [N07/P1/29]

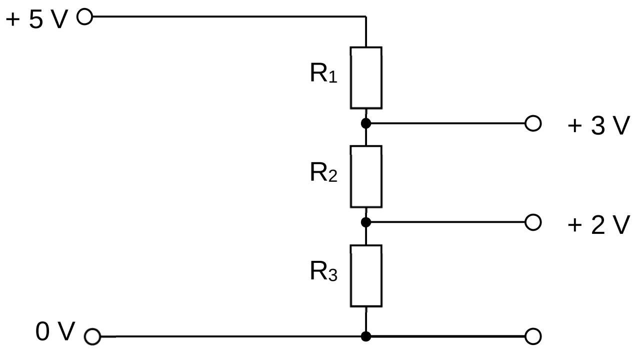
4. Three resistors of resistance 2 Ω, 3 Ω and 4 Ω are used to make the combinations **X, Y** and **Z** as shown. List the combination in order of increasing resistance. [Answer: **ZXY**]



5. Four resistors are connected as shown. State the two points between which the resistance of the combination is a maximum. [Answer: between **Q** and **S**] [J00/P1/15]



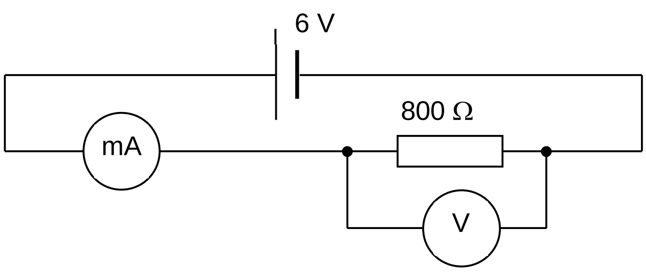
6. A potential divider is used to give outputs of 2 V and 3 V from a 5 V source, as shown.



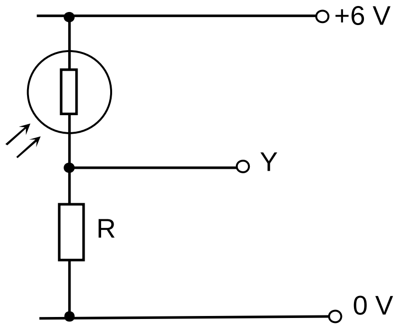
Which combination of resistances R_1, R_2 and R_3 gives the correct voltages? [J96/P1/15]

	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

7. A circuit is set up as shown to measure the p.d. across and current through an 800 Ω device. The battery, ammeter and voltmeter have an internal resistance of 20 Ω, 50 Ω and 12000 Ω respectively. Determine the reading of the ammeter and the voltmeter. [Answer: 7.32 mA, 5.49 V]



8. The light dependent resistor (LDR) in the circuit shown below has a resistance of 1200 Ω when illuminated, and a resistance of 10 MΩ when in the dark.



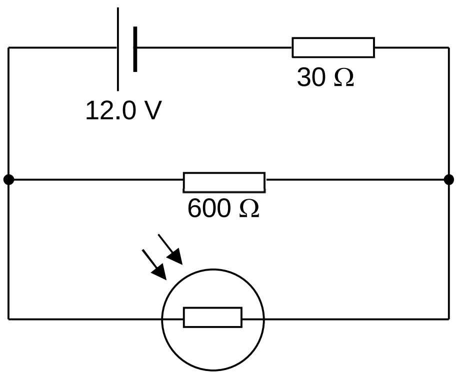
Determine the value R of a suitable resistor which can be placed in series with it so that the potential at Y changes from zero to 2 V when the LDR is illuminated. [Answer: 600 Ω]

9. Two resistors of resistance R_1 and R_2 are connected in parallel. The equivalent single resistance is R.

(a) Calculate the value of R when

(i) R_1 = 600 Ω and R_2 = 3000 Ω [Answer: 500 Ω]
(ii) $R_1 = R_2$ = 600 Ω [Answer: 300 Ω]
(iii) R_1 = 600 Ω and R_2 is infinite. [Answer: 600 Ω]

(b) Sketch a graph showing how R varies with R_2 for a constant R_1 = 600 Ω
(c) A light dependent resistor (LDR) is placed in parallel with a 600 Ω resistor and connected to a 12.0 V battery of internal resistance 30 Ω as shown below.



(i) In conditions of low intensity light, the resistance of the LDR is 3000 Ω. Calculate

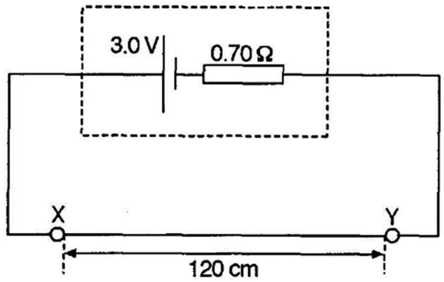
(1) the current through the LDR.
(2) the power dissipated in the LDR. [Answer: 3.77 mA, 0.0427 W]

(ii) Accidentally, the LDR is exposed to sunlight and its resistance falls to 100 Ω. Discuss whether the LDR, which is marked 0.5 W, will be damaged.

(d) Draw a labelled diagram showing how a potentiometer could be connected to the circuit in the figure above to compare the potential differences across the LDR in (c) for different levels of illumination.

[N06/III/6 mod]

10. A uniform wire XY of length 120 cm and radius 0.55 mm is connected in series with a cell of e.m.f. 3.0 V and internal resistance 0.70 Ω, as shown below.

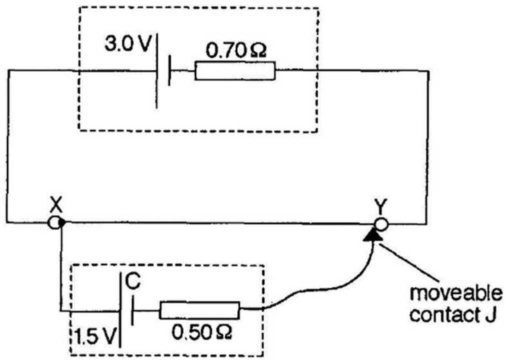


(a) The resistivity of the material of the wire is 1.1×10^{-6} Ω m. Show that the resistance of the wire XY is 1.4 Ω.

(b) Calculate the potential difference per unit length of XY. [Answer: 1.7 V m^{-1}]

The diagram below shows a simple potentiometer circuit. The length and resistance of the wire XY is 1.2 m and 1.4 Ω respectively.

(c)



The moveable contact J can be connected to any point along the wire XY.

(i) Initially, the contact J is connected to end Y. The P.D. across the wire XY is then equal to the P.D. applied across cell C. On the figure above, mark with an arrow the direction of the current through the cell C.

(ii) Determine the position of the contact J on XY such that there is no current through the cell C. [Answer: 0.9 m from X]

(iii) To improve accuracy, the position found in (ii) should be nearer to end Y. Suggest one way in which the circuit above may be modified so that this is achieved.

[N02/II/6]

11. In the figure, AB is a 10 Ω slide wire, 50 cm long. E_1 is a 2 V accumulator of negligible resistance. R_1 and R_2 are resistances of 15 Ω and 5 Ω respectively. When the keys K_1 and K_2 are both open, the galvanometer shows no deflection when AJ is 31.25 cm. When keys K_1 and K_2 are both closed, the balance length AJ is 5 cm.

Calculate

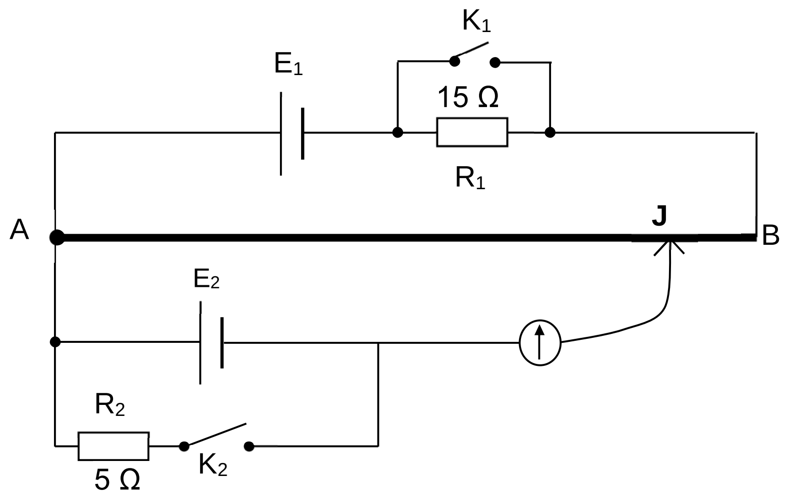
(i) The e.m.f. of cell E_2

(ii) The internal resistance of the cell E_2

(iii) The balance length AJ when K_2 is open and K_1 is close.

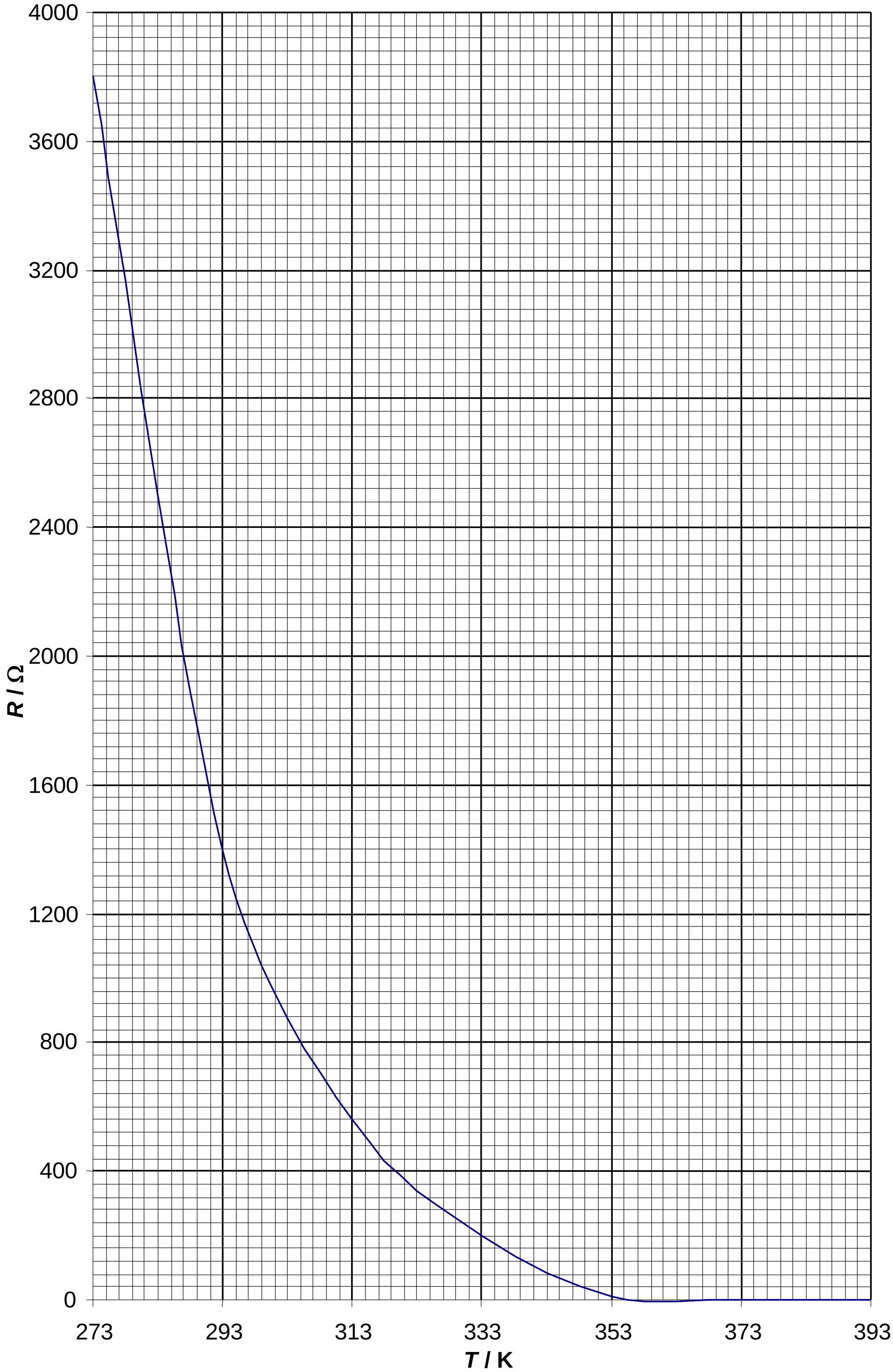
(iv) The balance length AJ when K_2 is close and K_1 is open.

[Answer: 0.5 V, 7.5 Ω, 12.5 cm, 12.5 cm]



12. (a) State two reasons why the temperature of a body is not a measure of the quantity of thermal energy in the body.

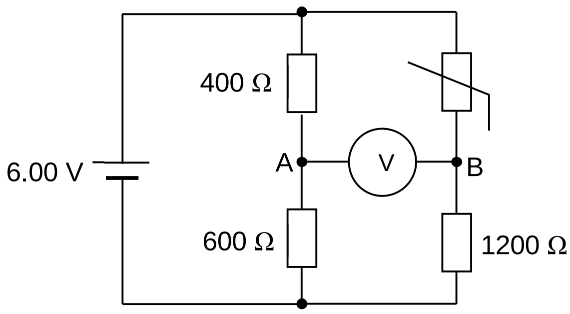
(b) The variation with thermodynamic temperature T of the resistance R of a thermistor is shown below.



(i) Suggest, with a reason, why the thermistor, used as a thermometer, is more appropriate for measuring temperature in the range 273 K to 293 K than in the range 313 K to 333 K.

(ii) Use the graph to determine the temperature corresponding to a thermistor resistance of 1500 Ω when measured on the thermodynamic scale of temperature.

(c) The thermistor is connected into the circuit below.



The voltmeter connected between A and B has infinite resistance. The battery has e.m.f. 6.00 V and negligible internal resistance.

(i) Determine the thermodynamic temperature at which the voltmeter reads zero. Explain your working.

(ii) The temperature of the thermistor is now changed and the voltmeter reads 1.20 V.

(1) Suggest why the thermistor could be at one of two different thermodynamic temperatures.

(2) Calculate the lower of these two thermodynamic temperatures.

[N06/II/4 mod]

[Answer: (b) (ii) T = 292 K; (c) (i) 305 K, (ii) (2) 289 K]