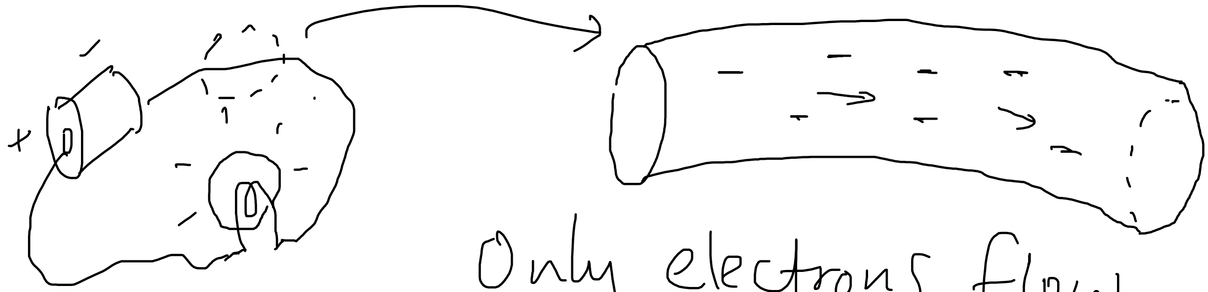
Elecric Current

Dr K M Hock

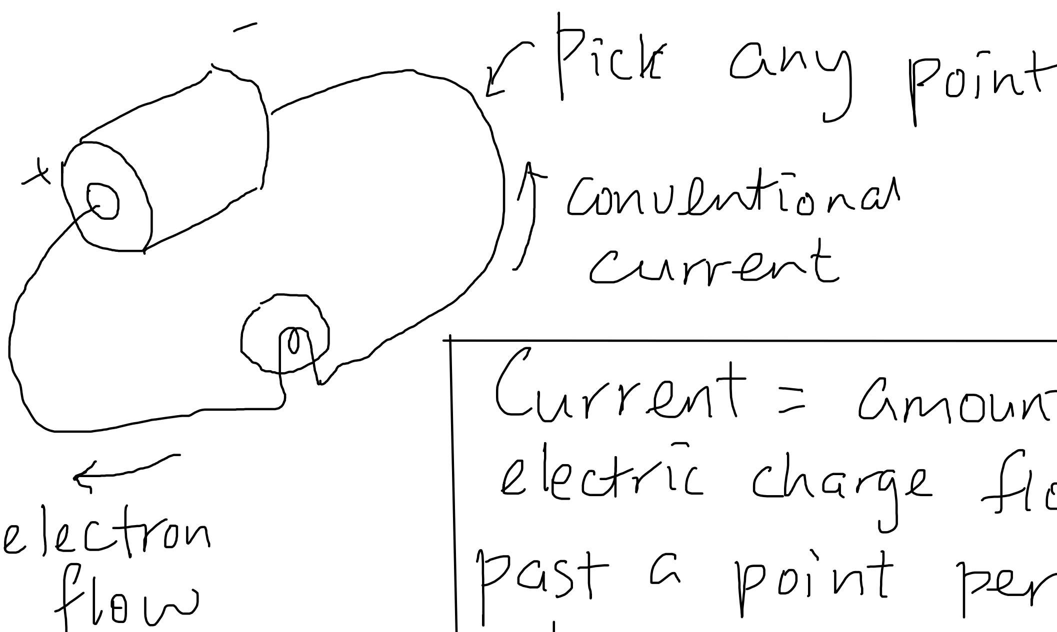


Only electrons flow.
The rest of the atoms don't.
(10000 x heavier)

→ Current in wires :

Negative electrons from -ve to +ve poles.

"Conventional Current" - imaginary/equivalent +ve charges from +ve to -ve poles.



Current = amount of electric charge flowing past a point per unit time.

Charge, Coulomb

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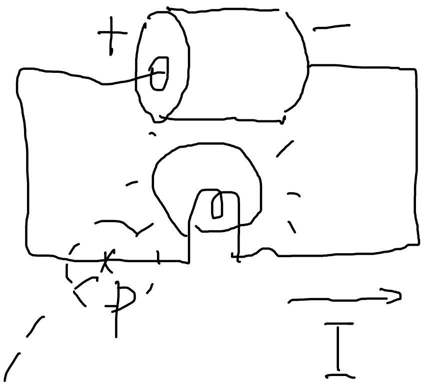
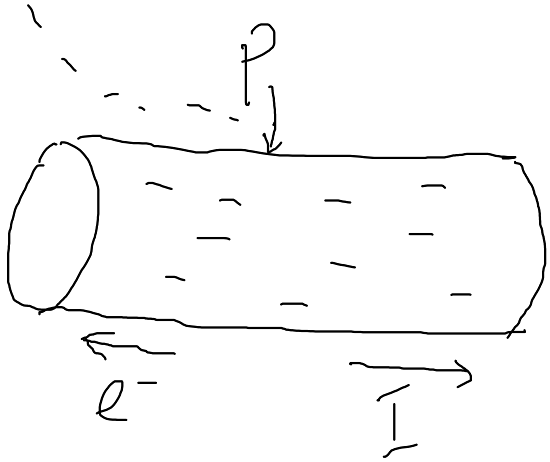


If I just say a current flows to the right, it means a conventional current.

So electrons flow to the left!



e.g. Current $I = 1$ Ampere (A) means 1 Coulomb (C) of charge flows past a point (e.g. P) in 1 s.

But how many electrons actually flow past P?

1 electron's charge, $e = 1.6 \times 10^{-19}$ C.

No. of electrons in 1 C $= \frac{1\,C}{1.6\times10^{-19}\,C} = 6.25 \times 10^{18}$

$\therefore$ 1 A of current $\rightarrow 6.25\times10^{18}$ electrons in 1 s.

Electric Current 2

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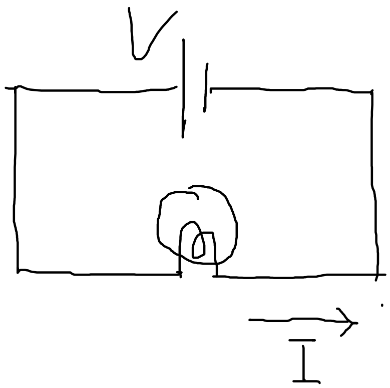

Current = $\frac{\text{Charge}}{\text{time}}$

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

Charge Q flows past a point in time t.

e.g. 2A of current flows through a light bulb. How much charge flows through the bulb in 1 min.

$$Q = It = 2A \times 60\,s = 120\,C.$$

e.g. How many electrons flow through?

$e = 1.6 \times 10^{-19} C.$

$$\text{no. of } e^- = \frac{Q}{e} = \frac{120}{1.6 \times 10^{-19}} = \_\_\_\_\_\_$$

Potential Difference

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Battery must do work to push e⁻ as they knock against atoms.

e.g. 2 J of work is done to move 1 C of charge from A to B.

Say: Potential difference between A and B is 2 volts (V).

Potential difference between 2 points is the work done to move unit charge from one point to the other point.

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

p.d. — V, work — W, charge — Q

unit = Volt (V)

$1 V = 1 J/C$.

recall and solve problems using V = W/Q

Potential Difference 2

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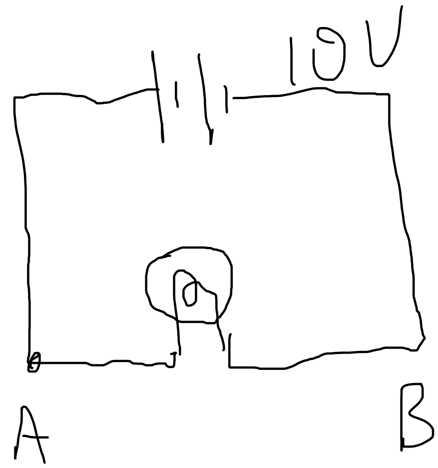


e.g. resistance in battery and wires can be ignored.

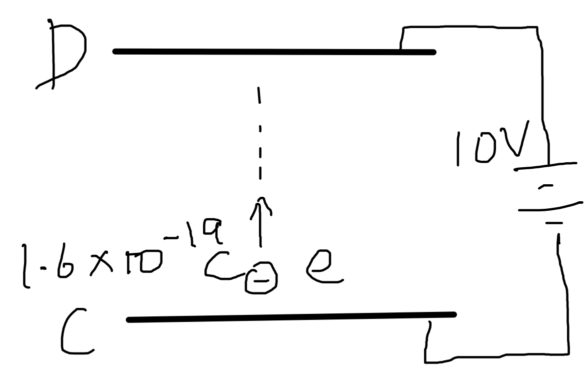
How much work is needed to bring 5C from A to B?

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

$$W = QV = 5C \times 10V = 50J$$

What happens to this energy? → Light, heat

How much work is done to move an electron from C to D?



$$W = QV$$
$$= 1.6\times10^{-19} \times 10$$
$$= 1.6\times10^{-18}\ J$$

What happens to this energy?

→ KE of e^-

recall and solve problems using P = V I , P = I^2 R

Electric Power

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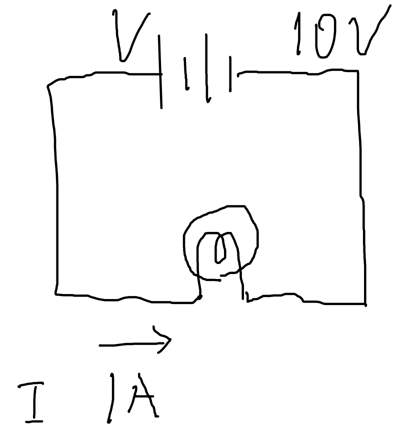

e.g. how much charge goes thru' the bulb in 5s?

how much work is done?

What is the power?

Charge $Q = It = 1 \times 5 = 5C$

Work $W = QV = 5C \times 10V = 50J$

Power $P = \frac{W}{t} = \frac{50J}{5s} = 10W$

↓

$$P = \frac{W}{t} = \frac{QV}{t} = IV$$

Can also do $P = IV = 1A \times 10V = 10W$

Ohm's law $V = IR$ — resistance

$\therefore$ $P = IV = I^2R$

define resistance and the ohm
recall and solve problems using V = I R

Ohm's law

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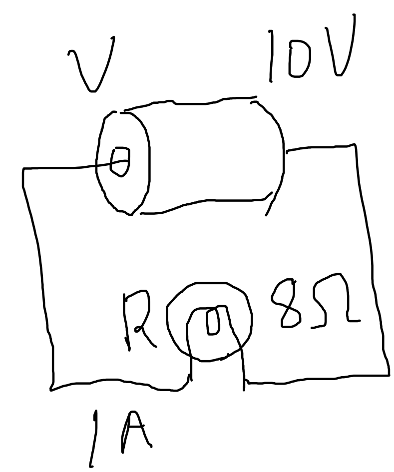
e.g. Find resistance of the light bulb.

$$V = IR$$

$$R = \frac{V}{I} = \frac{10V}{1A} = 10\,\Omega$$

e.g. find internal resistance of cell.



Total resistance in circuit

$$R_T = \frac{V}{I} = \frac{10V}{1A} = 10\,\Omega$$

Internal resistance = $R_T - R = 10 - 8\,\Omega$

sketch and explain the I-V characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp

I-V Characteristics

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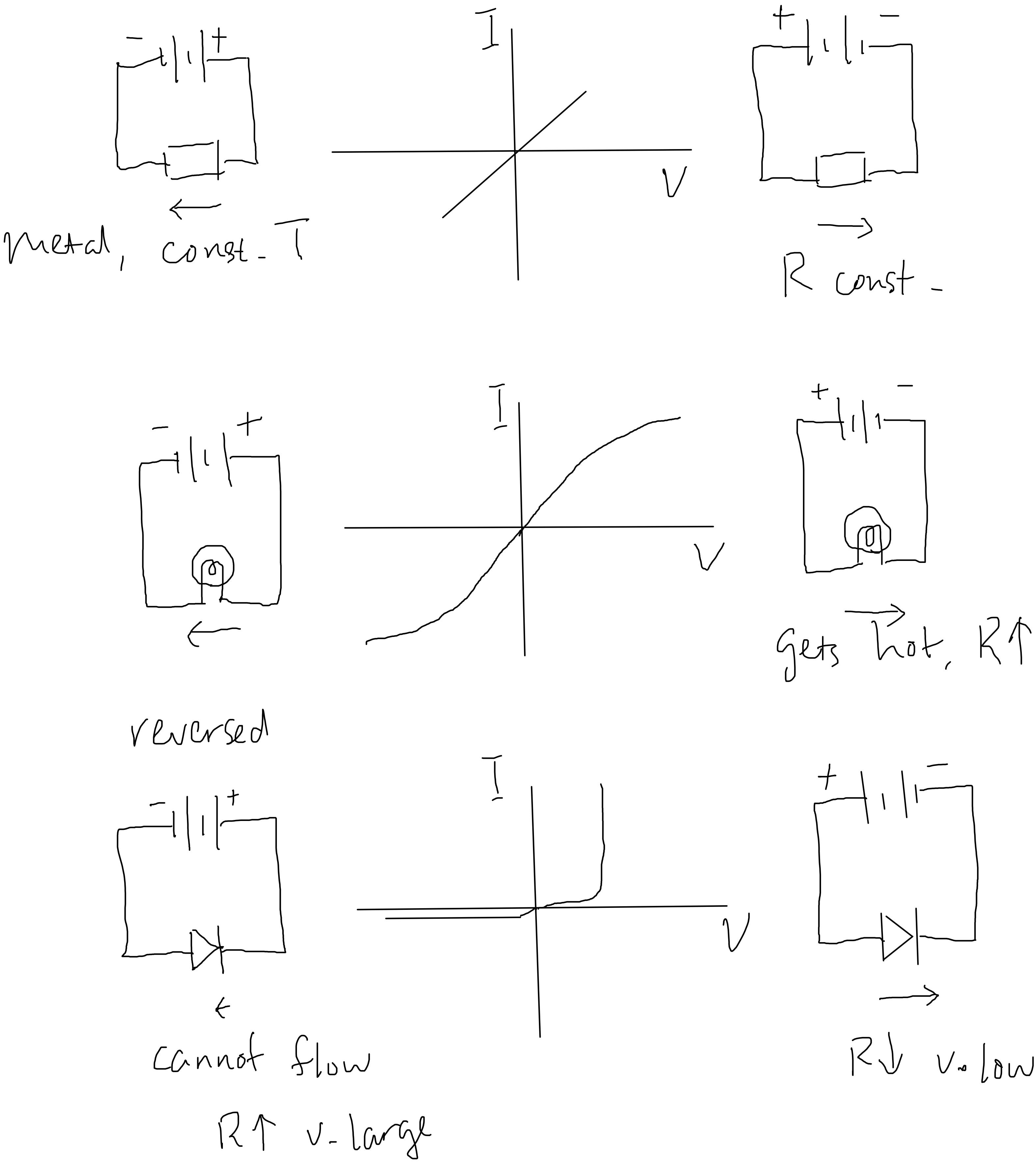

sketch the temperature characteristic of a thermistor

Thermistor

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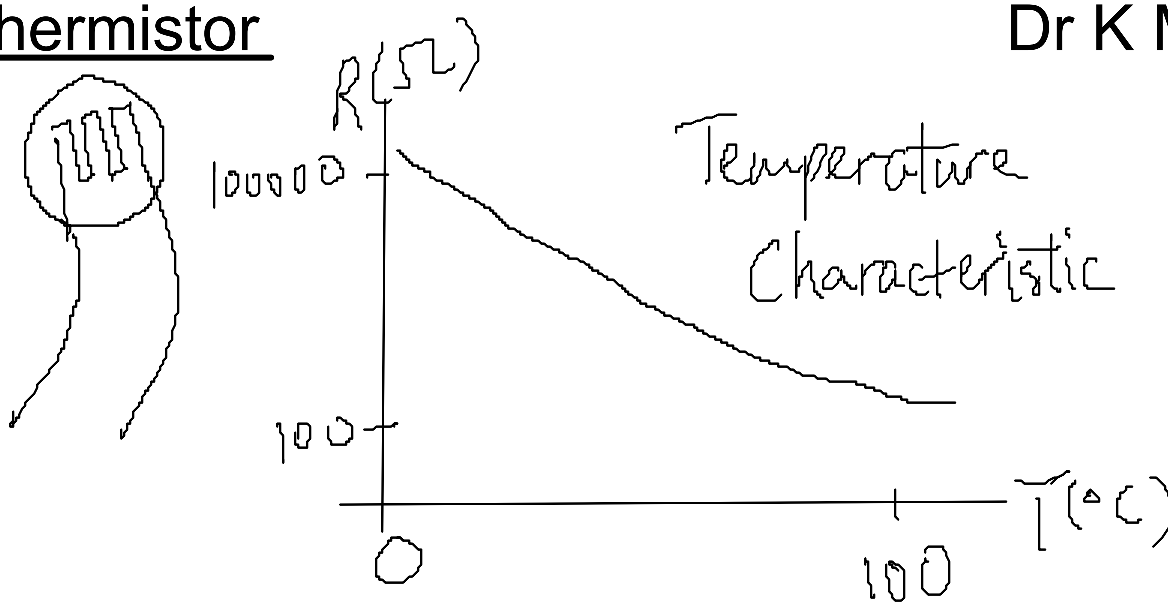

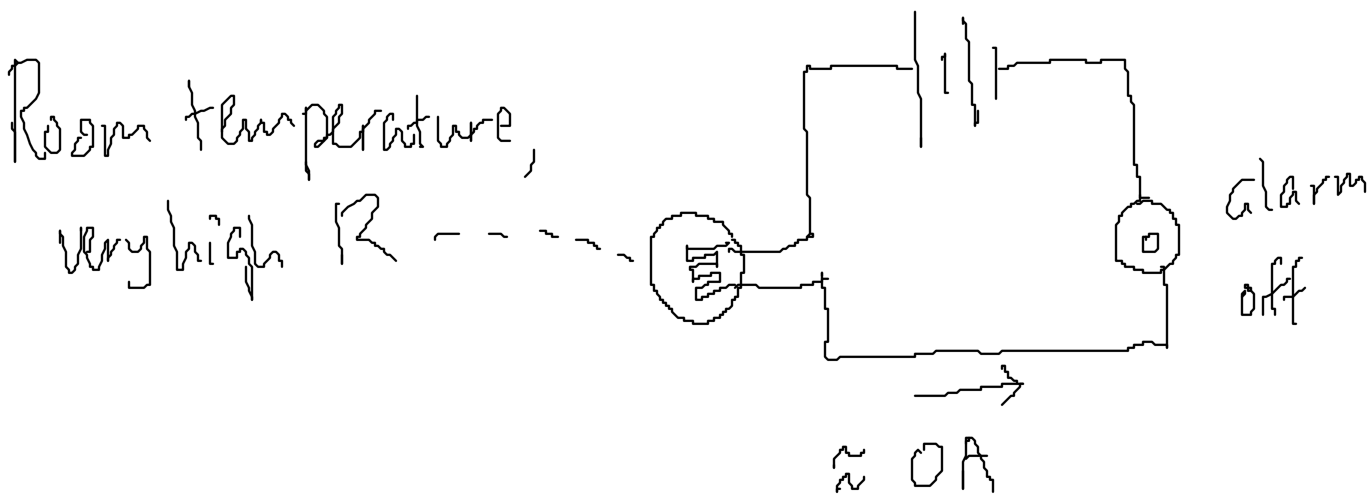

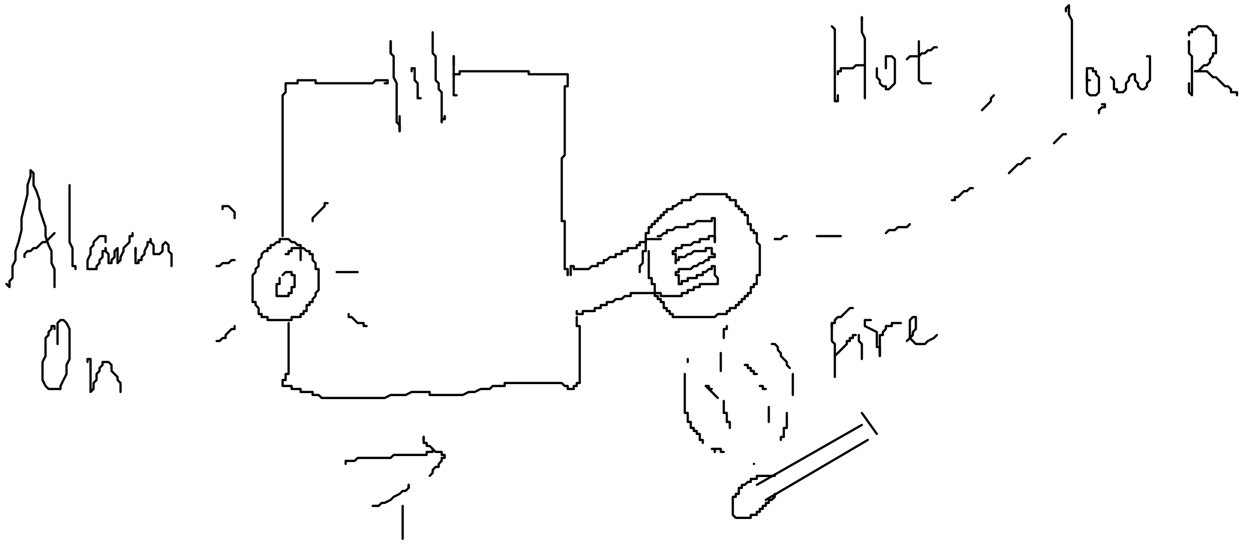

Resistivity

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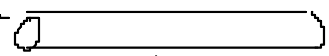
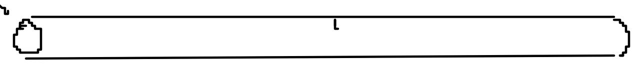
conductor



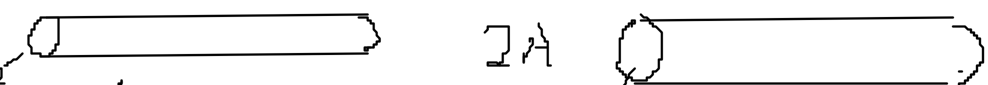
1 cm² A — L 10 cm — R: 0.1 Ω



1 cm² A — 2L 20 cm — 0.1 Ω × 2

Resistance proportional to length

$$R \propto L$$



A 1 cm² — L 20 cm   2A 2 cm² — L 20 cm

R: 0.1 Ω $\frac{1}{2} \times 0.1\,\Omega$

Resistance proportional to $\frac{1}{\text{area}}$

$$R \propto \frac{1}{A}$$

Combining:

$$R = \rho \frac{L}{A}$$ (ρ — constant)

e.g. find resistivity ρ.

Using the 0.1 Ω wire above,

$$\rho = \frac{AR}{L} = \frac{10^{-4}\,m^2 \times 0.1\,\Omega}{0.2\,m} = \_\_\_\_\ \Omega\,m$$

define e.m.f. in terms of the energy transferred by a source in driving unit charge round a complete circuit

Electromotive Force

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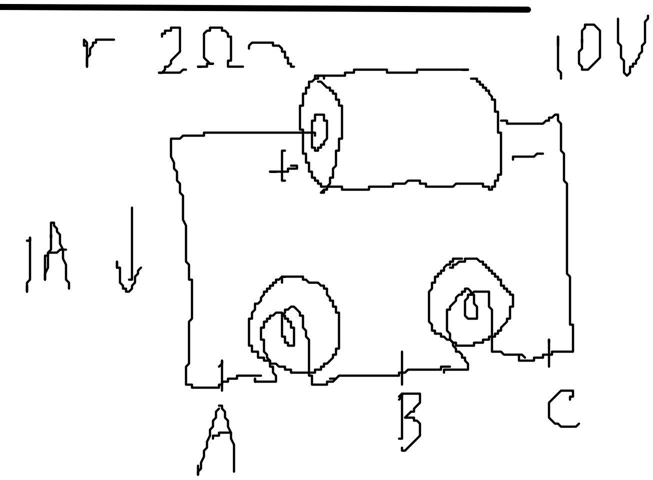

Recall potential difference p.d.

e.g. work done to bring unit charge from A to B.

e.g. Cell voltage is 10V. Is this p.d. between + and − poles?

No. because cell may have resistance r. Part of the 10V must do work to bring charge thru' the cell itself.

The 10V is the work done to bring 1C of charge round the whole circuit.

↓

Electromotive force e.m.f.

–

Work done to bring unit charge round the whole circuit.

e.m.f. versus p.d.

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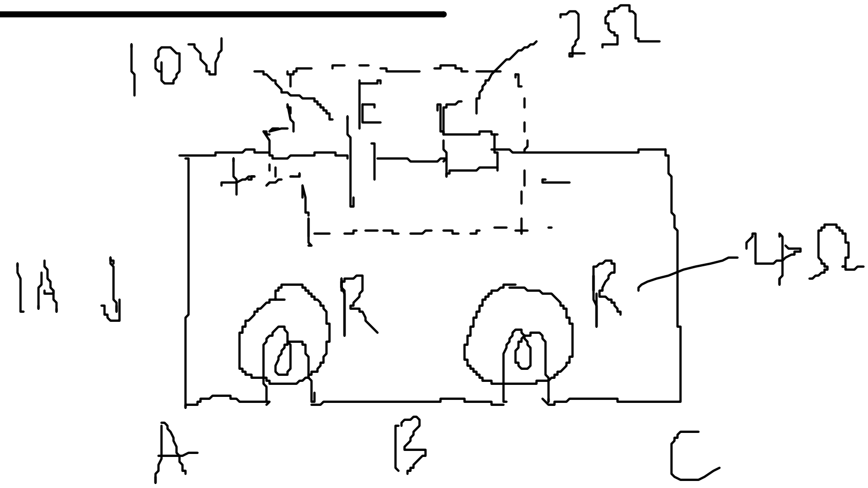

e.g. Find p.d. across AB.

$V = IR = 1A \times 4\Omega = 4V$.

e.g. Find p.d. across AC

Since 2 light bulbs have same R, work done on 1C from A to C is 2x " " from A to B.

So answer = $2 \times 4V = 8V$.

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e.g. Find voltage across +, - poles.

10V? X charge from + to - flows from A to C. So answer is 8V.

Why not 10V??

show an understanding of the effects of the internal resistance of a source of e.m.f. on the terminal potential difference and output power.

Internal Resistance

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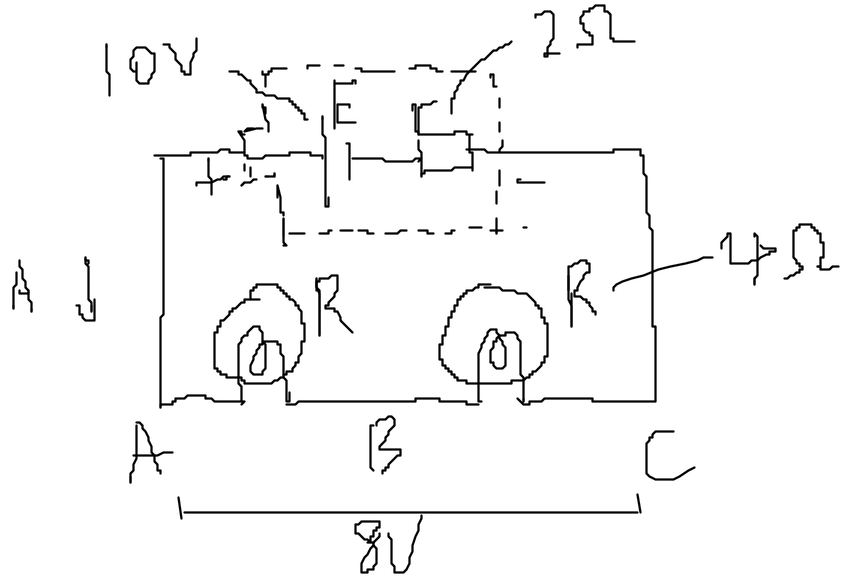
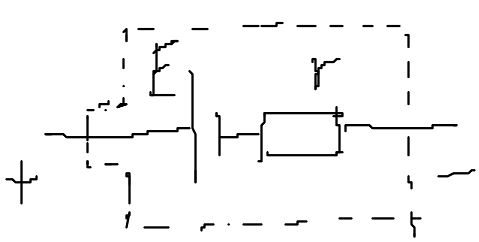


e.g. 8 V across AC
→ 8 J to bring 1C from A to C.

10 V e.m.f.
→ 10 J to bring 1C round whole circuit.

The difference ?
→ 2 J to bring 1C thru' cell's own resistance r

Internal resistance



e.g. What if I remove the circuit ?
What is the terminal p.d. now ?
across +, −

Ans. 10V, ∵ no work thru' r.