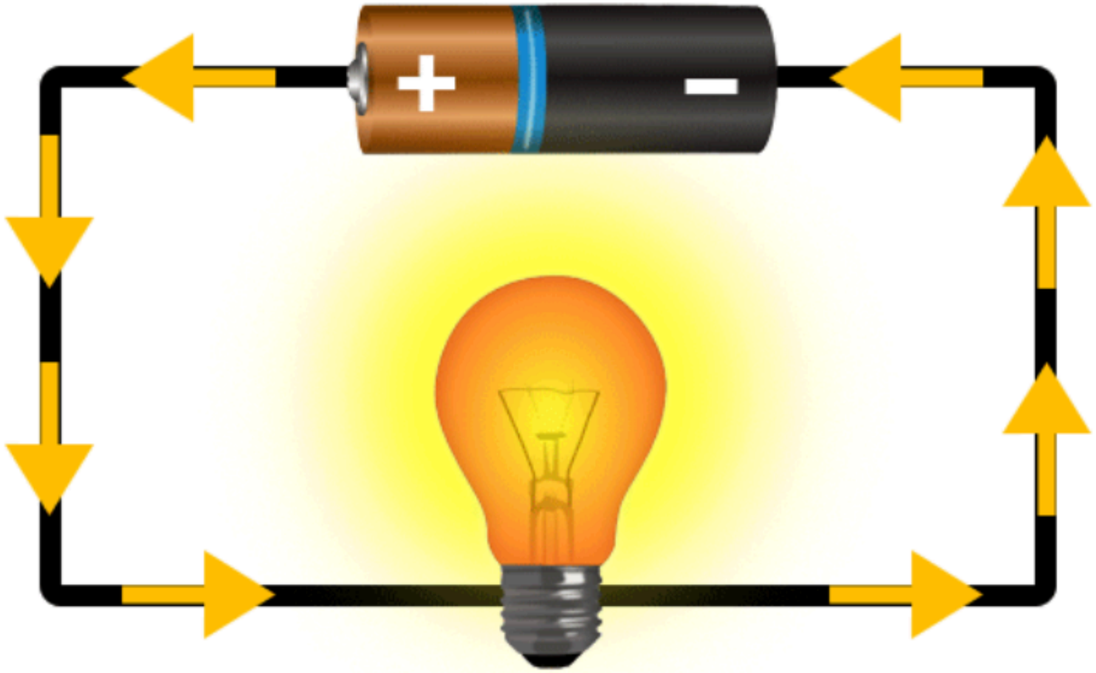
Chapter 18.
Electrical Quantities

New Words

flow; switch; wire; component; device;
Current(conventional current); ampere; ammeter; galvanometer
voltage/potential difference; electromotive force(e.m.f.); volt; voltmeter;
resistance; resistor; ohm;
Power supply; cell; battery; a.c.; d.c.;
in series; in parallel
filament lamp; diode
macroscopic microscopic
characteristic
Positive terminal; negative terminal; electrode

Current

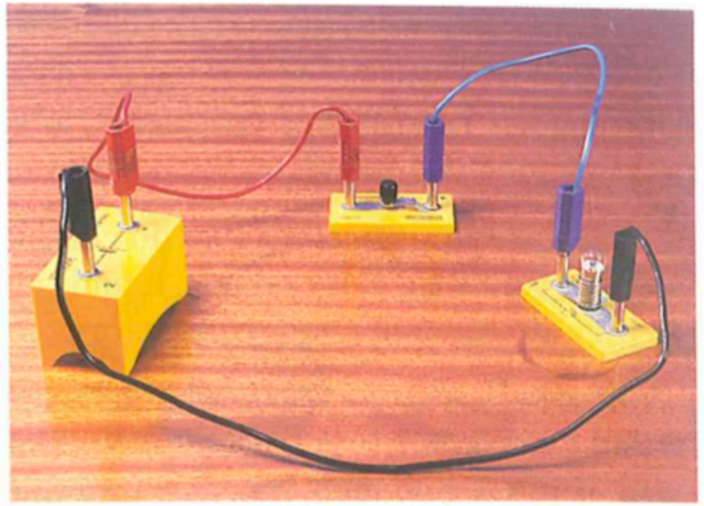
What is static electricity? In chapter 17, we discussed static charge. Apart from static charge, do we have “non-static” charge? What is **electric current**?

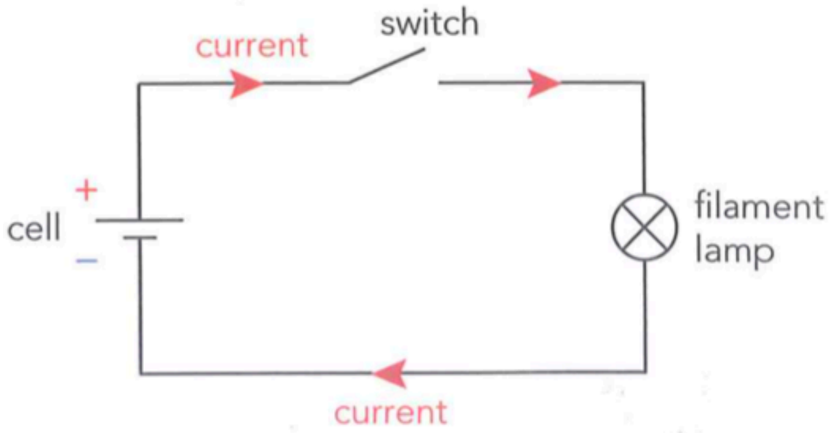


Current

How to make a current?

1. Complete circuit





Why do we use **cooper/steel** as wire?

Good conductors e.g. metal vs bad ***conductors*** *(good insulators)e.g. polymers, glass*
Explanation: (why some materials are good conductors while some are not?)
Metal contains ***free/delocalized*** *electrons/Electrons in non-metal are* ***bonded***

2. “push” provided by battery (two or more cells connected end-to-end)

Current

What is the difference between **static charge** and **electric current**?

Static electricity describes the situation when electric charges remains **stationary**. This occurs best with **insulators**.
Electric current occurs when electric charges are **moving** from one place to another. This occurs best with **conductors**.

Current

Electric current: flow of charge

Def: the rate at which charge flows

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

Unit: ampere, A

Current and charge:

Quantity	Symbol for quantity	Unit	Symbol for unit
current	I	amps	A
charge	Q	coulombs	C
time	t	seconds	s

Exercise

A current of 120 microamps flows around a circuit for one hour. How much electric charge flows around the circuit in this time?

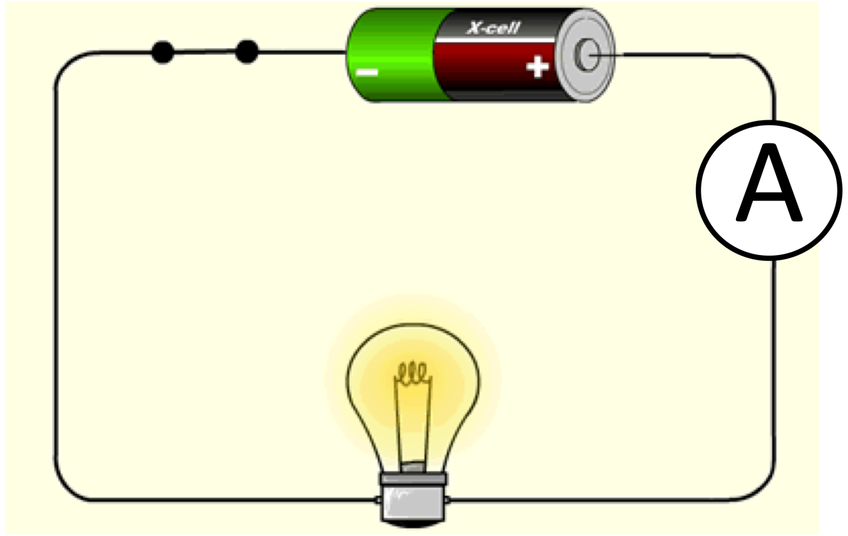
Exercise

Calculate the missing values a-d in the table below.

Charge	Current	Time
charge	current	time
220 C	2 A	**a**
57.6 C	**b**	3 hours
c	0.5 A	9 minutes
5.4 C	70 mA	**d**

Current

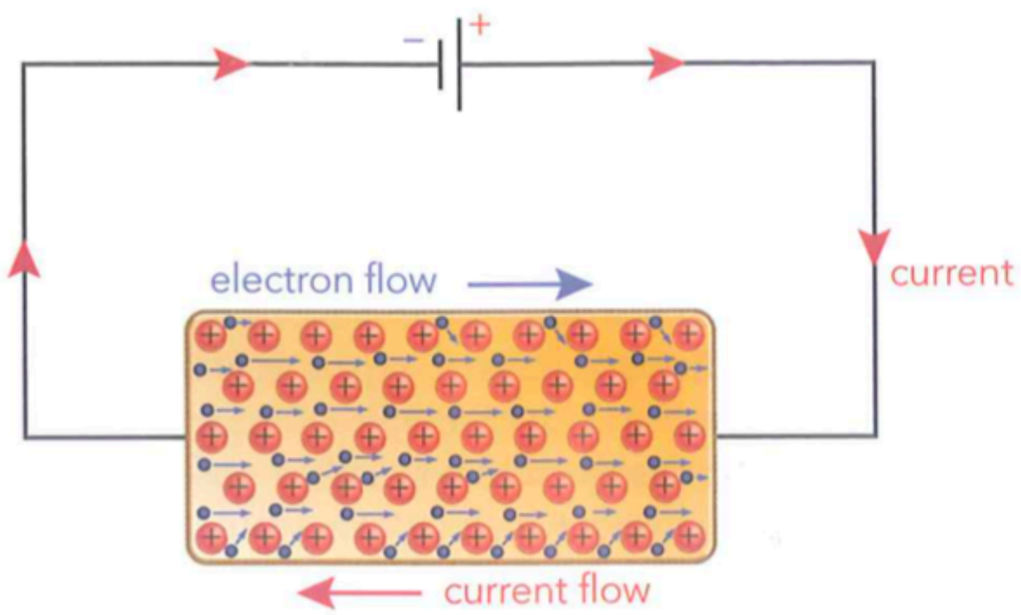
Measuring electric current: Ammeter vs galvanometer

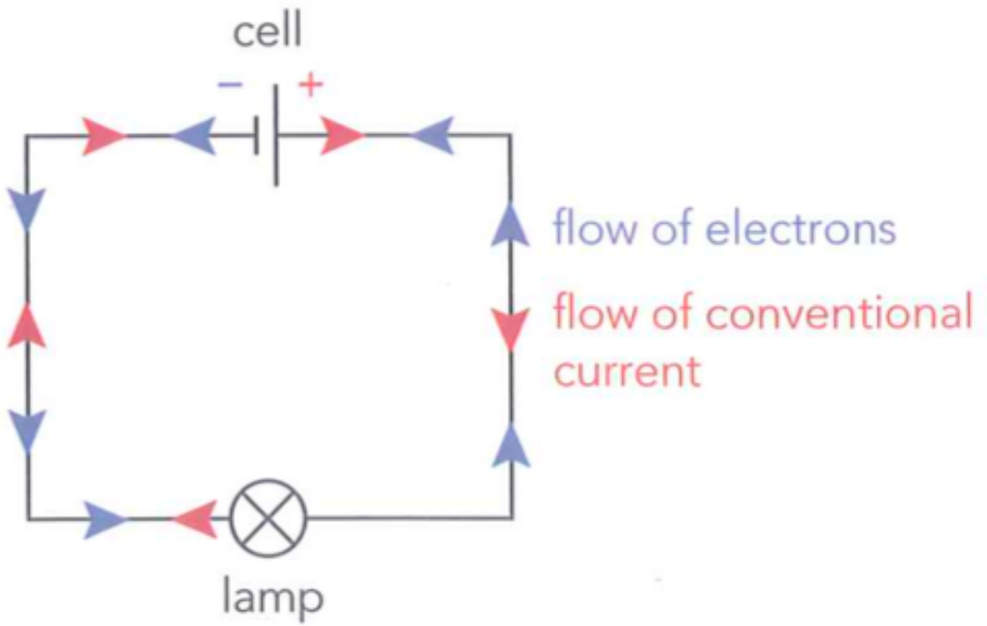


Current

conventional current: from **positive** terminal to **negative** terminal

electrons: from **negative** terminal to **positive** terminal





Voltage

What make electric current flow?

Voltage/potential difference(p.d.) makes a current flow through a conductor

Def: Work done per unit charge

Eq: $V = \frac{W}{Q}$ Work done and voltage: $W = QV$

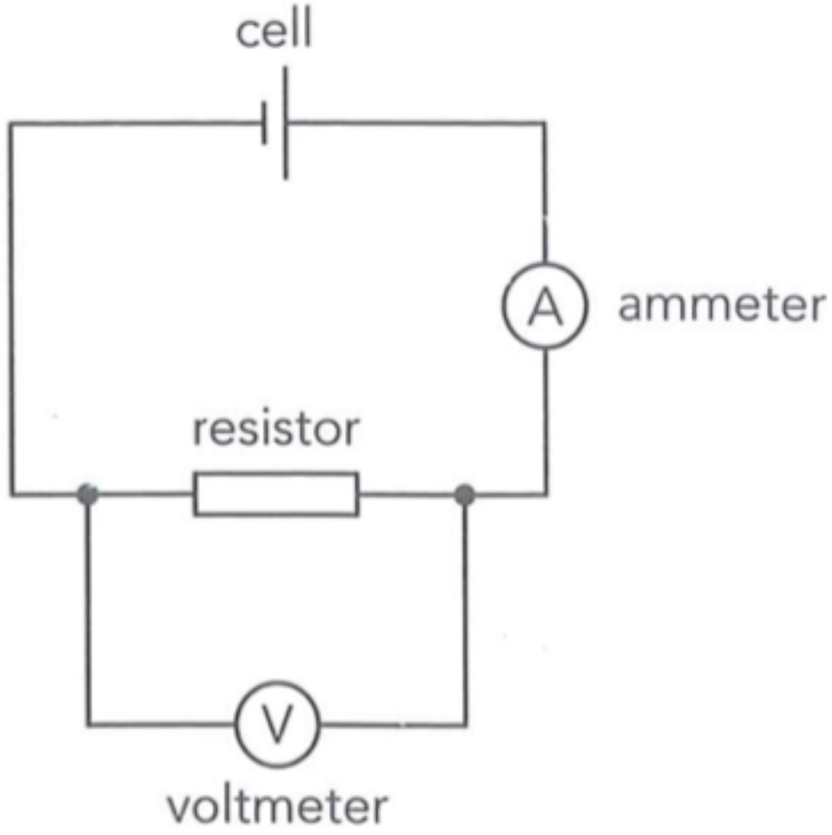
Unit: V, volt

Electromotive force(e.m.f.):
EMF of a cell is the **work done per unit of charge** by the cell in driving charge round a complete circuit.

EMF is the maximum PD between two electrodes

Voltage

Measuring voltage:



Voltage

Combining e.m.f.s

a

b

c

Exercise

Calculate the e.m.f. of a battery that gives 60J of energy to a charge 5C.

Exercise

The p.d. across a lamp is 12V. The lamp is connected for 10s. Calculate how many joules of energy are transferred when:

A. a charge of 1C passes through it.

B. a charge of 5C passes through it.

C. a current of 2A flows.

Resistance

What if we connect the positive and negative terminal of a cell together with a short wire?

Resistance: how difficult for I to flow 阻碍能力

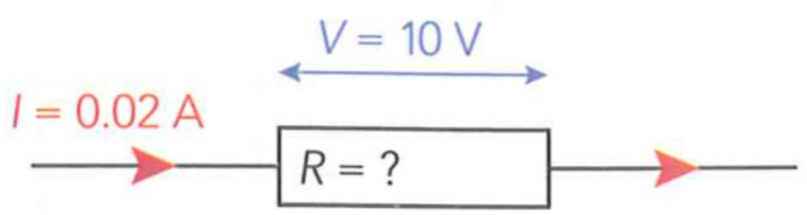
Def: p.d. across component divided by I passing through it

Eq: $R = \frac{V}{I}$

Unit: ohm, Ω

Exercise

A resistor allows a current of 0.02A to flow through it when there is a p.d. of 10.0 V between its ends. What is its resistance?



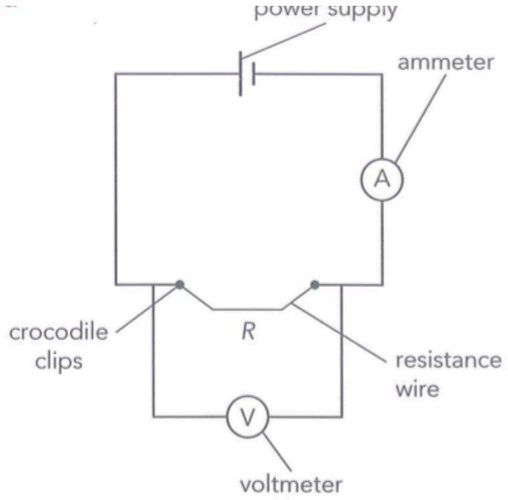
Resistance

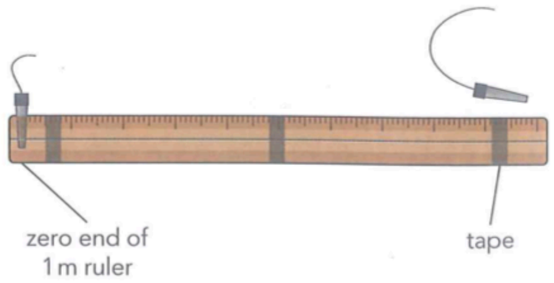
Resistance and thickness & length?

Assumption: Area increase => R decrease

Length increase => R increase

Method: measuring resistance





Resistance

$R \propto L$ R is **directly proportional** to length

$R \propto \frac{1}{A}$ R is **inversely proportional** to cross-sectional area

Exercise

A 2.0 meter length of wire has a resistance of 4.0 ohm.

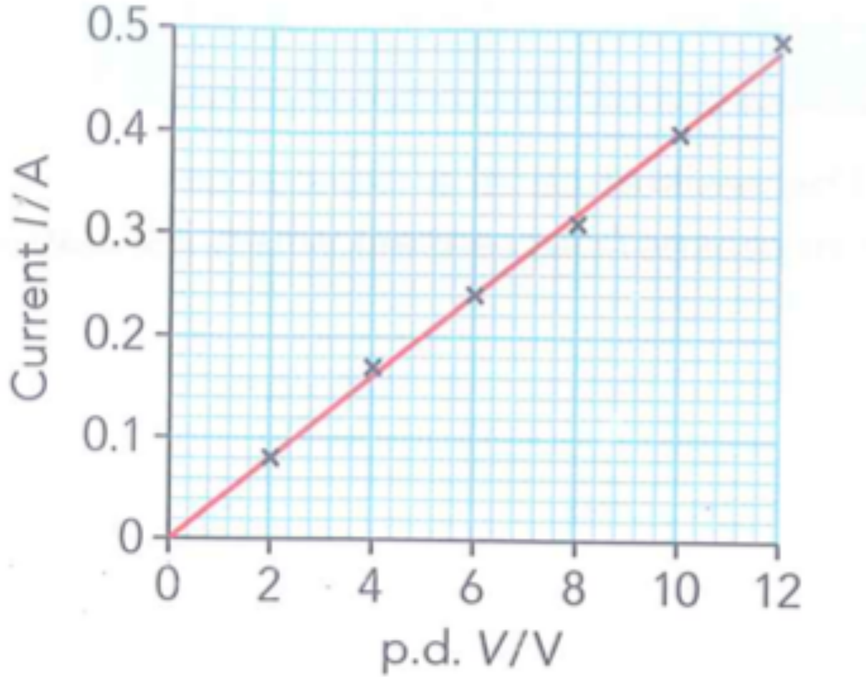
A. what is the resistance of a piece of the same wire of length 20.0 meters?

B. what is the resistance of a 4.0 meter wire with half the cross-sectional area, made of the same material?

Resistance

current-voltage characteristics: ohmic vs non-ohmic resistor

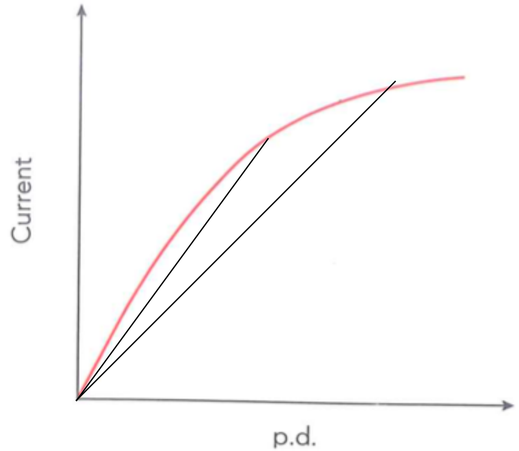
p.d. V/V	Current I/A	Resistance R/Ω
2.0	0.08	25.0
4.0	0.17	23.5
6.0	0.24	25.0
8.0	0.31	25.8
10.0	0.40	25.0
12.0	0.49	24.5



Ohmic resistor: constant resistance;

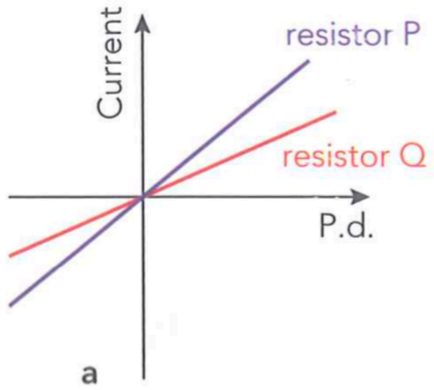
Resistance

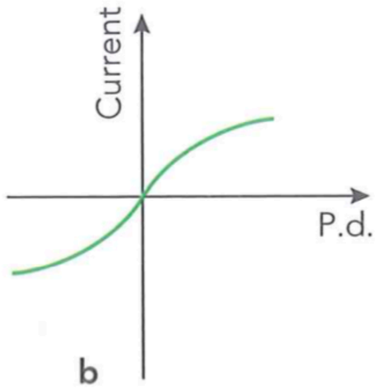
Non-ohmic device:

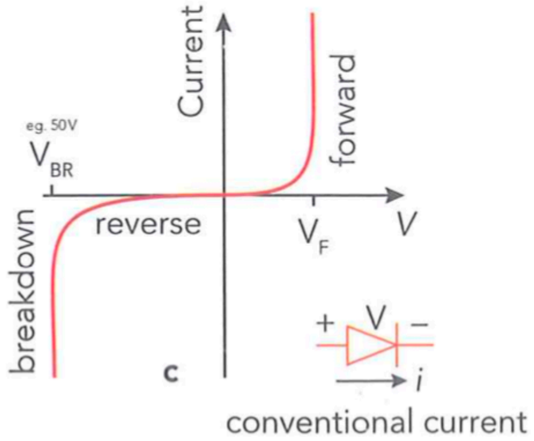


slope = 1/R

Typical current-voltage characteristics







For filament lamp:
T increase => R increase

Diode: only allows current flow in one direction

Electrical energy, work and power

Why do we need electric current?

Transfer energy

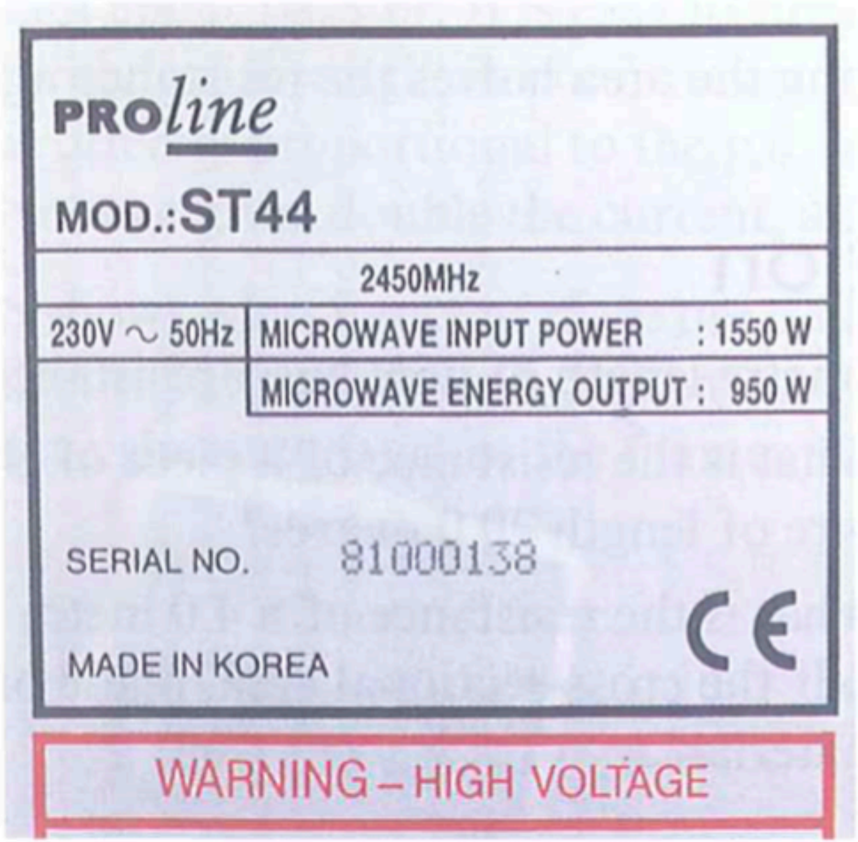
Electrical power & energy

$$p = \frac{W}{t} = \frac{QV}{t} = VI = I^2R = \frac{V^2}{R},$$

$$E = W = QV = VIt$$

Exercise

A electric fan runs from the 230V mains supply. The current flowing through it is 0.40A. At what rate is electrical energy transferred by the fan? How much energy is transferred in one minute?



Electrical energy, work and power

Unit of electrical energy: kWh

$$1kw \times 1h = 3.6 \times 10^6 J$$

Marcus switches on a water heater for two hours. The power of the heater is 3.5 kW. How much energy is transferred in kWh?

Applications of electrostatics