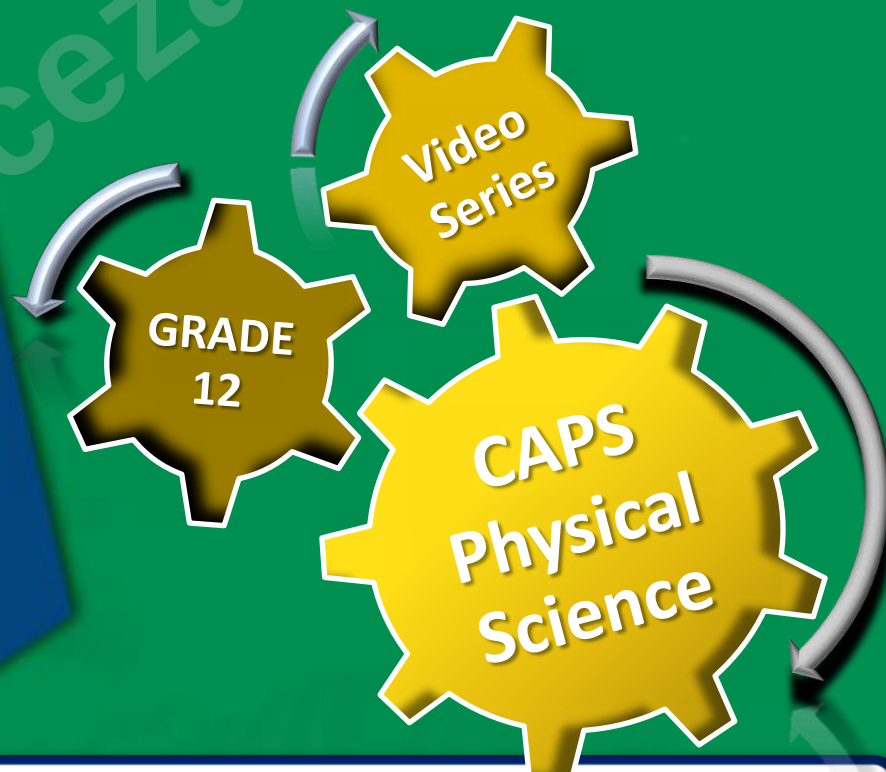
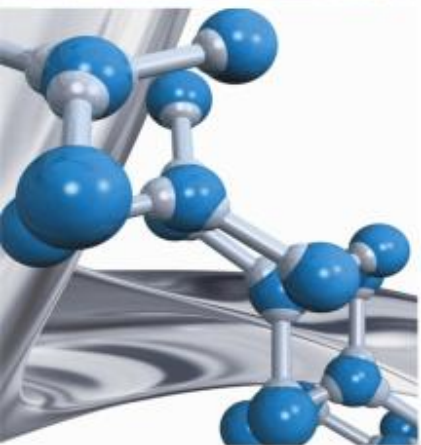




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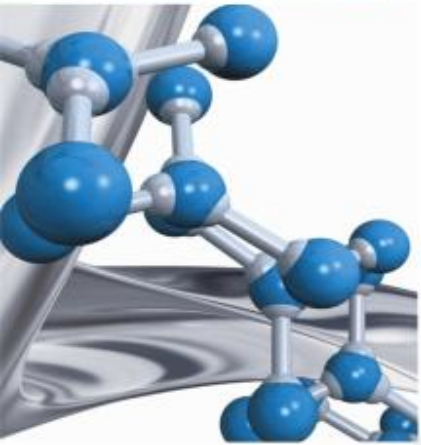


ELECTRICITY AND MAGNETISM

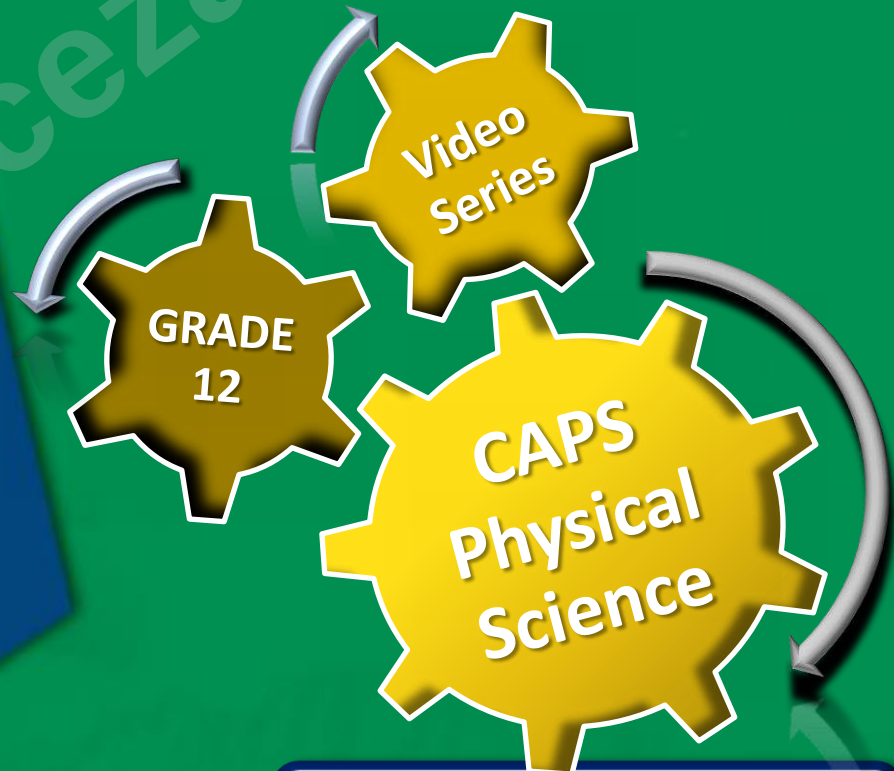
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Lesson 1: Internal Resistance

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Electric Circuits

Electric Circuit

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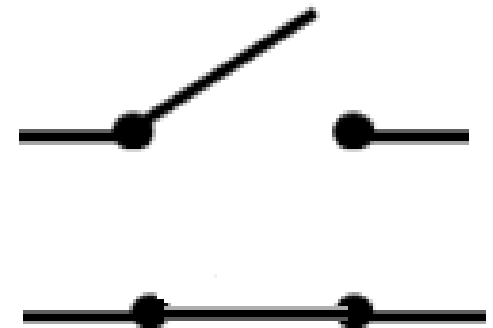
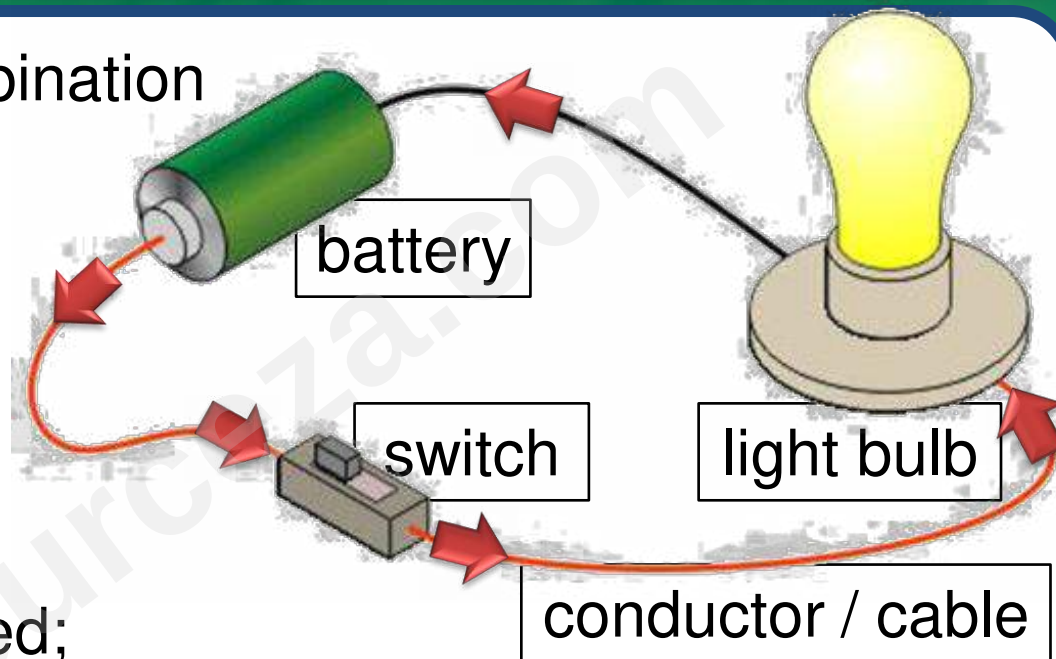
An electric circuit is a combination of electrical components connected to one another, enabling electrical charge to flow through the circuit.

For the charge to flow:

- A power source is needed;
- The circuit must be closed (completed).

Remember that when the switch is:

- *open*, the switch prevents charges from flowing since it *breaks the circuit*
- *closed*, the switch allows charges to pass through.



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Unit of Charge

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Charge (symbol Q) is measured in units called
COULOMBS (C).

One coulomb of charge is **a very large charge.**

The charge on an electron was found to be: $q_e = 1,6 \times 10^{-19} \text{ C}$.
Number of electrons constituting 1 C of charge:

$$\begin{aligned} &= \frac{1 \text{ C}}{1,6 \times 10^{-19} \text{ C}} \\ &= 6,25 \times 10^{18} \\ &= 6\,250\,000\,000\,000\,000\,000 \end{aligned}$$

LAW OF CONSERVATION OF CHARGE: The net (total) charge of an isolated system remains constant during any physical process. Charges cannot be created or destroyed.

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Current

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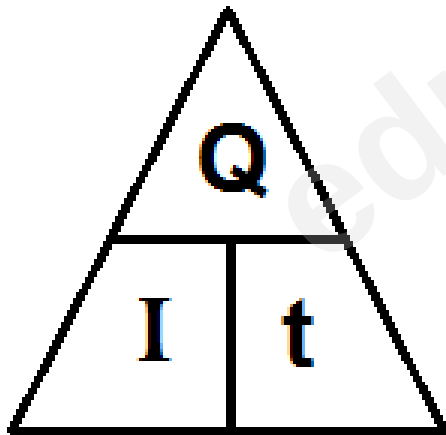
CURRENT is defined as the **RATE OF FLOW OF CHARGE**,
i.e. how much charge flows past a particular point (*flow of charge*) per unit time (*rate*).

$$\text{Electric Current} = \frac{\text{charge flowing past a point}}{\text{time elapsed}}$$

into symbols, as
FORMULA

$$I = Q / \Delta t$$

Q = charge - in coulomb (C)
I = current - in ampere (A)
 Δt = time taken / elapsed



$$Q = I \times \Delta t$$

$$I = Q / \Delta t = Q \div \Delta t$$

$$\Delta t = Q / I = Q \div I$$

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Direction of current
is **from + to -**
(although current in
metal conductors is
actually electrons
flowing from - to +)

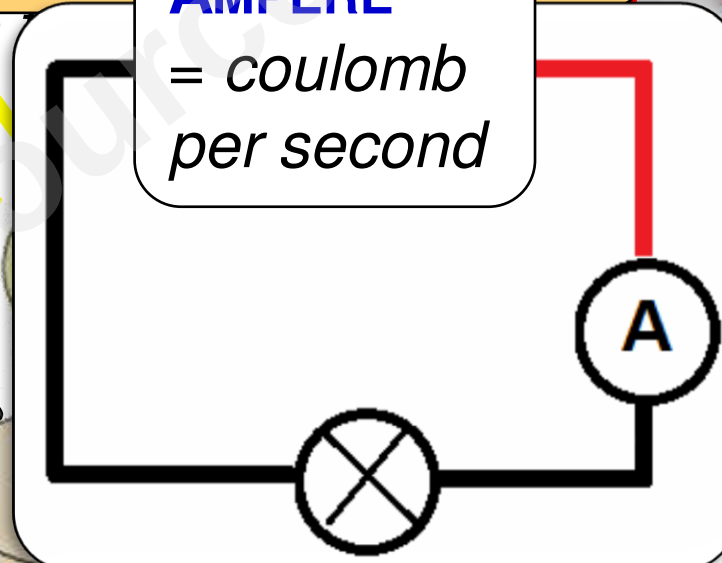
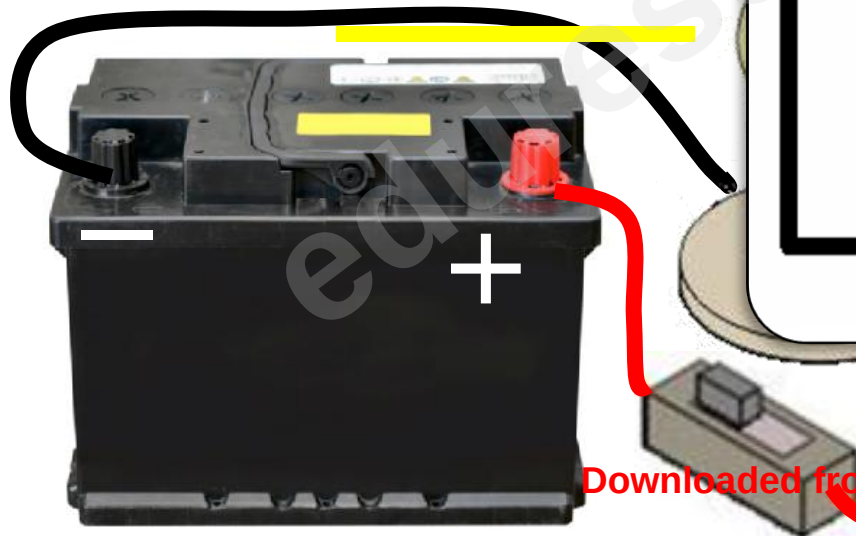
Ammeter

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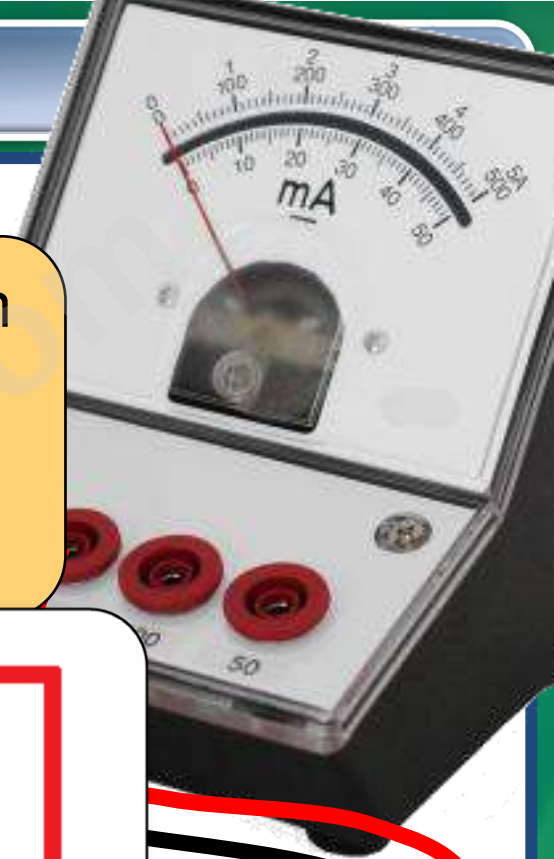
ELECTRIC CURRENT is measured with an ammeter in amperes (A). An ammeter connected in series with a circuit (including a switch) has a **very low** (negligible) resistance.

NB! Never connect an ammeter across a battery without an external resistance first so as not to damage it.

AMPERE
= coulomb
per second



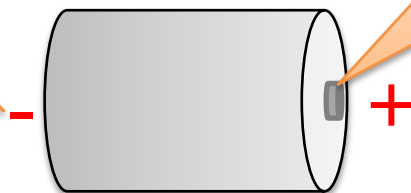
then switch on ...



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The ordinary cell has 2 poles or terminals: a positive and a negative.

Electrons supplied



Electrons taken in

Using symbols:



The chemical reaction within the cell moves the electrons from the positive to the negative pole.

During this reaction, chemical potential energy is transformed into **ELECTRICAL POTENTIAL ENERGY**, which is supplied to the circuit.

The **maximum** amount of electrical E_p being supplied per unit of charge. Note that the voltmeter is connected with

FORCE (e

When the

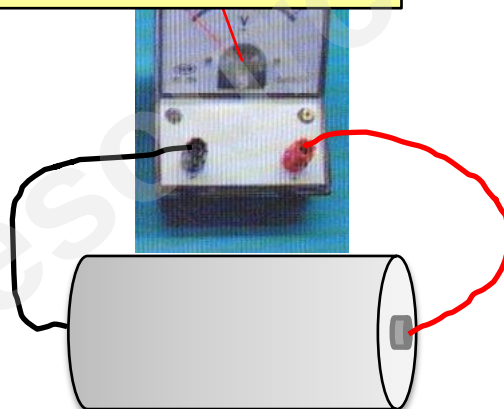
Note that the voltmeter

is connected with

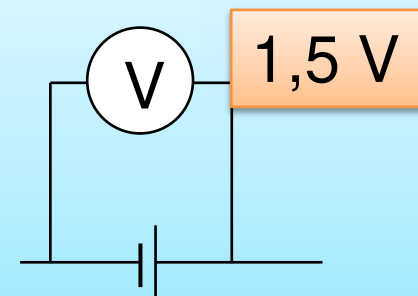
+ to + and - to - .

to an external circuit, a

the cell, will
ter the emf.



Using symbols:



The **voltmeter** has a **very high resistance**, blocking current from passing through it.

The emf is determined by the physical properties of the cell, such as size and chemical composition.

Potential Difference

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POTENTIAL DIFFERENCE: The difference in electrical potential energy between two points in an electric field
– the work done per unit charge to move charge between the two points.

$$\text{Potential difference} = \frac{\text{work done}}{\text{amount of charge}}$$

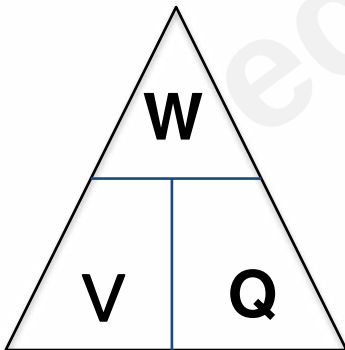
into symbols, as
FORMULA

$$V = W/Q$$

Q = charge - in coulomb (C)

V = p.d. - in volt (V)

W = energy - in joule (J)



$$W = V \times Q$$

$$V = W/Q = W \div Q$$

$$Q = W/V = W \div V$$

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Also called:
VOLTAGE

Resistance

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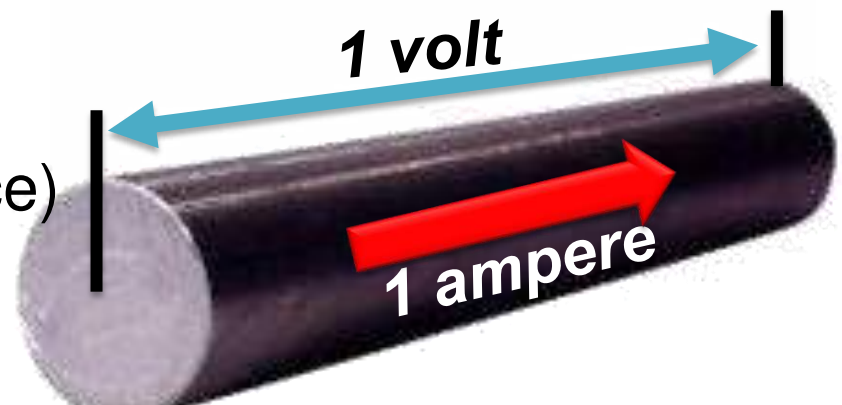
Resistance is **OPPOSITION TO** the **FLOW** of electric charge

Resistance (symbol: R) ...

- is measured in **OHM (Ω)**
- the resistance across the length of the steel rod is $1\ \Omega$ (ohm) if a potential difference of $1\ \text{V}$ (volt) is necessary to move $1\ \text{A}$ (ampere) of charge across it.

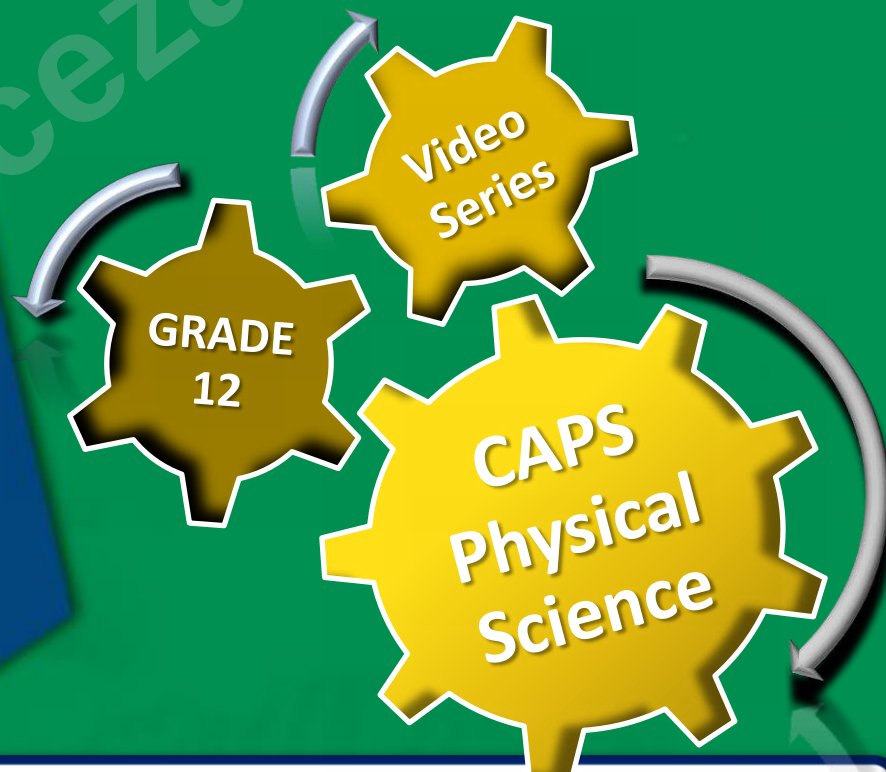
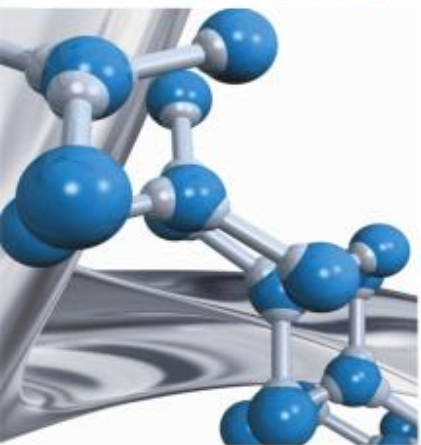
Factors that influence the resistance of a conductor:

- Type of material
- Length (longer, more resistance)
- Width (wider, less resistance)
- Temperature (hotter, more resistance)



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ELECTRICITY AND MAGNETISM

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Class Exercise 1/1

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1. Determine the resistance of R_3 .

$$V_{\text{total}} = V_1 + V_2 + V_3$$

$$V_3 = 4 \text{ V}$$

$$\begin{aligned} V_1 : V_3 \\ 2 \text{ V} : 4 \text{ V} \\ 1 : 2 \end{aligned}$$

then

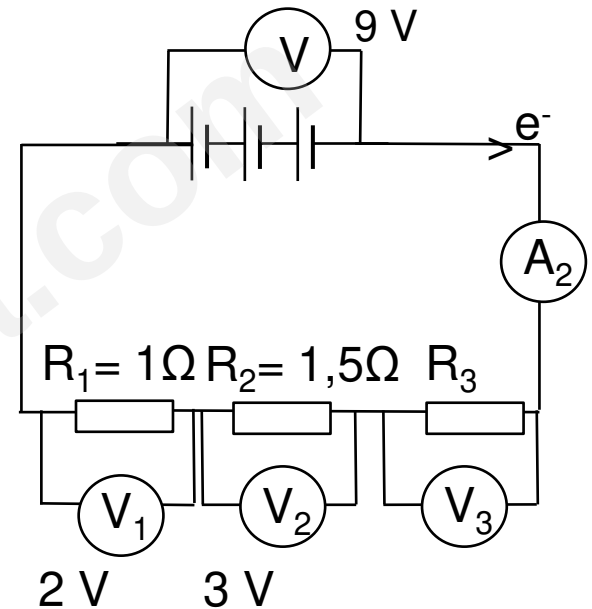
$$\begin{aligned} R_1 : R_3 \\ 1 : 2 \\ 1\Omega : x \\ x = 2\Omega \end{aligned}$$

OR

$$V_3 = 4 \text{ V}$$

$$\begin{aligned} I_{\text{tot}} &= \frac{V_1}{R_1} \\ &= \frac{2\text{V}}{1\Omega} \\ &= 2 \text{ A} \end{aligned}$$

$$\begin{aligned} R_3 &= \frac{V_3}{I_3} \\ &= \frac{4\text{V}}{2\text{A}} \\ &= 2\Omega \end{aligned}$$



Series circuits are **POTENTIAL DIVIDERS**.

The **bigger the resistance**, the **greater the potential difference** over it.

Current in a series circuit **is the same** through all components.

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Class Exercise 1/2

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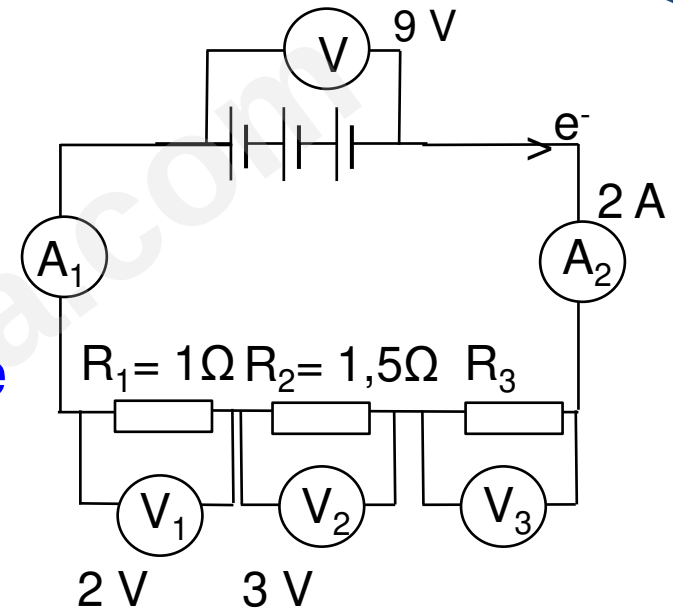
2. Name advantages and disadvantages of series circuits.

Advantages:

- More cells in series provide more energy to charges and increase the current.

Disadvantages:

- If one cell is flat or one bulb / resistor blown, the current is interrupted.
- All lights (resistors) must be turned on or off at once.
- More resistors in series increase the total resistance and decrease the current.



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Class Exercise 1/3

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4. Find the equivalent resistance in this circuit.

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{5\Omega} + \frac{1}{0,2\Omega} + \frac{1}{30\Omega}$$

$$= \frac{6}{30\Omega} + \frac{150}{30\Omega} + \frac{1}{30\Omega}$$

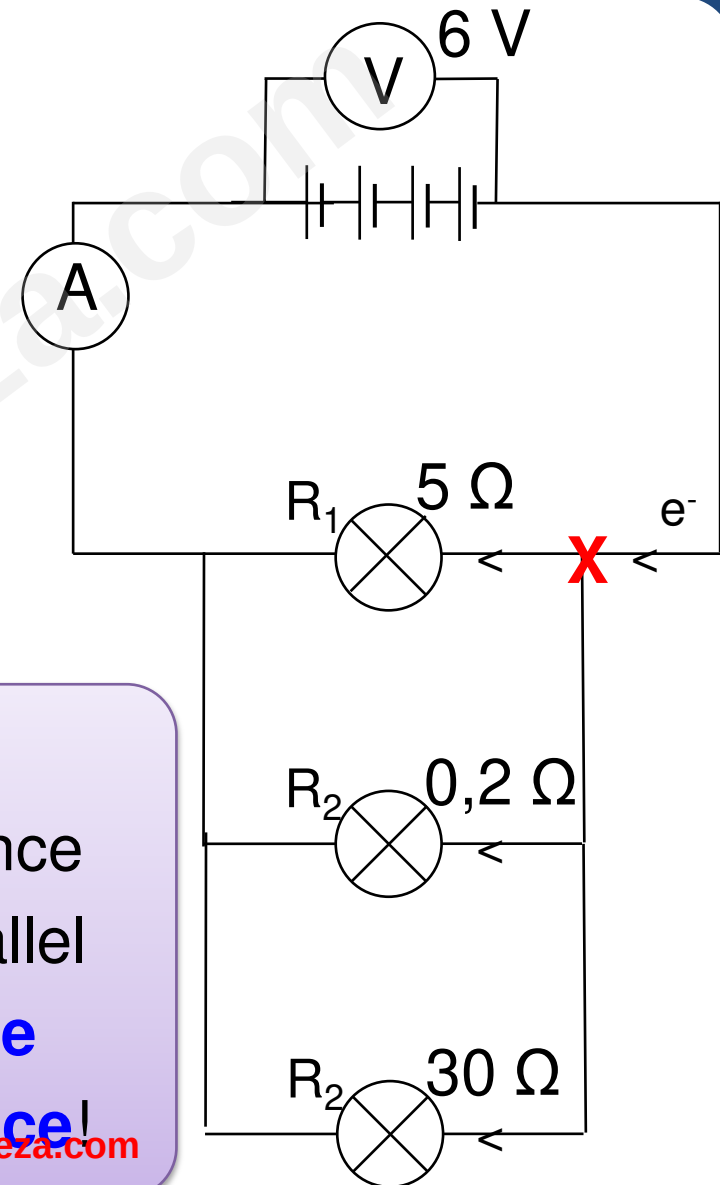
$$\frac{1}{R_p} = \frac{157}{30\Omega}$$

$$\frac{R_p}{1} = \frac{30\Omega}{157}$$

$$R_p = 0,19 \Omega$$

Note that the equivalent resistance of resistors in parallel is **smaller than the smallest resistance!**

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Class Exercise 1/4

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5. Give the readings on V_2 and V_3 .

Explain your answer.

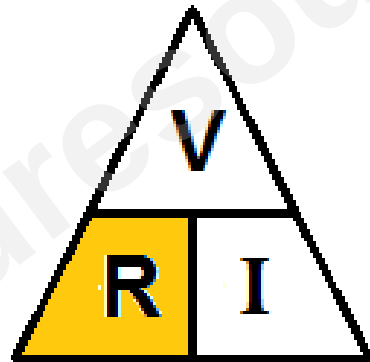
$$V_2 = 6 \text{ V and } V_3 = 6 \text{ V}$$

Potential difference is the same over all parallel components.

$$V_{\text{total}} = V_1 = V_2 = \dots$$

6. Determine the current through resistor R_3 .

$$\begin{aligned} I_3 &= \frac{V_3}{R_3} \\ &= \frac{6 \text{ V}}{30 \Omega} \\ &= 0,2 \text{ A} \end{aligned}$$

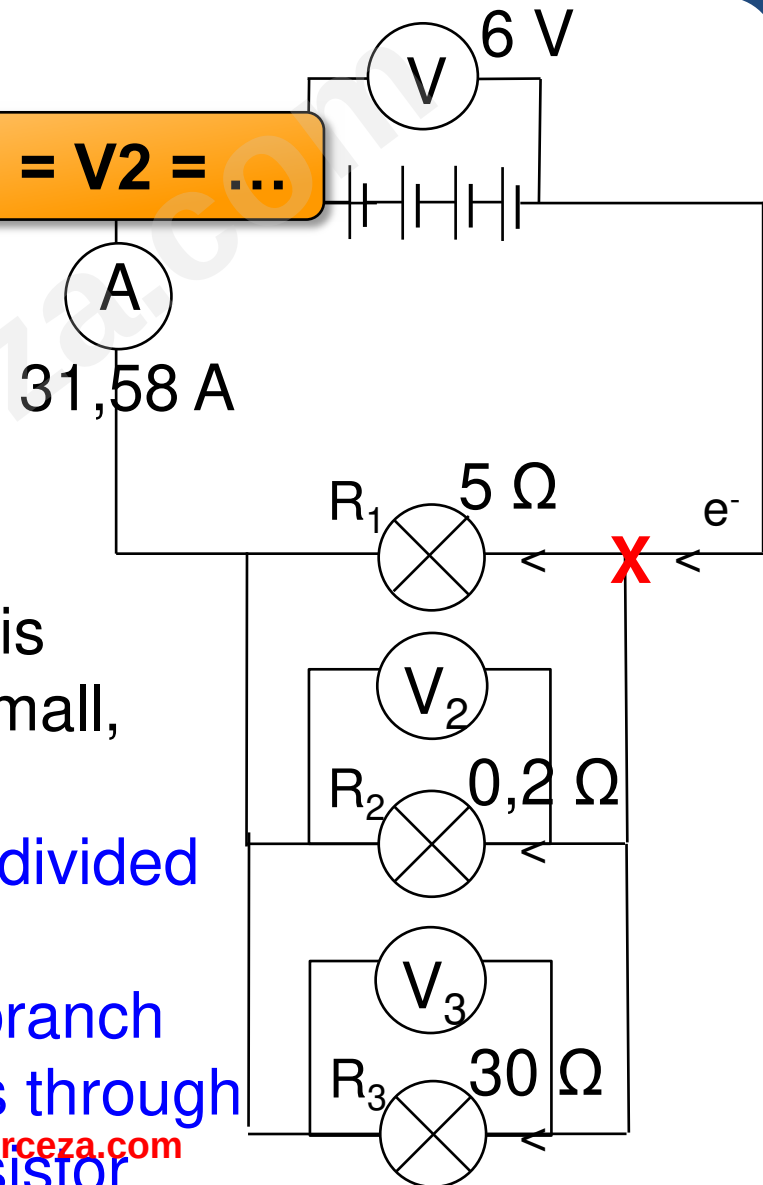


why this is so small, going to X. Current is divided

The smallest branch current passes through the biggest resistor.

Parallel circuits are **current dividers**.

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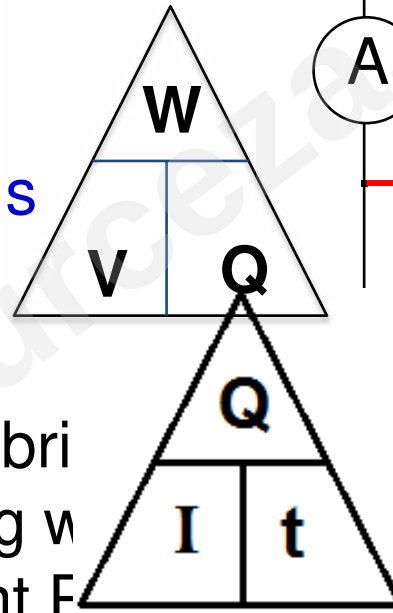


Class Exercise 1/5

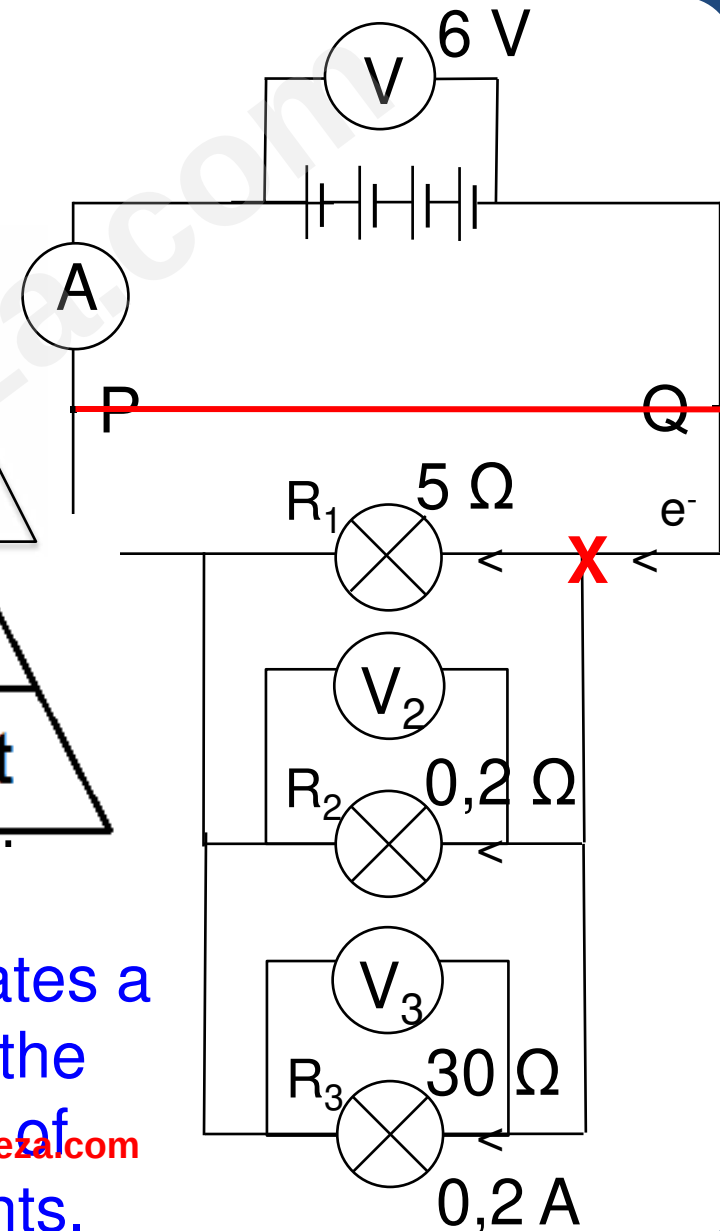
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8. Determine how much energy is transferred to bulb R_3 in 4 minutes.

$$\begin{aligned} W_3 &= V_3 \cdot Q_3 \\ &= V_3 \cdot I_3 \cdot \Delta t \\ &= 6 \text{ V} \times 0,2 \text{ A} \times 240 \text{ s} \\ &= 288 \text{ J} \end{aligned}$$



9. What will happen to the brightness of the lamps if a conducting wire is connected between point P and Q. Explain.
- All lamps would die, since PQ creates a **short cut / short circuit**, causing the current to flow through PQ instead of through the other circuit components.



Class Exercise 1/6

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10. Give advantages and disadvantages of parallel circuits.

Advantages:

- The equivalent resistance of parallel resistors is smaller than the smallest individual resistance and therefore increases the current.
- If a cell is flat or a resistor / bulb is blown, the current can still continue.
- Lights (resistors) can be turned on or off individually.
- Cells in parallel last longer, since each cell only have to supply a part of the charges with energy.

Disadvantage:

- Cells in parallel do not provide the unit charge with more energy.

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Class Exercise 1/7

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11. Determine the total resistance in the circuit.

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

$$= \frac{1}{2\Omega} + \frac{1}{2\Omega}$$

$$= \frac{2}{2\Omega}$$

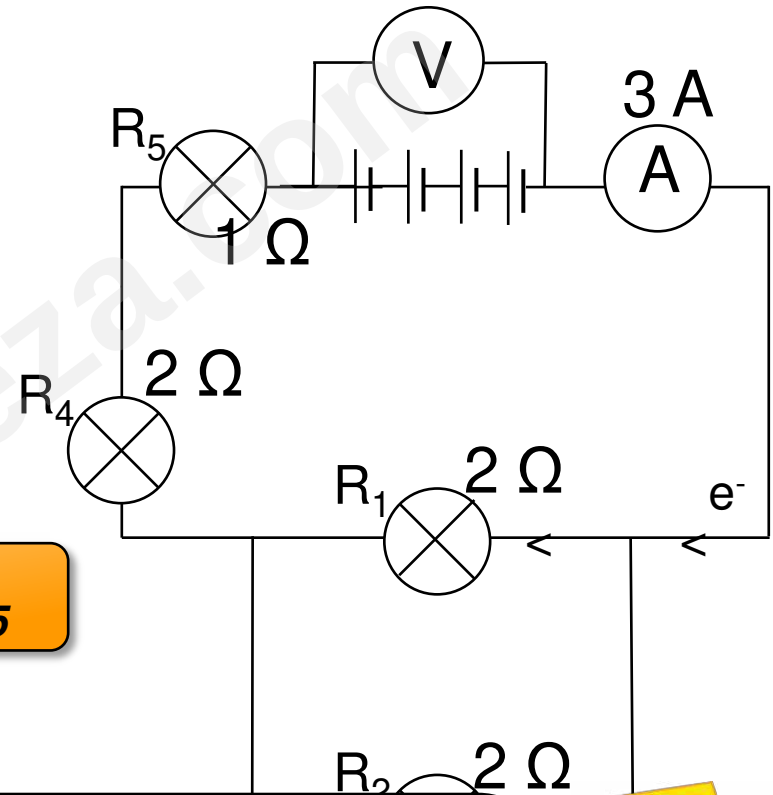
$$\frac{R_p}{1} = \frac{2\Omega}{2}$$

$$R_p = 1\Omega$$

$$R_{total} = R_p + R_4 + R_5$$

$$= 1 + 2 + 1$$

$$= 4\Omega$$

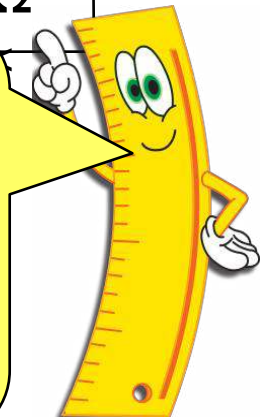


10. Determine the reading

$$\begin{aligned} V_{tot} &= I_{tot} \times R_{tot} \\ &= 3\text{ A} \times 4\Omega \\ &= 12\text{ V} \end{aligned}$$

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Remember that the equivalent resistance of 2 identical resistors in parallel = half of each resistance.



Key Concepts 1

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Series circuits are **POTENTIAL DIVIDERS**.

Parallel circuits are **CURRENT DIVIDERS**.

Resistance of circuit components are influenced by:

- Type of metal
- Length
- Width
- Temperature

CURRENT is defined as the **RATE OF FLOW OF CHARGE**.

$$I = Q / \Delta t$$

POTENTIAL DIFFERENCE: The work done per unit charge to move a unit charge between two points.

$$V = W / Q$$

RESISTANCE is the measure of the potential difference needed per unit of current passing through the resistor.

$$R = V / I$$

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Key Concepts 2

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When doing calculations on electric circuits:

- Always pair information according to the applicable resistor, e.g.

$$I_3 = \frac{V_3}{R_3}$$

$$I_{tot} = \frac{V_{tot}}{R_{tot}}$$

- Remember that

- current in a series circuit is the same at all points
- p.d. is the same over all parallel components

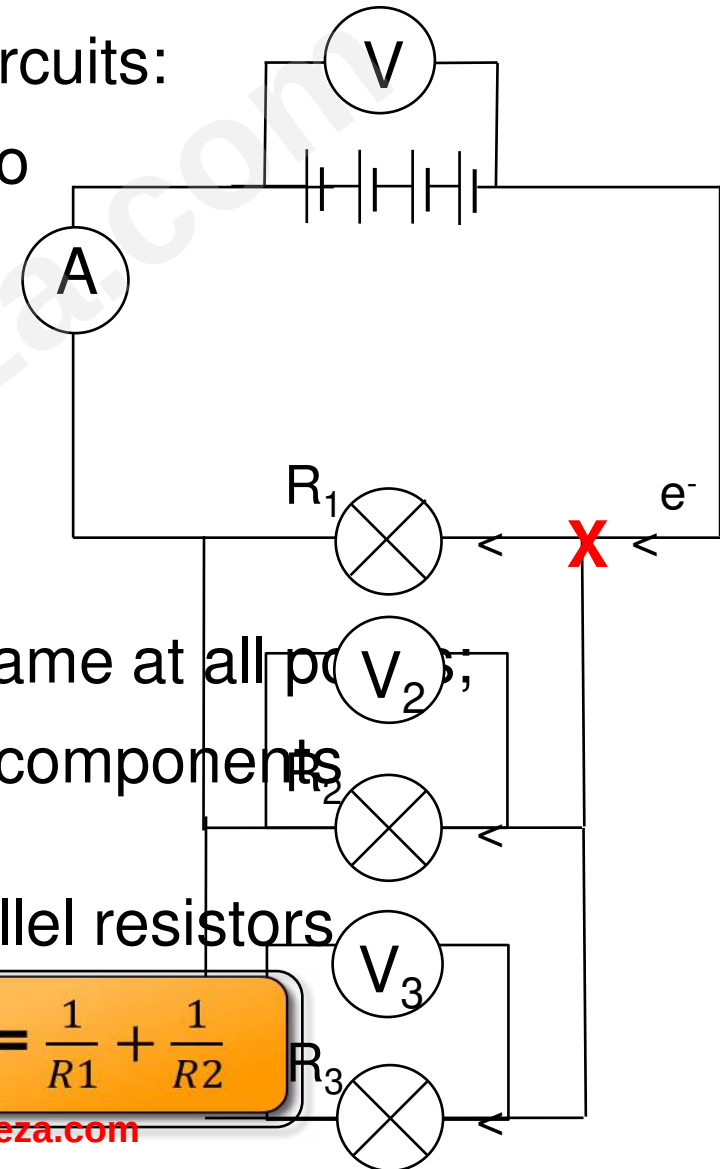
Series resistors

$$R_{total} = R_p + R_4 + R_5$$

Parallel resistors

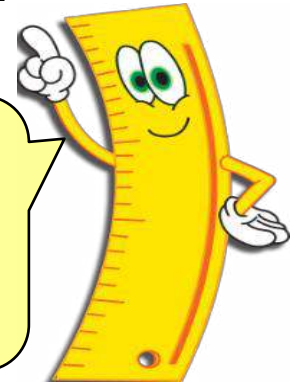
$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

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- **Memorise** the various definitions
- **Review** the exercises you had difficulty with ...
- and do some **additional exercise** ...
 - as given in your **workbooks** that accompany this video series or from your school textbook

Continue your learning by watching the
next video lesson in this series:
Lesson 2: Internal Resistance



Phinished