Electricity and Electromagnetism
ANSWERS

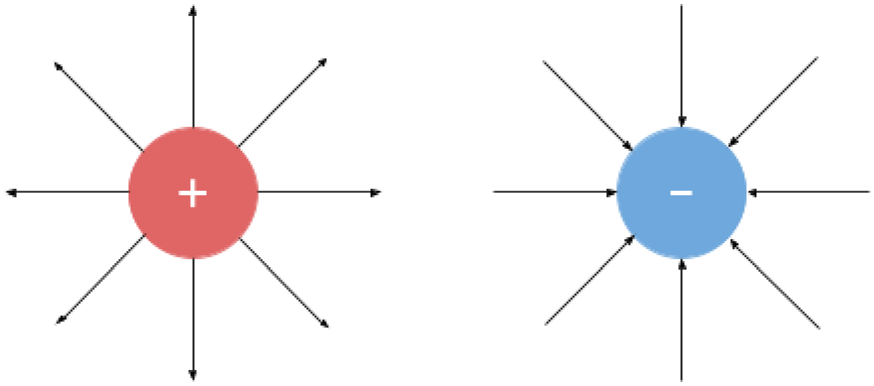
Static Electricity

Electricity
STOP AND CHECK (PAGE 11)

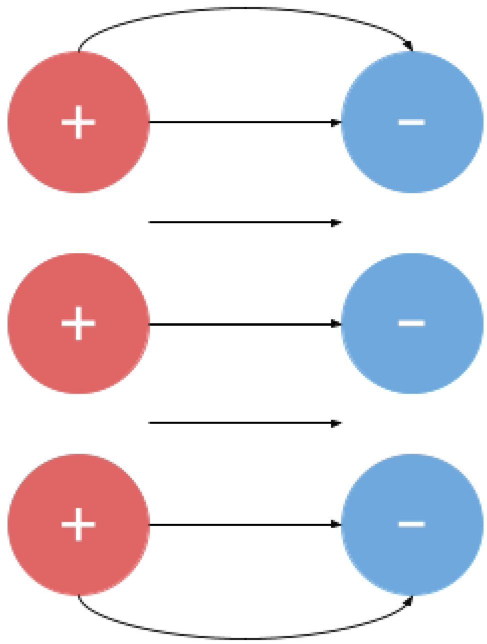
- Proton: positively charged. Electron: negatively charged.
- Symbol: q.
  - Unit: Coulomb, C.
- The electric force depends on both the charge on the particle (q) and the strength of the electric field the particle is in (E). This gives us the equation F = Eq, where F means electric force.

Electric Fields
STOP AND CHECK (PAGE 14)

- A source charge is a charge that creates an electric field around it. To choose which is the source charge depends on what we want to focus on.
- To draw the field lines around a charged particle, lines go out of the positive charges and into negative charges.



Between two lines of charge: Lines go from positive to negative (and note how the ends are curved out:



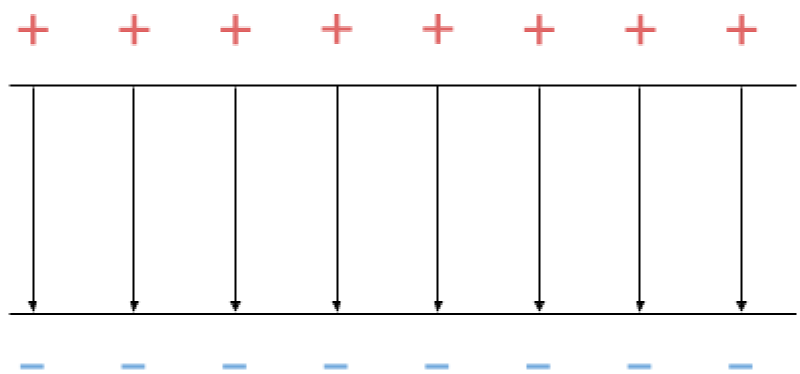
The direction of an electric field is shown by which way the arrows are pointing (which should always be from positive to negative charges). The strength of an electric field is shown by the number of lines in the diagram.

- The symbol for electric field strength: E
  - Units: Newtons per Coulomb, NC^{-1}.
- c because the charges will be attracted to different sides of the electric field (remember that electrons have a negative charge and protons have a positive charge.) We know that they will accelerate differently because there are double the amount of protons than there are electrons, which means that the protons have double the amount of charge. So, because F = Eq, we know that the electric field strength is the same for both the electron and the protons but the amount of charge changes. Protons have more charge, so there's a larger force acting on them, meaning that they will accelerate quicker than the electrons.

Uniform Electric Fields

STOP AND CHECK (PAGE 16)

- Uniform electric fields have uniform strength (same strength everywhere in the field).
- Straight, parallel, evenly spaced lines from the positive plate to the negative plate. Note the ends don't curve out!



Electric Potential Energy

STOP AND CHECK (PAGE 20)

- The particle has electric potential energy. Just like something with gravitational potential energy wants to move, something with electric potential energy wants to move too.
- Protons (or positively charged particles) will move in the same direction as the arrows/field lines, or towards the negative plate. Electrons (or negatively charged particles) will move in the opposite direction to the arrows/field lines, or towards the positive plate.
- Since the particle starts moving when you let it go, the electric potential energy is being converted into kinetic energy (all moving things have kinetic energy).
- When a particle is in an electric field, it has electric potential energy due to its position in the electric field. When it is released, that particle starts moving as the potential energy converts to kinetic energy. By the end, due to the conservation of energy, all of the potential energy will become kinetic energy
- In order to counteract the gravity acting on the oil and make the oil 'float', the drop needs to be attracted to the top plate. We know that opposites attract, so

the negatively charged oil had to be attracted to the positively charged plate at the top.

Static Electricity

QUICK QUESTIONS (PAGE 21)

- Plate B is positively charged because the arrows (field lines) are pointing away from it. This means plate A must be negatively charged because the field lines are pointing towards it. Field lines always go from the positive plate to the negative plate.
- This electric field is uniform because the field lines are straight, parallel and evenly spaced (we don't have any curved lines at the ends of the two plates). This means we have the same strength across the whole field.
- It will stay on plate B, as it has zero electric potential energy, so there is no force acting on it and it cannot convert any of its zero potential energy into kinetic energy.
- The maximum speed of the electron will happen when we've converted all our electric potential energy to kinetic energy, so we need to start by working out its electric potential energy, using the equation ΔEp = Eqd. The electric field strength is $6.66\times10^{6}NC^{-1}$, the charge on the electron is -1.06×10^{-19} C, and the distance between the two plates is 10cm=0.1m (we have to put everything in metres or our equations won't work properly!) We combine these to get:
  - $\Delta E_p = (6.66\times10^{6})\times(-1.06\times10^{-19})\times0.1$

  So, we get our calculators out and find $\Delta E_p = -7.0596\times10^{-14}$. The minus sign in the ΔEp is telling us about the direction the electron is travelling but we don't care about that because the question is asking us about speed, not velocity. So, we drop out the minus sign. This means the electron's maximum speed happens when $E_k = +7.0596\times10^{-14}$.
- We can use our rearranged equation from earlier:
  - $v = \sqrt{\frac{2E_k}{m}}$
- plus the mass of the electron, which is 9.11×10^{-31}kg, to get:
  - $v = \sqrt{\frac{2 \times 7.0596 \times 10^{-14}}{9.11 \times 10^{31}}}$
  - v = 393682270.3
  - $V = 3.94\times10^{8}ms^{-1}$

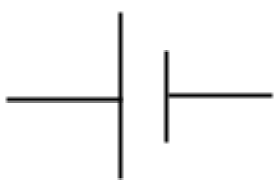
DC Circuits

All About Circuits

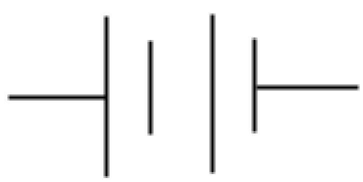
STOP AND CHECK (PAGE 28)

- **Voltage source:** There are a few ways to draw them, all of which are fine. The longer line is the positive end:

Option 1:



Option 2:



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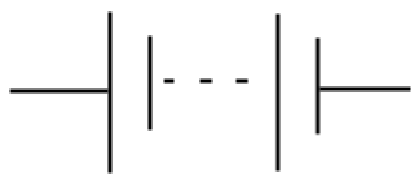
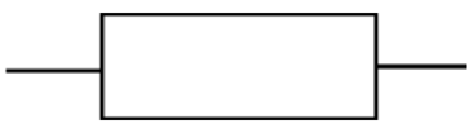
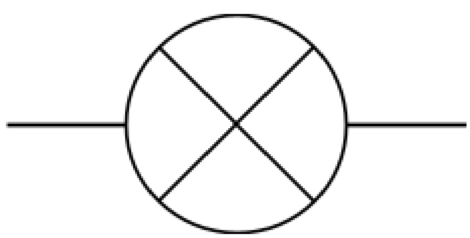


- **Wire:** A straight line that connects components
- **Resistor:** A box with a wire sticking out each end:



- **Light bulb:** A circle with a cross inside it and some wires coming out:



- **Current:** The electrons moving around the circuit and through components like the lamp.
- **Resistance:** Stuff that makes it harder for electrons to travel around the circuit has resistance; it makes electrons slow down.

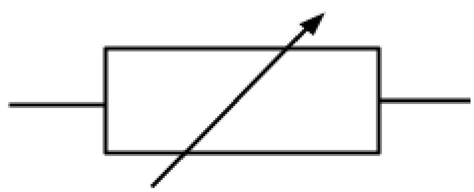
- **Voltage:** The amount of push given to electrons as they leave the power source. The more voltage they get, the less they're slowed by resistance.

More Complex Circuits

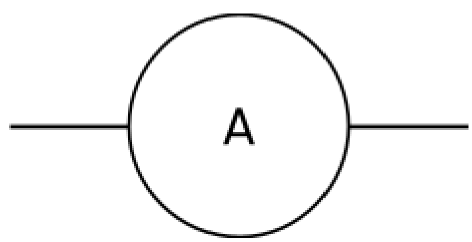
STOP AND CHECK (PAGE 15)

- **Switch:** A wire with a section that's broken.

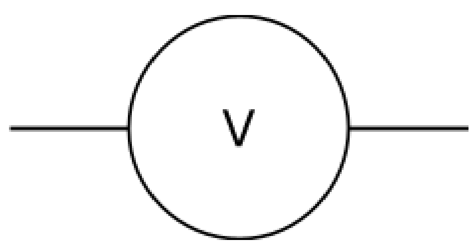
- **Variable resistor:** Like a resistor, but with an arrow through it.



- **Ammeter:** Like a lightbulb, but with an 'A' instead of a cross.



- **Voltmeter:** Like an ammeter, but with a 'V' instead of an 'A'.



- Two components in a series have the same current flowing through both of them. If either one of them breaks, neither of them will work as the current

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stops flowing because it has nowhere to go. Two components in parallel have different currents flowing through them. If one of them breaks, the other component will still work as it still has its own current flowing through it (and it will get the 'stopped' current from the other component flowing through it too).

- It's good to have a parallel circuit because if one section breaks, the other section will still function and let current flow through it.

Ohm's Law

STOP AND CHECK (PAGE 36)

- **Current:** The amount of charge moving past a point in a circuit in a certain amount of time. The symbol is I, the unit is amps (A).
  - **Formula:** $I = \frac{q}{t}$
- **Voltage:** The amount of energy given to each charge as it passes through a battery, or taken away from each charge as it passes through a resistor/lamp/other components. The symbol is V, the unit is Volts (also V).
  - **Formula:** $V = \frac{\Delta E}{q}$
- **Resistance:** How much an electron is slowed down by a component as it bumps around inside it. The symbol is R, the unit is Ohms (Ω, which is a capital omega, from the Greek alphabet).
  - **Formula:** $R = \frac{V}{I}$
- The current in a series circuit flows through every component in the circuit, dropping off energy as it goes along but not changing after each component. The current in a parallel circuit splits down each of the branches, with more current going down branches with lower resistance and less current going down branches with higher resistance. The current only drops off energy to components it goes through along its branch.
- The voltage across components in a series circuit adds up to the total voltage given out by the battery. Since we only have one path, all the voltage gets used up down that one path. In a parallel circuit, the voltage down each branch is equal to the battery voltage. When we look at each single path, however, we pretend we're dealing with a series circuit; all the voltage has to get used up down that one path.
- In series, we use the $R_1 + R_2 + ... = R_T$ formula.
- In parallel, we use the $\frac{1}{R_1} + \frac{1}{R_2} + ... = \frac{1}{R_T}$ formula.

Power in Electric Circuits

STOP AND CHECK (PAGE 39)

- Power is the amount of energy transferred per second (that might come from a lot of electrons dropping off a small amount of energy each, or a few electrons dropping off a lot of energy each, or something in the middle).
- The symbol for power is P and the unit is Watts (W). We might also use kilojoules per second (kJs^{-1}) if we're doing a question that's looking at energy. They mean the same thing!
- The lamp with more power will be brighter, as it's giving off more energy per second. More voltage is more power, so the lamp with more voltage will be brighter.

DC Circuits

QUICK QUESTIONS (PAGE 39)

- We have a battery (top, marked with 12V), an ammeter (right, a circle with an A in it), two lamps/lightbulbs (marked A and B), a closed switch (bottom right, with two little circles on the wire and a dotted line arm), a voltmeter (bottom, circle with a V in it), and three resistors (left, marked R_1, R_2, and R_3).
- We're going to think about conventional current here, so the current flows from the positive end of the battery (the longer arm) to the negative end (the shorter arm). First, the current flows through resistor R_1 and all of the charges will lose some voltage. Next, because the switch is closed, the current will split through our two branches (if it was open, the lower branch would have a 'dead end' and no current would flow through it). The current that flows through the top branch has to pass through resistor R_2 and lamp A, dropping off some voltage as it goes along. The current that flows through the bottom branch has to flow through resistor R_3 and lamp B, also dropping off some voltage as it does so. The amount of voltage dropped off by the two currents is exactly the same. Both currents meet up again just before the ammeter, then return to the battery.

Magnetism

Magnetic Fields

STOP AND CHECK (PAGE 43)

- The symbol of the strength of a magnetic field is B and the unit is Teslas (T)
- Moving charged particles generate a magnetic field. If a lot of those particles are in a moving object, that counts too (the particles are still moving, after all) and a magnetic field is generated.
- Just like electric field lines going from positive to negative, magnetic field lines go from north to south.
- Magnetic field lines going into the page are drawn as crosses (like the back/fletchings of an arrow) and coming out of the page are drawn as dots (like the tip of an arrow).
- Use the right-hand grip rule: your thumb points in the direction of the current and your fingers curl in the direction of the magnetic field lines.

Force on a Charged Particle

STOP AND CHECK (PAGE 45)

- The right-hand slap rule helps us link the directions of charged particle movement, magnetic field lines, and the force felt by a particle in a magnetic field. Your thumb is the direction the particle is moving, your fingers are the direction of the field lines, and the direction you would slap is the direction of the force felt by the particle.
- A particle moving parallel to a magnetic field doesn't feel any force on it as a result of the field, so it will just keep moving in the same direction.

Force on Current-Carrying Wires

STOP AND CHECK (PAGE 47)

- F is the force the wire 'feels' (the force acting on the wire), B is the magnetic field strength, I is the current flowing through the wire, and L is the length of the wire that is in the magnetic field.
- The part of the wire that is in the magnetic field is the only part that counts as the length.
- You use the left-hand slap rule to work out the force direction; your thumb is the current direction, your fingers the magnetic field direction, and your palm slaps in the direction of the force.
- Induced voltage is generated as the wire starts moving in the field. It tries to resist the force from the magnetic field, so it's in the opposite direction to your palm slap.

Induced Voltage

STOP AND CHECK (PAGE 49)

- As the wire is moved through the magnetic field, the electrons inside the wire are also moving. This means they feel a force (use your left-hand slap rule to see this) and are pushed towards one end of the wire. As the electrons have a force acting on them, and voltage is a kind of force that acts on electrons to make them move, we can think of this force as a kind of voltage that has been induced by the magnetic field.

Magnetism

QUICK QUESTIONS (PAGE 49)

- Putting a magnet too close to a computer means that the electrons travelling around the circuits inside the computer are suddenly in a magnetic field. We know that charged particles moving in a magnetic field experience a force (think about the right-hand slap rule), so a lot of the electrons in the circuits will experience this force. If the magnet is strong enough and the circuit's battery voltage is weak enough, the electrons will experience much more force from the magnet than the battery, which will stop the circuit from working properly. Since a computer has a lot of circuits in it, this adds up pretty quickly and can easily break the computer.

- The blades of a turbine rotating in the wind are connected to a setup that causes a length of wire to move through a magnetic field. As the wire moves through the field, the electrons in the wire experience a force from the field and are pushed to one end of the wire. This wire is connected up to some other wires and circuit components, like a rechargeable battery, and the electrons are pushed around the circuit. This means we're generating a current, which is the same thing as generating electricity.

