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IGCSE PHYSICS 0625 · TOPICAL PAST PAPERS

Electric Charge — Paper 2

Worked Solutions (Theory / Structured)

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Electric Charge — Paper 2 · Worked Solutions

Megalecture worked solutions — model answers with working; please verify before classroom use. These are original **Megalecture** structured-answer solutions for the topical Paper 2 compilation on **Electric Charge / Static Electricity (IGCSE Physics 0625)**. Every part was solved from first principles by the Megalecture team. Calculations use the equation **Q = It** (charge = current × time); finals are shown in bold with units. Drawing parts (field lines, induced charges) are answered in words describing exactly what to draw.

Part A · May / June papers

Q1 · Charging by friction (petrol can)

5054/02 M/J/03 · Q5

Electrostatic charges placed on objects by friction; hazard of charged fuel.

(a) Name of the transferred particle.

Electrons. (Friction transfers electrons from one object to the other.)

(b)(i) Why this is dangerous.

As more charge builds up, the potential difference between the charged petrol/pipe and a nearby earthed object rises. Eventually a **spark** jumps across the gap. The spark (a tiny electric discharge) can **ignite the petrol vapour, causing a fire or explosion**.

(b)(ii) How to stop the charge building up.

Earth (ground) the pipe and the can with a metal conductor so the charge flows safely to earth as it is produced (alternatively, fit a metal/earthing wire connecting pipe to can).

Q2 · Two charged conducting spheres

5054/02 M/J/06 · Q5

Charging by rubbing in terms of electrons; electric field; current from Q = It.

(a) How they become charged (movement of electrons).

When the two spheres are rubbed together, **electrons are transferred from one sphere to the other**. The sphere that gains electrons becomes **negatively** charged; the sphere that loses electrons becomes **positively** charged. (No charge is created — only electrons move.)

(b) Draw the electric field between the spheres.

Draw **field lines running from the positive (+) sphere to the negative (−) sphere**, with **arrowheads pointing from + to −**. Lines start on the + sphere surface and end on the − sphere surface, meeting both surfaces at right angles.

(c) Current in the connecting wire.

$$I = Q / t = (1.8 \times 10^{-13}) \div (2.0 \times 10^{-3})$$
$$I = \mathbf{9.0 \times 10^{-11}\ A}$$

Q3 · Plastic rod, induction & earthing

5054/02 M/J/07 · Q11

Charging by friction; induced charge on a conductor; earthing; a charging device.

(a) Why the rod becomes negatively charged when rubbed with a cloth.

Friction transfers **electrons from the cloth onto the rod**. The rod gains electrons (extra negative charge) so it is negatively charged; the cloth loses electrons and becomes positively charged.

(b)(i) What happens to the free electrons in the metal-coated sphere as it approaches the (negative) rod.

The negative rod **repels free electrons**, so they move to the **far side** (away from the rod, towards point X). The near side is left positively charged and the far side negatively charged (charge separation by induction).

(b)(ii) Diagram of charge distribution.

Draw **+ signs on the side of the sphere nearest the rod** and **− signs on the far side (near X)**.

(b)(iii) Why the uncharged sphere is attracted to the negative rod.

The induced **positive charge is nearer the rod than the induced negative charge**, so the force of attraction (on the near + charges) is greater than the force of repulsion (on the far − charges), giving an **overall attraction**.

(c)(i) Meaning of *earthing* the sphere.

Connecting the sphere to the earth (ground) by a conductor so that charge can flow to or from the earth.

(c)(ii) What happens to free electrons when X is earthed (rod still close).

The repelled electrons on the far side **flow down through the earth wire to earth**, leaving the sphere with an overall positive charge.

(c)(iii) Charge distribution after the rod is removed.

The remaining positive charge is now free to spread out, so it becomes **spread evenly over the whole surface of the sphere** (the sphere keeps a net positive charge).

(d) Device that charges by friction continuously (with diagram).

A Van de Graaff generator. A motor drives a rubber/insulating **belt** over rollers; friction between belt and rollers charges the belt. The belt carries charge up to the inside of a hollow **metal dome**, where a metal comb removes the charge; the charge spreads over the outside of the dome, building up a large static charge. (Diagram: dome on top, belt over two rollers inside an insulating column, driven by a motor.)

Q4 · Charged aeroplane

5054/22 M/J/10 · Q6

Loss of electrons gives positive charge; discharge through earth; safe refuelling.

(a)(i) Particles lost from the metal surface.

Electrons.

(a)(ii) What happens to the charge when it lands (conducting tyres).

The conducting tyres connect the aeroplane to the earth (ground). **Electrons flow up from the earth through the tyres to neutralise the positive charge**, so the aeroplane is discharged (loses its charge to earth).

(b) Why earth it during refuelling.

During refuelling, friction can charge the fuel and aircraft. If charge builds up, a **spark could jump and ignite the fuel vapour (fire/explosion)**. Earthing lets the charge flow safely to earth, preventing a dangerous spark.

Q5 · Polythene rod, field & water stream

5054/22 M/J/13 · Q5

Charging by friction; definition of electric field; attraction of a water stream.

(a) Charging process (movement of electrons).

Electrons are transferred from the cloth to the rod. The rod gains electrons and becomes negative; the cloth loses electrons and becomes positive.

(b) What is meant by an *electric field*.

A region (around a charge) in which a charge experiences an electric force.

(c)(i) How the rod makes positive and negative particles in the water move.

The negative rod **attracts the positive particles (ions) towards it** and **repels the negative particles away from it**. The water molecules become polarised, so the near side of the stream becomes positive.

(c)(ii) Charge on the stream of water (drawing).

Draw **+ charges on the side of the stream nearest the rod** (the side facing the rod is positive), so the stream is attracted and bends towards the rod.

Q6 · Induction & charge sharing (spheres C and U)

5054/21 M/J/14 · Q5

Induced charge; sharing of charge on contact; like charges repel.

(a) Induced charges on sphere U (drawing).

Draw **− charges on the side of U nearest C** (attracted by the + sphere) and **+ charges on the far side of U**.

(b)(i) What happens to the charge on C and U as they touch.

Charge on C: some of its positive charge is **shared with U**, so the charge on C decreases (it stays positive). **Charge on U:** U **gains positive charge** (electrons flow from U to C), so U becomes **positively charged**. Both spheres end up positively charged.

(b)(ii) Why U is repelled by C.

After contact both spheres carry **positive charge of the same sign; like charges repel**, so U is pushed away from C.

Q7 · Balloon rubbed on hair

5054/22 M/J/15 · Q5

Charging by friction; attraction of neutral hair; importance of insulator; uses of static.

(a) How rubbing makes the balloon negative.

Electrons are rubbed off the hair onto the balloon. The balloon gains electrons and becomes negatively charged (the hair loses electrons and becomes positive).

(b) Why the hair is pulled towards the balloon.

The negative balloon **induces a positive charge on the near surface of each hair** (it attracts positive charge / repels electrons in the hair). The opposite charges then **attract**, pulling the hair towards the balloon. (Also, the positively charged hairs are attracted to the negative balloon.)

(c) Why the balloon must be an electrical insulator.

An insulator **holds the charge in place** — the charge cannot flow away/leak off, so the balloon stays charged. (On a conductor the charge would flow to earth.)

(d) One useful example of static electricity.

Electrostatic precipitator (removing smoke/dust from chimneys) — or spray painting / photocopier / inkjet printer.

Q8 · Metal P: induction and earthing

5054/22 M/J/16 · Q7

Insulator example; induced charge on a conductor; earthing to give a permanent charge.

(a) A material that is an electrical insulator.

Plastic (polythene) — or rubber / glass.

(b) Charge distribution on P (positive rod near, no earth).

Draw **− charges on the end of P nearest the rod** (electrons attracted towards the + rod) and **+ charges on the far end**.

(c)(i) Charge distribution on P with the earth wire connected.

The far-end positive charge is neutralised: **electrons flow up from earth**. Draw **− charges on the end of P nearest the rod, and no charge on the far end** (P now has an overall negative charge held near the rod).

(c)(ii) 1. Rod removed, earth wire still connected.

The induced negative charge is no longer held, so the **extra electrons flow back to earth and P becomes uncharged (neutral)**.

(c)(ii) 2. Rod removed after the earth wire is disconnected.

The extra electrons are trapped on P, so P keeps a **negative charge, now spread evenly over the whole of P**.

Q9 · Charges on a rod and a cloth

5054/22 M/J/17 · Q8

Recognising neutral objects; friction charging; testing for charge.

(a) How Fig. 8.1 shows the rod and cloth are uncharged.

Each object has **equal numbers of positive and negative charges**, so the overall (net) charge on each is zero.

(b)(i) What happens to the charges during charging (rod becomes negative).

Electrons move from the cloth to the rod. The rod gains electrons (becomes negative) and the cloth loses an equal number (becomes positive). The total charge stays the same (charge is conserved).

(b)(ii) Simple experiment to show the rod is charged.

Hold the rod near **small pieces of paper / a thin stream of water / a suspended charged rod**. If the rod is charged, it **attracts the small pieces of paper** (or bends the water stream, or attracts/repels the suspended rod). The movement shows the rod carries charge.

Q10 · Electrostatic spray painting

5054/22 M/J/18 · Q7

Repulsion of like charges spreads paint; attraction coats hidden surfaces.

(a) A person walks across a carpet and gets a shock at a door handle — explain.

Friction between the person and the carpet **charges the person by transfer of electrons**. When they touch the (earthed) metal handle, the charge suddenly flows to earth as a small current — they feel this **discharge as an electric shock**.

(b)(i) Why the charged paint spreads out more (Fig. 7.1 vs 7.2).

All the charged drops carry the **same sign of charge, so they repel each other**. This pushes the drops apart, spreading the spray over a wider area for a more even coat.

(b)(ii) Why the paint reaches the back of the chair leg.

The charged drops carry charge **opposite to the (earthed/oppositely charged) chair**, so they are **attracted to all sides of the leg**, including the back (the field lines curve round to the back). Attraction wraps the paint around the leg.

Q11 · Van de Graaff & photocopier

5054/22 M/J/19 · Q5

Charging ball P by induction + earthing; ordering the photocopier process.

(a) How the negative dome makes ball P positive.

The negative dome **repels free electrons in ball P**; these electrons flow down the conducting rod **to earth through the earth wire**. P is left short of electrons, so it becomes **positively charged** (charging by induction with earthing).

(b) Correct order of the photocopier sentences.

A → C → B → D → E → F

A: drum given a positive charge → C: light hits the drum, the positive charge leaks away → B: positively charged parts of the drum attract black powder → D: an image of the original page is projected onto the drum → E: drum rolls against the paper, transferring powder → F: paper is heated so the powder sticks.

(First box A and last box F are fixed; the two middle steps C and B are placed so the charge image is formed, then the powder is attracted.)

Part B · October / November papers

Q12 · Power-station boiler & precipitator

5054/2 O/N/02 · Q5

Convection & conduction (context); how an electrostatic precipitator removes dust/ash.

(a)(i) Why the hot gases rise.

The hot gas **expands and becomes less dense than the surrounding cooler air**, so it is forced upwards by the denser surrounding air (convection).

(a)(ii) How energy passes through the metal pipes by conduction (particles).

Hot particles (atoms/ions) at the surface **vibrate faster** and pass energy on to neighbouring particles by collisions. In a metal, **free (delocalised) electrons also move and carry energy quickly** from the hot side to the cooler side.

(b) How the electrostatic precipitator works.

The fine wires give the **dust and ash a negative charge** as the gases pass (charge is induced/ transferred to the smoke particles). The negatively charged particles are then **attracted to the positively charged plates**, where they stick. The clean gas continues up the chimney; the trapped dust is collected. (Opposite charges attract.)

Q13 · Charging a sphere by induction

5054/02 O/N/04 · Q6

Full induction sequence: induced charge, earthing, permanent opposite charge.

(a)(i) Movement of electrons as the negative rod is brought near.

The negative rod **repels free electrons** in the sphere, so they move to the **far side of the sphere (away from the rod)**. The near side is left positive and the far side becomes negative.

(a)(ii) Charges on the sphere (drawing).

Draw **+ charges on the side nearest the rod** and **− charges on the far side**.

(b) Charges on the sphere when point A is earthed (rod still near).

The repelled electrons on the far side **flow out through the earth wire to earth**. Draw **+ charges only, on the side nearest the rod** (no charge on the far side).

(c) Charges after the earth wire and then the rod are removed.

The sphere keeps its overall positive charge, which spreads out: draw **+ charges spread evenly over the whole surface**. (The sphere has been charged positively — opposite to the rod — by induction.)

(d) Material for the insulating support.

Plastic — or glass / rubber.

Q14 · Electrostatic generator & spark

5054/02 O/N/05 · Q6

Charging the discharge ball by induction; most-positive point; current from Q = It.

(a)(i) Movement of electrons that makes the discharge ball positive.

The negative dome **repels free electrons** in the discharge ball and conducting rod; the electrons **flow down the rod to the base/earth**. The ball is left short of electrons, so it becomes **positively charged**.

(a)(ii) Mark X where the charge is most positive.

Mark X on the discharge ball **at the point nearest the negative dome** (charge concentrates on the surface closest to the dome / on the most curved part facing the dome).

(b) Average current in the spark.

$I = Q / t = 0.000\ 16 \div 0.012$

$I = \mathbf{0.013\ A}$ $(1.3 \times 10^{-2}\ \text{A})$

Equation used: current = charge ÷ time, $I = Q / t$.

Q15 · Hockey player on nylon surface

5054/02 O/N/09 · Q3

Friction charging (loss of electrons); electric shock; charge from Q = It.

(a)(i) How he becomes positively charged.

Friction between his shoes and the surface **rubs electrons off him onto the surface**. He loses electrons, so he is left with a net positive charge.

(a)(ii) What happens to the nylon surface.

The surface **gains the electrons, so it becomes negatively charged**.

(b)(i) How the shock is produced.

When he touches the (earthed) metal gate, his **charge flows to earth as a sudden current/ discharge** through his body, which he feels as a shock.

(b)(ii) Size of the charge before he touches the gate.

$Q = I \times t = (1.6 \times 10^{-3}) \times (0.15 \times 10^{-3})$

$Q = \mathbf{2.4 \times 10^{-7}\ C}$

$0.15\ \text{ms} = 0.15 \times 10^{-3}\ \text{s}$; $1.6\ \text{mA} = 1.6 \times 10^{-3}\ \text{A}$.

Q16 · Nylon rod and conducting sphere
5054/21 O/N/11 · Q5

Friction charging; induced charge on a conductor; attraction of neutral sphere.

(a)(i) How rubbing makes the nylon rod negative.

Electrons are transferred from the woollen cloth onto the rod, so the rod gains electrons and becomes negative.

(a)(ii) What happens to the cloth.

The cloth **loses electrons, so it becomes positively charged**.

(b)(i) Distribution of charges on the sphere (drawing).

The negative rod repels electrons in the sphere. Draw **+ charges on the side of the sphere nearest the rod** and **− charges on the far side**.

(b)(ii) Why the sphere is attracted to the rod.

The induced **positive charge is closer to the rod than the induced negative charge**, so the attractive force is larger than the repulsive force, giving an **overall attraction** towards the rod.

Q17 · Refuelling an aeroplane
5054/22 O/N/13 · Q6

Friction charging of fuel (gain of electrons); hazard; earthing through a metal cable.

(a) How the fuel becomes negatively charged.

As the fuel rubs against the pipe, **electrons are transferred from the pipe to the fuel**. The fuel gains electrons and becomes negatively charged.

(b) One problem caused by a charged aeroplane.

Charge builds up to a high voltage, so a **spark may jump between the aeroplane and earth/the pipe; this spark could ignite the fuel vapour and cause a fire or explosion**.

(c)(i) Why the cable is made of metal.

Metal is a **good electrical conductor**, so charge can flow easily through it to the ground.

(c)(ii) How the cable prevents charging.

It **earths the aeroplane — charge flows safely to the ground** through the cable as fast as it builds up, so no large charge can accumulate.

Q18 · Storm cloud and lightning

5054/21 O/N/14 · Q6

Induced charge on the ground; meaning of electric field; current from Q = It.

(a) How the ground becomes positively charged.

The negative base of the cloud **repels electrons in the ground**, pushing them down/away. The surface of the ground beneath the cloud is left short of electrons, so it becomes **positively charged (induced charge)**.

(b) What is meant by an *electric field*.

A region in which a charge experiences an electric force.

(c) Average current in the lightning strike.

$I = Q / t = 180 \div 0.0015$
$I = \mathbf{1.2 \times 10^5\ A}$ (120 000 A)

Q19 · Two spheres K and L (induction & separation)

5054/22 O/N/18 · Q5

Conductor vs insulator structure; charging two touching conductors by induction.

(a) How an insulator differs from a conductor; one example.

In an insulator the **electrons are tightly bound to their atoms, so there are no free electrons to move** (charge cannot flow). In a conductor there are **free (delocalised) electrons** that can move through it. Example of an insulator: **plastic** (or rubber / glass).

(b)(i) Charges on K and L (positive rod near K, spheres touching).

The positive rod attracts electrons. Draw **− charges on K (the sphere nearest the rod)** and **+ charges on L (the far sphere)**.

(b)(ii) 1. L moved far away, then the rod removed — charge on K.

K keeps the electrons that were attracted to it, so K stays **negatively charged** (the charge spreads evenly over K).

(b)(ii) 2. An earthing wire is connected to L — charge on L.

L was positive (short of electrons); when earthed, **electrons flow up from earth to neutralise it, so L becomes uncharged (neutral)**.

Note from Megalecture. These are original Megalecture worked solutions prepared for revision use. Drawing-based parts (field lines, induced-charge diagrams) are described in words; refer to the figure in the question when adding the marks. Calculations all use Q = It. Please verify before classroom use.