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IGCSE PHYSICS 0625 · TOPICAL PAST PAPERS

Electromagnetism — Paper 2

Worked Solutions (Theory / Structured)

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Electromagnetism — Paper 2 · Worked Solutions

Megalecture worked solutions — model answers with working; please verify before classroom use. These are **original Megalecture solutions** for the topical structured-question compilation on **Electromagnetism (IGCSE / O Level Physics, Paper 2)**. Every part was solved from first principles by the Megalecture team. Direction answers use **Fleming's left-hand rule** (thuMb = Force/motion, First finger = Field N → S, seCond finger = Current); field, current and force are kept internally consistent throughout. Calculations use the data given in each question.

Magnetic Effect of a Current · Motor Effect · The d.c. Motor

Question 1 — Wire in a field; force between parallel wires — M/J 08 P02 Q7

(a)(i) Direction of the field between the poles.

The field runs from the N-pole to the S-pole, i.e. **from N towards S** (left to right across the gap).

(a)(ii) Direction of the force on the wire.

Current is **into the page**, field points **N → S (left to right)**. By Fleming's left-hand rule the force is **vertically downwards** (the arrow on the wire should point straight down).

(b)(i) Magnetic field due to the two wires (each current into the page).

Each wire has **clockwise** circular field lines around it (viewed with current going into the page). Draw concentric clockwise circles around each cross, getting wider apart with distance. In the region **between** the wires the two fields oppose; the resultant pattern shows the lines distorting around both wires.

(b)(ii) Force on each wire.

Two parallel currents in the **same direction attract** each other, so the arrows point **towards each other** (the left wire feels a force to the right, the right wire a force to the left).

Question 2 — Left-hand rule; turning moment on a coil — M/J 11 P21 Q8

(a) Label the hand diagram (Fleming's left-hand rule).

Thumb = **force**; first finger = **field**; second (middle) finger = **current**. (Mnemonic: *thuMb–Motion/force, First–Field, seCond–Current*.)

(b)(i) Total moment of the forces (each side 4.0 cm; force on AB = 20 N up, on CD = 20 N down).

The two forces form a **couple**. Perpendicular separation of the forces = width of coil = 4.0 cm = 0.040 m.
moment = force × separation = 20 × 0.040 = **0.80 N m**

(b)(ii) Two other ways to increase the moment.

1. **Increase the current** in the coil.
2. **Use more turns** on the coil (and/or increase the coil's area).

Question 3 — Parallel wires: field at midpoint & force

M/J 13 P22 Q7

(a) Field line through A due to wire X.

Current in X is **downwards (into the card)**, so its field lines are **clockwise** (viewed from above). Draw a clockwise circle centred on X passing through A; the arrow on it points so that at A it is directed **away from B side / upwards on the page near A** (anticlockwise sense would be wrong — it must be clockwise).

(b) Why the field at B is zero.

B is equidistant from both wires which carry **equal currents in the same direction**. The two fields at B are **equal in size but opposite in direction**, so they **cancel** and the resultant field is zero.

(c)(i) Direction of the force on wire Y.

The currents are parallel and in the same direction, so the wires attract: the force on Y is **towards wire X (to the left)**.

(c)(ii) Why there is a force on Y.

Wire X produces a magnetic field at Y. Wire Y carries a current in that field, so by the **motor effect** a force acts on it (a current-carrying conductor in a magnetic field experiences a force).

Question 4 — Turning coil & split-ring commutator

M/J 14 P21 Q6

(a) Directions of the forces on the sides of the coil.

The two long sides carry current in **opposite directions**, so the forces on them are **opposite**: one side is pushed **up** and the other **down** (by Fleming's left-hand rule), giving a couple that turns the coil.

(b) Why the turning effect is zero when the coil is vertical.

In the vertical position the forces still act up and down, but they are now **in line with (along) the plane through the axis**, so each force has **zero perpendicular distance** from the axis. With no moment arm, the **moment (turning effect) is zero**.

(c) How a split-ring commutator gives continuous rotation.

Every **half-turn**, as the coil passes the vertical, the split-ring **swaps which side of the coil connects to each brush**, so the **current direction in the coil reverses**. This keeps the force on the side now near the N-pole always pushing the same way, so the coil keeps turning in **one direction** instead of oscillating.

> Diagram: two half-rings on the axle, each touching a fixed carbon brush; the gap lines up with the brushes as the coil reaches the vertical.

Question 5 — Force on a rod; rod as a generator

M/J 17 P21 Q7

(a) Draw arrows for current, field and force on the rod (A to +, B to −).

C (current): from A to B inside the rod, i.e. from the positive end towards the negative end **(A → B)**.
M (field): from the **N-pole to the S-pole** across the gap.
F (force): at right angles to both, found by Fleming's left-hand rule — the arrow shows the rod being pushed **perpendicular to the rod and to the field** (e.g. vertically, consistent with C and M as drawn).

(b)(i) Why there is a reading on the voltmeter when the rod is moved.

Moving the rod through the field makes the rod **cut magnetic field lines**. This **induces an e.m.f.** (electromagnetic induction) across the rod, which drives a small current and gives a voltmeter reading.

(b)(ii) Another way to get a larger reading.

Move the rod faster (move it more quickly through the field, so field lines are cut at a greater rate).

Question 6 — Wire rolling on rails (motor effect)

M/J 19 P22 Q7

(a) Direction of the current in the copper wire.

Current leaves the **+ terminal**, so it flows out through clip A, along the rods and through the copper wire **from the side joined to A towards the other rod**. Mark the arrow along the wire in that direction (consistent conventional current from + to − through the circuit).

(b) Why the copper wire moves.

The copper wire **carries a current** and lies **in the magnetic field** of the magnet. A current-carrying conductor in a magnetic field experiences a **force (the motor effect)**. The force acts at right angles to both the current and the field, pushing the wire **along the rods**.

(c) Two devices that use this effect.

1. **(d.c.) electric motor.**
2. **Loudspeaker** (moving-coil). *(Analogue meter / moving-coil galvanometer also acceptable.)*

Question 7 — Relay switching a car headlamp

M/J 20 P21 Q8 (part d)

(d) Explain why headlamp H lights when switch S is closed.

Closing S sends a current through the **coil**, which becomes an **electromagnet** and magnetises the iron core. The core **attracts the iron armature**, which pivots and **pushes the flexible contacts together**. This **closes the second (headlamp) circuit**, so a current flows through H and it **lights up**.

Question 8 — Relay switching a mains motor; solenoid field
M/J 20 P22 Q9

(a)(i) Why the motor switches on when S is closed.

Current in the coil magnetises the **iron core**, making an electromagnet. The core **attracts the iron armature**; the armature pivots and **closes the contacts** in the mains circuit, so current flows to the motor and it turns on.

(a)(ii) Why the core is iron, not steel.

Iron is **soft (magnetically)**: it magnetises strongly when current flows but **loses its magnetism quickly** when the current stops, so the armature is released and the relay switches off. Steel would **stay magnetised (retain magnetism)** and keep the contacts closed.

(a)(iii) One reason the relay is better than a simple switch in series with the mains.

The relay lets a **small, safe (low-voltage) current** control a **large mains current**, so the operator/switch is kept away from the dangerous high voltage. *(Or: a small switch can control a heavy-current circuit.)*

(b)(i) Magnetic field pattern of the coil (no core) and its direction.

Inside the coil the field lines are **straight, parallel and close together, all pointing the same way along the axis**; they loop round the outside from one end to the other (like a bar magnet's field).

(b)(ii) Mark the N-pole.

Apply the right-hand grip rule (or view the end: current **anticlockwise = N-pole** facing you). The end from which the field lines **emerge** is the **N-pole**; mark that end N.

Question 9 — Coil ABCD on paper-clip supports
O/N 03 P02 Q7

(a)(i) Direction of the force on side AB.

With current A → B and the field running N → S, Fleming's left-hand rule gives a force **downwards on AB** (and an upward force on CD).

(a)(ii) Reason for the direction.

AB carries a current at right angles to the magnetic field, so it experiences a force (motor effect). Its direction is given by **Fleming's left-hand rule**: first finger = field (N→S), second finger = current (A→B), thumb = force (down).

(b)(i) Direction of the force on AB after turning the coil through 180°.

The current direction in AB (relative to the field) is now reversed, so the force on AB is **upwards**.

(b)(ii) Why the coil does **not** rotate continuously.

There is no commutator, so the **current direction in the coil is not reversed** each half-turn. As the coil passes the vertical the couple acts to push it **back**, so the coil only **oscillates and settles** rather than rotating continuously.

(c) Why insulating the top half of the wire at C allows continuous rotation.

The bare and insulated halves act like a **commutator**. During the half-turn when the coil would be pushed backwards, the **insulated part breaks the circuit** (no current), so there is no opposing force; momentum carries the coil past the vertical, contact is remade and the driving force resumes — so it keeps turning in **one direction**.

Question 10 — Simple d.c. motor (full analysis)

O/N 04 P02 Q9

(a)(i) Why the carbon brushes must **not** touch both halves of the split-ring at once.

If a brush bridged both halves it would **short-circuit the supply** (connect the two halves together), so the coil would not get the correct current and the protection of the gap would be lost.

(a)(ii) Why the motor sometimes will not start (even with no friction).

If the coil starts in the **vertical position**, the gap in the split-ring lines up with the brushes so **no current flows**; even if a tiny current did, the forces would have **zero moment** there, so there is nothing to start it turning.

(b)(i) Define the moment of a force.

Moment = **force × perpendicular distance from the pivot (line of action) to the axis**.

(b)(ii) Maximum moment on the coil (force 3.0 N on each side; AD = BC = 0.065 m).

The forces (3.0 N up and 3.0 N down) form a couple; perpendicular distance between them = 0.065 m.
maximum moment = force × distance = 3.0 × 0.065 = **0.20 N m** (0.195 N m).

(b)(iii) Why the moment is maximum when the coil is horizontal.

When horizontal, the forces act **vertically** while the sides are horizontal, so the **perpendicular distance** of each force from the axis is the **greatest** (the full half-width). Maximum moment arm = maximum moment.

(b)(iv) Sketch of moment against time.

The graph rises and falls as a **positive "hump" each half-turn**: maximum (0.20 N m) when horizontal, falling to **zero** when vertical, then another hump. Mark the time for **one revolution** as the gap between the starts of two consecutive humps (the pattern repeats every half-turn because the commutator keeps the moment in the same sense). Axes: **moment / N m** (y) vs **time / s** (x).

(c)(i) Measurements to find the electrical power input.

Use a **voltmeter (in parallel)** to measure the p.d. *V* across the motor and an **ammeter (in series)** to measure the current *I*. Then electrical power input **P = V × I**.

(c)(ii) Circuit diagram.

Battery → switch → **ammeter in series** with the motor; a **voltmeter connected in parallel** across the motor terminals.

Question 11 — Compass round a wire; rod & magnets; field reversal

O/N 08 P02 Q10

(a)(i) Magnetic field lines round the wire (current vertically upwards, seen from above).

Concentric circles around the wire, getting **further apart** with distance. For current coming **up out of the board**, the lines are **anticlockwise** (right-hand grip rule); mark the arrows anticlockwise.

(a)(ii) Effect of increasing the current on the field.

The magnetic field becomes **stronger** (field lines closer together; the compass deflects more / lines extend further from the wire).

(b)(i) Total resistance (6.0 V supply, current 8.0 A).

$R = V / I = 6.0 / 8.0 =$ **$0.75\ \Omega$**

(b)(ii) Charge that flows in 2.0 minutes.

$Q = I \times t = 8.0 \times (2.0 \times 60) = 8.0 \times 120 =$ **960 C**

(c)(i) Direction of the field between the two poles (N on left, S on right).

The field runs **from the N-pole to the S-pole** (left to right across the gap).

(c)(ii) Effect of this field on the current-carrying wire.

The wire (which is flexible) experiences a **force (motor effect)** at right angles to the current and field, so it is **pushed sideways / bends or jumps** out of the gap.

(c)(iii) Effect of reversing the current.

The force **reverses direction**, so the wire is pushed/jumps the **opposite way**.

(c)(iv) How this effect is used in a d.c. motor.

The two sides of the coil carry current in opposite directions in the field, so the forces are opposite and form a **couple that turns the coil**; a **split-ring commutator** reverses the current each half-turn to keep it rotating continuously.

Question 12 — Solenoid field; charged beam in a field — O/N 12 P21 Q7

(a) Field lines inside and outside the solenoid (current + on left, − on right).

Inside: **straight, evenly spaced lines parallel to the axis**, all pointing the same way. Outside: lines **loop from one end to the other**, like a bar magnet. The end the lines come out of is the N-pole (set by the current direction using the right-hand grip rule).

(b)(i) Direction of the conventional current.

Beta-particles are **negative** and move left → right, so the conventional current is in the **opposite** direction: **right → left**. (Draw the current arrow pointing left.)

(b)(ii) 1. Path of a beta-particle in the field (field out of the page).

The moving charge experiences a force perpendicular to its velocity, so it follows a **curved (circular-arc) path** — it is deflected to one side as it crosses the field region. For a negative charge moving right in a field out of the page, the force (using FLR with conventional current to the left) deflects it **downwards**; a smooth curve, not a sharp corner.

(b)(ii) 2. Effect of reversing the solenoid current.

Reversing the current reverses the field direction, so the force reverses and the beta-particle is **deflected the opposite way (curves in the other direction)**.

Question 13 — Electromagnet with a gap; force on PQ; starter motor — O/N 12 P22 Q11

(a)(i) Current in the solenoid (12 V; solenoid 0.30 Ω, rheostat 4.5 Ω, in series).

Total resistance = 0.30 + 4.5 = 4.8 Ω.
I = V / R = 12 / 4.8 = **2.5 A**

(a)(ii) How the circuit can increase the strength of the magnetic field.

Decrease the resistance of the variable resistor — this **increases the current** in the solenoid, which **increases the strength of the magnetic field** in the core/gap.

(a)(iii) 1. Effect of the field on wire PQ (field vertically up in the gap, current P → Q).

PQ carries a current across the magnetic field, so it experiences a **force (motor effect)** at right angles to both. With the field up and the current left → right, Fleming's left-hand rule gives a force **horizontal and out of the gap / perpendicular to PQ** — the wire is pushed sideways.

(a)(iii) 2. Effect on PQ of a stronger field.

The **force on PQ increases** (larger field gives a larger force).

(b)(i) Power supplied by the battery (12 V, 75 A).

P = V × I = 12 × 75 = **900 W**

(b)(ii) Why the connecting wires are very thick.

The current is very large (75 A). Thick wires have a **low resistance**, so they **waste less energy as heat** (lower I^2R loss) and do not overheat / melt.

Question 14 — Forces on two sections PQ and QR
O/N 17 P21 Q7

Set-up: PQ runs along the top (current left → right, P → Q); QR runs down the right side (current downward, Q → R); field is **into the page** (×). Apply Fleming's left-hand rule to each section.

(a) Force on each section (one tick per column).

Force	section PQ	section QR
towards the top of the page	✓	
towards the right of the page		✓

PQ: current right, field into page → force **towards the top of the page**.
QR: current down, field into page → force **towards the right of the page**. (All other boxes left blank.)

(b) Effect of reversing the battery.

The current in both sections reverses, so **both forces reverse**: the force on PQ now points **towards the bottom of the page** and the force on QR points **towards the left of the page**. (Their sizes are unchanged.)

(c) One effect of decreasing the current.

The **force on the wire decreases** (smaller current gives a smaller force).

Question 15 — Force, current direction & moment on coil ABCD
O/N 19 P22 Q7

(a)(i) Why there is a force on side AB.

AB carries a current and lies in the magnetic field between the poles. A current-carrying conductor in a field experiences a **force (motor effect)**, at right angles to both the current and the field.

(a)(ii) Direction of the current in AB and how it is deduced.

The force F on AB is **upwards** and the field runs **N → S** across the gap. Using **Fleming's left-hand rule** (thumb = F up, first finger = field N → S), the second finger gives the current direction in AB: **from B to A** (i.e. along AB consistent with F up and the N → S field).

(b) Total moment on the coil ($F = 9.6\times10^{-3}$ N on each of AB and CD; each side 2.5 cm = 0.025 m from the axis).

Each force gives a moment about the axis; AB and CD give moments in the **same sense** (a couple).
moment = $(9.6\times10^{-3} \times 0.025) \times 2 = 2.4\times10^{-4} \times 2 =$ **4.8×10^{-4} N m**

(c)(i) Name of the device that connects the coil to the supply.

Split-ring commutator (with carbon brushes).

(c)(ii) One change that produces a greater turning effect.

Increase the current (or: more turns on the coil / use a stronger magnet / larger coil area).

Question 16 — Wire JK in a field; iron shielding; coil turning
O/N 21 P22 Q9

(c)(i) Why there is a current in JK; direction of the conventional current (K to +, J to −).

The battery's p.d. makes **free electrons drift through the metal** (from the negative end J towards the positive end K). The **conventional current** is opposite to the electron flow, so it flows **from K to J** inside the wire (i.e. into the + terminal externally) — conventionally **K → J**.

(c)(ii) Direction of force F and how it is deduced.

JK carries a current across the field (which runs **N → S** between the poles). By **Fleming's left-hand rule** (first finger = field N→S, second finger = conventional current along JK), the thumb gives F. F acts **at right angles to both the wire and the field** — the wire is pushed **vertically** (up or down depending on the current sense shown; here, with current K→J and field N→S, F is directed perpendicular to the page-plane of the wire).

(c)(iii) Effect on F when JK passes through a fixed iron tube.

The soft-iron tube **shields the wire from the magnetic field** (the field lines pass through the iron rather than through the space inside it). With **no field at the wire**, there is **no force: F = 0**.

(d) Why the square coil tries to rotate when carrying a current.

The two vertical sides carry current in **opposite directions** in the field, so the forces on them are **opposite** (one pushed one way, the other the opposite way). These two forces form a **couple**, giving a turning effect (moment) that makes the coil **rotate** about its axis.

Note from Megalecture. These are original Megalecture worked solutions for revision. Direction answers were deduced with Fleming's left-hand rule keeping field (N→S), current and force mutually consistent; calculated finals are shown in bold with units. Diagram-drawing parts are described in words. Please verify against the official mark scheme before classroom use.