

AC DC generators and output graphs

AQA GCSE Separate Physics 8463 | Higher tier only | Mainly Paper 2; AC/DC link to Paper 1

Worked answers | Separate Physics Higher only | 28 parts | 48 marks

Specification points covered

4.7.3.1: induced p.d., factors affecting output, direction and opposing magnetic effects
4.7.3.2: alternators, dynamos and graphs of generated p.d. against time
4.2.3.1: direct and alternating potential difference
4.2.1.3: selected $V = IR$ calculations for a fixed test load

A harbour team tests a small turbine-driven generator for walkway marker lights. Two contact arrangements connect the same rotating coil to an external load. You will interpret the output and decide whether it meets the lighting driver's requirements.

Original PhysicsUK practice, not an official AQA resource. 28 parts, 48 marks. Separate Physics Higher only throughout. Distinguish the alternating p.d. induced across the coil from the unidirectional p.d. across a dynamo's external load. Ideal contacts are assumed; ignore brief brush-gap interruptions. Contact drawings are schematics, not a literal coil assembly. Timing is estimated and untrials.

1 Explaining the generator output

The test coil turns between magnetic poles. A fixed-resistance test load is connected across the external output. The mechanism is driven by the turbine, not by an electrical supply.

1(a) State the difference between alternating current and direct current in terms of direction. **[2 marks]**

Answer / mark points: Alternating current repeatedly reverses direction. [1]
Direct current flows in one direction when it flows. [1] Direct does not mean its magnitude must be constant.

1(b) Explain why rotating the coil can produce a p.d. and why a complete external circuit is needed to produce a load current. **[2 marks]**

Answer / mark points: The moving coil conductors cut magnetic field lines / move through the magnetic field, inducing a p.d. across the coil. [1]
A complete conducting circuit allows that p.d. to drive an induced current through the load. [1] P.d. can exist with an open circuit.



2 Comparing the contact arrangements

Figure 1 shows simplified contact schematics. The coil and shaft are omitted. The two complete rings in A are drawn side by side for clarity. Each ring or half-ring rotates with its coil end; the brushes and external load remain stationary. Ignore the short contact gaps during switching.

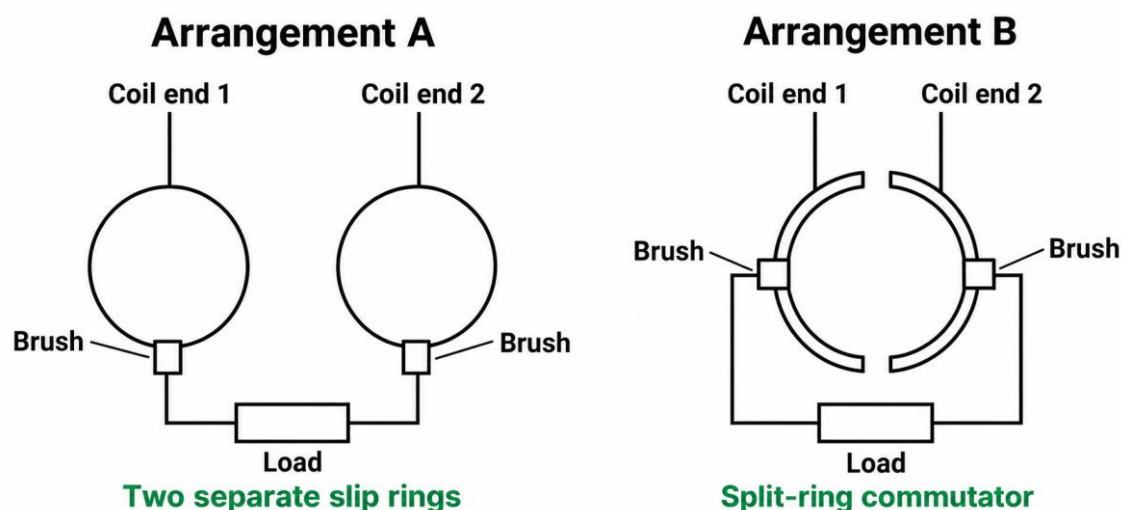


Figure 1

2(a) Name the rotating contact arrangement in A and the rotating contact arrangement in B. **[2 marks]**

Answer / mark points: A: two separate slip rings. [1]

B: a split-ring commutator. [1] A single solid ring connected to both coil ends would join them electrically.

2(b) State the function of the stationary brushes. **[1 mark]**

Answer / mark points: They maintain sliding electrical contact between the rotating rings and the stationary external circuit. [1] They do not generate the p.d.

2(c) Why must the two halves of B be electrically insulated from each other? **[1 mark]**

Answer / mark points: To prevent the coil ends being joined directly / short-circuited through the ring, rather than connected through the external load. [1] Mechanical attachment alone does not require electrical contact between the halves.

2(d) The p.d. induced between the coil ends reverses every half-turn. Explain how B can still produce current in only one direction through the external load. **[2 marks]**

Answer / mark points: Each half-turn, the coil ends swap brushes. [1]

This connection reversal compensates for the reversal of the coil's p.d., so the external current keeps the same direction. [1] The coil-induced p.d. itself still alternates.

2(e) Why does A not compensate for the reversal of p.d. between the coil ends? **[1 mark]**

Answer / mark points: Each brush remains connected through its own complete ring to the same coil end; the connections do not swap. [1] Therefore the external p.d. reverses with the coil p.d.



3 Reading the alternator trace

Arrangement A is tested at constant speed. Figure 2 shows p.d. across the external test load, using fixed lead connections. Positive p.d. gives current in one reference direction; negative p.d. gives the opposite direction. The load has constant resistance.

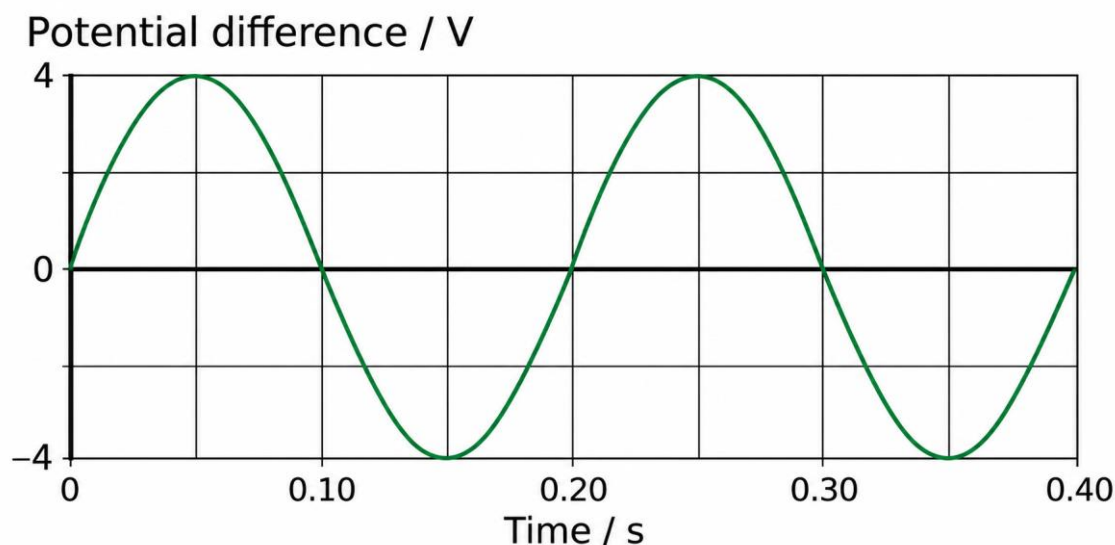


Figure 2

3(a) Read the p.d. at 0.05 s, including its sign. **[1 mark]**

Answer / mark points: +4.0 V. [1] This is a positive peak, not the mean output.

3(b) Read the p.d. at 0.15 s, including its sign. **[1 mark]**

Answer / mark points: -4.0 V. [1] The magnitude is 4.0 V but the polarity has reversed.

3(c) Compare the direction of load current at 0.05 s and 0.15 s. Use the signs on the graph. **[1 mark]**

Answer / mark points: The current is in opposite directions because the p.d. changes from positive to negative. [1] A negative value does not mean a smaller positive current.

3(d) Determine the time for one complete electrical cycle. **[1 mark]**

Answer / mark points: 0.20 s. [1] For example, $0.25 - 0.05 = 0.20$ s between successive positive peaks. A positive half-cycle alone lasts 0.10 s.

3(e) Calculate how many complete coil rotations occur in one minute at this speed. **[2 marks]**

Answer / mark points: There is one rotation per 0.20 s, so $60 \text{ s} / 0.20 \text{ s} = 300$ rotations per minute. [2: 1 for correctly converting 1 minute to 60 s and 1 for 300 using the full-cycle period] Accept an equivalent rotations-per-second route.

3(f) A trainee says the coil must stop whenever the trace reaches zero. Explain why this is incorrect for the stated test. **[2 marks]**

Answer / mark points: The coil rotates continuously at the stated constant speed. [1] At these instants the coil conductors move parallel to the field / momentarily do not cut field lines, so induced p.d. is zero without the coil stopping. [1] Zero output at an instant is not zero mechanical speed.



4 Predicting the dynamo trace

Now use Arrangement B at the same speed, with the same coil and magnet. Choose output leads so its first pulse is positive. Its peak p.d. is 4.0 V and it returns to zero at the same times as Figure 2. Ideal commutation reverses the connection to the coil every half-turn. Figure 3 is for the external load, not the coil ends.

4(a) Sketch the p.d. across the external load on Figure 3 for the two complete coil rotations from 0 to 0.40 s. **[2 marks]**

Answer / mark points: Four rounded positive pulses with peaks +4.0 V at 0.05, 0.15, 0.25, 0.35 s, meeting zero at 0, 0.10, 0.20, 0.30, 0.40 s. [1 for four correctly timed humps; 1 for all at / above zero, correct peak level and zero crossings]

Do not accept two alternating cycles or a horizontal 4.0 V line.

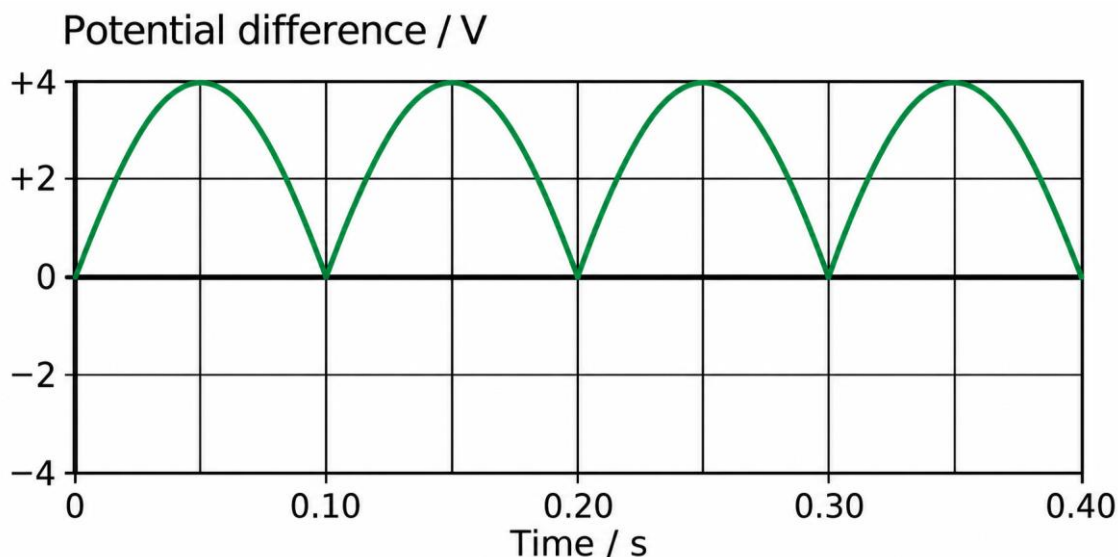


Figure 3

4(b) Explain why four positive pulses in this time do not mean four complete coil rotations. **[1 mark]**

Answer / mark points: There are two pulses per full rotation, one from each half-turn; four pulses therefore represent two rotations. [1] Do not count each half-turn as a full turn.

4(c) Explain why this output is described as direct but not constant. **[2 marks]**

Answer / mark points: Its polarity does not reverse, so current through the resistor flows in only one direction. [1]

Its magnitude varies between zero and a peak, rather than remaining at a fixed value. [1] Zero at isolated instants does not make it alternating.

4(d) The test load is a constant 20 Ω resistor. Calculate its current at 0.05 s and at 0.10 s for your Figure 3 trace. **[2 marks]**

Answer / mark points: At 0.05 s: $I = V / R = 4.0 / 20 = 0.20$ A. [1]

At 0.10 s: $I = 0 / 20 = 0$ A. [1] These are instantaneous values, not an average over the cycle.

4(e) Only the two external load leads are swapped. Describe how the plotted dynamo p.d. changes and state whether it is still direct. **[2 marks]**

Answer / mark points: The trace reverses sign: the pulses lie below zero, reaching -4.0 V. [1]

It is still unidirectional / direct for this steady rotation; the reference polarity has reversed, not alternated each half-cycle. [1]



5 Testing changes to the generator

Each change below is a separate test from the original Figure 2 conditions. Keep the original coil, magnet and connections unless a change is explicitly stated.

5(a) Suggest two changes that could increase peak induced p.d. without turning the coil faster. **[2 marks]**

Answer / mark points: Use a stronger magnetic field / stronger magnets. [1]

Increase the number of turns on the coil. [1] Accept greater effective coil area in this simple rotating-coil geometry. Do not accept changing slip rings to a commutator as a peak-increasing change.

5(b) The coil now turns twice as fast. State the new cycle time and explain the expected change in peak p.d. Do not calculate a new peak value. **[2 marks]**

Answer / mark points: The cycle time halves to 0.10 s. [1]

Peak p.d. increases because the conductors cut the magnetic field faster. [1] A smaller period does not mean a smaller peak.

5(c) Describe a fair workshop test of how turning speed affects peak p.d. Include what to measure and what to keep unchanged. **[3 marks]**

Answer / mark points: Keep the same coil, magnetic field, contact arrangement and measuring connections. [1]

Vary and measure rotation speed (for example by counting turns in a measured time), and record peak p.d. using a suitable low-voltage sensor / oscilloscope. [1]

Take several speeds with repeat readings at each, then compare mean peak p.d. values against measured speed. [1] Use an appropriately rated sensor and guard moving parts; never use mains as a test supply.

5(d) With A, only the direction of rotation is reversed. Compare the p.d. at the same coil positions and decide whether the output becomes direct. **[2 marks]**

Answer / mark points: The p.d. at a given coil position reverses sign because the motion through the field reverses. [1]

It remains alternating; reversing rotation is not rectification. [1] Compare the same positions, not an unstated reset of the time axis.

5(e) Both the magnet poles and the rotation direction are reversed. Predict the polarity at a given coil position compared with the original, and explain. **[2 marks]**

Answer / mark points: It is the same as originally. [1]

Either change alone reverses the induced p.d.; making both reversals compensates, so the two sign changes cancel. [1] This is not a claim that the coil output has become direct.



6 Choosing an output for the walkway

Driver D operates only with a positive, unidirectional input. It tolerates pulses from 0 to 5.0 V; negative p.d. is not allowed. Driver S instead needs an almost steady 3.0 V supply. Neither driver contains smoothing or additional polarity-control equipment. The original generator peaks at 4.0 V.

6(a) For the original rotation direction and the chosen leads, which arrangement could supply Driver D directly? Justify your decision using its output trace. **[2 marks]**

Answer / mark points: B, the dynamo arrangement: its external p.d. is positive / unidirectional. [1] Its pulses range from 0 to 4.0 V, within the allowed 0–5.0 V range; A includes negative p.d. and fails that requirement. [1] This decision depends on the stated driver tolerances.

6(b) Could the unsmoothed B output supply Driver S as specified? Use one feature of the trace to justify your answer. **[1 mark]**

Answer / mark points: No: it repeatedly falls to 0 V and reaches 4.0 V, rather than staying almost steady at 3.0 V. [1] “It is dc” alone does not establish a constant voltage.

6(c) The load circuit is opened, but the coil keeps rotating at the original speed. Is p.d. still induced across the coil ends? **[1 mark]**

Answer / mark points: Yes. Relative motion through the field still induces a p.d.; a closed load circuit is not required for induction of p.d. [1]

6(d) Explain why opening the load circuit makes the generator easier to turn, even though its bearings are unchanged. **[3 marks]**

Answer / mark points: No load current flows in the open circuit. [1]
There is therefore no magnetic field generated by that induced load current. [1]
The corresponding magnetic opposition to the coil’s motion is removed, so less turning effort is needed. [1] Bearing friction may remain; the permanent magnet’s field has not disappeared.

6(e) The team later lets the same turbine reverse its rotation when the tide changes. The magnet and Driver D leads remain unchanged. Is the original compatibility decision guaranteed to remain valid? Explain. **[2 marks]**

Answer / mark points: No. Reversing rotation with the field and external leads unchanged reverses the dynamo’s output polarity. [1]
Its pulses are now negative relative to Driver D’s required input, so the driver requirement is not met without an additional arrangement. [1] The commutator maintains one direction during a given rotation direction; it does not guarantee one chosen polarity for both mechanical directions.

Review and improve

Use “p.d. increases/decreases/reverses polarity” and “current reverses direction”. A pulsating unidirectional output is not a steady supply. Induced p.d. may remain when the load circuit is open.

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