

Electromagnetic induction and generator effect

AQA GCSE Separate Physics 8463 | Higher only | Paper 2

Worked answers | Separate Physics Higher only | 26 parts | 49 marks

Specification points covered

4.7.3.1: induced p.d., current, size and direction factors, and opposition to change

4.7.1.1: supporting magnetic pole attraction and repulsion

4.1.2.1: supporting energy transfers when the coil supplies a load

A railway workshop develops a contactless motion detector. A magnet on a carriage moves towards and away from a fixed coil. You will interpret its signal, improve detection and investigate the force when a load is connected.

Original PhysicsUK practice, not an official AQA resource. Whole sheet: Separate Physics Higher only, not Combined or Foundation. 26 parts, 49 marks. Signs use the stated recorder convention, not an assumed winding rule. Credit equivalent explanations and supported conclusions.

1 Establishing the effect

For an initial test, the workshop connects a resistor across the coil, forming a complete circuit. Current is detected as the carriage magnet approaches without touching the coil.

1(a) Name the effect that produces this current. **[1 mark]**

Answer / mark points: The generator effect / electromagnetic induction. [1] The motor effect is not the required answer.

1(b) Explain why moving the magnet towards the coil produces a current in the resistor circuit. **[3 marks]**

Answer / mark points: The magnetic field through/around the coil changes as the magnet approaches. [1]

A p.d. is induced across the coil ends. [1]

The resistor and coil form a complete circuit, so a current flows. [1] Do not say current jumps from the magnet to the coil.

1(c) The magnet is then held still near the coil. Explain why the current falls to zero even though a magnetic field is still present. **[2 marks]**

Answer / mark points: The field at the coil is now constant, not changing. [1]

There is no induced p.d. and hence no induced current. [1] A strong field alone is insufficient.



2 Predicting signal direction

Figure 1 shows the magnet and coil with their terminals open. The recorder is not drawn. When used, its leads are connected so the reference north-pole approach gives a positive reading. In (a)–(d), change only the stated condition.

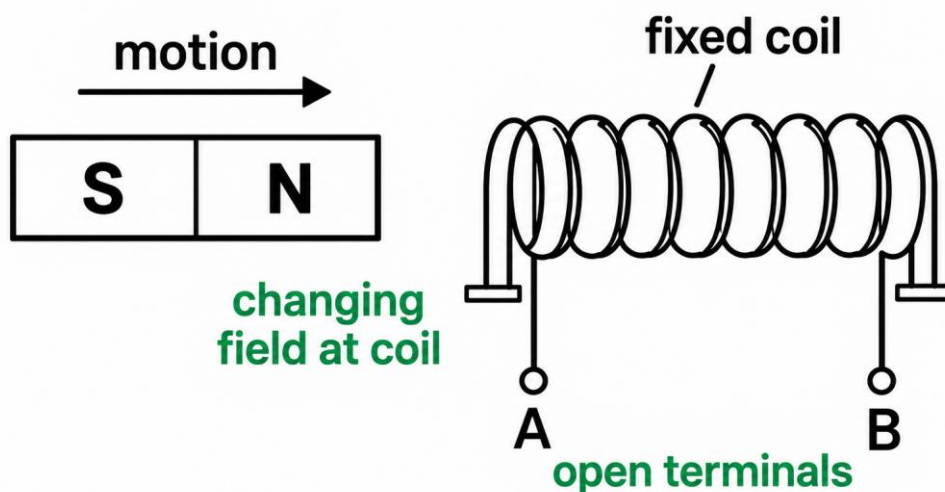


Figure 1

2(a) The same north pole is withdrawn to the left instead of approaching. Predict the sign of the recorder reading while it moves. **[1 mark]**

Answer / mark points: Negative. [1] Motion is reversed at corresponding positions with pole and connections unchanged.

2(b) The magnet is turned around so its south pole approaches from the left. Predict the sign of the reading. **[1 mark]**

Answer / mark points: Negative. [1] Reversing the magnetic polarity reverses the induced p.d. for the same approach.

2(c) The south pole is now withdrawn to the left. Predict the sign and explain it by comparing this with the reference north-pole approach. **[2 marks]**

Answer / mark points: Positive. [1]

Both the pole and motion direction are reversed compared with the reference; the two reversals restore the original sign. [1] These are same-side trials, not an unspecified journey through the coil.

2(d) For the reference north-pole approach only, the recorder leads are swapped. What happens to the displayed sign? **[1 mark]**

Answer / mark points: It becomes negative. [1] Swapping the measuring leads reverses the displayed polarity; it does not reverse the magnet's motion.

2(e) The magnet and coil are both fixed to the same moving carriage, with their positions relative to each other unchanged. Predict the induced p.d. and explain your answer. **[2 marks]**

Answer / mark points: Zero in this model. [1]

There is no change in the magnetic field at the coil because the magnet and coil move together with unchanged separation and orientation. [1] Motion relative to the workshop alone does not ensure induction.



3 Interpreting the trace

For this test a high-resistance voltage recorder is connected across the coil. It draws negligible current. The north pole approaches along the coil axis, is held still, then is withdrawn along the SAME path on the LEFT. Figure 2 is qualitative: no numerical scale is provided.

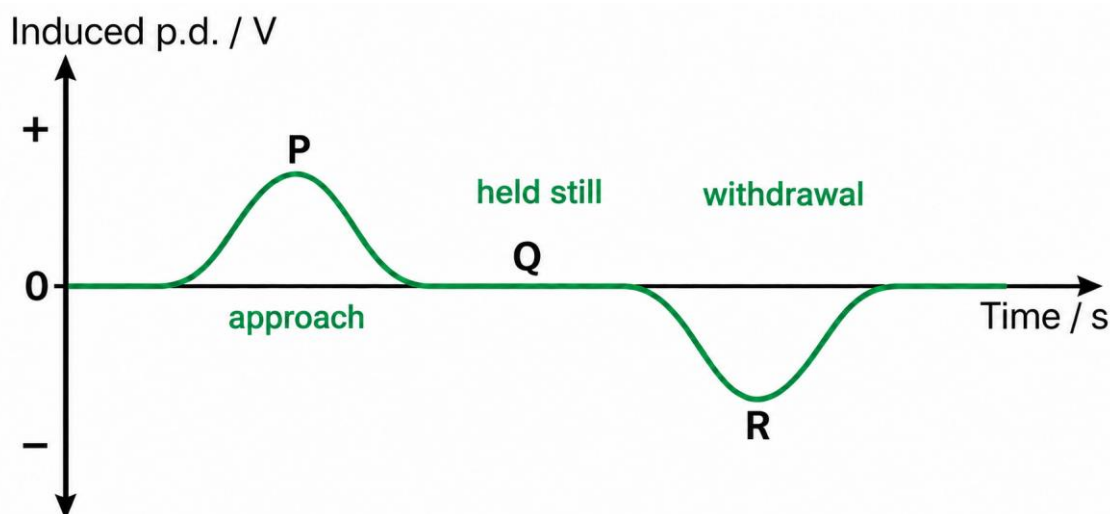


Figure 2

3(a) For the stated approach–hold–withdraw test, identify the magnet's motion at P, Q and R. **[3 marks]**

Answer / mark points: P: approaching the coil. [1]

Q: held stationary. [1]

R: withdrawing from the coil along the same left-hand path. [1] These identifications use the stated test sequence.

3(b) Explain why the p.d. at R has the opposite sign to the p.d. at P. **[1 mark]**

Answer / mark points: The direction of motion, and therefore the direction of the magnetic change, is reversed while the pole and recorder connections are unchanged. [1] Negative p.d. does not mean energy is negative.

3(c) The magnet repeats the same approach path more quickly, with all other conditions unchanged. Predict two changes to the positive pulse. **[2 marks]**

Answer / mark points: A larger positive peak p.d. [1]

A shorter-duration pulse because the same approach takes less time. [1] No exact multiplication factor is required.



4 Making the detector reliable

Table 1 gives measured positive peak p.d.s for the same magnet and 400-turn coil. Path, magnet orientation and recorder connections are unchanged. A detector triggers only when its displayed p.d. is at least +0.060 V.

Table 1

Test	Speed / m s^{-1}	Coil turns	Peak p.d. / mV
A	0.10	400	+40
B	0.20	400	+80
C	0.30	400	+120

4(a) Convert the peak reading for test B into volts. State the relationship between approach speed and peak p.d. shown by the table. **[2 marks]**

Answer / mark points: 80 mV = 0.080 V. [1]

Greater approach speed gives a greater positive peak p.d. for these controlled tests. [1] The table alone does not establish a universal formula.

4(b) Choose the slowest TESTED speed that triggers the detector. Justify your choice using the threshold and table readings. **[2 marks]**

Answer / mark points: 0.20 m s^{-1} (test B). [1]

Its 0.080 V peak exceeds +0.060 V; test A gives only 0.040 V and fails. [1] Do not claim an untested minimum speed from the table.

4(c) A withdrawal produces a peak of -80 mV. Will the positive-only detector trigger? Explain and suggest a threshold rule that detects either direction. **[2 marks]**

Answer / mark points: No: -0.080 V is not at least +0.060 V. [1]

Trigger at p.d. $\geq +0.060$ V OR p.d. ≤ -0.060 V; equivalently use a magnitude of at least 0.060 V regardless of sign. [1] A negative pulse can still be a valid motion signal.

4(d) A stronger magnet is fitted for test A at the same speed and on the same path. Predict the change in peak p.d. and explain why this does not guarantee that the detector will trigger. **[2 marks]**

Answer / mark points: The peak p.d. should be larger because the magnetic field changes more strongly during the approach. [1]

The increase is not specified, so it may still be below +0.060 V; it must be measured. [1] Do not invent a doubling factor.



4 Making the detector reliable continued

4(e) Three repeated peaks at test B's speed are 76 mV, 80 mV and 84 mV. Calculate the mean peak p.d. [1 mark]

Answer / mark points: Mean = $(76 + 80 + 84)/3 = 80$ mV (0.080 V). [1]

4(f) Suggest a change to the coil that could help detect a slowly approaching carriage, without changing the magnet or its speed. Explain the expected effect. [2 marks]

Answer / mark points: Increase the number of turns in the coil. [1]

The same magnetic change then induces a larger p.d. across the coil, helping the peak reach the voltage threshold. [1] Do not assume that every change guarantees a chosen threshold.

5 Planning a fair coil comparison

The workshop now compares 400-turn and 800-turn coils of the same dimensions. Use the same high-resistance recorder. Complete (a)–(c) to build a six-mark-style comparative method.

5(a) Describe the comparison: state what you change, what you measure and two conditions you keep the same. [3 marks]

Answer / mark points: Change only the coil turn number (400 versus 800). [1]

Measure the peak induced p.d. during each matched approach using the same recorder. [1]

Keep approach speed the same AND keep the same magnet with the same path/orientation/start and finish positions. [1 for both types of control] Coil dimensions must also remain matched.

5(b) Describe how you would make or check comparable motion at the coils, rather than relying on “the same push”. [1 mark]

Answer / mark points: Use a controlled drive at the same measured speed along a fixed guide, or check the speed at each coil with light gates and match the runs. [1] The same push can produce different motion.

5(c) Explain how repeats and the spread of readings would help you reach a supported conclusion about turn number. [2 marks]

Answer / mark points: Repeat each turn-number trial several times and compare the mean peak p.d.s. [1]

Check the spread/consistency of repeats before concluding that the difference is convincing; do not base it on one unusual reading. [1] Repeats do not remove every systematic error.



6 Connecting a load

The recorder is replaced by a resistor connected across the coil, forming a COMPLETE circuit. For (b) and (c), the magnet stays on the LEFT of the coil with its NORTH pole facing the coil. Ignore ordinary friction when comparing open and loaded trials.

6(a) First disconnect the resistor, leaving the coil ends open. As the magnet moves, explain why there can be an induced p.d. but no current through the coil. **[2 marks]**

Answer / mark points: The changing magnetic field still induces a p.d. across the coil ends. [1]
There is no complete conducting circuit, so no induced conduction current flows. [1] This open-circuit trial has no recorder or resistor connected.

6(b) Reconnect the resistor. As the north pole approaches from the left, state the induced pole at the coil's near end and the direction of the magnetic force on the magnet. **[2 marks]**

Answer / mark points: The near (left) coil end is a north pole. [1]
The magnet is repelled to the left, opposing its rightward approach. [1] The induced field opposes the increase/change that causes it.

6(c) The north pole is now withdrawn to the left. State the induced near-end pole and the force direction, explaining why the force still opposes the motion. **[2 marks]**

Answer / mark points: The near end becomes south. [1]
Attraction pulls the north pole to the right, opposing its leftward withdrawal. [1] The field acts to oppose the decrease in the original magnetic effect; it is not always opposite to the original field.

6(d) An operator moves the magnet towards the coil at the same constant speed in open and loaded trials. Explain why more work is required in the loaded trial and where the extra energy is transferred. **[3 marks]**

Answer / mark points: Current in the complete coil/load circuit produces a magnetic effect opposing the motion. [1]
The operator must do extra work against this resistive magnetic force to maintain the same speed. [1]
Energy is transferred electrically to the load and dissipated by heating in the resistor/coil. [1] The magnet's kinetic energy is not decreasing in this constant-speed comparison.

6(e) A trainee claims that leaving a strong permanent magnet still beside the loaded coil will power the detector continuously. Explain why this claim is wrong. **[2 marks]**

Answer / mark points: A stationary magnet and coil give an unchanging field at the coil, so there is no continuous induced p.d./current. [1]
A permanent magnetic field alone is not a continuing energy supply; generation requires a changing field and an energy input. [1] Ignore brief switching or positioning transients.

6(f) The carriage is instead coasting towards the loaded coil with no additional push. Predict the effect on its speed compared with the open-coil case and explain the energy transfer. **[2 marks]**

Answer / mark points: Its speed decreases more because of the additional opposing magnetic force. [1]
Energy is transferred from the carriage's kinetic store to electrical energy transfer and heating in the circuit. [1] Do not say this extra energy is created by the magnet.

Review and improve

Check complete-circuit conditions, controlled comparisons and sign conventions. At constant speed the extra energy comes from external work; without extra work the carriage slows. Timing is estimated and untrials.

Continue your physics journey

Videos, practice and support for your next step

www.physicsuk.co.uk

