Name	Date started	Target end date

GCE A LEVEL — MAGNETIC FIELDS QUESTION PACK

1325-01 (Legacy PH5)

REVISE
.wales

PHYSICS — UNIT 4 TOPIC 4

Magnetic fields — force on currents & moving charges

Every magnetic-fields question from the legacy WJEC PH5 papers (June 2011 – June 2016)

LEGACY 2008 SPECIFICATION · MAPS TO NEW UNIT 4 TOPIC 4

Estimated time for entire question pack: ~1 hour 25 minutes

*Derived from the legacy PH5 pace of **~1.3 min/mark** (80 marks in 1¾ hours).*

*You are advised to **not** attempt to complete all of this in one sitting.*

For Examiner's use only

Q	Source	Max	Mark
1	Jun 11 Q2	10	
2	Jun 12 Q4	9	
3	Jun 14 Q4	9	
4	Jun 13 Q4	11	
5	Jun 15 Q5	11	
6	Jun 16 Q5	14	
Total		64	

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every magnetic-fields question (force on currents, force on moving charges, circular motion in B-fields, cyclotrons, synchrotrons) from the legacy WJEC PH5 papers between June 2011 and June 2016.

Questions are grouped by sub-topic, then ordered roughly by difficulty.

INSTRUCTIONS

Use black ink or black ball-point pen. Answer all questions in the spaces provided.

A calculator is required. The Data Booklet is allowed.

Unit 4 Topic 4 — Magnetic fields

WJEC GCE A Level Physics (from 2015) · Unit 4 Assessment Unit *Fields and Options*. The magnetic force, circular motion and accelerator strand maps directly onto the legacy PH5.2 specification.

Magnetic flux density & the tesla A

- B measures the strength of a magnetic field at a point.
- SI unit: **tesla (T)** $= 1$ N A^{-1} m^{-1}.
- A field of 1 T exerts 1 N on each metre of a wire carrying 1 A perpendicular to the field.

Force on a current-carrying conductor A

- $F = BIL\sin\theta$ where θ is the angle between $\boldsymbol{B}$ and $\boldsymbol{I}$.
- Maximum when wire is perpendicular to $\boldsymbol{B}$.
- Zero when wire is parallel to $\boldsymbol{B}$.
- Direction: **Fleming's left-hand rule**.

Force on a moving charge A

- $F = Bqv\sin\theta$ on a charge q moving with speed v in field B.
- The force is always perpendicular to the velocity — so no work is done.
- Direction from Fleming's left-hand rule (conventional current direction for $+q$; reverse for $-q$).

Circular motion of charged particles B

- If $\boldsymbol{v} \perp \boldsymbol{B}$, the magnetic force provides centripetal force.
- Radius of circular path: $r = \frac{mv}{Bq}$.
- Period: $T = \frac{2\pi m}{Bq}$ — independent of v and r.

Cyclotrons & synchrotrons B

- **Cyclotron:** uniform B, alternating electric field across dees accelerates particles each crossing. Frequency $f = \frac{Bq}{2\pi m}$ is constant for given particle.
- **Synchrotron:** B is increased to keep r fixed as v grows.

Magnetic field of currents A

- Long straight wire: $B = \frac{\mu_0 I}{2\pi a}$ at distance a.
- Long solenoid: $B = \mu_0 n I$ inside, with n = turns per metre.
- Two parallel wires carrying current in the same direction *attract*; opposite directions *repel*.

Section index for this question pack

Magnetic fields in one page

Quick-reference notes — revisit before each section.

Force on a current

A straight wire carrying current I in a magnetic field B feels a force:

$$F = BIL\sin\theta$$

- θ = angle between $\boldsymbol{B}$ and the wire.
- Max when $\theta = 90^\circ$ → $F = BIL$.
- Zero when wire is parallel to $\boldsymbol{B}$.

Force on a moving charge

A charge q moving with speed v across a field B:

$$F = Bqv\sin\theta$$

- Always perpendicular to $\boldsymbol{v}$ — no work done.
- So $|\boldsymbol{v}|$ stays constant; only direction changes.

Fleming's left-hand rule

- ThuMb: Motion / force on wire.
- First finger: Field $\boldsymbol{B}$.
- SeCond finger: Current (conventional, $+q$).
- For negative charges, reverse the current direction.

Circular motion in a B-field

Magnetic force supplies centripetal force:

$$Bqv = \frac{mv^2}{r} \quad \Rightarrow \quad r = \frac{mv}{Bq}$$

- Heavier or faster → larger orbit.
- Stronger B or larger q → tighter orbit.

Period & frequency

Period of orbit:

$$T = \frac{2\pi m}{Bq}$$

Frequency:

$$f = \frac{Bq}{2\pi m}$$

- Both independent of v and r.
- This is the cyclotron frequency.

The tesla

SI unit of magnetic flux density.

$$1\,\mathrm{T} = 1\,\mathrm{N\,A^{-1}\,m^{-1}}$$

- From $F = BIL$: $B = F/(IL)$.
- Earth's field ~ $50\,\mu\mathrm{T}$; MRI scanner ~ 1–3 T.

Long straight wire

Field at perpendicular distance a:

$$B = \frac{\mu_0 I}{2\pi a}$$

- Field lines: concentric circles around wire.
- Direction: **right-hand grip rule** — thumb along I, fingers curl with B.

Long solenoid

Uniform field along the axis inside:

$$B = \mu_0 n I$$

- n = turns per metre.
- Field outside is essentially zero.
- Want large B? Use superconductor — allows huge I with no I^2R heating.

Two parallel wires

Each wire sits in the field of the other.

- Same direction of I → **attract**.
- Opposite direction of I → **repel**.
- Force per metre: $\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi a}$.

The cyclotron

A uniform B keeps the charged particles on circular arcs inside two D-shaped electrodes (dees).

- An alternating p.d. accelerates particles each time they cross the gap.
- $f = Bq/2\pi m$ stays constant as the radius grows — only the speed changes.
- Spiral path of increasing radius.

The synchrotron

Particles travel a fixed-radius loop. As v increases, B is ramped up so that $r = mv/Bq$ stays the same.

- Used for very high energies (LHC, Diamond).
- Superconducting magnets give the large B needed.

Strategy — 4 steps

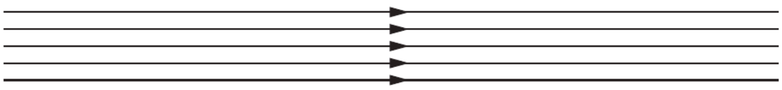
1. Identify whether the force is on a wire ($F = BIL$) or a charge ($F = Bqv$).
2. Use Fleming's LHR for direction (reverse current for negative charges).
3. For circular motion: equate magnetic = centripetal → $r = mv/Bq$.
4. For two wires: each sits in the field of the other — superpose contributions.

SECTION A

Magnetic flux density & force calculations

Questions 1 – 3 · 28 marks

2. Each of five long, straight, parallel wires carries a current of 0.3A.



(a) The wires are very close together. Show that the magnetic field strength, *B*, at a distance of 12.5 cm away from them is 2.4 μT. [2]

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(b) An α particle travelling with speed 8.8×10^6 m s^{-1} passes through a point where the magnetic field strength is 2.4 μT. Explain briefly in which direction the α particle is travelling when it experiences

(i) no force, [2]

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(ii) a force of 3.38×10^{-18} N. [2]

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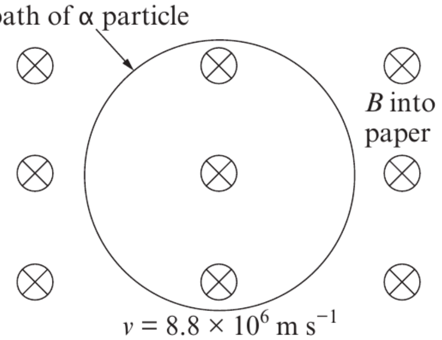
(c) The α particle travels in the Earth's magnetic field. This may be assumed to be uniform and of strength 2.4 μT as shown. The α particle travels in a circular path, as shown, at a constant speed of 8.8×10^6 m s^{-1}.
The mass of the α particle is 4 u.



(i) **Indicate with an arrow** the direction of motion of the α particle. [1]

(ii) Calculate the radius of the path of the α particle. [3]

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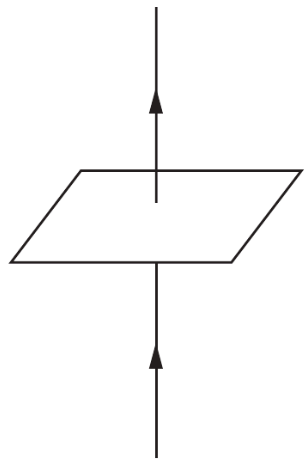
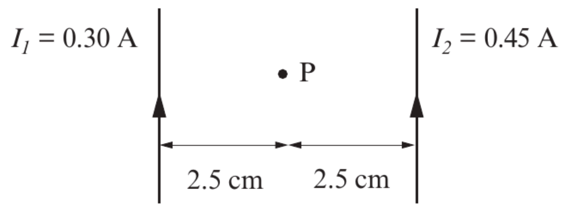
4. *(a)* Sketch the magnetic field due to the current-carrying wire shown. [2]



(b) Two long, straight wires carry currents as shown.



(i) Calculate the resultant magnetic field strength at point P in the above diagram and **state its direction**. [4]

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Examiner only

(ii) Explain why there is an attractive force between the two long wires in the diagram on the opposite page. [3]

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4. *(a)* A long solenoid of length 1.45 m has 9 560 turns. Calculate the magnetic field strength *(B)* inside the solenoid when it carries a current of 320 mA. [2]

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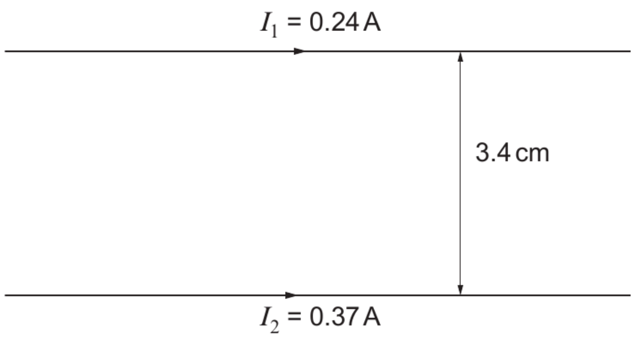
(b) Calculate the resultant magnetic field strength *(B)* half way between the two long wires shown and **state its direction**. [4]



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Examiner only

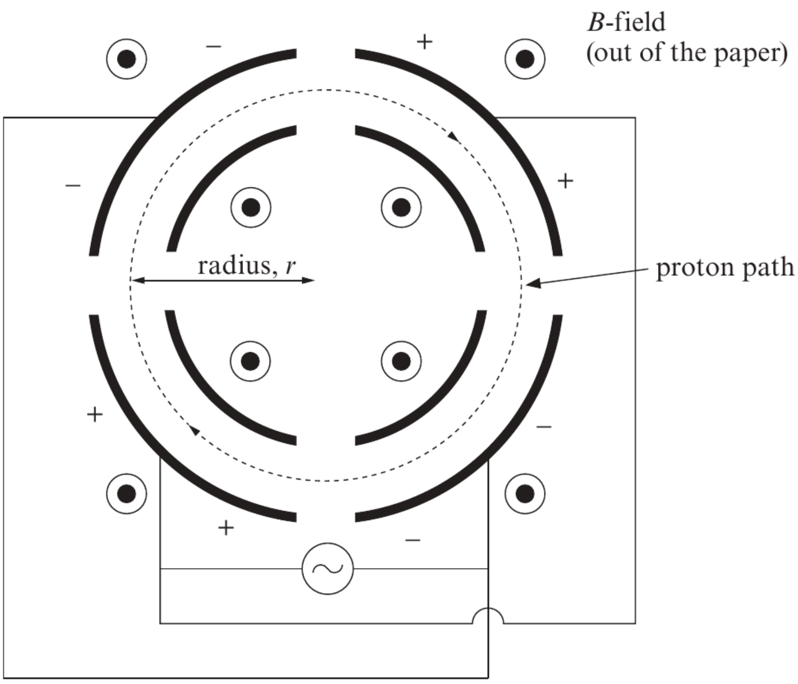
(c) Calculate the position between the two wires where the magnetic field strength is zero. [3]

SECTION B

Circular motion & accelerators

Questions 4 – 6 · 36 marks

4. The diagram below is an example of a particle accelerator called a synchrotron. In this synchrotron, protons are accelerated and their path is kept circular by a magnetic field which has to increase as the speed of the protons increases. The protons themselves are accelerated by the alternating potential difference applied to the quarter circle plates (see + and - in the diagram).



(a) Derive the equation $r = \frac{mv}{Be}$ for a particle of mass m and charge e moving with velocity v at right angles to a uniform magnetic field, B. [2]

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Examiner only

(b) Use the equation $r = \frac{mv}{Be}$ to explain why the magnetic field must be increased as the speed of the protons increases. [2]

(c) Protons take 1.78 μs to complete a circuit of a synchrotron of radius 8.50 m. Calculate the strength of the magnetic field, B, required. [$m_{proton} = 1.67 \times 10^{-27}$ kg.] [4]

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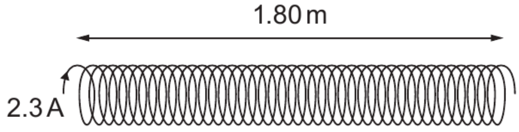
(d) (i) Modern synchrotrons use magnetic fields up to 10 T which cannot be produced using copper wires at room temperature. Explain why not, using $B = \mu_0 nI$. [2]

(ii) Hence, explain why superconducting magnets are used to produce large magnetic fields in synchrotrons. [1]

Examiner only

5. *(a)* A long thin solenoid carries a current of 2.3 A, has 12 000 turns and a length of 1.80 m. Calculate the magnetic field strength (B) in the centre of the long solenoid. [2]



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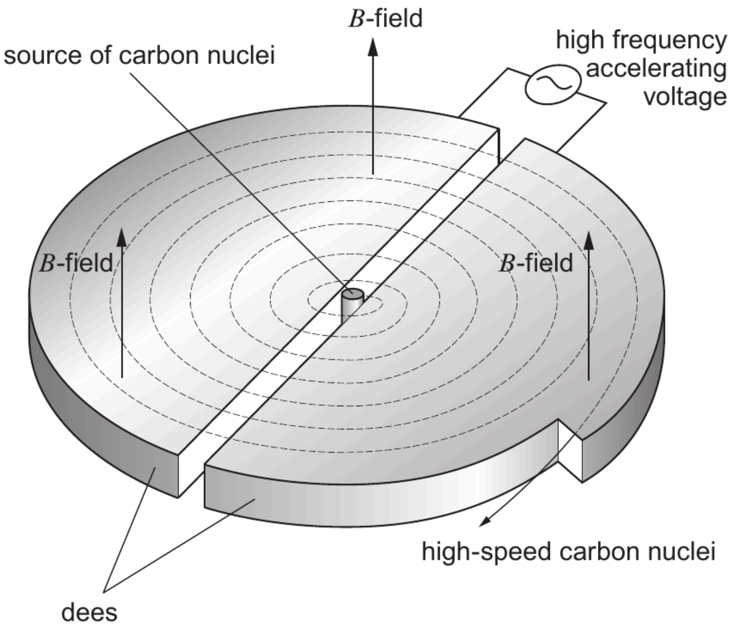
(b) In a cyclotron a uniform magnetic field (B) provides a centripetal force while an electric field accelerates the charged particles as they cross between the dees. The resulting motion is a spiral as shown.



Examiner only

(i) By equating the centripetal force to the magnetic force, show that the frequency of the a.c. supply is given by: [3]

$$f = \frac{Bq}{2\pi m}$$

where q is the charge and m is the mass of the particle.

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(ii) Calculate the cyclotron frequency for a carbon nucleus with $q = 6e$ and mass $m = 12\,\text{u}$ in a strong B-field of 3.3 T. [2]

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(iii) Calculate the final speed of a carbon nucleus after it has completed 12 'orbits' of the cyclotron and the potential difference between the dees is 14.5 kV (assume that the carbon nucleus starts from rest). [4]

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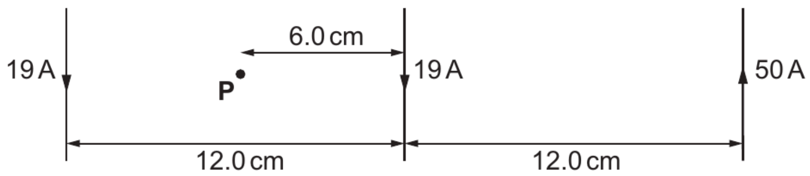
5. *(a)* An electron-positron pair is produced by a photon of energy 1.04 MeV.

(i) Show that the energy required to produce an electron-positron pair is 1.02 MeV. [2]

(ii) State what happens to the remaining 0.02 MeV of the photon energy in this electron-positron pair production. [1]

(b) Point **P** is half way between two long wires each carrying a current of 19 A and 18.0 cm away from a third long wire carrying a current of 50 A. Show that the resultant magnetic flux density due to the **three** long wires at point **P** is approximately 6×10^{-5} T and **state its direction**. [4]



Examiner only

(c) A positron travels with velocity, v perpendicularly to a uniform magnetic field, B.

(i) Show in clear steps that the radius of the circular motion of the positron is given by: [4]

$$r = \frac{m_e v}{Be}$$

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(ii) Calculate the radius of motion of a positron moving perpendicularly to a uniform magnetic flux density (B) of 6.0×10^{-5} T when the speed of the positron is $6.0 \times 10^{7}\,\mathrm{m\,s^{-1}}$. [1]

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(iii) Hence, explain why a positron produced at point **P** initially moving to the left will not travel with uniform circular motion. [2]

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END OF QUESTION PACK

6 questions · 64 marks · ~1 h 25 min

Mark schemes available from WJEC and Physics & Maths Tutor.