ELECTROMAGNETISM

Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by The Physics Cafe

1 Fig 31 shows the top view of a current balance. The wire frame ABCD is supported by the pivots P and Q. PBCQ lies within the magnetic field, whose flux density is to be measured. The sides AD and BC are equidistant from the pivots. Electrical connections are made to the frame through the pivots.

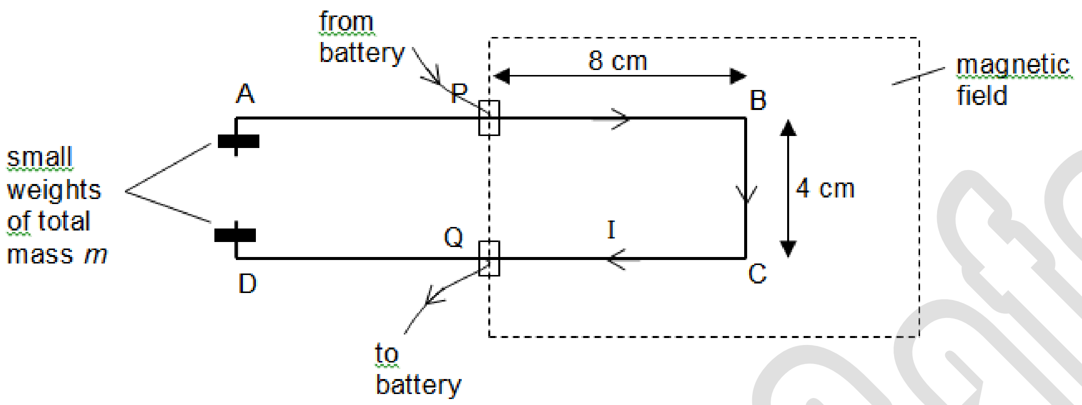


Fig 31

Given that the current I flowing in the current balance is 1.2 A, and the total mass of small weights m is 30 g, calculate the flux density of the magnetic field.

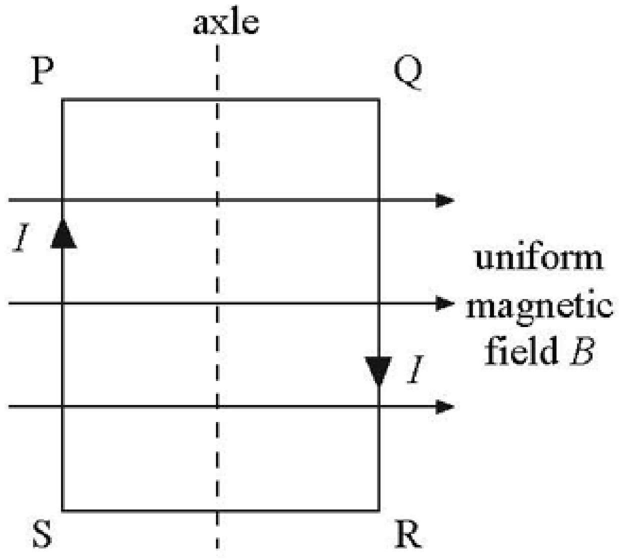
A 0.625 T **B** 3.1 T **C** 6.1 T **D** 625 T

2 An α-particle and a β-particle both enter the same uniform magnetic field, which is perpendicular to their direction of motion. If the β-particle has a speed 15 times that of the α-particle, what is the value of the ratio

$$\frac{\text{magnitude of force on } \beta-\text{particle}}{\text{magnitude of force on } \alpha-\text{particle}}?$$

A 3.7 **B** 7.5 **C** 60 **D** 112.5

3 A coil PQRS mounted on an axle, has its plane parallel to the flux lines of a uniform magnetic field *B*, as shown.



When a current *I* is switched on, and before the coil is allowed to move,

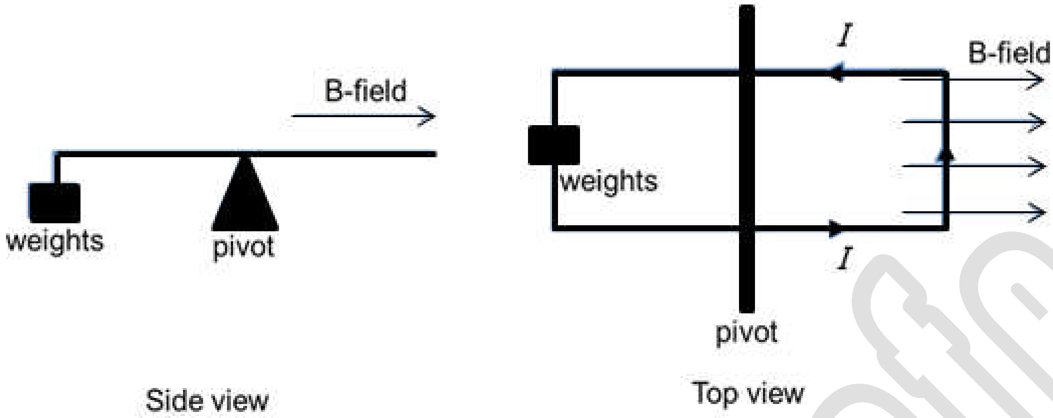
A there are no forces due to *B* on the sides SP and QR.

B there are no forces due to *B* on the sides PQ and RS.

C sides SP and QR tend to attract each other.

D sides PQ and RS tend to attract each other.

4 A simple model of a current balance is assembled as shown in the diagram below:



When current, *I,* flows through the setup, the wire frame is balanced.

If the strength of the magnetic field is halved, which of the following changes to the setup will ensure that the wire frame remains balanced?

A doubling the mass of the weights

B reversing the direction of the current

C shifting the pivot in the direction of the weights

D reducing the magnitude of the current, *I,* by half

5 Four particles independently move at the same speed in a direction perpendicular to the same magnetic field.

Which particle is deflected the most?

A a copper ion

B a helium nucleus

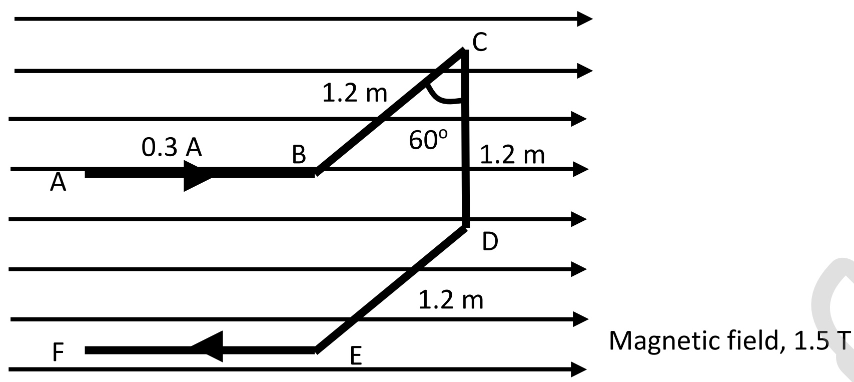
C an electron

D a proton

6 A cosmic ray proton falls vertically downwards from sky at a speed of 4.0×10^5 m s^{-1} in a region where the magnetic field of the Earth has the magnitude 5.0×10^{-5} T and is directed towards the north and downward at 30° below horizontal. The magnitude and direction of the magnetic force on the proton is

	Magnitude	**Direction**
A	1.60×10^{-18} N	Towards the East
B	1.60×10^{-18} N	Towards the West
C	2.77×10^{-18} N	Towards the East
D	2.77×10^{-18} N	Towards the West

7 A current of 0.3 A flows in a conductor that lies on the plane of the paper as shown in the figure below.



The conductor is inside a region of space containing a uniform magnetic field of 1.5 T. AB and FE are parallel to the magnetic field. BC and ED are parallel to each other. Angle BCD is 60°. The lengths of segments BC, CD and DE are 1.2 m long each. Segment CD is perpendicular to the magnetic field. The magnitude of the resultant force on the conductor is

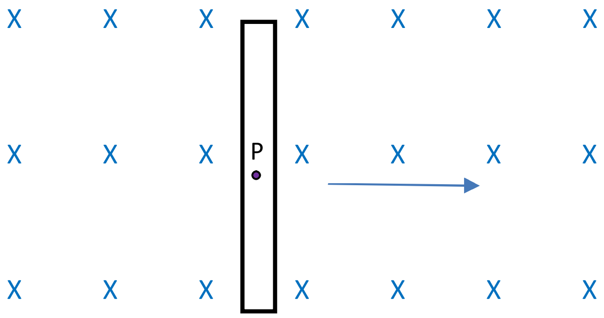
A 0.27 N

B 0.47 N

C 0.54 N

D 1.08 N

8 A metal rod is moving at a constant speed perpendicular to a magnetic field as shown. A conduction electron in the rod is represented by the dot marked P.



After some time, the electron experiences (apart from gravity)

A both an electric and a magnetic force.

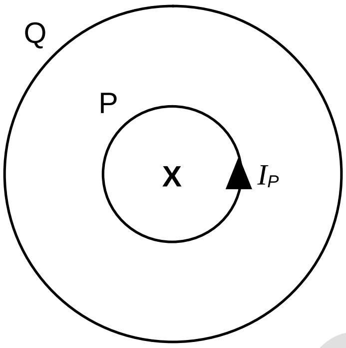
B neither an electric nor a magnetic force.

C a magnetic force only.

D an electric force only.

9 The magnetic flux density at the centre of a flat circular coil is proportional to the number of turns and to the current in the coil and is inversely proportional to its radius. The diagram show two circular coils P and Q lying in the same plane and are concentric.

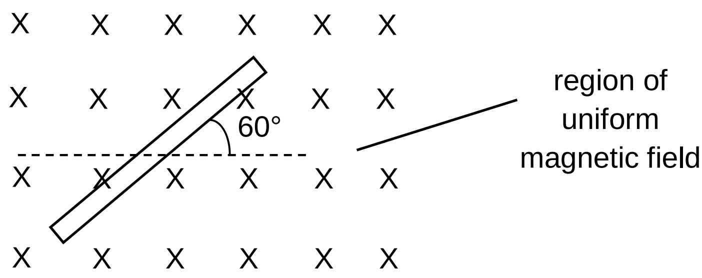
Coil P of radius 4.0 cm has 10 turns and carries a current, I_P of 2.0 A. Coil Q of radius 16.0 cm has 40 turns. The current in coil Q is adjusted such that the resultant magnetic field at the common centre X is zero.



Which is the magnitude and direction of the current in coil Q?

	magnitude of current in coil Q	direction of current
A	0.5 A	clockwise
B	1.0 A	anti-clockwise
C	2.0 A	clockwise
D	4.0 A	anti-clockwise

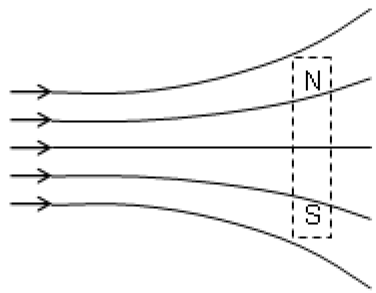
10 The diagram shows a 4.0 cm straight conductor carrying a current of 5.0 A, and placed in a region of uniform magnetic field of flux density 0.04 T.



What is the magnitude of the force acting on the conductor?

A 4.0×10^{-3} N **B** 6.0×10^{-3} N **C** 7.0×10^{-3} N **D** 8.0×10^{-3} N

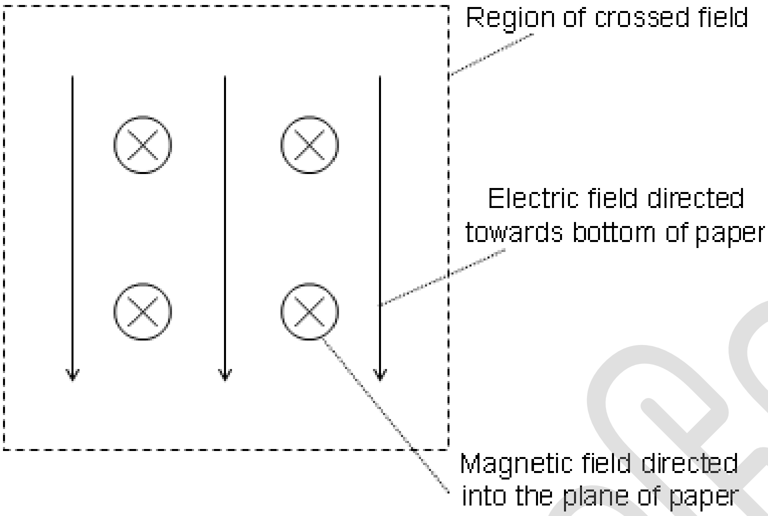
11 A bar magnet is placed in a non-uniform magnetic field as shown below.



Which of the following describes the subsequent motion of the magnet?

	Rotation	Movement
A	Anticlockwise	To the left
B	Anticlockwise	To the right
C	Clockwise	To the left
D	Clockwise	To the right

12 An electron beam enters a region in which there is a uniform electric field and a uniform magnetic field directed at right angles to each other as shown below. The beam passes straight through the region without deflection.



A second electron beam travelling along the same path but twice as fast as the first beam also enters the same region of crossed field.

Which of the following gives the direction of the first beam and the deflection of the second beam?

	Direction of the first beam	**Deflection of the second beam**
A	Right to left	Towards top of page
B	Right to left	Towards bottom of page
C	Left to right	Towards top of page
D	Left to right	Towards bottom of page

13 Four different units labelled P, Q, R and S are given as shown:

P: volt second^{-1}

Q: volt second

R: tesla metre^{-2}

S: tesla metre^{2}

Which pair of units are equivalent to the weber?

A P and R **B** P and S **C** Q and R **D** Q and S

14 A doubly charged ion is moving in a uniform magnetic field of flux density B in a circle of radius r at a speed v.

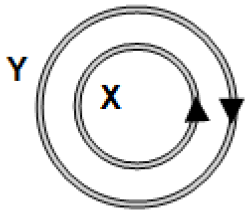
What is the flux density which will maintain a singly-charged ion of the same mass in a circle of half the radius at the same speed?

A $\frac{B}{4}$ **B** $\frac{B}{2}$ **C** $2B$ **D** $4B$

15 The magnetic flux density at the centre of a flat circular coil is given by the equation

$$B = \frac{\mu_o NI}{2r}.$$

Two such coils, **X** and **Y**, each with 50 turns, are arranged as shown in the diagram



X has radius 0.060 m and carries a current of 1.5 A in the anti-clockwise direction, Y has radius 0.12 m and carries a current of 1.0 A in the clockwise direction.

What is the magnitude and direction of the total magnetic flux density at the centre of the coils?

A $417\mu_o$ out of the page

B $417\mu_o$ into the page

C $833\mu_o$ out of the page

D $833\mu_o$ into the page

ELECTROMAGNETISM WORKED SOLUTIONS

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1 Ans: **C**

$$weight = F_B$$
$$mg = BIL$$
$$B = \frac{mg}{IL}$$
$$= \frac{0.030 \times 9.81}{1.2 \times 0.04}$$
$$= 6.1\,T$$

2 Ans: **B**

F=Bqv

$$\frac{F_\alpha}{F_\beta} = \frac{B(2e)v}{B(e)(15v)} = \frac{2}{15} = 7.5$$

3 Ans: **B**

F = B*Il*sin α

For sides PQ and RS, $\alpha = 0^o$ and 180^o, hence F = 0

For sides SP and QR, $\alpha = 90^o$, F = BI*l*.

Direction of the forces on SP and QR can be found by Fleming's left-hand rule. The force on QR points out of the plane of the diagram and the force on SP points into the plane of the diagram.

4 Ans: **C**

When the B-field is halved, the force on the right side of the frame reduces by half, causing the clockwise moments to be also halved.

Any changes that should be made should either increase the force (and thus the moments) to the original magnitude, increase the clockwise moment or decrease the anti-clockwise moment.

The mass of the weights will increase the anti-clockwise moment, so this is rejected.

Reversing the current direction will change the direction of the force and lead to a net anti-clockwise moment in the frame.

Halving the current will decrease the force on the wire, and thus decrease the clockwise moment further.

Moving the pivot to the left will increase the clockwise moment and decrease the anti-clockwise moments, and this will help restore the balance in the frame.

5 Ans: **C**

6 Ans: **C**

7 Ans: **C**

8 Ans: **A**

9 Ans: **C**

$B \propto IN / r$

Hence, for the resultant magnetic flux density at the common center to be zero,

$(IN / r)_Q = (IN / r)_P$ and the current in coil Q must in the clockwise direction.

Hence, $I_Q = (2.0 \times 10 / 0.04)(0.16 / 40)$

= 2.0 A

10 Ans: **D**

$F = BIL \sin \vartheta$

ϑ is the angle between the magnetic field and the current.

In this case, $\vartheta = 90°$

Hence, $F = BIL$

$F = (0.04)(5.0)(0.04) = 8.0 \times 10^{-3}$ N

11 Ans: **C**

Imagine the external magnetic field is due to a strong North pole on the left side and a weak South pole on the right side. The magnet therefore rotates clockwise. Due to the non-uniform external magnetic field, it will experience a resultant force towards the left.

12 Ans: **D**

The electric force on the electrons will be towards the top of page so the magnetic force on them must be towards the bottom of the page so that they can cancel out as in the case of the first beam. Applying Fleming's Left Hand Rule, the electrons are found to be travelling towards the right of page. When the speed of electrons is doubled, the electric force remain the same but the magnetic force is doubled so the second beam will be deflected towards the bottom of the page.

13 Ans: **D**

Using $\varepsilon = -\frac{d\Phi}{dt}$, volt = $\frac{\text{weber}}{\text{second}} \Rightarrow$ weber = volt second which is Q

Using $\Phi = BA \Rightarrow$ weber = tesla metre^2 which is S.

14 Ans: **D**

$B_1(2q)v = \frac{mv^2}{r_1}$ Equation (1)

$B_2(q)v = \frac{mv^2}{r_2}$ Equation (2)

Combine both equations ➔ $r_2 = \frac{1}{2} r_1$ ➔ $B_2 = 4B_1$

15 Ans: **A**

From X, $B = \frac{\mu_o NI}{2r}$ = $(50)(1.5)\mu_o / (2)(0.060) = 625\ \mu_o$ pointing out of page (using RHGR)

From Y, $B = \frac{\mu_o NI}{2r}$ = $(50)(1.0)\mu_o / (2)(0.12) = 208\ \mu_o$ pointing into page (using RHGR)

Net B = $625\ \mu_o - 208\ \mu_o = 417\ \mu_o$ pointing out of page