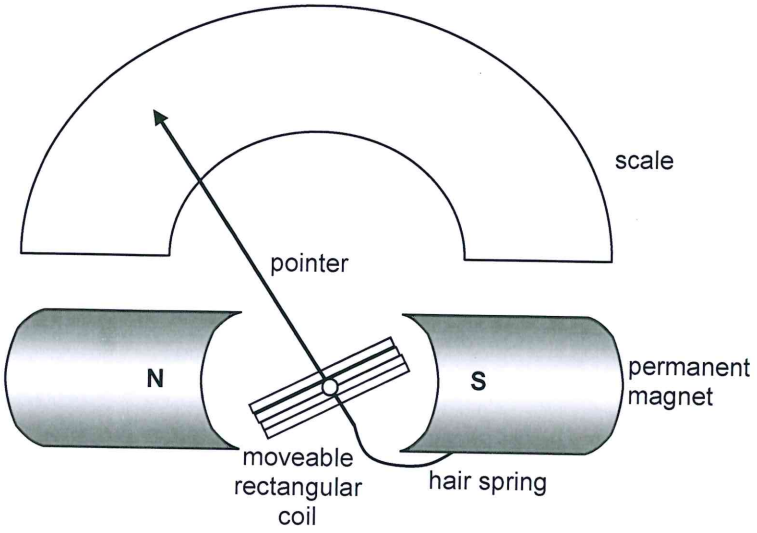
Exam Answer
Chapter 5.4 - Electric Motors
Answer 1 - 2010:2:16

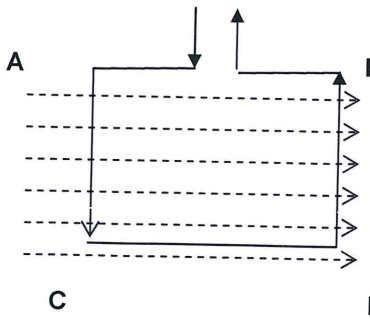
(13 marks)

Analogue meters, like the one shown in the diagram below, have many applications: for example, in pool chlorination systems. The interaction of the electric current in the coil and the permanent magnet creates a torque. A fine spring (hair spring) provides a restoring torque.



(a) When a current flows in the rectangular coil a force is produced on each side of the coil that interacts with one magnetic field. Explain the reason for this force and comment on its direction. You must draw a diagram to illustrate your explanation. (2 marks)

Description	Marks
Interaction of the field due to the wire and the field due to the permanent magnet.	1
Direction at right angles to both the current and the field. Diagram is essential (see below).	1
It is in a different direction on each side of the coil (that is why it rotates).	1
	Total 3



Show force on AC is out of the page and on BD into page

(b) The coil has a length of 0.100 m and a width of 0.0800 m and has 50.0 turns. There is a current of 4.00 A in the coil and it is in a uniform magnetic field of 0.0100 T.

(i) Calculate the force on one of the long sides of the coil. (4 marks)

Description	Marks
Appropriate formula $F = NBi\ell$ 1 mark for $Bi\ell$ and 1 mark for multiplying by N	1-2
Substitute $F = 50 \times 0.01 \times 4 \times 0.1$	1
$= 0.200$ N	1
Total	**4**

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(ii) Hence determine the torque acting on the coil. (3 marks)

Description	Marks
Appropriate formula $T = 2 (F \times r)$	1
Subs $T = 2 (0.200 \times 0.0400)]$	1
$= 1.60 \times 10^{-2}$ N m	1
Total	**3**

(c) Why will the coil rotate? (2 marks)

Description	Marks
An unbalanced torque will cause rotation.	1-2
	Total 2

(d) The loosely coiled spring provides a torque that opposes the coil's rotation. When the coil is stationary, with a current flowing in it, state the relationship between the torque acting on the coil because of the magnetic field, and the torque provided by the spring. (1 mark)

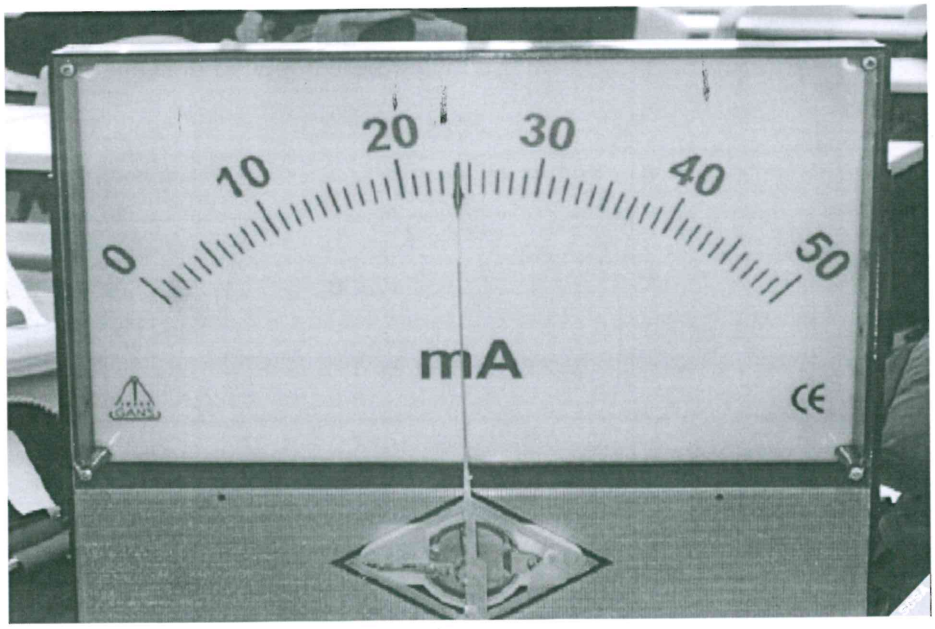
Description	Marks
Equal size and opposite in direction. Note: Only need to say equal as question states opposes	1
	Total 1

Answer 2 2013:2:14

(16 marks)

An ammeter is a device that is used to determine the magnitude of an electric current. The unknown current is passed through a coil of wire in a magnetic field. The turning effect of the current-carrying coil is balanced by a spring and a corresponding value is read from the meter.

(a) Use the photograph below of an ammeter's scale to determine the magnitude of the current passing through it, as well as the absolute and relative uncertainty for this value. (3 marks)



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Answer 2 continued

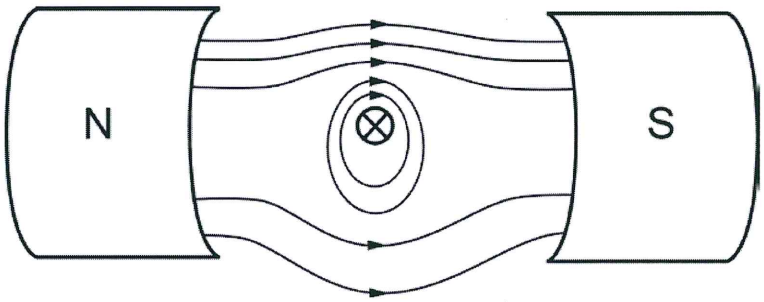
Current: _____ mA

Absolute uncertainty: _____

Relative uncertainty: _____

Description		Marks
24 (units not needed)		1
±1 (in the value)	or ±0.5 (in the reading)	1
% uncertainty 1/24 × 100 = 4.2%	0.5/24 × 100 = 2%	1
	Total	**3**

(b) A simplified diagram representing one current-carrying wire of the ammeter's coil between two magnets, is shown below. Draw at least **five** field lines to show the resultant magnetic field between the magnets. (4 marks)



Description	Marks
At least five field lines drawn	1
From N to S **or** clockwise around wire	1
Diagram shows good understanding of field interaction	1–2
Total	**4**

(c) Calculate the magnitude of the force, in newtons, acting on the wire carrying a current of 1.45 A in the simplified diagram on page 14, given that the magnetic field strength is 4.25×10^{-2} T and the length of the wire in the field is 2.50×10^{-2} m. (2 marks)

Description	Marks
$F = I\ell B = 1.45 \times 2.50 \times 10^{-2} \times 4.25 \times 10^{-2}$	1
$= 1.54 \times 10^{-3}$ (N)	1
Total	**2**

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(d) The actual ammeter shown has 250 turns of wire that form a square coil with sides of 3.20×10^{-2} m. Determine the magnitude of the current in amperes, given that the spring provides a restoring torque of 2.65×10^{-2} N m in the magnetic field strength of 4.25×10^{-2} T. (4 marks)

Description	Marks
$\tau = Fr = 2NI\ell Br$ (or torque = N I AB) $I = \tau/2N\ell Br$	1–2
$= 2.65\times10^{-2}/(2\times250\times3.20\times10^{-2}\times 4.25\times10^{-2}\times3.20\times10^{-2}/2)$ $= 2.44$ (A)	1–2
Total	**4**

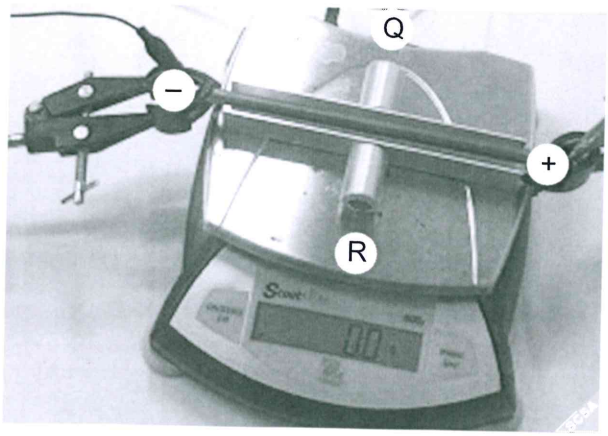
(e) When the ammeter is disconnected, the spring rotates the coil so that the marker needle returns to zero. This causes a change in flux of 2.18×10^{-5} Wb to occur in the coil in 0.115 s. Determine the average potential difference induced in the coil during this change. Include the units in your answer. (3 marks)

Description	Marks
$emf = -N\,\Delta\Phi/t = 250 \times 2.18 \times 10^{-5}/0.115$	1
$= 4.74 \times 10^{-2}$ (or -4.74×10^{-2})	1
V (units)	1
Total	**3**

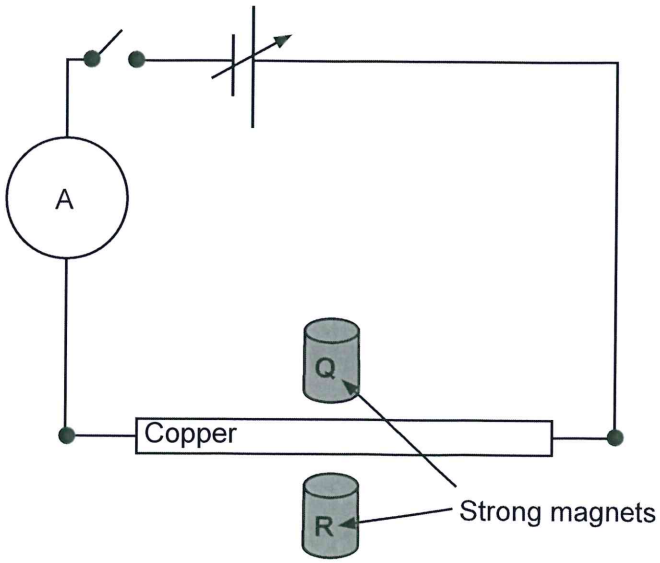
Answer 3 2014:2:20

(18 marks)

Jake wanted to determine the strength of a magnetic field by conducting an investigation. In this investigation, two identical cylindrical permanent magnets, each 2.0 cm in diameter, were placed opposite each other on either side of an aluminium channel. A current was passed along a 20 cm copper rod, which in turn was placed perpendicularly in the magnetic field. The interaction between the permanent magnets and the current-carrying wire produced a downward force acting on the magnets which was measured using a digital balance. Photographs of the equipment are shown below, as is a schematic diagram of the circuit.



Close up of magnets and copper rod on digital balance



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Answer 3 continued

(a) Using the photograph above, for magnets labelled Q and R, write either 'North' or 'South' in the space below to indicate which pole the magnet would need to have next to the channel to provide the magnets with a force directed downward (into the pan of the balance). (2 marks)

Description	Marks
Q is North and R is South (Poles are incorrect but opposite, 1 mark only)	1–2
Total	**2**

(b) A table of results for this investigation is shown below:

Potential difference (V)	Current (A)	Scale reading (g)	Force (N)
0.00	0.00	0.00	0.0
2.0	0.94	0.30	2.9×10^{-3}
4.0	1.81	0.70	6.9×10^{-3}
6.0	2.67	0.90	8.8×10^{-3}
8.0	3.66	1.3	1.3×10^{-2}
12	5.30	1.9	1.9×10^{-2}

(i) Complete the last column in the table above with values expressed to **two** significant figures. (2 mark)

Description	Marks
Table completed correctly	1
2 significant figures	1
Total	**2**

(iv) Determine the gradient of your line of best fit. Include units in your answer. (3 marks)

Description	Marks
Uses line of best fit and not data points	1
gradient = 3.2 to 3.8×10^{-3} (actual=3.5×10^{-3})	1
Units $N\ A^{-1}$	1
Total	**3**

(v) Use your gradient to determine the experimental value of the magnetic field strength. Include units in your answer. Show **all** workings. (4 marks)

Description	Marks
$F = B\ I\ \ell$ Gradient = $F / I = B\ell$	1
ℓ = 0.02 m Diameter of magnets, rather than the length of rod; can accept larger with justification of expanding field, but not 0.2 m	1
$3.46 \times 10^{-3} = B\ \ell$ $3.46 \times 10^{-3} = B \times 0.02$ B = 0.17 Allow range 0.15–0.19	1
tesla (T) (or $N\ A^{-1}m^{-1}$ or $N\ ms^{-2}\ A^{-1}m^{-1}$ or $N\ s^{-2}\ A^{-1}$)	1
Total	**4**

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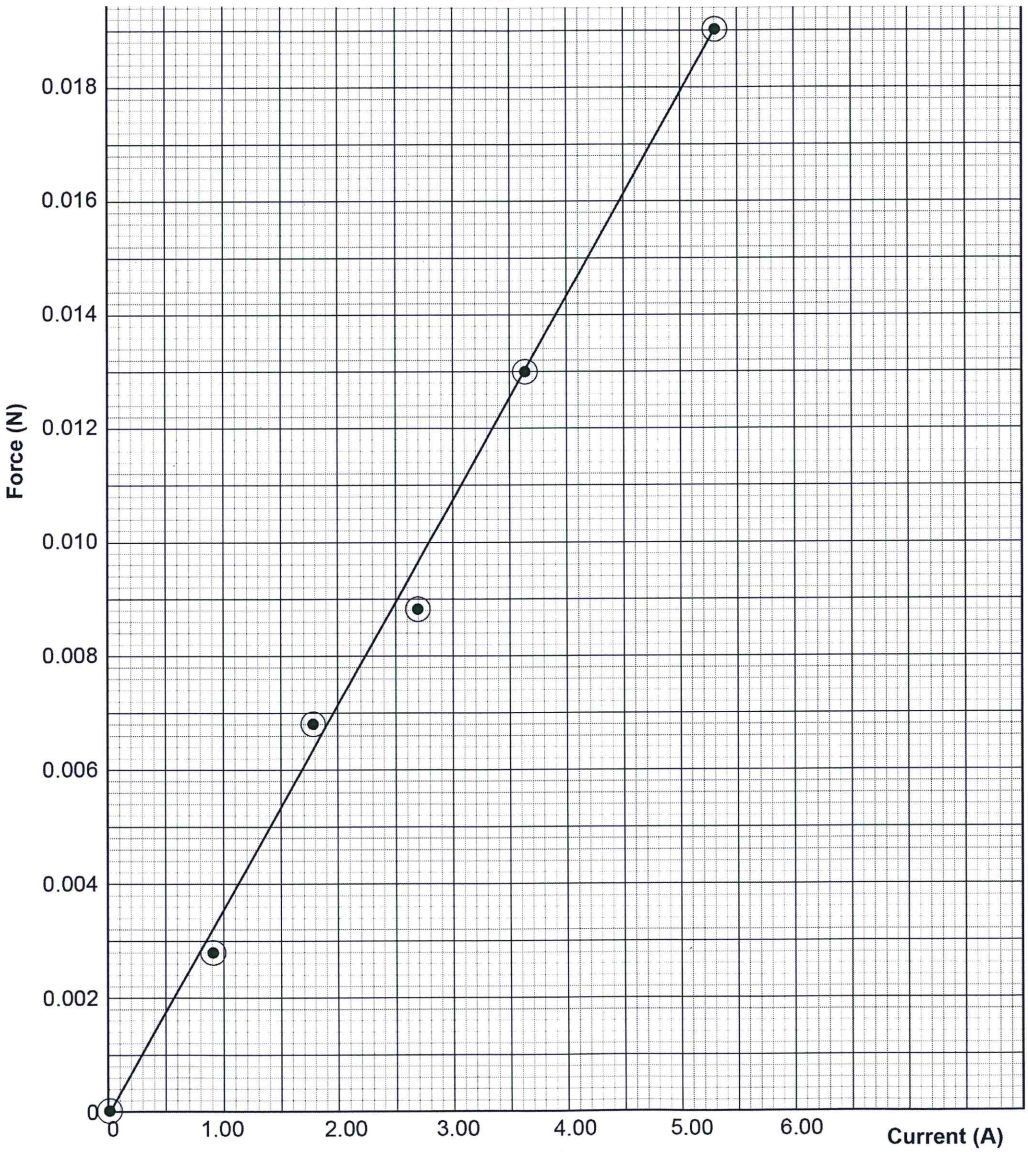
Answer 3 continued

(ii) Use the data from the table to plot a straight line graph on the grid provided, demonstrating the relationship between the current and force. (4 marks)

Description	Marks
Current is on the x axis	1
Axes labelled with units	1
Points correct	1
Line of best fit	1
Total	**4**



(iii) Use your graph to determine the force that should be measured when a current of 4.0 A flows through the copper rod. Express your answer using appropriate significant figures. (3 marks)

Description	Marks
Shows evidence of using graph (line on graph or correct value stated)	1
14×10^{-3} (determined by graph)	1
2 significant figures	1
Total	**3**