Multiple choice solutions

Example 1 2000 Question 13, 80%

When the switch closes, the current will flow in the circuit as shown in the figure.
This will cause of force to act on the LHS of the coil in an upward direction. The coil will rotate 90^0 in a clockwise direction about the axis of rotation.
At this point the force will want to keep acting in the same direction (up).
What happens next depends on friction.
Assume a lot of friction, then the coil will stay at this position.

∴ **A** **(ANS)**

Assume not much friction, then the coil will overshoot the vertical position, so now the force will act to make it rotate in an anti-clockwise direction, etc, etc.
This means that the coil will oscillate about this vertical position eventually coming to rest in a vertical plane.

∴ **B** **(ANS)**

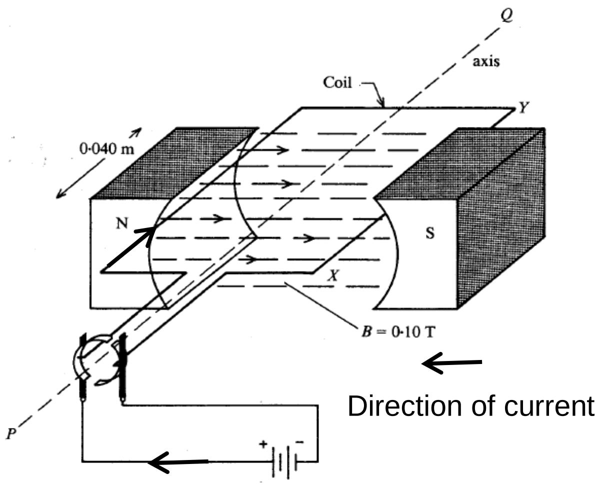
The examiners accepted both responses.

Example 2 2000 Question 14, 80%

The purpose of the split rings (commutator) is to reverse the direction of the current every half cycle, so the coil will continue to rotate.

∴ **D** **(ANS)**

Example 3 1986 Question 69



The field is from left to right, the current is from front to back, so the force on the LHS is down
Therefore the loop will rotate anti-clockwise.

∴ **A** **(ANS)**

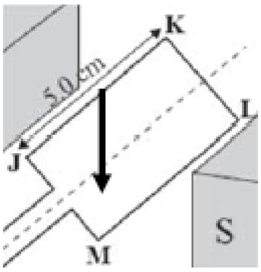
Extended response solutions

Example 4 2011 Question 3, 83%

The role of the commutator is to reverse the direction of the current every half turn, so that the direction of the force on the current carrying wire is reversed every half turn, in order to keep the motor rotating in the same direction. The current changes when the coil is at right angles to the field

Example 5 2011 Question 4, 70%

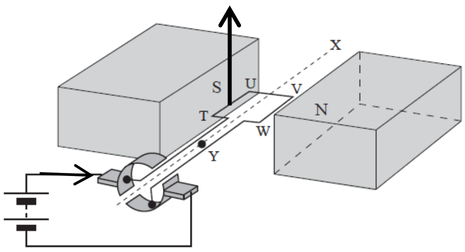
Use the right hand slap rule. Thumb (current) pointing from J to K, fingers (field) pointing from N to S (in this case left to right). The palm is now in the direction of the force. It should be facing down.



Example 6 2011 Question 5, 85%

Use F = nBIL
And remember the L = 5 cm = 0.05 m.
∴ F = 50 × 0.3 × 6 × 0.05
∴ **4.5 N (ANS)**

Example 7 2009 Question 5, 75%



The field is from North to South, the current is flowing from T to U, so the force is UP.

Example 8 2009 Question 6, 90%

F = nBIL
= 1 × 0.25 × 2 × 0.0090
= 4.5×10^{-3} N (ANS)

Example 9 2009 Question 7, 85%

As shown, the side UV was parallel to the magnetic field, therefore the force was zero.

∴ **0 N (ANS)**

Example 10 2009 Question 8, 80%

The role of the split ring commutator is to reverse the direction of the current in a DC motor every half rotation.
This (reversal every half cycle) keeps the torque in the same direction which allows the motor to keep rotating in the same direction.

Example 11 2008 Question 2, 90%

Using the right hand rule, the hand is opened flat and the fingers are aligned with the magnetic field. The thumb is pointed in the direction of current flow and the palm is now facing the direction of the force.
Use the right – hand slap rule and you will see that the direction of the current is from A to B

∴ **AB (ANS)**

Example 12 2008 Question 3, 85%

It was important to see that the length of wire in the magnetic field was 40 cm or 0.4 m from the diagram.

$F = BIL$

$= 2.0\times10^{-3} \times 5.0 \times 0.4$

$\mathbf{= 4.0\times10^{-3}}$ **N (ANS)**

Example 13 2007 Question 4, 70%

a. Anti-clockwise

b. When the switch is closed the current will flow from J to K to L to M. The magnetic field is from left to right (N to S.
Using the right hand rule, the force on JK will be down. The loop will rotate anti-clockwise.

Example 14 2007 Question 5, 65%

The role of the split ring commutator is to reverse the direction of the current in a DC motor every half rotation.
This (reversal every half cycle) keeps the torque in the same direction which allows the motor to keep rotating in the same direction.

Example 15 1999 Question 4, 68%

Use F = nBiL

∴ F = 50 x 0.040 x 1.5 x 0.05

∴ **F = 0.15 N (ANS)**

Example 16 1999 Question 5, 68%

The force on KL is zero, as it is parallel to the field.

∴**0 N (ANS)**

Example 17 1999 Question 6, 42%

With the coil in a vertical position, the force on JK will be up. The force on LM will be down. These two forces will not cause a rotation, but will have a tendency to stretch the coil.
The force on KL will also be outward, to the back of the coil, and the force on JM will be outward, but to the front of the coil, again tending to cause the coil to stretch outwards.

Therefore the coil will remain stationary.

Example 18 1998 Question 6

F = nBIL
F = 1 × 0.010 × 0.30 × 0.30
∴ F = 0.0009 N
= 9×10^{-4} N

Example 19 1998 Question 7

a) pointing to the left
b) pointing to the left
c) pointing to the left

(a) The field is down, the current is into the page, so the thumb points into the page with the fingers pointing down. This makes the palm of your hand face left, so the force is in the direction pointing to the left

(b) The field is down, the current is into the page, so the thumb points into the page with the fingers pointing down. This makes the palm of your hand face left, so the force is in the direction pointing to the left

(c) The field is down, the current is into the page, so the thumb points into the page with the fingers pointing down. This makes the palm of your hand face left, so the force is in the direction pointing to the left

There isn't any change in the 3 orientations, the field was constant, and the wire had a current going into the page in these three situations, so each ANS)wer has to be identical. Don't get fussed that on the exam, they actually gave you such a simple question. You need to solve every problem on its merits.

Example 20 1998 Question 8

a) NF
b) Into the plane of the page

(a) The section of wire XY is parallel to the field, so this means that the force acting on it will be zero.

(b) Now the wire is at right angles to the field, so there will be a force acting on it. The field is down the page (direction of your fingers the current is from left to right across the page (direction of your thumb). So your palm must be facing into the page (you need a flexible wrist for this. So the force is into the plane of the page. Remember that you need to circle the head of the arrow.

Example 21 1997 Question 9, 50%

Place your fingers in the direction of the field, from left to right. For the loop to rotate clockwise the force on KL must be upwards. So have your palm facing up. This means that your thumb points from K - L.
So the current flows from K to L.

Example 22 1997 Question 10, 70%

F = nBIL
0.60 = 1 × 1.5 × I × 0.1
∴I = 4 amp

Example 23 1997 Question 11, 43%

a. If the coil starts in this position, the forces acting on KL and MN will spin the loop in the direction shown, because of the torques acting.

b. If the coil starts in this position the forces acting on KL and MN will tend to try to squeeze or expand the loop, but not spin it.

Example 24 1996 Question 7

Use F = nBiL

$\therefore$ F = 20 x 3.0 x 10^{-2} x 2.0 x 0.05

$\therefore$ **F = 0.06 N (ANS)**

Example 25 1996 Question 8

The wire is parallel to the magnetic field, therefore the force is zero.

0 N (ANS)

Example 26 1996 Question 9

When the coil is in the horizontal plane the torque will be exactly the same as before. Once it moves from this plane the torque will be greater than if the sides were perpendicular. This is because the magnetic field is perpendicular to the wire longer. This means that the maximum torque is exerted on the wire for a greater time.

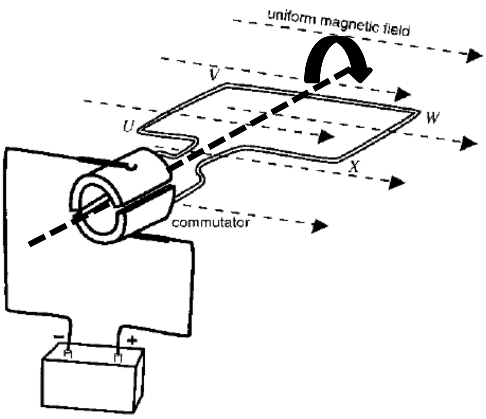
Example 27 1995 Question 9, 40%

The force on VW is zero, as it is parallel to the field.

$\therefore$**0 N (ANS)**

Example 28 1995 Question 10, 35%

The current will flow from X to Y, so the force on XY is down. The force on VU will be up. These two forces combine to produce a torque initially causes the loop to rotate in a clockwise direction around the dotted line on the figure.



When UV is at the top, the commutator will reverse the direction of the current, and hence the direction of the force will also reverse, so now instead of UV having a force acting up, the force will act down, to continue with the clockwise rotation.

Example 29

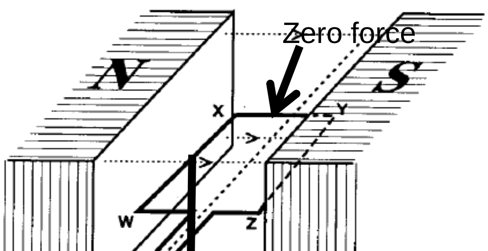
The force on UV is given by

F = nBiL

$\therefore$ F = 1 x 0.50 x 500 x 10^{-3} x 0.03

$\therefore$ **F = 7.5 x 10^{-3} N (ANS)**

Example 30 1994 Question 1



The force on WX is down, as given by the right hand rule

The force on XY is zero, as it is parallel to the field.

Example 31 1994 Question 2

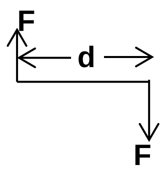
Use F = nBiL

$\therefore$ F = 50 x 0.048 x 2.0 x 0.05

$\therefore$ **F = 0.24 N (ANS)**

Example 32 1994 Question 3

The force on WX is perpendicularly (to the field) up, and the force on YZ is down.
The maximum torque will occur when the plane of the loop is horizontal.
Hence τ = F x d



$\therefore$ bigger ‘d’, for same ‘F’, leads to bigger torque.

$\therefore$ **C + F (ANS)**

Example 33 1994 Question 4

Increase the number of coils,
$\therefore$ bigger F $\Rightarrow$ larger τ
Longer length of coils,
$\therefore$ bigger F $\Rightarrow$ larger τ
Stronger magnets
$\therefore$ bigger F $\Rightarrow$ larger τ
Wider coils, $\therefore$ bigger d $\Rightarrow$ larger τ
Increase the current,
$\therefore$ bigger F $\Rightarrow$ larger τ

Example 34 1993 Question 4

The split-ring commutator reverses the direction of the current every half cycle, as the coil moves through the position where its plane is perpendicular to the field.
This reversal of current reverses the direction of the force acting on both wires.
This allows the loop to continue to rotate in the one direction.

Example 35 1993 Question 5

The field is from left to right.
To get the coil to rotate clockwise the force on ‘ad’ needs to be up.
Therefore the current is from ‘d’ to ‘a’

This means that Y needs to connect to the positive terminal of the battery.

Example 36 1986 Question 70)

The force on XY is given by

$F = nBiL$

$\therefore F = 1 \times 0.1 \times 5.0 \times 0.04$

$\therefore$ **F = 0.02 N (ANS)**

✓**Question 16** (6 marks)

A diagram of a DC motor is shown in Figure 21.

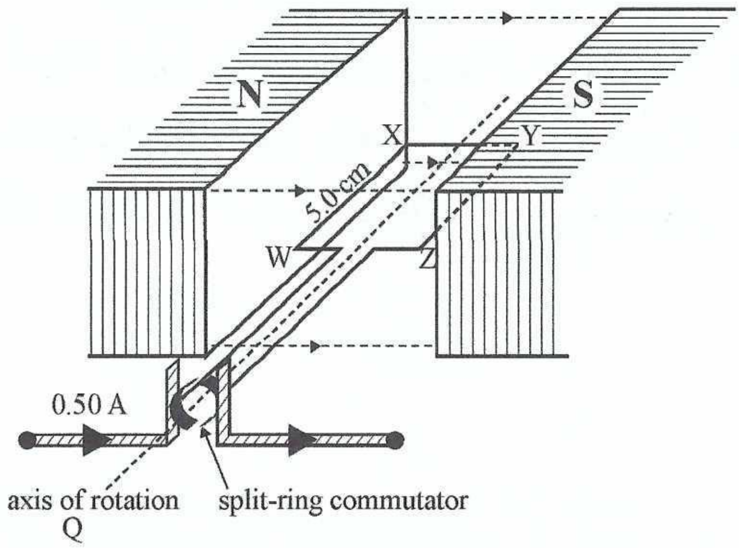


Figure 21

a. The motor is operating and the rectangular coil is rotating about the axis of rotation. Mary views the operating motor from point Q.

Is the direction of rotation clockwise or anticlockwise? Give a reason for your answer. 2 marks

Anticlockwise. Force on WX is down according to RHS rule, on LY – up. Magnetic field from left to right, current in WX into the page (from W to X) 50%

b. While in the position shown in the diagram, a current of 0.50 A is flowing in the rotating coil. The coil has 20 turns and the magnetic field at the side labelled WX has a strength of 500 mT. The side WX has a length of 5.0 cm.

Calculate the magnitude of the force on the side WX. 2 marks

$F = nBIl$ 66%

$= 20 \times 0.5 \times 0.5 \times 0.05$

0.25 N

c. There is a split-ring commutator fitted to the motor. Mary suggests that the split-ring commutator causes a lot of friction on the motor, and that the motor would rotate faster if the split-ring commutator were removed and, instead, slip-rings were used to connect the input DC current to the rotating coil.

Would this change improve the operation of the motor? Give reasons for your answer. 2 marks

It would not improve the operation. The coil will turn 90° and stop as slip rings wouldn't reverse the current in the coil. So torque on the coil will not rotate it. 40%

Question 17 (11 marks)

Students conduct an experiment that is shown in Figure 22. An aluminium ring is made to oscillate vertically between point A and point B. Point C is the midpoint between A and B. A strong, small bar magnet is fixed at the centre of the oscillation, as shown in Figure 22.

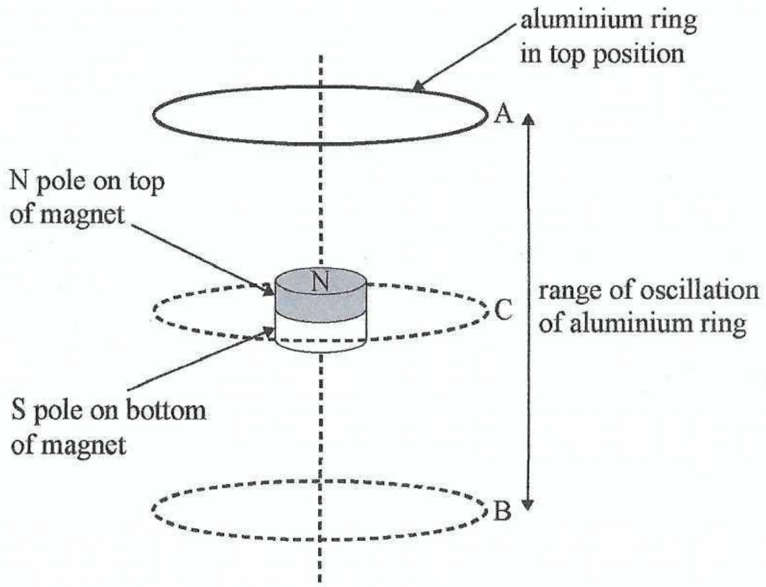


Figure 22

The vertical dashed line goes through the centre of the aluminium ring and also through the centre of the bar magnet in the diagram.

✓**Question 14** (5 marks)

Students build a simple electric motor, as shown in Figure 18.

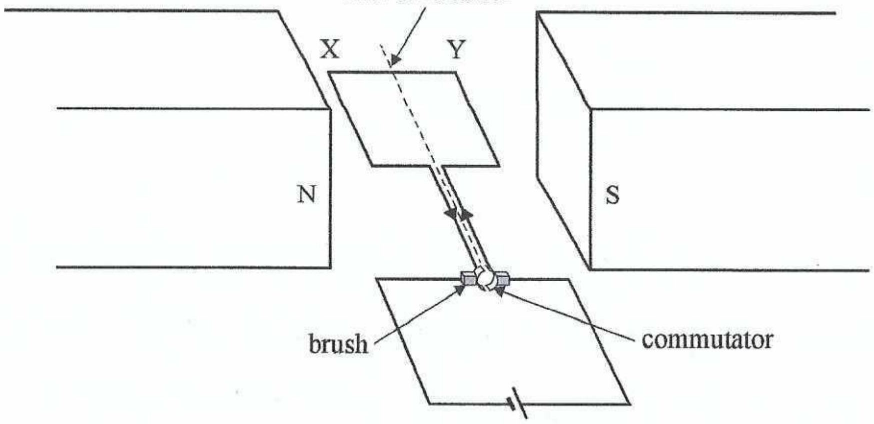


Figure 18

a. At what position(s) (**A.–D.**) of the rotating coil is the magnetic force on the side XY zero? One or more answers may be selected. 1 mark

40%

A. horizontal with the current as shown in Figure 18

B. horizontal with the current in the opposite direction to that shown in Figure 18

C. vertical

D. at all orientations of the coil

A and B

b. The students discover that the motor starts moving more easily with the coil in some orientations than in others.

Explain the best orientation(s) for starting the motor to move from rest. 2 marks

18%

The best orientation is horizontal. In this position the torque is maximal.

c. To increase the speed of rotation of the motor, the students suggest a number of improvements.

Which suggested improvement(s) (**A.**–**D.**) is likely to increase the speed of rotation of the coil? One or more answers may be selected. Explain your answer. 2 marks

34%

A. increase the battery voltage

B. replace the single coil of the motor with several turns

C. increase the resistance of the coil

D. reverse one of the poles of the permanent magnets

A and B

Increasing voltage will increase current in the loop. According to $F = nBIL$ force will increase. If number of turns will increase force will increase ($F = nBIL$)

✓ **Question 13** (6 marks)

Students build a simple electric motor consisting of a single coil and a split-ring commutator, as shown in Figure 21.

The magnetic field between the pole pieces is a constant 0.02 T.

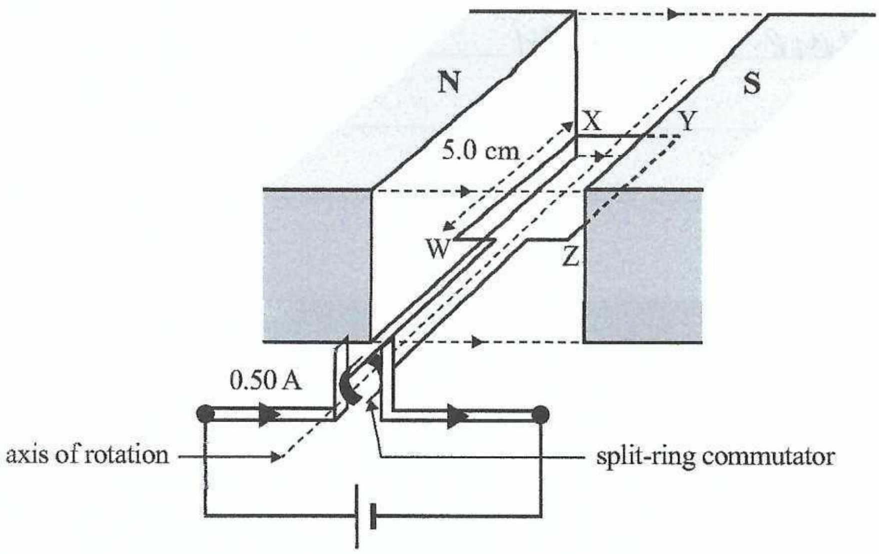


Figure 21

a. Calculate the magnitude of the force on the side WX. 2 marks

F = BIL

= 0.02 × 0.5 × 0.05

5×10^{-4} N

b. Will the coil rotate in a clockwise or anticlockwise direction as seen by an observer at the split-ring commutator? Explain your answer. 2 marks

Anticlockwise. Force on WX is ~~up~~ down according to RHS rule (magnetic field from left to right, current from W to X), on YZ fore is up.

c. Explain the role of the split-ring commutator in the operation of the electric motor. 2 marks

Role is to reverse the direction of the current every half turn to keep the motor rotating in the same direction

✓ **Question 3** (5 marks)

Figure 2 shows a schematic diagram of a simple DC motor.

It consists of two magnets, a single 9.0 V DC power supply, a split-ring commutator and a rectangular coil of wire consisting of 10 loops.

The total resistance of the coil of wire is 6.0 Ω.

The length of the side JK is 12 cm and the length of the side KL is 6.0 cm.

The strength of the uniform magnetic field is 0.50 T.

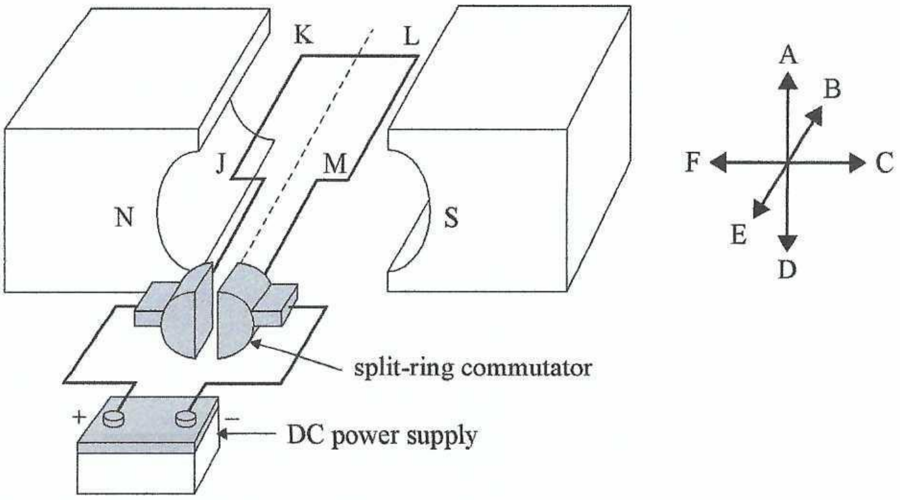


Figure 2

a. Determine the size and the direction (A–F) of the force acting on the side JK. 3 marks

48%

$I = \frac{V}{R} = \frac{9}{6} = 1.5A$

$F = nBIL = 10 \times 0.5 \times 1.5 \times 0.12 = 0.9 N$

0.9 N	Direction down

b. What is the size of the force acting on the side KL in the orientation shown in Figure 2? Explain your answer. 2 marks

Current is parallel to the magnetic field 69%

0 N

Question 3 (5 marks)

Students build a model of a simple DC motor, as shown in Figure 3.

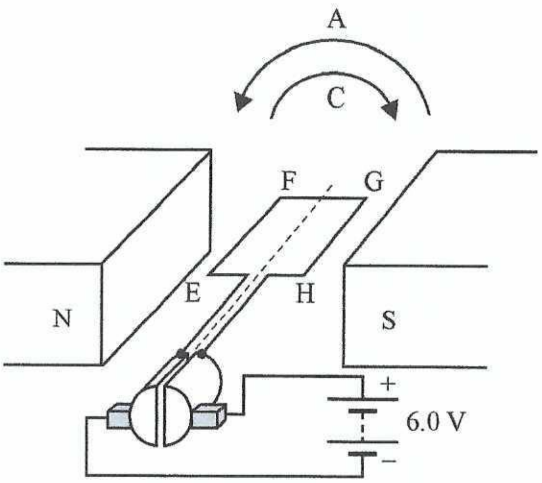


Figure 3

a. The motor is set with the coil horizontal, as shown, and the power source is applied.

Will the motor rotate in a clockwise (C) or anticlockwise (A) direction? Explain your answer. 3 marks

47%

Clockwise

Current is from H to G, magnetic field from Left to right. According to RHS rule force on HG is up.

b. One student suggests that slip rings would be easier to make than a commutator and that they should use slip rings instead.

Explain the effect that replacing the commutator with slip rings would have on the operation of the motor, if no other change was made. 2 marks

23%

Motor will not work. Loop will rotate quarter of the ~~tur~~ revolution and stop in the vertical position.

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided.
Where an answer box is provided, write your final answer in the box.
If an answer box has a unit printed in it, give your answer in that unit.
In questions where more than one mark is available, appropriate working **must** be shown.
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
Take the value of g to be 9.8 m s^{-2}.

Question 1 (5 marks)

Figure 1 shows four positions (1, 2, 3 and 4) of the coil of a single-turn, simple DC motor. The coil is turning in a uniform magnetic field that is parallel to the plane of the coil when the coil is in Position 1, as shown.

When the motor is operating, the coil rotates about the axis through the middle of sides *LM* and *NK* in the direction indicated. The coil is attached to a commutator. Current for the motor is passed to the commutator by brushes that are not shown in Figure 1.

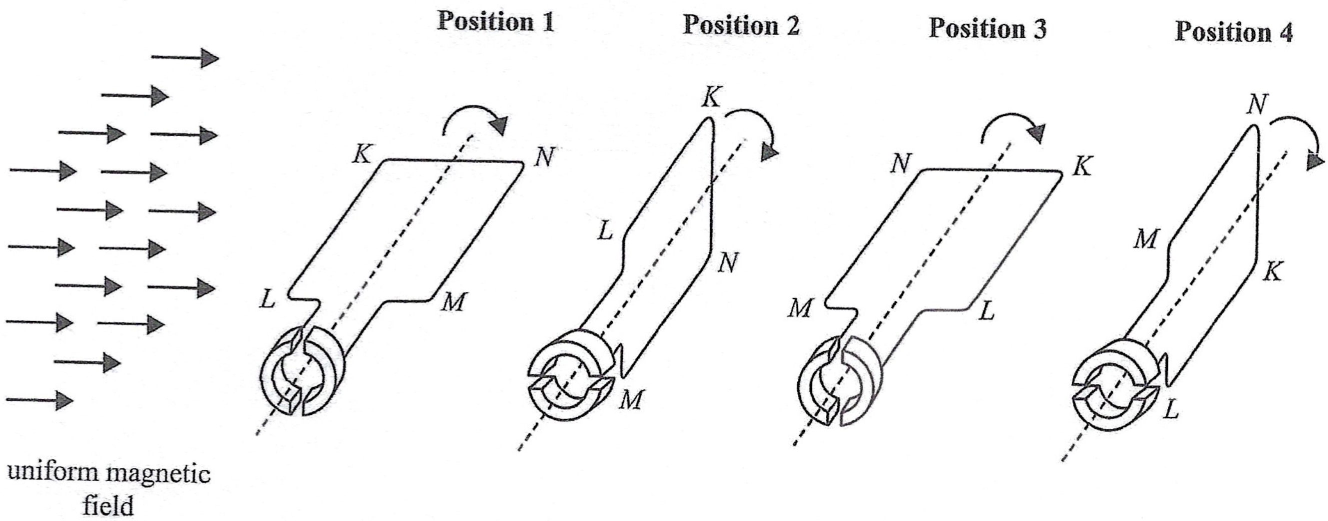


Figure 1

a. When the coil is in Position 1, in which direction is the current flowing in the side *KL* – from *K* to *L* or from *L* to *K*? Justify your answer. 2 marks

Applying RHSR current flows from K to L (1m) 42%