Year 12 Science: Magnetic forces and induced voltage

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. What force acts on 0.50 m of wire carrying 4.0 A at right angles to a 0.20 T field?

2. The same wire is turned to lie along the field lines. What is the force now?

3. A proton moves at 3.0×10^{5} m s^{-1} at right angles to a 0.80 T field. What force acts on it?

4. A 2.0 m rod moves at 5.0 m s^{-1} across a 0.10 T field. What voltage is induced between its ends?

5. At what speed would the same rod need to move to induce 0.25 V?

Exam-style question: a model motor

A model motor has a rectangular coil of 25 turns between a north pole on the left and a south pole on the right, where the field is 0.30 T. Each long side has 4.0 cm of wire in the field and the coil carries 1.2 A. Seen end-on, side P carries current out of the page and side Q carries it into the page.

6. State the direction of the force on side P, and the rule you used.

7. Calculate the size of the force on side P.

8. In the position shown, the short ends of the coil run along the field. Explain why they feel no force.

9. The battery is removed and the coil is spun so each long side moves at 0.50 m s^{-1}. Calculate the biggest voltage the whole coil can produce.

10. Explain where the coil must be in its turn to give that biggest voltage, and where it gives none.

Fix the mistake

11. Correct this statement: "In V = BvL the two V's are the same thing, so a 12 V generator means v = 12."

12. Correct this statement: "For an electron moving right, point your thumb right and read the force off your palm."

13. Correct this statement: "The side of the coil that lies along the field feels the same force as the other sides."

14. Correct this statement: "The positive pole of the magnet is on the left."

Answer key (for parents and tutors)

1. What force acts on 0.50 m of wire carrying 4.0 A at right angles to a 0.20 T field?
   $F = BIL = 0.20 \times 4.0 \times 0.50 = 0.40$ N.
2. The same wire is turned to lie along the field lines. What is the force now?
   0 N, because current parallel to the field feels no force.
3. A proton moves at 3.0×10^5 m s^{-1} at right angles to a 0.80 T field. What force acts on it?
   $F = Bqv = 0.80 \times 1.6 \times 10^{-19} \times 3.0 \times 10^5 = 3.8 \times 10^{-14}$ N.
4. A 2.0 m rod moves at 5.0 m s^{-1} across a 0.10 T field. What voltage is induced between its ends?
   $V = BvL = 0.10 \times 5.0 \times 2.0 = 1.0$ V.
5. At what speed would the same rod need to move to induce 0.25 V?
   $v = V \div (BL) = 0.25 \div (0.10 \times 2.0) = 1.25$ m s^{-1}.
6. State the direction of the force on side P, and the rule you used.
   Upwards, towards the top of the page: fingers along the field to the right, thumb out of the page, and the palm faces up (Achieved).
7. Calculate the size of the force on side P.
   $F = NBIL = 25 \times 0.30 \times 1.2 \times 0.040 = 0.36$ N (Merit: L in metres and all 25 turns counted).
8. In the position shown, the short ends of the coil run along the field. Explain why they feel no force.
   Their current runs parallel to the field lines, and a force needs current that crosses the field, so F = BIL is zero (Merit for the reason).
9. The battery is removed and the coil is spun so each long side moves at 0.50 m s^{-1}. Calculate the biggest voltage the whole coil can produce.
   One side of one turn: $V = BvL = 0.30 \times 0.50 \times 0.040 = 6.0 \times 10^{-3}$ V; both long sides of all 25 turns add: $6.0 \times 10^{-3} \times 2 \times 25 = 0.30$ V (Excellence for counting both sides and every turn).
10. Explain where the coil must be in its turn to give that biggest voltage, and where it gives none.
    Achieved: biggest when the coil lies flat, as shown. Merit: then P and Q move up and down, at right angles to the field, so they cut field lines fastest. Excellence: when the coil stands upright, across the field, P and Q move sideways along the field lines, cut none, and V = BvL gives zero because only the part of the velocity across the field counts; between these positions the voltage rises and falls.
11. Correct this statement: "In V = BvL the two V's are the same thing, so a 12 V generator means v = 12."
    Capital V is the voltage in volts and small v is the speed in m s^{-1}; rearrange to $v = V \div (BL)$.
12. Correct this statement: "For an electron moving right, point your thumb right and read the force off your palm."
    The slap rule is for positive charge or conventional current; for an electron, reverse the force you find.
13. Correct this statement: "The side of the coil that lies along the field feels the same force as the other sides."
    Current parallel to the field feels no force; only current that crosses the field lines is pushed, most strongly at right angles.
14. Correct this statement: "The positive pole of the magnet is on the left."
    Magnets have north and south poles; positive and negative describe electric charge, and field lines run from north to south.