Electromagnetic Induction Worksheet

Module 6: Electromagnetism

Instructions

Complete all questions. Show all working for calculation questions.

Data provided: - $\mu_0 = 4\pi \times 10^{-7}$ T · m/A - $e = 1.6 \times 10^{-19}$ C

Part A: Magnetic Flux (10 marks)

Question 1 (3 marks)

A square coil of side 0.2 m is placed in a uniform magnetic field of 0.5 T.

Calculate the magnetic flux through the coil when:

(a) The plane of the coil is perpendicular to the field. (1 mark)

(b) The plane of the coil is parallel to the field. (1 mark)

(c) The normal to the coil makes an angle of 60° with the field. (1 mark)

Question 2 (3 marks)

A circular coil of radius 10 cm has 50 turns. It is placed perpendicular to a magnetic field that increases uniformly from 0 to 0.4 T in 2 seconds.

Calculate:

(a) The change in magnetic flux through one turn. (1 mark)

(b) The total change in flux linkage. (1 mark)

(c) The induced EMF. (1 mark)

Question 3 (4 marks)

A rectangular coil (0.3 m $\times$ 0.2 m) with 100 turns rotates in a 0.25 T magnetic field. At the instant when the plane of the coil makes an angle of 30° with the field direction:

(a) Calculate the magnetic flux through the coil. (2 marks)

(b) If the coil completes one rotation in 0.1 s, calculate the average rate of change of flux over a quarter rotation starting from this position. (2 marks)

Part B: Faraday's Law (15 marks)

Question 4 (4 marks)

A solenoid has 500 turns and cross-sectional area 0.005 m^2. The magnetic field inside changes from 0.6 T to 0.2 T in 0.04 s.

(a) Calculate the change in magnetic flux. (1 mark)

(b) Calculate the induced EMF. (1 mark)

(c) If the resistance of the solenoid is 5 Ω, calculate the induced current. (1 mark)

(d) What is the direction of the induced current according to Lenz's Law? (1 mark)

Question 5 (4 marks)

A conducting rod of length 0.5 m moves at 4 m/s perpendicular to a uniform magnetic field of 0.3 T.

(a) Calculate the EMF induced across the ends of the rod. (2 marks)

(b) If the rod is connected to a circuit with resistance 2 Ω, calculate the current. (1 mark)

(c) Calculate the force required to maintain constant velocity. (1 mark)

Question 6 (3 marks)

Explain, using Lenz's Law and conservation of energy, why:

(a) A magnet falling through a copper tube falls slower than in free fall. (2 marks)

(b) Energy must be supplied to move a conductor through a magnetic field when it is part of a closed circuit. (1 mark)

Question 7 (4 marks)

A search coil has 200 turns and area 2 cm^2. When removed from a magnetic field in 0.05 s, an average EMF of 0.4 V is induced.

(a) Calculate the average rate of change of flux. (2 marks)

(b) Calculate the magnetic field strength. (2 marks)

Part C: Transformers (15 marks)

Question 8 (4 marks)

A step-down transformer has 2000 primary turns and 100 secondary turns. The primary voltage is 240 V AC.

(a) Calculate the secondary voltage. (1 mark)

(b) If the secondary current is 10 A, calculate the primary current (assuming 100% efficiency). (1 mark)

(c) Calculate the power transferred. (1 mark)

(d) Explain why the transformer would not work with DC input. (1 mark)

Question 9 (5 marks)

A transformer has efficiency of 92%. The primary coil has 1500 turns connected to 240 V AC supply. The secondary delivers 24 A at 50 V.

(a) Calculate the output power. (1 mark)

(b) Calculate the input power. (1 mark)

(c) Calculate the primary current. (1 mark)

(d) Calculate the power lost in the transformer. (1 mark)

(e) Suggest TWO ways this power loss could be reduced. (1 mark)

Question 10 (6 marks)

Electricity is transmitted from a power station at 500 kW. The transmission lines have total resistance of 10 Ω.

Compare the power loss when transmitting at:

(a) 10,000 V (3 marks)

(b) 250,000 V (2 marks)

(c) Explain why high voltage transmission is used. (1 mark)

Extended Response (10 marks)

Question 11 (10 marks)

A student investigates electromagnetic induction by moving a bar magnet in and out of a solenoid connected to a galvanometer.

(a) Describe what the student would observe when:

- The magnet is moved toward the coil (1 mark)
- The magnet is stationary inside the coil (1 mark)
- The magnet is moved away from the coil (1 mark)

(b) Explain the observations using Faraday's Law. (3 marks)

(c) Explain how Lenz's Law determines the direction of the induced current. (2 marks)

(d) How would the induced EMF change if:

- The magnet is moved faster (1 mark)

- A stronger magnet is used (1 mark)

Answers

Part A Answers

Q1: (a) $\Phi = 0.02$ Wb (b) $\Phi = 0$ Wb (c) $\Phi = 0.01$ Wb
Q2: (a) $\Delta\Phi = 0.0126$ Wb (b) Flux linkage = 0.628 Wb-turns (c) $\varepsilon = 0.314$ V
Q3: (a) $\Phi = 0.0075$ Wb per turn (b) Average rate = 0.60 Wb/s

Part B Answers

Q4: (a) $\Delta\Phi = -0.002$ Wb (b) $\varepsilon = 25$ V (c) $I = 5$ A (d) Current opposes the decrease in flux (creates field in same direction)
Q5: (a) $\varepsilon = BLv = 0.6$ V (b) $I = 0.3$ A (c) $F = BIL = 0.045$ N
Q6: (a) Induced currents create magnetic field that opposes motion; energy from gravitational PE is converted to electrical energy in eddy currents → heat (b) Work must be done against the magnetic force on the induced current
Q7: (a) Rate = 0.002 Wb/s (b) $B = 1.0$ T

Part C Answers

Q8: (a) $V_s = 12$ V (b) $I_p = 0.5$ A (c) $P = 120$ W (d) DC produces constant flux - no change, no induced EMF
Q9: (a) $P_{out} = 1200$ W (b) $P_{in} = 1304$ W (c) $I_p = 5.43$ A (d) $P_{loss} = 104$ W (e) Laminated core, thicker wires, better core material
Q10: (a) At 10 kV: $I = 50$ A, $P_{loss} = 25$ kW (5%) (b) At 250 kV: $I = 2$ A, $P_{loss} = 40$ W (0.008%) (c) High voltage means low current, reducing I^2R losses