

Magnetic flux, Faraday's law and Lenz's law

AP Physics 2 (algebra-based) · Worksheet

Name: _____ Date: _____ Class: _____

These 20 problems build the skills for electromagnetic induction in AP Physics 2: calculating flux, applying Faraday's law, finding current directions with Lenz's law and analysing rods on rails. Difficulty rises from one-step calculations to energy and force arguments. They suit AP students and anyone meeting induction at A Level or in an introductory university course. Sketch the field and the loop before you start.

Level: AP Physics 2 (algebra-based) · **Curriculum:** AP P2 Unit 12

Problem 1 Flux through a loop (easy)

A loop of area 0.020 m^2 is perpendicular to a uniform field of 0.50 T .

1. Calculate the magnetic flux.
2. State the angle between the field and the normal to the loop.

Problem 2 Flux at different angles (easy)

A loop of area 0.040 m^2 is in a field of 0.30 T . Calculate the flux when the angle between the field and the normal is:

1. 0°
2. 60°
3. 90°

Problem 3 Ways to change flux (easy)

State three different ways of changing the magnetic flux through a loop.

Problem 4 Average emf (easy)

The flux through a single loop changes from 0.020 Wb to 0.060 Wb in 0.40 s .

1. Calculate the change in flux.
2. Calculate the average induced emf.

Problem 5 Approaching magnet (easy)

A north pole moves towards a loop.

1. State whether the flux through the loop increases or decreases.
2. State the direction of the induced current as seen from the magnet.
3. Explain the direction using Lenz's law.

Problem 6 Rod emf (easy)

A 0.40 m rod moves at 3.0 m/s at right angles to a uniform field of 0.50 T. Calculate the emf across the ends of the rod.

Problem 7 Units of flux (easy)

Chiamaka in Lagos checks units.

1. Show that 1 Wb is equal to 1 T·m².
2. Convert 25 cm² to m².
3. State the unit of Wb/s.

Problem 8 Coil in a rising field (medium)

A coil of 150 turns and area $4.0 \times 10^{-3} \text{ m}^2$ is perpendicular to a field that rises from 0 to 0.60 T in 0.20 s. Calculate the emf.

Problem 9 Flipping a coil (medium)

A coil of 50 turns and area 0.010 m² is in a field of 0.20 T, perpendicular to the coil. It is flipped over through 180° in 0.10 s.

1. Calculate the change in flux through one turn.
2. Calculate the average emf.

Problem 10 Rod on rails (medium)

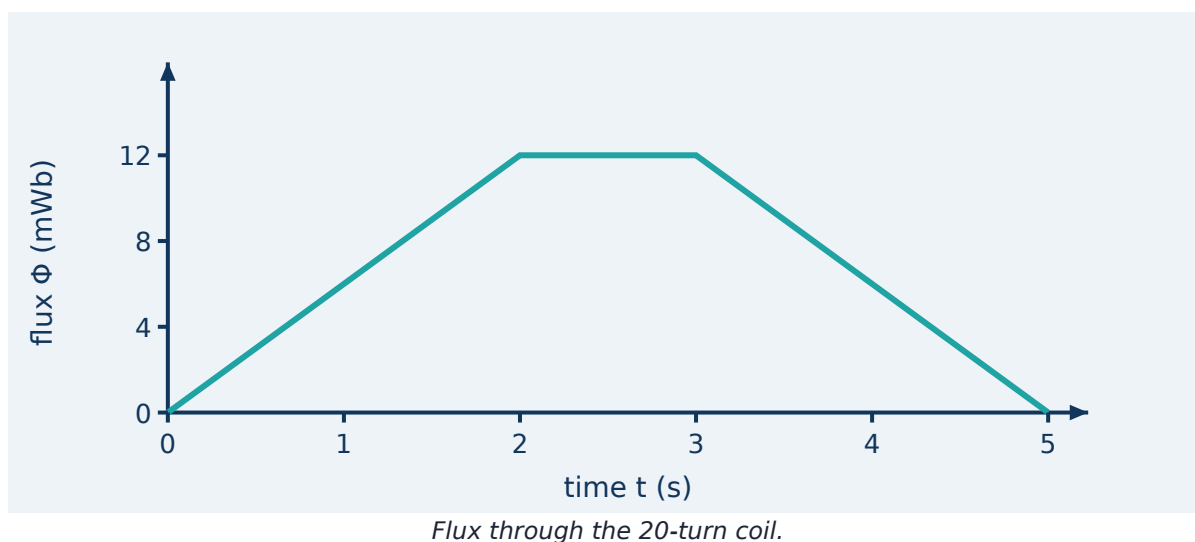
A 0.30 m rod slides at 5.0 m/s on rails in a field of 0.40 T. The circuit resistance is 3.0 Ω.

1. Calculate the emf.
2. Calculate the current.
3. Calculate the force needed to keep the rod moving at constant speed.
4. Calculate the power supplied.

Problem 11 Reading a flux graph (medium)

The graph shows the flux through a coil of 20 turns.

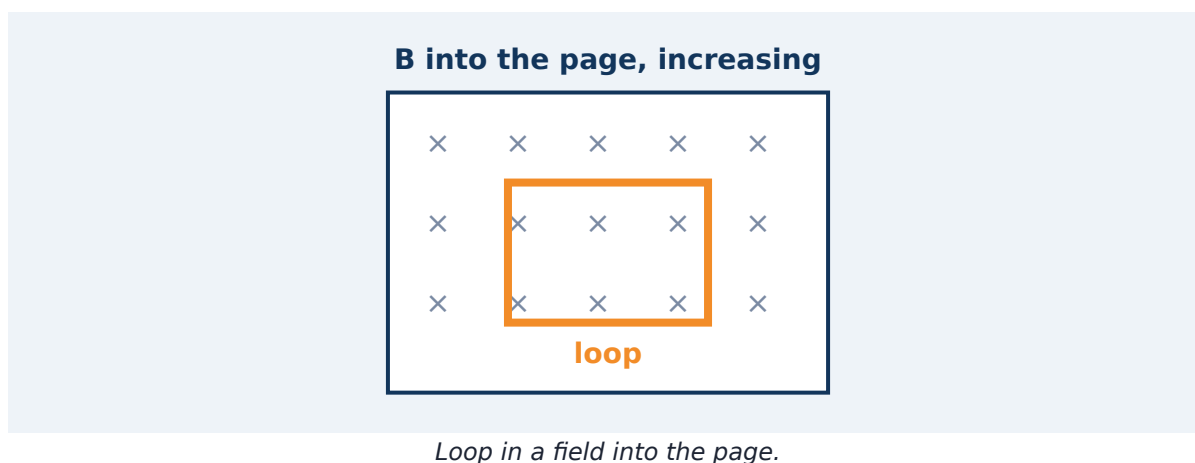
1. Calculate the emf from 0 to 2 s.
2. State the emf from 2 to 3 s.
3. Calculate the emf from 3 to 5 s and state its sign compared with the first interval.



Problem 12 Direction of the current (medium)

A loop lies in the page with a uniform field into the page through it.

1. The field is increasing. State the direction of the induced current.
2. The field is decreasing. State the direction of the induced current.
3. Explain both answers.



Problem 13 Falling magnet (medium)

A magnet of mass 0.050 kg falls 0.80 m at constant speed through a copper tube. Use $g = 9.81 \text{ N/kg}$.

1. Calculate the gravitational energy lost.
2. Explain why the magnet falls slowly and where the energy goes.

Problem 14 Expanding loop (medium)

A circular loop is in a field of 0.20 T perpendicular to its plane. Its radius grows from 0.10 m to 0.15 m in 0.50 s.

1. Calculate the initial and final areas.

- Calculate the average emf.

Problem 15 Aircraft wings (medium)

An aircraft with wingspan 36 m flies at 250 m/s. The vertical component of the Earth's field is 4.0×10^{-5} T. Calculate the emf between the wing tips.

Problem 16 Quarter turn of a coil (hard)

A generator coil has 100 turns and area 0.020 m^2 . It rotates in a field of 0.50 T, completing 50 turns each second (period 0.020 s). It starts with the normal along the field.

- Calculate the flux through one turn at the start.
- Calculate the flux after a quarter turn.
- Calculate the average emf during the quarter turn.

Problem 17 Pulling a bar (hard)

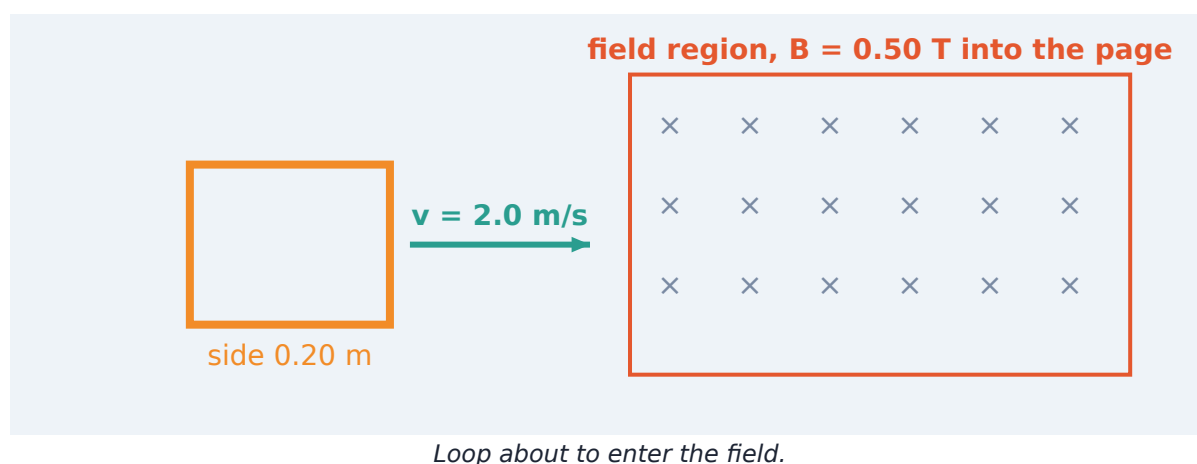
A bar of length 0.50 m on rails of resistance 0.80Ω is in a field of 0.60 T. A force of 0.45 N pulls it at constant speed.

- Show that the magnetic force is $BIL = B^2 L^2 v / R$.
- Calculate the speed.
- Calculate the emf and the power dissipated.

Problem 18 Loop entering a field (hard)

A square loop of side 0.20 m and resistance 0.040Ω enters a region of field 0.50 T at 2.0 m/s.

- Calculate the emf while the loop enters.
- Calculate the current and the force that must be applied.
- State the emf once the loop is completely inside the field.



Problem 19 Magnet through a coil (hard)

A coil of 40 turns has the following flux readings as a magnet moves towards it.

Time (ms): 0, 10, 20, 30, 40

Flux per turn (mWb): 0, 2.0, 4.0, 6.0, 8.0

1. Calculate the induced emf.
2. Predict the emf if the magnet moves twice as fast.
3. The coil has a resistance of $16\ \Omega$ in a closed circuit. Calculate the total charge that flows during the 40 ms.

Problem 20 Spot the errors (hard)

A student writes: (i) "Lenz's law says the induced field is always opposite to the original field." (ii) "A very strong magnet at rest next to a coil induces a large emf."

1. Explain the mistake in (i) with an example.
2. Explain the mistake in (ii).