

How changing flux creates an emf

Physics grades 11-12 (A Level · IB · Class 11-12) · Worksheet answers

Each answer shows the formula, the substitution and the result with its unit. For direction questions, always say what is changing, then state how the induced current must oppose it. Small rounding differences in the last digit are acceptable.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB D.4

Problem 1 Flux through a coil

$$\Phi = BA \cos 0^\circ = 0.30 \times 0.020 \times 1 = \mathbf{6.0 \times 10^{-3} \text{ Wb}} = 6.0 \text{ mWb}.$$

Problem 2 Tilted coil

$$\Phi = BA \cos \theta = 0.50 \times 0.040 \times \cos 60^\circ = 0.020 \times 0.50 = \mathbf{0.010 \text{ Wb}}.$$

Problem 3 Single loop emf

$$\varepsilon = \Delta\Phi/\Delta t = (8.0 - 2.0) \times 10^{-3} / 0.30 = \mathbf{20 \text{ mV}} \text{ (0.020 V)}.$$

Problem 4 More turns

- $\varepsilon = N\Delta\Phi/\Delta t = 150 \times 6.0 \times 10^{-3} / 0.30 = \mathbf{3.0 \text{ V}}.$
- The emf is **proportional to N**, because each turn contributes the same emf in series.

Problem 5 Aircraft wing

$$\varepsilon = BLv = 4.0 \times 10^{-5} \times 35 \times 250 = \mathbf{0.35 \text{ V}}. \text{ The emf is small and cannot be used to light a bulb.}$$

Problem 6 Which pole forms?

- A **north pole** forms on the near end.
- The flux through the coil from the magnet is increasing. The induced current produces a field that opposes this increase, so the near end of the coil repels the approaching north pole.

Problem 7 Unit conversion

- $A = 0.12 \times 0.080 = \mathbf{0.0096 \text{ m}^2}$ ($9.6 \times 10^{-3} \text{ m}^2$).
- $35 \text{ mT} = \mathbf{0.035 \text{ T}}.$
- $\Phi = BA = 0.035 \times 9.6 \times 10^{-3} = 3.36 \times 10^{-4} \text{ Wb} = \mathbf{336 \text{ }\mu\text{Wb}}.$

Problem 8 Coil in a fading field

1. $\varepsilon = N A \Delta B / \Delta t = 500 \times 4.0 \times 10^{-3} \times 0.60 / 0.20 = \mathbf{6.0 \text{ V}}$.
2. $I = \varepsilon / R = 6.0 / 25 = \mathbf{0.24 \text{ A}}$.

Problem 9 Sliding bar and force

1. $\varepsilon = BLv = 0.50 \times 0.40 \times 2.5 = \mathbf{0.50 \text{ V}}$.
2. $I = \varepsilon / R = 0.50 / 0.50 = \mathbf{1.0 \text{ A}}$.
3. $F = BIL = 0.50 \times 1.0 \times 0.40 = \mathbf{0.20 \text{ N}}$.

Problem 10 Reading a flux graph

1. $\varepsilon = -\Delta\Phi/\Delta t = -4.0 \times 10^{-3} / 0.2 = \mathbf{-20 \text{ mV}}$ (magnitude 20 mV).
2. The flux is constant, so $\varepsilon = \mathbf{0}$.
3. $\varepsilon = -(0 - 4.0 \times 10^{-3}) / 0.1 = \mathbf{+40 \text{ mV}}$. It is twice as large and has the **opposite sign**, because the flux falls instead of rises.

Problem 11 Peak emf of a generator

1. $\omega = 2\pi f = 2\pi \times 50 = \mathbf{314.2 \text{ rad/s}}$.
2. $\varepsilon_0 = NBA\omega = 100 \times 0.15 \times 0.020 \times 314.2 = \mathbf{94.2 \text{ V}}$.
3. $\varepsilon = \varepsilon_0 \sin \omega t = 94.2 \times \sin(314.2 \times 0.0020) = 94.2 \times \sin(0.628 \text{ rad}) = \mathbf{55.4 \text{ V}}$.

Problem 12 Bicycle dynamo

1. $\varepsilon_0 = NBA\omega$ is proportional to f , so the peak emf doubles to $\mathbf{24 \text{ V}}$.
2. The emf frequency equals the rotation frequency, $\mathbf{16 \text{ Hz}}$.
3. The flux changes faster at higher speed, so the emf and the power in the lamp are larger.

Problem 13 Magnet in a metal tube

1. As the magnet falls, the flux through each ring of the tube changes, inducing eddy currents. By Lenz's law these currents produce fields that oppose the motion, giving an upward force that nearly balances the weight.
2. The energy is transferred to the tube as **thermal energy** by the eddy currents.

Problem 14 Pulling a coil faster

1. $\varepsilon = BLv$, so the emf is **doubled**.
2. The current doubles, so $F = BIL$ **doubles**.
3. $P = Fv$: force doubles and speed doubles, so the power is **four times** greater.

Problem 15 Direction of induced current

1. The area of the loop and the flux out of the page both increase. The induced current must create a field into the page inside the loop, which means a **clockwise** current.
2. Clockwise means the current flows down the rod; with B out of the page, $F = IL \times B$ points to the **left**, opposing the motion.

Problem 16 Terminal speed of a falling rod

1. $\varepsilon = BLv$, $I = BLv/R$, $F = BIL = B^2L^2v/R$.
2. At terminal speed $B^2L^2v/R = mg$, so $v = mgR/(B^2L^2) = 0.020 \times 9.81 \times 0.50 / (0.16 \times 0.090) = \mathbf{6.8 \text{ m/s}}$.
3. As v rises, the upward magnetic force grows until it equals the weight; the resultant force is then zero.

Problem 17 Heating by induction

1. $\varepsilon = A \Delta B / \Delta t = 0.15 \times 0.20 \times 0.50 = \mathbf{0.015 \text{ V}}$.
2. $I = \varepsilon / R = 0.015 / 0.30 = \mathbf{0.05 \text{ A}}$.
3. $E = I^2 R t = 0.05^2 \times 0.30 \times 4.0 = \mathbf{3.0 \text{ mJ}}$ ($3.0 \times 10^{-3} \text{ J}$).

Problem 18 Spinning metal disc

1. Area per second $= \pi r^2 \times f = \pi \times 0.15^2 \times 10 = \mathbf{0.707 \text{ m}^2/\text{s}}$.
2. $\varepsilon = B \times (\text{area swept per second}) = 0.20 \times 0.707 = \mathbf{0.141 \text{ V}}$, about 0.14 V.

Problem 19 Search coil measurement

1. The flux changes from $+BA$ to $-BA$, so $\Delta\Phi = \mathbf{2BA}$ per turn.
2. $\varepsilon = N(2BA)/\Delta t$, so $B = \varepsilon \Delta t / (2NA) = 0.45 \times 0.040 / (2 \times 60 \times 2.0 \times 10^{-4}) = 0.018 / 0.024 = \mathbf{0.75 \text{ T}}$.

Problem 20 Spot the error

1. The student used the final field instead of the **change** in field: $\Delta B = 0.60 - 0.20 = 0.40 \text{ T}$.
2. $\varepsilon = N \Delta B / \Delta t = 30 \times 0.010 \times 0.40 / 0.10 = \mathbf{1.2 \text{ V}}$.
3. 1.8 V is correct for a field rising from 0 to 0.60 T in 0.10 s.