

Exercise walk-through

13.4

Inductance

AP Physics C: Electricity and Magnetism

Inductance

An **inductor** resists a **change** in current, creating a **back emf** :

Back emf and stored energy

$$\varepsilon = -L \frac{dl}{dt}, \quad U = \frac{1}{2} L I^2$$

Energy density $u = \frac{B^2}{2\mu_0}$ – the magnetic mirror of $\frac{1}{2}\varepsilon_0 E^2$.

Worked example

2 H with I rising at 3 A/s:

$$\varepsilon = L \frac{dI}{dt} = 2 \times 3 = 6 \text{ V}$$

At a steady 4 A: $U = 16 \text{ J}$, and the back emf vanishes.

The inductor, and the solenoid that makes one

inductance

L relates flux to current: $\varepsilon = -L \frac{dI}{dt}$ – it opposes a *change* in current, not current itself

inductor

a component built to have large L – usually a **solenoid**

the geometry

$L = \frac{\mu_0 N^2 A}{\ell}$: turns **squared**, so doubling N quadruples L

stored energy

$U_L = \frac{1}{2} L I^2$ – held in the **magnetic field**, the mirror of $\frac{1}{2} C (\Delta V)^2$ in a capacitor

An inductor is to current what mass is to velocity: it resists change. That analogy carries all the way through the RL and LC results.

Exercises 2.1-2.3

2.1 An inductor produces a back emf of 6.0 V when the current changes at 3.0 A s^{-1} .
Find its inductance. [2]

2.2 Find the energy stored in a 0.50 H inductor carrying 4.0 A. [2]

2.3 State the SI unit of inductance. [1]

Exercises 2.1-2.3

2.1 An inductor produces a back emf of 6.0 V when the current changes at 3.0 A s^{-1} . Find its inductance. [2]

2.1

- $$L = \frac{|\varepsilon|}{|dI/dt|} = \frac{6.0}{3.0} = 2.0 \text{ H}$$

2.2 Find the energy stored in a 0.50 H inductor carrying 4.0 A. [2]

2.2

- $$U = \frac{1}{2}LI^2 = \frac{1}{2}(0.50)(4.0)^2 = 4.0 \text{ J}$$

2.3 State the SI unit of inductance. [1]

2.3

- the henry (H)

Exercises 3.1-3.2

3.1 The back emf across an inductor is

[1]

☐

A LI

B $-L \frac{dI}{dt}$

C $\frac{1}{2}LI^2$

D I/L

3.2 The energy stored in an inductor is

[1]

☐

A LI

B $\frac{1}{2}LI^2$

C $\frac{1}{2}L^2I$

D LI^2

Exercises 3.1-3.2

3.1 The back emf across an inductor is

[1]

☐

A LI

B $-L \frac{dI}{dt}$

C $\frac{1}{2}LI^2$

D I/L

3.1 B

- $-L \frac{dI}{dt}$.

3.2 The energy stored in an inductor is

[1]

☐

A LI

B $\frac{1}{2}LI^2$

C $\frac{1}{2}L^2I$

D LI^2

3.2 B

- $\frac{1}{2}LI^2$.

Exercise 3.3 (a)

3.3 A 0.20 H inductor carries a current rising at 5.0 A s^{-1} .

(a) Find the back emf.

[2]

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3.3 A 0.20 H inductor carries a current rising at 5.0 A s^{-1} .

(a) Find the back emf.

[2]

(a)

- $|\epsilon| = L \frac{dI}{dt} = 0.20 \times 5.0 = 1.0 \text{ V}$

Exercise 3.3 (b)

3.3 A 0.20 H inductor carries a current rising at 5.0 A s^{-1} .

(b) Find the energy stored when the current reaches 3.0 A .

[2]

Exercise 3.3 (b)

3.3 A 0.20 H inductor carries a current rising at 5.0 A s^{-1} .

(b) Find the energy stored when the current reaches 3.0 A .

[2]

(b)

- $U = \frac{1}{2}(0.20)(3.0)^2 = 0.90\text{ J}$