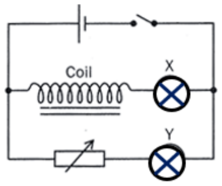
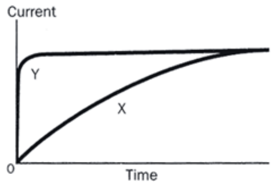
Inductors

Definitions

Inductors



Inductors produce magnetic fields when current is **changing** within the coil. They oppose **any change** in current (either an increase or a decrease). This **opposition** is non-linear (just like capacitors)



Y represents what would happen to the current without an inductor, X with an inductor.

The **time constant, τ,** for this circuit is when I reaches 63% of maximum I.

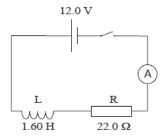
The curve can be explained using Lenz's law and the creation of a back EMF. The EMF (Voltage) created by the inductor is in the opposite direction to the voltage that made it.

Equations

$\varepsilon = -L\dfrac{\Delta I}{\Delta t}$	EMF	ε	V
	Inductance	L	H
	Current	I	A
	Time	t	s
$E = \dfrac{1}{2}LI^2$	Energy	E	J
	Inductance	L	H
	Current	I	A
$\tau = \dfrac{L}{R}$	Time constant	τ	s
	Inductance	L	H
	Resistance	R	Ω

Questions

ELECTROMAGNETISM (2022;2)



David uses a 1.60 H, 22.0 Ω inductor, and connects it to a 12.0 V power supply. The inductor can be considered as a pure inductor in series with a resistor, as shown in the diagram.

(a) Calculate the circuit current after two time constants, once the switch is closed and current begins to flow.

(b) State the voltage across the pure inductor **and** the voltage across the resistor once the current is steady.

(c) Once the current has reached a steady value, the switch is opened, and current falls to zero in 2.50 × 10^{-2} s. Calculate the size of the average induced voltage. State the direction of the induced voltage across the inductor.

(d) The 22.0 Ω resistor is replaced with a 44.0 Ω resistor, and the switch is then closed. Explain, by comparing quantitatively (how much), the changes that will take place for:
- the size of the maximum current drawn from the circuit
- the time constant
- the energy stored in the inductor once the current is steady.

Terms

Tips

- An inductor is regarded to have a stable magnetic field or no magnetic field after 5 x τ (although theoretically this never happens)
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Answers

(a) $I_{max} = \dfrac{V_s}{R} = \dfrac{12.0}{22.0} = 0.545\text{ A}$

Current after two time constants $= I = I_{max}\left(1-e^{-2}\right)$

$I = 0.545\left(1-e^{-2}\right) = 0.471\text{ A}$

(b) $V_L = 0$, $V_R = 12$ V

(c) Voltage opposes the change in current, it will try to prevent the current from decreasing and so will act in the same direction as the source voltage.

$V = \dfrac{L\Delta I}{t}$

$I = \dfrac{V}{R} = \dfrac{12.0}{22.0} = 0.545\text{ A}$

$V = \dfrac{1.60 \times 0.545}{2.50 \times 10^{-2}} = 34.9\text{ V}$

(d) If the resistance was changed to 44.0 Ω, then the size of the maximum current once it was steady would halve, since $I = V/R$. The increased resistance will have an effect on the time constant as $\tau = L/R$, so time constant would halve. Hence it will take less time for the current to become steady. Since the energy stored in the inductor $E_p = ½ L I^2$, and the current has halved, the energy stored in the inductor once the current is steady would be ¼.

$\varepsilon = -L\frac{\Delta I}{\Delta t}$	EMF	ε	V
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$\tau = \frac{L}{R}$	Time constant	τ	s
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	Resistance	R	Ω