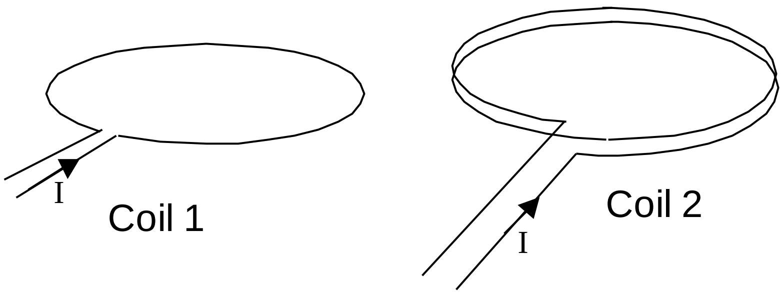
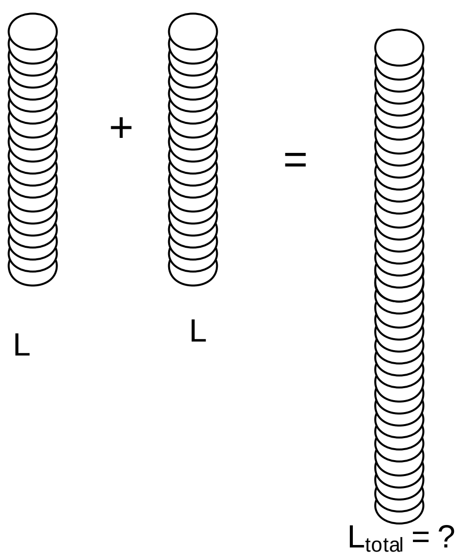
I-1. Inductor 1 consists of a single loop of wire. Inductor 2 is identical to 1 except it has two loops. How do the self-inductances of the two loops compare?



A) $L_2 = 2\,L_1$ B) $L_2 > 2L_1$ C) $L_2 < 2L_1$

Answer: $L_2 > 2L_1$, in fact, $L_2 = 4\,L_1$. The self inductance L increases by 4. $L = \Phi/I$. If we keep I fixed, but double the number N of turns, Φ increases by **<u>4</u>**. Total flux $\Phi_{total} = N\Phi_1$. N doubles, but $\Phi_1 = BA$ also doubles because when we double the number of turns, that doubles the current and so B is doubled.

I-2. Two identical long solenoids, each of inductance L, are connected together in series to form a single very long solenoid of inductance L_{total}. What is L_{total}?



A) 2L

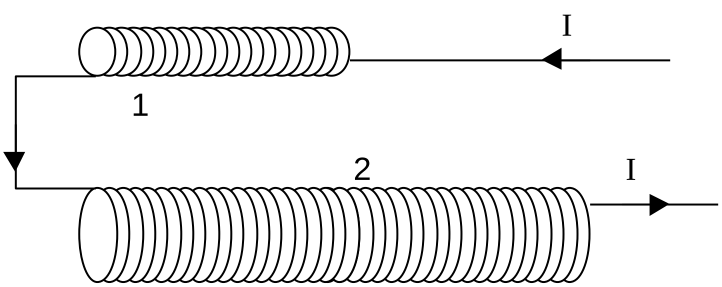
B) 4L

C) 8L

D) none of these

Answer: 2L. The inductance of a solenoid is $L = \mu_o n^2 A\, z$, where n is the number of turns per length $n = N/z$ and z is the length. In this case, we did not change n, but z (length) doubled, so L doubles.

I-3. The same current I is flowing through solenoid 1 and solenoid 2. Solenoid 2 is twice as long and has twice as many turns as solenoid 1, and has twice the diameter. (Hint: for a solenoid $B = \mu_o n I$)



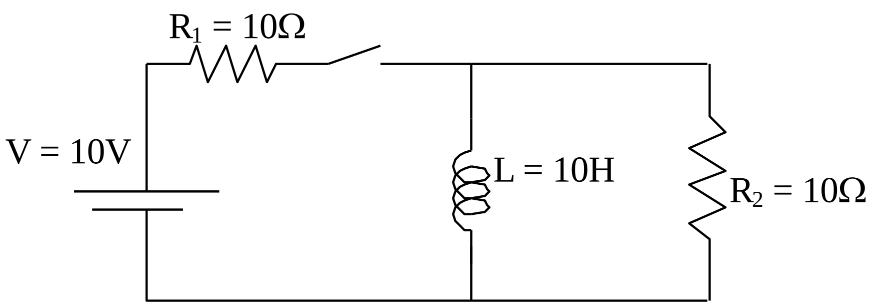
What is the ratio of the magnetic energy contained in solenoid 2 to that in solenoid 1, that is, what is $\frac{U_2}{U_1}$?

A) 2 B) 4 C) 8 D) 16 E) None of these.

Answer: There is 8 times as much magnetic field energy in the large solenoid as in the small solenoid.

The B-field is the same in both solenoids (same n = turns/length so same $B = \mu_o n I$) so both solenoids contain the same energy per volume $u = U/vol = B^2/(2\mu_o)$. The larger solenoid has 8 times the volume (2X the length, 4X the cross-sectional area) so it has 8 the energy.

I-4. An LR circuit is shown below. Initially the switch is open. At time t=0, the switch is closed. What is the current thru the inductor L immediately after the switch is closed (time = 0+)?
A) Zero B) 1 A C) 0.5A D) None of these.

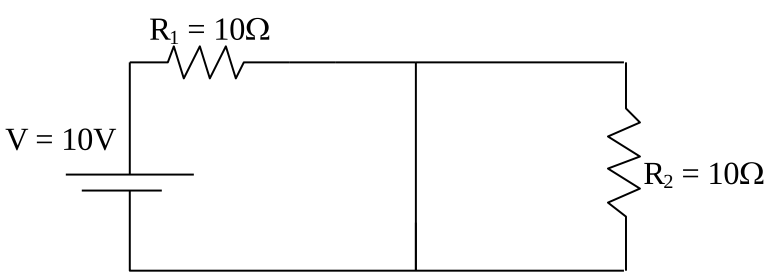


After a long time, what is the current from the battery?
A) 0A B) 0.5A C) 1.0A D) 2.0A
E) None of these.

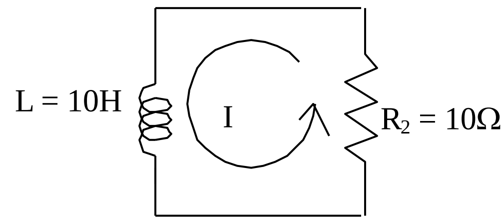
Now suppose the switch has been closed for a long time and is then opened. Immediately after the switch is opened, the current thru R_2 is
A) zero B) not zero

Answers:
Q1: zero. The current thru an inductor cannot change instantly.

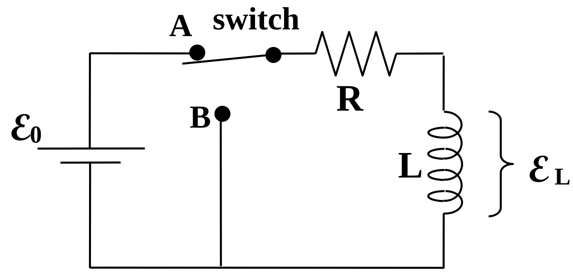
Q2: current = 1 A. After a long time, the current I is constant, the emf across the inductor is zero, and the inductor acts like a wire (a short). The circuit acts as shown below. The resistor R_2 is shorted out by the inductor, no current flows thru R_2, and
$I = V/R_1 = 10/10 = 1A$.



Q3: Not zero. After the switch is opened, the battery and R_1 are no longer in the circuit. The circuit is now as shown here. The current thru the inductor will continue (it can't change instantly) and the current thru the inductor must flow thru the resistor, since they are in series.



I-5. The switch has been in position A for a long time.



What is the current in the circuit?

A) Zero   B) $\dfrac{\mathcal{E}_0}{R}$ C) $\dfrac{\mathcal{E}_0}{R+L}$

Answer: current is $\dfrac{\mathcal{E}_0}{R}$. The inductor acts like a short, since current I is constant.

I-6. Consider $\dfrac{dI}{dt} = -\dfrac{1}{\tau} I$

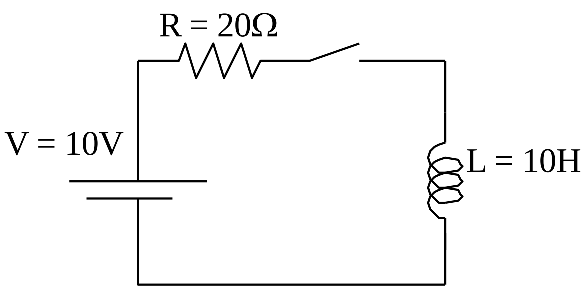
What is the solution to this differential equation? $I(t) =$

A) $I_0 e^{-t/\tau}$ B) $I_0 e^{+t/\tau}$ C) $I_0 \sin(\omega t / \tau)$

D) More than one of these is a solution

Answer: $I_0 e^{-t/\tau}$

I-7. The switch in the circuit below is closed at t=0.



What is the current in the circuit immediately after the switch closed (t = 0+)?
A) 0 A B) 0.5 A C) 1 A D) 10 A

E) None of these.

What is the initial rate of change of current dI/dt in the inductor, immediately after the switch is closed ? (Hint:what is the initial voltage across the inductor?)

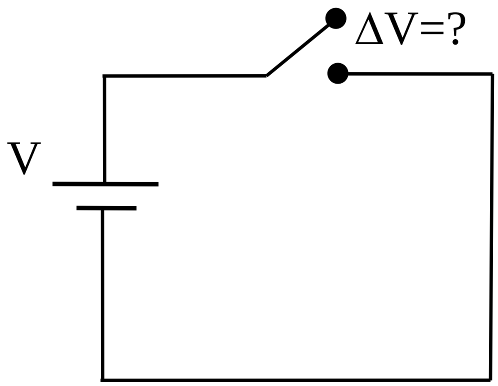
A) 0 A/s B) 0.5A/s C) 1A/s D) 10A/s

E) None of these.

Answers:
Q1: 0 A, the current through the inductor cannot change instantly.

Q2 : 1A/s. By the Loop Law, V(battery voltage) = IR + LdI/dt. Immediately after the switch is closed , the current is zero (because the current thru the inductor cannot change instantly), so IR is zero, so V = L dI/dt. So dI/dt = V/L = 10V/10H = 1 A/s.

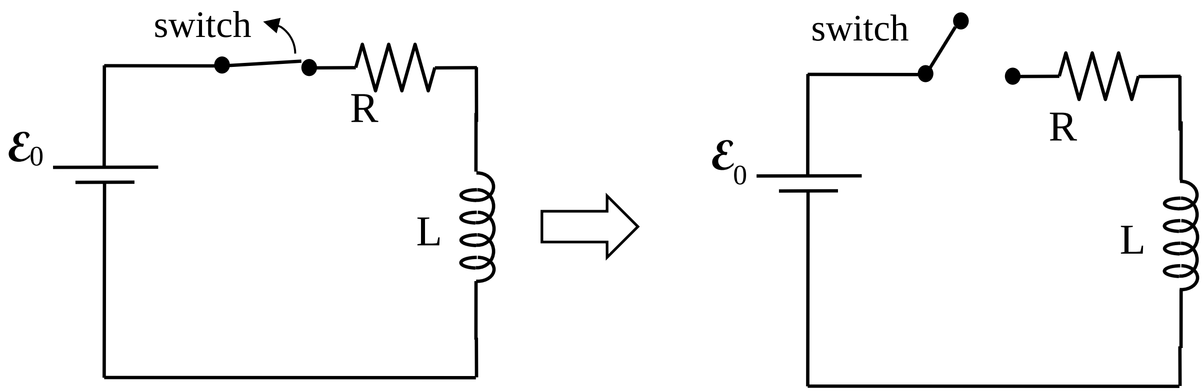
I-8. What is the voltage difference across the switch?



A) V B) 0 C) V/2 D) None of these

Answer: V

I-9. The switch has been closed for a long time. Then at $t = 0$, the switch is opened. What is the voltage across the switch at $t = 0+$?



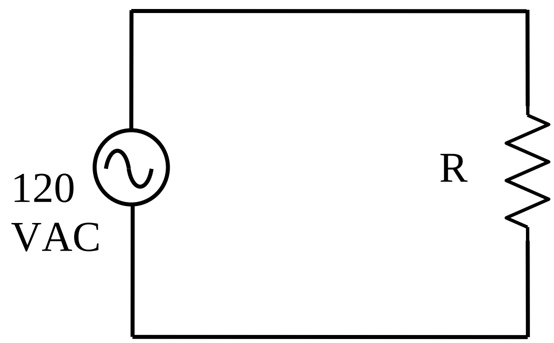
A) zero B) **extremely** high C) $\mathcal{E}_0 - IR$

D) $\mathcal{E}_0$ E) None of these

Answer: The voltage across the switch will be **extremely high**. Opening the switch would ordinarily have the effect of stopping the current instantly. However, because of the presence of the inductor, a sudden change in the current will produce a very large emf (emf = $-L\, dI/dt$). The emf will get so large that the air in the switch is ionized and creates a conducting channel of ionized air, so that the current continues to flow.

(about 3:38)
https://www.youtube.com/watch?v=rOcFbXka_AY&list=PLXftJrfB4EamiSluo9WK5w5Hgfc4tcmry&index=42

I-10. A resistor R is attached to a 120 VAC source.
The voltage is $V(t) = V_0 \sin(\omega t)$. What is the current in the resistor?



A) zero

B) $\dfrac{V_0}{R}\sin(\omega t)$

C) $\dfrac{V_0}{R}\cos(\omega t)$

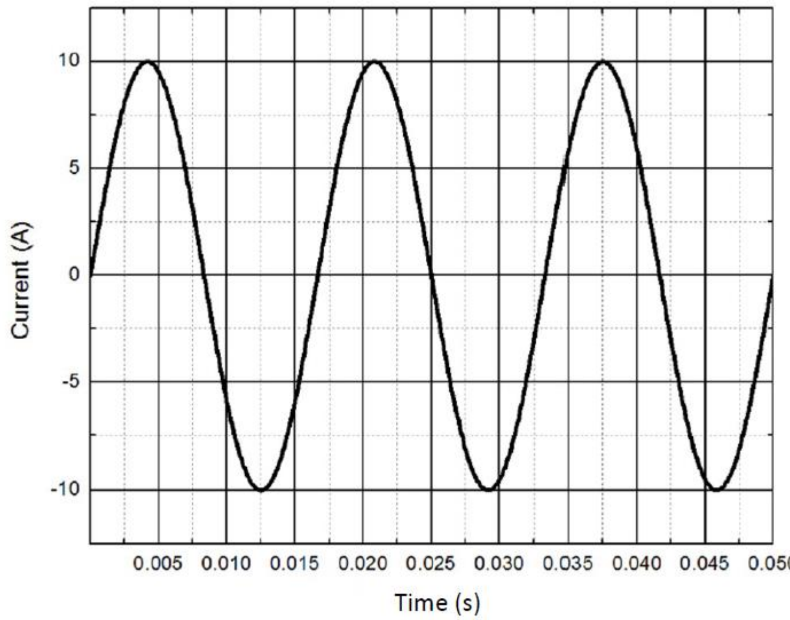
D) $\dfrac{V_0}{R}$

E) $\dfrac{V_0}{\sqrt{2}\,R}$

Answer: $\dfrac{V_0}{R}\sin(\omega t)$

I-11. The graph shows current vs time for a hairdryer plugged into a standard American electrical outlet (120 VAC). What is the resistance of the hairdryer?

HINT: $\frac{1}{\sqrt{2}} \simeq 0.7$



A) 24 Ω B) 21 Ω C) 17 Ω

D) 14 Ω E) 12 Ω

Answer: 17 Ω. This is an AC circuit. We can either use $V_{rms} = I_{rms} R$ or $V_{peak} = I_{peak} R$. From the graph we see that $I_{peak} = 10$ A. $I_{rms} = I_{peak}/\sqrt{2} \cong 7$ A. Using R = Vrms/Irms = 120V/7A ≅ 17 Ω.

I-12. A 100 W light bulb (average power) is attaced to a wall plug (120 V rms 60 Hz). What is the **peak** power output to the bulb?

A) 100 W   B) $\sqrt{2}\,100\,\mathrm{W}$ C) 200 W

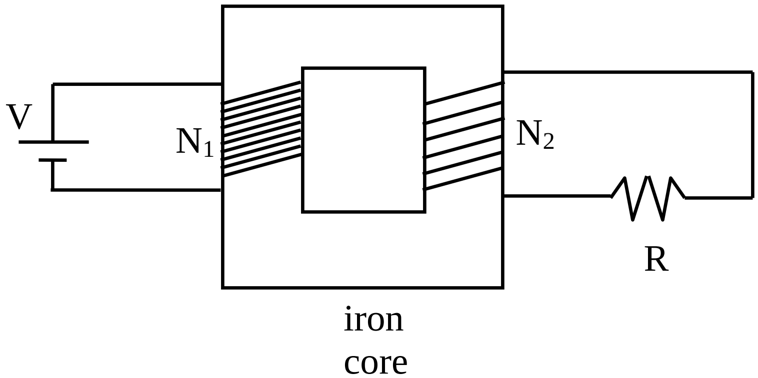
D) none of these

Answer: 200 W. Average power is less than peak power.
$P_{avg} = 100$ W $= I_{rms} V_{rms} = (I_{peak} V_{peak})/ 2$ (using $I_{rms} = I_{peak}/\sqrt{2}$ and $V_{rms} = V_{peak}/\sqrt{2}$).
Peak power is $I_{peak} V_{peak} = 2\times100$ W

I-13. A transformer is connected to a battery as shown. The voltage difference across the resistor R is ...

A) V N_2/N_1 B) V N_1/N_2 C) V

D) zero. E) not enough information to answer.



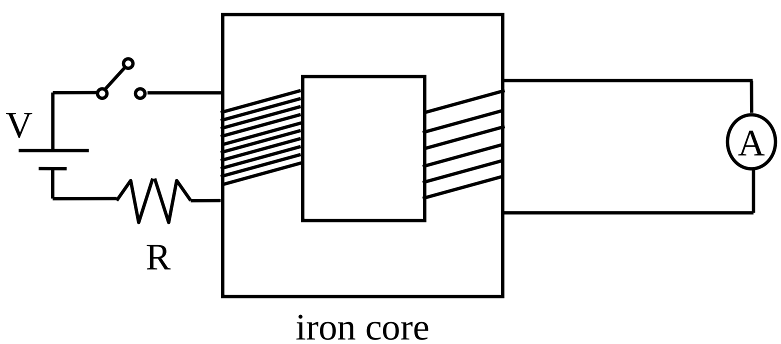
Answer: zero!! It's a trick question! Transformers only work with *AC voltages*. The DC voltage V from the battery produces a DC current in the primary coil, but produces no voltage of any kind in the secondary coil. Transformers work because of Faraday's Law: the *changing* flux produced by the AC current in the primary coil produces an emf in the secondary coil. If the flux is not changing, there is no emf.

I-14. The primary coil of a transformer is connected to a battery, a resistor, and a switch. The secondary coil is connected to an ammeter. When the switch is thrown closed, the ammeter shows..

A) a zero current all the time

B) a non-zero current for a brief time when the switch is closed

C) a steady non-zero current after the switch is closed



Answer: There is a non-zero current briefly as the switch is closed, but then, after a short time, there is no current. As the switch is closed, the current in the primary changes from zero to some non-zero value. While the current is changing, there is a changing B-field and a changing flux which causes an emf in the secondary and a current flow in the secondary. (The time period over which the current changes from zero to non-zero as the switch is closed is L/R where L is the inductance of the primary coil and R is its resistance.)

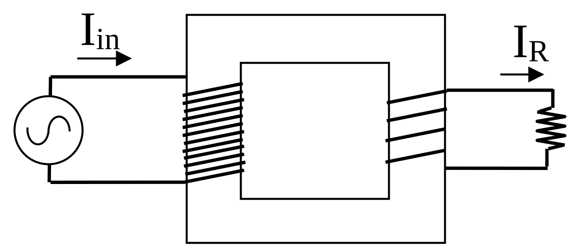
I-15. A step-down transformer is attached to an AC voltage source and a resistor as shown. How does the current in the resistor I_R compare to the current drawn from the AC source I_{input}? (With AC circuits, we always use rms values of I and V.)

A) $I_R > I_{in}$

B) $I_R < I_{in}$

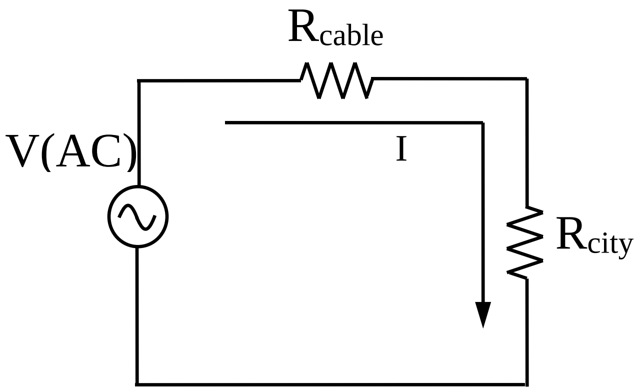
C) $I_R = I_{in}$

D) Depends on the value of I_{in}



Answer: $I_R > I_{in}$ This is a step-down transformer (since the number of turns in the secondary is less than the number of turns in the primary). So the voltage is stepped down. If the voltage is stepped down, the current is stepped up.

I-16. An electrical engineer at a power plant wants to reduce the energy wasted during power transmission from the plant to the city. The power output P_o=IV of the plant is fixed at 100MW. The engineer decides to double output voltage V. By what factor does the power lost in the cable ($P_{lost} = I^2 R_{cable}$) change?



A) No change
B) factor of 2 decrease in power lost
C) factor of 4 decrease
D) factor of 8 decrease
E) Power lost in cable increases

Answer: factor of 4 decrease. When V increases by 2, I decreases by 2 (since P = IV = constant). When I decrease by 2, I^2 decreases by a factor of 4, $P_{lost}=I^2R_{cable}$ decreases by 4.

The formula $P = V^2/R$ is not useful in this case. In the formula $P=V^2/R$, V is the voltage difference *across the resistor R*. But in this problem the voltage difference across R_{cable} is not known.
