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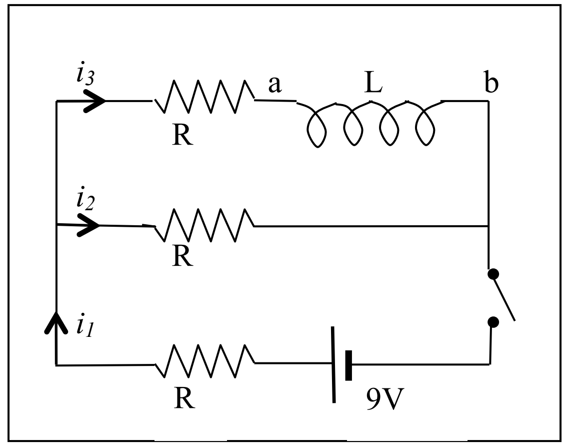
Part I: Lecture Multiple Choice [90 pts total]



The figure to the right is related to the next five problems.

The circuit shown contains three resistors, each with the same resistance R=15Ω, an ideal inductor of inductance L, and an ideal battery with an EMF of 9V. The switch has been open for a long time and is then closed at time t=0.

1. [4 pts] Immediately after the switch is closed, what is the current through the battery, i_1?
   A. *0.15 A* ***B.*** *0.4 A* ***C.*** *0.9 A* ***D.*** *0.6 A* ***E.*** *0.3 A*

What is the voltage drop across the inductor (V_a-V_b) immediately after the switch is closed?

2. [2 pts] Sign?
   A. Positive **B.** Negative

3. [3 pts] Magnitude?
   A. *3 V* ***B.*** *4.5 V* ***C.*** *9.0 V* ***D.*** *0 V*

Long after the switch has been closed, it is reopened. What is the voltage drop across the inductor (V_a-V_b) immediately afterward?

4. [2 pts] Sign?
   A. Positive **B.** Negative

5. [4 pts] Magnitude?
   A. *3 V* ***B.*** *4.5 V* ***C.*** *6.0 V* ***D.*** *9.0 V* ***E.*** *0 V*

6. [5 pts] At time *2.1 ms* after the switch is reopened, the current through the inductor has dropped to half of the value it had immediately after the switch was reopened. What is L?
   A. *0.32 mH* ***B.*** *1.9 mH* ***C.*** *37 mH* ***D.*** *91 mH* ***E.*** *0.72 H*

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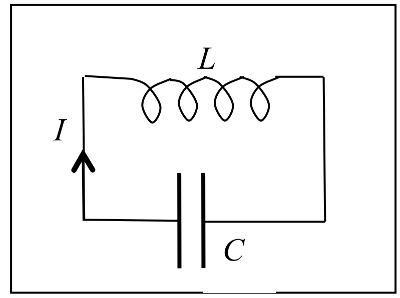
The figure to the right is related to the next two problems.



In the circuit shown to the right, the ideal inductor has $L=0.06H$, and the capacitor has $C=6\mu F$. At time t=0 the capacitor is uncharged and the current is $I=0.8\ mA$. Subsequently, the current oscillates.

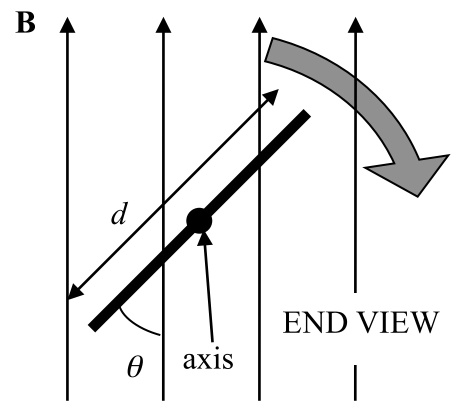
7. [5 pts] In the course of the oscillations, what is the maximum value of the charge stored on the capacitor?

   A. *2.1 nC* ***B.*** *54 nC* ***C.*** *480 nC* ***D.*** *82 μC* ***E.*** *0.96 mC*

8. [5 pts] What is the first time after t=0 at which the capacitor is again uncharged?

   A. *23 s* ***B.*** *0.63 s* ***C.*** *76 ms* ***D.*** *1.9 ms* ***E.*** *0.43 ms*

The figure to the right is related to the next three problems.



A square loop of width $w=10cm$, and resistance $R=5\Omega$, is pivoted about an axis passing through the center of two parallel sides. It is placed in a region of constant magnetic field of magnitude $B=0.5\ T$, and rotates in the direction shown at angular frequency $\omega=10\ rad/s$, so that $\theta=\omega t$.

9. [3 pts] At the instant shown, when $\theta=45^0$, what is the direction of the induced current on the end segment of the loop?

   A. *To the right along the end segment*
   B. *To the left along the end segment*
   C. *There is no induced current at this instant.*

10. [4 pts] If the magnetic flux passing through the loop from bottom to top is *0.0035Wb* what is B (in *T*)?

    A. *0.5* ***B.*** *0.35* ***C.*** *0.23* ***D.*** *0.05* ***E.*** *0.035*

11. [5 pts] What is the magnitude of the induced current in the loop at the instant shown (in *Amps*)?

    A. *0.035* ***B.*** *0.07* ***C.*** *0.018* ***D.*** *0.007* ***E.*** *0.0035*

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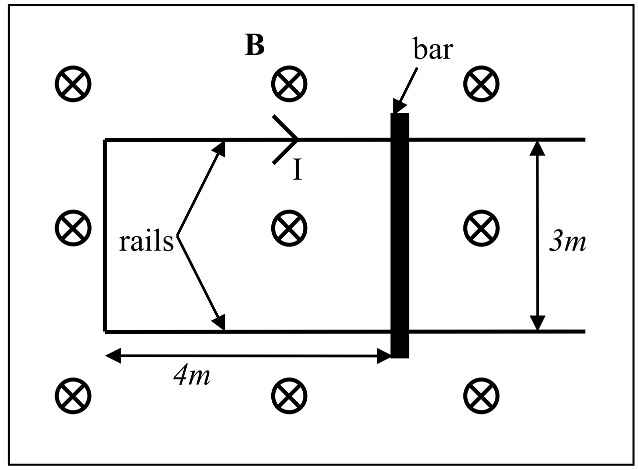
The figure to the right is related to the next three problems.



A metal bar slides without friction along two metal rails, as shown in top view in the sketch. A uniform magnetic field $B=0.5\ T$ points into the page. The rails (and the connector at the left end) are resistanceless, while the bar has resistance R. A force F is applied to the bar so that it moves at constant speed $v=20\ m/s$ (in a direction to be determined). An induced current $I=1.5\ A$ flows around the loop formed by the rails and the bar, in a clockwise direction as shown.

12. [2 pts] What direction is the bar moving?

***A.** To the left* ***B.** To the right* ***C.** Out of the page*

13. [5 pts] What is the resistance R (in Ohms)? (Choose the closest.)

***A.** 0.75* ***B.** 1.5* ***C.** 20* ***D.** 340* ***E.** 5600*

14. [4 pts] What is the magnitude of the applied force F (in N)? (Choose the closest.)

***A.** 0* ***B.** 0.5* ***C.** 2.25* ***D.** 15* ***E.** 45*

15. [4 pts] Which of the following statements contradicts one of Maxwell's equations?

A) *A changing magnetic field produces an electric field.*
B) *The net magnetic flux through a closed surface depends on the current inside.*
C) *A changing electric field produces a magnetic field.*
D) *The net electric flux through a closed surface depends on the charge inside.*

16. [5 pts] The electric field in a region of space varies according to $E = (1.25\ N/C)\ \sin(1500\ t)$ where t is in seconds. The maximum displacement current through a $2 m^2$ area perpendicular to E is approximately

***A.** 3.32 nA* ***B.** 13.3 nA* ***C.** 66.4 nA* ***D.** 16.6 nA* ***E.** 33.2 nA*

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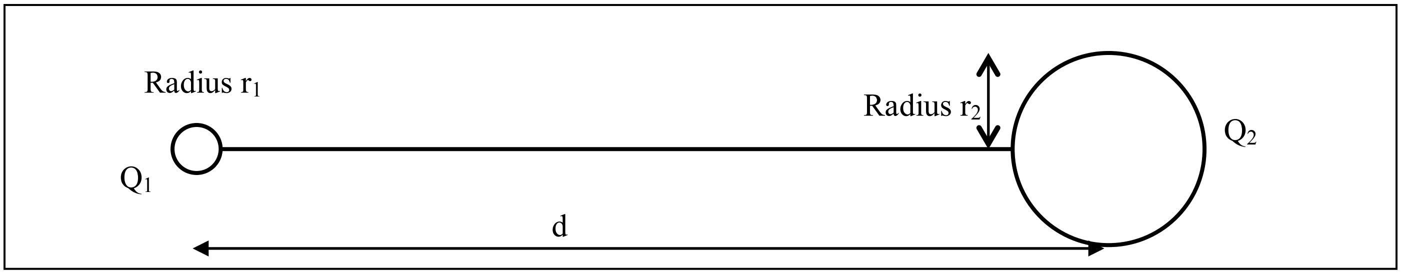
The figure below is related to the next three problems.

Two conducting spheres are connected by a long thin conducting wire. Their radii are $r_1=1cm$ and $r_2=4\ cm$, and the distance between them is much larger than either radius, $d >> r_2$. A total charge Q is placed on the system, which distributes itself between the spheres (the wire holds no charge as it is treated as infinitely thin). The resulting charge on the left sphere is $Q_1 = 2\ \mu C$. The spheres are far enough apart that each can be considered as isolated when calculating the potential and electric field around them.



17. [5 pts] What is the minimum work required to bring a proton from infinity to the surface of the left sphere (in Joules)? (Choose the closest.) Assume that the charge distribution on the spheres is unaffected by the approach of the proton.

A. 1.6×10^{-19} ***B.*** 2.9×10^{-13} ***C.*** 5.3×10^{-11} ***D.*** 3.2×10^{-7} ***E.*** 0.0078

18. [5 pts] What is total charge on the two spheres, Q (in μC)?

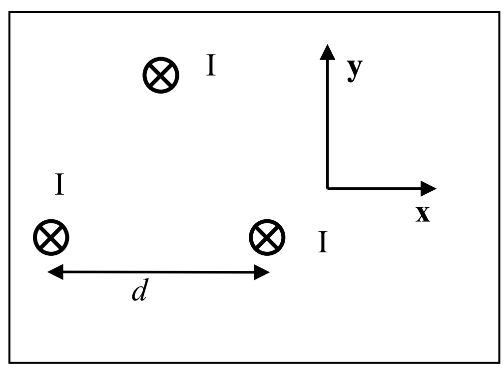
A. *0* ***B.*** *2* ***C.*** *4* ***D.*** *8* ***E.*** 10

19. [2 pts] Near which sphere is the magnitude of the electric field at the surface largest?

A. *Sphere 1 (the left one)* ***B.*** *Sphere 2 (right one)* ***C.*** *The fields are the same.*

The figure to the right is related to the next two problems.

Three long straight wires of length $L=2m$ lie at the corners of an equilateral triangle of side length $d=1cm$. They each carry current $I=4A$ flowing in the same direction.



20. [2 pts] What is the direction of the force on the top wire?

A. *+x* ***B.*** *–x* ***C.*** *+y* ***D.*** *-y*

21. [5 pts] What is the magnitude of the force on the top wire (in *mN*—chose the closest)?

A. *0.11* ***B.*** *0.32* ***C.*** *0.64* ***D.*** *1.1* ***E.*** *1.3*

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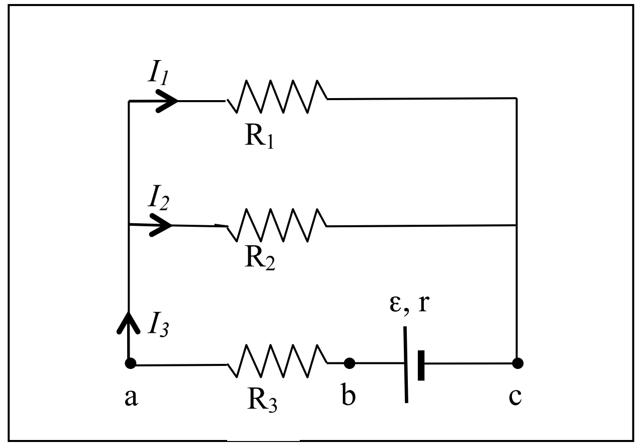
The figure to the right is related to the next two problems.



The circuit shown to the right consists of three resistors with resistances $R_1 = 30\Omega$, $R_2 = 60\Omega$ and $R_3 = 50\Omega$, and a *non-ideal* battery with EMF $\varepsilon = 7$ Volts and internal resistance $r = 0.1\Omega$. All wires are ideal. Three points on the circuit are labeled a-c.

22. [5 pts] What is the current through the battery, I_3 , in Amps? (Choose the closest.)

A. 0.042 **B.** 0.095 **C.** 0.10 **D.** 0.36 **E.** 1.3

23. [3 pts] If the resistance R_3 is decreased (with R_1, R_2, r and ε unchanged) what happens to the potential difference between points a and c, $V_a - V_c$?

A. *It increases* **B.** *It decreases* **C.** *It is unchanged*

24. [3 pts] If the resistance R_3 is decreased (with R_1, R_2, r and ε unchanged) what happens to the potential difference between points b and c, $V_b - V_c$?

A. It increases **B.** It decreases **C.** It is unchanged