PH202-1G
Spring 2014

Mock exam II

Print off your own copy of the mock exam and do your best to complete it before the mock exam session. We will not take any time during the mock exam session to complete the mock exam.

This mock exam will be most beneficial to you if you complete it under testing conditions. It should take you about 1 hour and 30 minutes to complete, but keep in mind that your class exam will be only 50 minutes. Use the equation sheet provided by Dr. Wenger on Blackboard and the same calculator that you plan to use during the actual exam. If you get stuck, try to use the strategy in the document called "How to solve a physics problem" to help you. Do not use your book or notes from class until you have attempted the problems in the mock exam on your own at least once.

1. Three capacitors each have a capacitance C. What is the ratio of the equivalent capacitance when the capacitors are wired in parallel to the equivalent capacitance when the capacitors are wired in series?

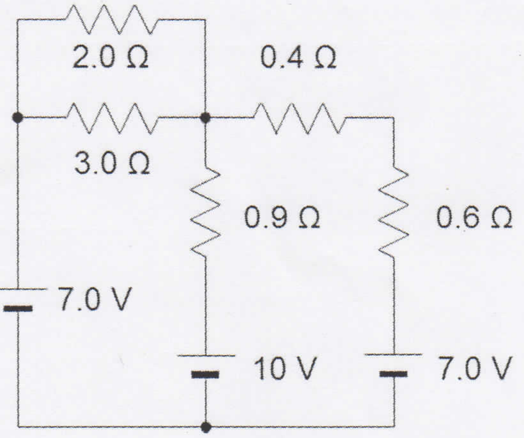
   A. 1 / 9
   B. 9
   C. $1 / C^2$
   D. C^2
   E. 1

In parallel, $C_p = C + C + C = 3C$

In series, $C_s = \left(\frac{1}{C}+\frac{1}{C}+\frac{1}{C}\right)^{-1} = \left(\frac{3}{C}\right)^{-1} = \frac{C}{3}$

Thus, the ratio is $\frac{3C}{\frac{C}{3}} = \frac{3}{C}\cdot 3C = 9$

2. Find the magnitude and direction of the current through each of the three batteries in the circuit depicted to the left.



First, simplify the circuit by combining resistors.

$R_p = \left(\frac{1}{2.0\,\Omega}+\frac{1}{3.0\,\Omega}\right)^{-1} = 1.2\,\Omega$ $\quad R_s = 0.4\,\Omega + 0.6\,\Omega = 1.0\,\Omega$

Then, redraw the simplified circuit and decide current directions.

Remember, current will be negative if you pick the wrong direction, so just pick one.

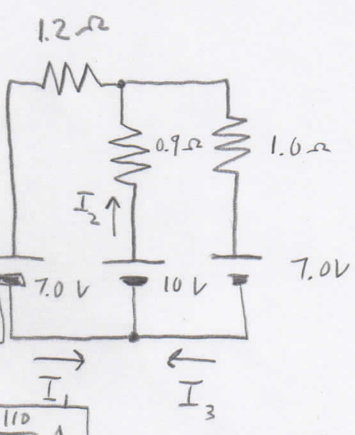
Now, apply Kirchhoff's junction rule and loop rule.

Junction rule (same for both junctions) - $I_2 = I_1 + I_3$

Loop rule (you can pick any two loops in either direction, but I picked the two starting from the center and going out)

$$\left.\begin{aligned} V_2 - I_2R_2 - I_1R_p - V_3 &= 0 \\ V_2 - I_2R_2 - I_3R_s - V_3 &= 0 \end{aligned}\right\} \text{subtract: } I_1R_p = I_3R_s$$

Simplified circuit



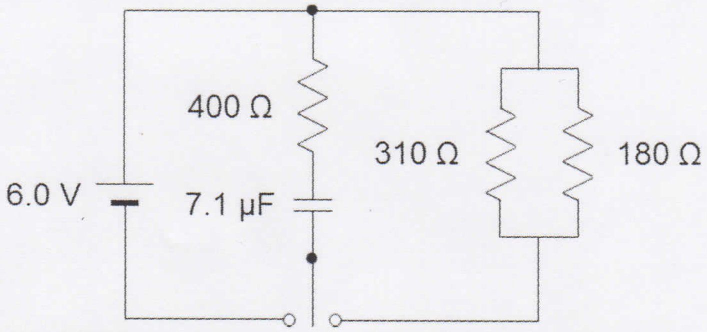
Plug $I_2 = I_1 + I_3 = \frac{R_s}{R_p}I_3 + I_3$ into second loop rule expression and solve:

$V_2 - \left(\frac{R_s}{R_p}+1\right)I_3R_2 - I_3R_s - V_3 = 0$ $\Rightarrow$ $I_1 = \frac{R_p}{R_s}I_3 = \frac{1.2\,\Omega}{1.0\,\Omega}\cdot\frac{60}{53}\,A = \boxed{\frac{50}{53}\,A}$

$$I_3 = \frac{V_2 - V_3}{\frac{R_sR_2}{R_p}+R_2+R_s} = \frac{10\,V - 7.0\,V}{\frac{1.0\,\Omega\cdot 0.9\,\Omega}{1.2\,\Omega}+0.9\,\Omega+1.0\,\Omega} = \boxed{\frac{60}{53}\,A}$$

$$I_2 = \frac{60}{53}\,A + \frac{50}{53}\,A = \boxed{\frac{110}{53}\,A}$$

3. The capacitor in the circuit depicted to the right initially contains no charge. At time t = 0, the switch is closed to the left. When the capacitor has reached its equilibrium charge, the switch is closed to the right. a) Find the time required for the capacitor to reach 63 % of its equilibrium charge. b) After the switch is closed, find the time required for the capacitor to lose 63 % of its equilibrium charge.



Time required to gain or lose 63 % of equilibrium charge is time constant.

a) $\tau = RC = 400\ \Omega \cdot 7.1\ \mu F = \boxed{0.0028\ s}$

b) $R_{eq} = 400\ \Omega + \left(\frac{1}{310\ \Omega} + \frac{1}{180\ \Omega}\right)^{-1} = 513.9\ \Omega$

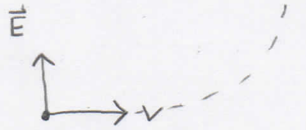
$\tau = R_{eq}C = 513.9\ \Omega \cdot 7.1\ \mu F = \boxed{0.0036\ s}$

4. T (T / F) Magnetic fields cause charged particles moving in a direction perpendicular to the field to accelerate.

Magnetic fields cause uniform circular motion. Although speed does not change, its direction does. A change in velocity (even just in direction) is acceleration.

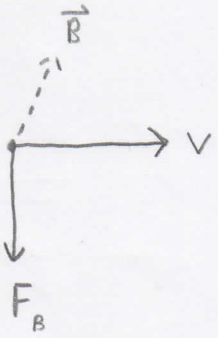
5. A physics professor is trying to perform an experiment which requires an electron to move in a straight line. The electric engineers in the lab upstairs have created a massive electric field to see if they can levitate a frog. Unfortunately, the electric field is causing the electron in the physicist's lab to be deflected upward. If the electron is moving to the right, in what direction should the physicist create a magnetic field to counteract the deflection of the electric field?

A. Upward
B. Downward
C. Into the page
D. Out of the page
E. To the left



Need a force downward.

Use the right hand rule for a negative particle.



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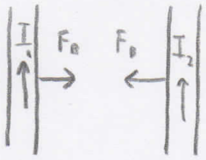
6. A 35 cm long wire carries a current of 0.17 A. A second wire with the same length carrying a current of 0.13 A in the same direction as the first wire is placed 10 cm away, oriented parallel to the first wire. Calculate the magnitude and direction of the magnetic force on each wire.

Current is in the same direction, so the force is attractive. Use right hand rule to verify.

The magnitude of the force will be the same.

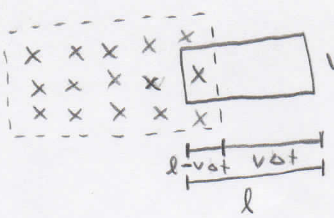


$$\underbrace{F_{B-1} = I_1 L B_2 \qquad B_2 = \frac{\mu_0 I_2}{2\pi r} \qquad\qquad F_{B-2} = I_2 L B_1 \qquad B_1 = \frac{\mu_0 I_1}{2\pi r}}$$

$$F_B = \frac{\mu_0 I_1 I_2 L}{2\pi r} = \frac{4\pi \cdot 10^{-7}\ T \cdot m \cdot A^{-1}\ (0.17\ A)\ (0.13\ A)\ (0.35\ m)}{2\pi\ (0.10\ m)} = \boxed{1.5 \cdot 10^{-8}\ N}$$

7. A rectangular loop of wire with a width of 5.0 cm and a length of 15 cm sits in a square region of uniform magnetic field. The magnetic field points into the page with a magnitude of 0.58 T. A force is applied to the shorter side of the wire such that it moves to the right with a constant speed of 1.2 m/s. Find the magnitude and direction of the induced emf when the loop a) is moving completely within the magnetic field and b) is moving out of the region containing the magnetic field.

a) Within the magnetic field, there is no change in flux and so no induced emf.

b) 

As the loop exits the field, the area within the field decreases by $w \cdot v \Delta t$.

Use Faraday's law to find magnitude: $\varepsilon = -N \frac{\Delta \Phi_B}{\Delta t} = -N \frac{B \Delta A}{\Delta t} = -N B \frac{w \cdot v \Delta t}{\Delta t}$

Notice this is the same for a wire moving in a magnetic field $\longrightarrow$ $\varepsilon = -N B w v = -(1)(0.58\ T)(0.050\ m)(1.2\ m \cdot s^{-1}) = \boxed{-0.035\ V}$

Use Lenz's law to find direction: Area within field is decreasing, so flux into the page is decreasing. The opposing flux must be into the page, so using the second right hand rule the emf must be clockwise.

8. T (T / F) An electrical generator produces alternating current.

Yes – emf oscillates sinusoidally with time, so current does also.

9. Which of the following changes will have the largest effect on the amplitude of the emf generated by a coil of wire rotating in a uniform magnetic field?

A. Increasing the number of turns in the coil by a factor of 2
B. Increasing the strength of the magnetic field by a factor of 2
C. Increasing the area of the coil by a factor of 2
D. Increasing the frequency of the coil's rotation by a factor of 2
E. These changes will all have the same effect on the amplitude of the emf

$$\mathcal{E}_0 = NBA\omega$$

10. If the number of turns in the primary coil of a transformer is increased while keeping the number of turns in the secondary coil the same, which of the following changes will not occur?

A. The ratio of the voltage in the primary coil to the voltage in the secondary coil will increase
B. The ratio of the current in the primary coil to the current in the secondary coil will increase
C. The ratio of the power in the primary coil to the power in the secondary coil will increase
D. Both B and C
E. All of the above

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

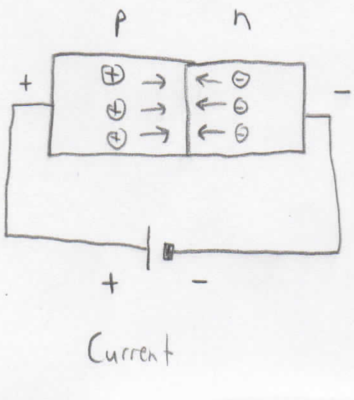
Increasing $\frac{N_p}{N_s}$ means:

$\frac{V_p}{V_s}$ increases

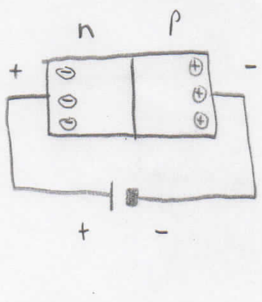
$\frac{I_p}{I_s}$ decreases

Average power is always the same in both coils.

11. T (T / F) In a diode consisting of a junction between an *n*-type semiconductor and a *p*-type semiconductor, current can flow from the *p*-type semiconductor to the *n*-type semiconductor but not from the *n*-type semiconductor to the *p*-type semiconductor.



Current



No current

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12. An ac generator with a peak voltage of 9.0 V is connected to a resistor, a capacitor, and an inductor in series. The resistor has a resistance of 7.5 Ω, the capacitor has a capacitance of 200 μF, and the inductor has an inductance of 40 mH. a) If the ac generator operates with a frequency of 400 Hz, what is the root-mean-square current in the circuit? b) What is the resonant frequency of this circuit? c) What is the root-mean-square current at the resonant frequency?

a) First, calculate impedance $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + \left(2\pi f L + \frac{1}{2\pi f C}\right)^2}$

$$Z = \sqrt{(7.5\,\Omega)^2 + \left(2\pi \cdot 400\text{ Hz} \cdot 40\text{ mH} - \frac{1}{2\pi \cdot 400\text{ Hz} \cdot 200\,\mu\text{F}}\right)^2} = 98.83\,\Omega$$

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{V_0}{\sqrt{2}\,Z} = \frac{9.0\text{ V}}{\sqrt{2} \cdot 98.83\,\Omega} = \boxed{0.064\text{ A}}$$

b) $$f_R = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{40\text{ mH} \cdot 200\,\mu\text{F}}} = \boxed{56\text{ Hz}}$$

c) At resonant frequency, $X_L - X_C = 0$. Thus, $Z = \sqrt{R^2} = R$ and $I_{rms} = \frac{V_{rms}}{R}$

$$I_{rms} = \frac{9.0\text{ V}}{\sqrt{2} \cdot 7.5\,\Omega} = \boxed{0.85\text{ A}}$$

13. Which of the following statements is true for an electromagnetic wave?

$E = cB$

A. The magnitude of the electric field is greater than the magnitude of the magnetic field
B. The electric field contributes more to the total energy of the wave than the magnetic field
C. The intensity of the wave does not depend on the magnitude of the magnetic field
D. Both A and B
E. Cats do not like to play with electromagnetic waves – laser pointers? Cat approved.

The electric and magnetic fields contribute equally to energy density. Intensity can be written using an expression that does not explicitly contain magnetic field, but $E \propto B$ so it's still there.

14. Calculate the speed necessary for the driver of a car to perceive the red light from a traffic stoplight as green light. Assume that red light has a wavelength of 650 nm and that green light has a wavelength of 510 nm.

Use the Doppler effect, where the source is red light and the observed frequency is green light.

$$f_o = f_s\left(1 + \frac{v}{c}\right) \Rightarrow \frac{f_o}{f_s} = \frac{\frac{c}{\lambda_o}}{\frac{c}{\lambda_s}} = \frac{\lambda_s}{\lambda_o} = 1 + \frac{v}{c}$$

$$v = \left(\frac{\lambda_s}{\lambda_o} - 1\right)c = \left(\frac{650\text{ nm}}{510\text{ nm}} - 1\right) \cdot 3.00 \cdot 10^8\text{ m} \cdot \text{s}^{-1} = \boxed{8.2 \cdot 10^7\text{ m} \cdot \text{s}^{-1}}$$

This is about 184 million mph. This will actually happen – but only if you can make your car go this fast!