STAPLE

Physics 201 Name KEY

# Final Exam

May 14, 2013

This is a closed book examination but during the exam you may refer to a 5"x7" note card with words of wisdom you have written on it. There is extra scratch paper available. Your explanation is worth ¾ of the points. Explain your answers!

A general reminder about problem solving:

- Show all your work.
- Really; Show All Work!
- Focus
  - Draw a picture of the problem
  - What is the question? What do you want to know?
  - List known and unknown quantities
  - List assumptions
- Physics
  - Determine approach – What physics principles will you use?
  - Pick a coordinate system
  - Simplify picture to a schematic (if needed)
- Plan
  - Divide problem into sub-problems
  - Modify schematic and coordinate system (if needed)
  - Write general equations
- Execute
  - Write equations with variables
  - Do you have sufficient equations to determine your unknowns?
  - Simplify and solve
- Evaluate
  - Check units
  - Why is answer reasonable?
  - Check limiting cases!

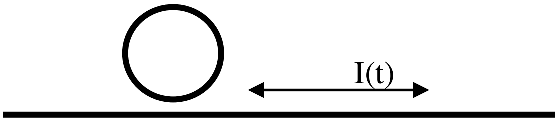
1. [4 PTS] You connect a resistor (222 Ω) and capacitor (500 μF) in series with a battery (1.5 Volts). What is the time constant?

a) $\tau = 0.009\ s$
[✓ b)] $\tau = 0.111\ s$
c) $\tau = 0.150\ s$
d) $\tau = 9.01\ s$
e) $\tau = 111\ s$

Given $\tau = RC$ solve for the time constant

2. [4 PTS] A closed loop is placed next to a wire (see below). The wire carries a steady DC current of I=50 mA. The loop does not move relative to the wire.

[✓ a)] There will be no induced current.
b) There will only be an induced current if the loop moves parallel to the wire.
c) There will only be an induced current if the loop is rotated 90° so its surface normal vector is parallel to the wire.
d) There is a constant induced current.
e) There is an oscillating induced current.
f) None of the above



Given $V_{emf} = \frac{-d\Phi_M}{dt}$, the induced voltage is zero since neither the area or magnetic field is changing in time.

3. [4 PTS] A generator with an effective (rms) voltage of 24 $V_{AC}$ is connected to a transformer on a side with 100 windings. The other side has 1500 windings. What is the effective (rms) output voltage?
[✓ a)] 360 V
b) 36 V
c) 16 V
d) 1.6 V
e) 0 V

Need AC voltage for a transformer to work. Given $\frac{V_p}{V_s} = \frac{N_p}{N_s}$ solve for the secondary voltage. This is a step-up transformer.

4. [4 PTS] A <u>proton</u> moving in the +*x* direction enters a region of uniform magnetic field that is also oriented in the +*x* direction. In which direction does the <u>proton</u> feel a force?
a) The +*y* direction.
b) The +*z* direction.
c) The -*y* direction.
d) The -*z* direction.
[✓ e)] There is no force.

The force on a charged particle moving in a magnetic field is $\vec{F} = q\vec{v}\times\vec{B}$. The cross product is zero for parallel vectors so the force is zero, $\hat{x}\times\hat{x} = 0$.

5. [4 PTS] A resistor ($R = 3.0\ \Omega$) is placed in series with a real battery ($V_{emf} = 8.8$ Volts) and you measure a current of 2.75 A. What is the current in this circuit if you replace the resistor with a $R = 5.0\ \Omega$ resistor?
a) $I = 4.58\ A$
b) $I = 1.76\ A$
[✓ c)] $I = 1.69\ A$
d) $I = 1.65\ A$
e) $I = 1.06\ A$

For an ohmic device $V = IR$ so $I = \frac{V}{R_{total}} = \frac{9.0V}{R+R_{int}}$ and $R_{int} = \frac{V}{I} - R$

6. [4 PTS] A charged object, $q = 25nC$, is moving through a region of space with a constant magnetic field, $\vec{B} = \langle 0, 0, 0.45 \rangle\, T$. When the object is at $\vec{x} = \langle 2, -1, 2 \rangle\, m$, it has a velocity $\vec{v} = \langle 4\times10^5, 0, 0 \rangle\, m/s$. Assume the object is nonrelativistic, $\gamma = 1$. What is the force on the object?
   [✓ a)] $\vec{F} = \langle 0, -4.5, 0 \rangle$ m$N$
   b) $\vec{F} = \langle 0, 4.5, 0 \rangle$ m$N$
   c) $\vec{F} = \langle 0, 0, 0 \rangle\, N$
   d) $\vec{F} = \langle 4.5, -2.25, 0 \rangle$ m$N$
   e) $\vec{F} = \langle -4.5, 2.25, 0 \rangle$ m$N$

The force on a charged particle moving in a magnetic field is $\vec{F} = q\vec{v}\times\vec{B}$. The velocity plane and magnetic field are at right angles so the magnitude of the force is $|\vec{F}| = |q||\vec{v}||\vec{B}| = (25\times10^{-9} C)\left(4\times 10^5 \frac{m}{s}\right)(0.45\ T)$ Using the right hand rule the force is in the $-\hat{y}$ direction.

7. [4 PTS] A long wire positioned along the x-axis has a current of $\vec{I} =< 1.2, 0, 0 > A$ flowing through it. You measure the magnitude of the magnetic field 2 cm from the center of the wire. You move so you are now 8 cm away. What happens to the magnitude of the magnetic field at your new observation point?
   a) Increases by a factor of 4
   b) Increases by a factor of 2
   c) Does not change
   d) Decreases by a factor of 2
   [✓ e)] Decreases by a factor of 4
   f) None of the above

$B \propto \frac{I}{r}$ so if $r$ increases by 4 then the magnitude of the magnetic field decreases by 4.

8. [4 PTS] You connect three identical capacitors ($C = 3\ mF$) in parallel. What is the value of the effective (or total circuit) capacitance?
   [✓ a)] $C = 9\ mF$
   b) $C = 6\ mF$
   c) $C = 1\ mF$
   d) $C = \frac{1}{3} mF$
   e) $C = \frac{1}{9} mF$

Capacitors in series add $\frac{1}{C_{tot}} = \sum_i \frac{1}{C_i}$
Capacitors in parallel add $C_{tot} = \sum_i C_i$
Add the capacitor to determine total capacitance.

9. [4 PTS] A hollow metal cube is placed 2 cm from the center of a 5 C charged object. The object and cube are in static equilibrium (neither is moving). What is the voltage inside the hollow metal cube?
   a) The voltage is zero.
   b) The voltage is largest on the side closest to the charged object.
   [✓ c)] The voltage is constant inside the cube.
   d) The voltage is largest on the side far away from the charged object.
   e) There is no voltage inside the cube.

$\vec{E} = -\frac{d}{dr} V\hat{r}$ or $V = -\int \vec{E}\cdot d\hat{r}$ and we know the electric field inside a conductor in static equilibrium is zero so the voltage must be constant i.e. the slope of a constant is zero.

10. [4 PTS] A charged particle (q = 35 μC), is moving with a constant speed along the x-axis, $\vec{v} =< 8\times10^4, 0, 0 >$ m/s. When the particle is just passing the origin, $\vec{x}_p =< 0, 0, 0 >$ m, what is the magnitude of the magnetic field at $\vec{x}_o =< 5, 0, 0 >$ cm?
    - a) $|\vec{B}| = 112$ mT
    - b) $|\vec{B}| = 5.6$ mT
    - c) $|\vec{B}| = 0.112$ mT
    - d) $|\vec{B}| = 5.60$ μT
    - [✓ e)] $|\vec{B}| = 0$ T

According to the Biot-Savart law $\vec{B} = \frac{\mu_o}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$ so the magnetic field is zero if q=0, v=0 or if the velocity and observation vector are parallel.

11. [4 PTS] Two small charged spheres are located in an empty region of space. Sphere one has twice the charge on it than sphere two ($q_1 = 2q_2$). The magnitude of the force on sphere one is 12 N when the center-to-center separation of the spheres is 1.2 meter. What is the magnitude of force on the sphere two when the spheres are 0.6 meters apart?
    - a) 3 N
    - b) 6 N
    - c) 12 N
    - d) 24 N
    - [✓ e)] 48 N

Force is proportional to 1/r². $\vec{F} = \frac{kq_1q_2}{r^2}\hat{r}$ We are only interested in the magnitude $\frac{F}{F_o} = \frac{r_o^2}{r^2} = \frac{r_o^2}{(\frac{r_o}{2})^2} = 4$ so F=4x12N=48N

12. [4 PTS] A large neutral metal sphere is grounded through a switch. A positively charged balloon is brought near it (but does not touch it) while the switch is closed. The switch is opened (the sphere is no longer grounded) and the balloon is taken away. The sphere is now
    - a) charged but we cannot know its polarity.
    - b) neutral (has no net charge).
    - [✓ c)] negatively charged.
    - d) positively charged.
    - e) none of these.

The balloon induces the positive charges to move away to ground since they have a path. When the switch is opened the positive charges cannot return. Hence sphere is left with a negative charge.

13. [4 PTS] An electron is placed exactly in the middle between two parallel plates. One plate is held at 50V while the other is held at -50V. Circle every correct statement.
    - [✓ a)] The electron moves toward the 50V plate.
    - b) The electron moves with constant velocity.
    - c) The electron moves toward the -50V plate.
    - d) The electron does not move since it is at 0V.
    - e) The electron moves in a circle due to the right hand rule.
    - [✓ f)] The electron moves with constant acceleration.

Force is proportional to charge and electric field $\vec{F} = q\vec{E}$. The electric field points from high voltage to low voltage.

The next two problems concern a double convex plastic (n=1.2) lens you are using on the beach.

14. [4 PTS] You are using this lens as a magnifying lens. Circle every correct statement.
    - a) The lens has a focal length less than zero.
    - [✓ b)] The lens has a focal length greater than zero.
    - c) A real, magnified image is produced if $s_o > 2f$
    - [✓ d)] A real, magnified image is produced if $2f > s_o > f$
    - [✓ e)] A virtual, magnified image is produced if $s_o < f$
    - f) A virtual, magnified image is produced if $s_o > f$

Need a positive lens ($f$>0) to magnify an object. Use the thin lens equation $\frac{1}{f} = \frac{1}{s_o} + \frac{1}{s_i}$ and the magnification $m = -\frac{s_i}{s_o}$ to show that (d) and (e) are true for a positive lens.

15. [4 PTS] You decide to take the lens you were using above and use it under water (n=1.33) to magnify the pretty coral and shells you are interested in while scuba diving.
    - a) This works for any object distance.
    - [✓ b)] This does not work for any object distance.
    - c) This works so long as the object is closer than the focal distance.
    - d) This works so long as the object is further than the focal distance.

This will not work since the index of refraction of the water is greater than the index of refraction of the lens so the focal length will now be negative.

The problem can be done using a problem solving sheet or on additional paper. Follow the problem solving guidelines.

16. [12 PT] You are visiting your Aunt Peg when you notice that she is holding her reading glasses 10 cm from her eyes to read a book placed 45 cm in front of her eyes. You know she should have her reading glasses (D=+2.5 m$^{-1}$) resting on her nose 2 cm in front of her eyes when she is reading her book 25 cm in front of her eyes. She tells you not to bother but you want to get her new glasses. The problem is she won't go to the store with you so you have to determine the correct prescription. Good thing you took physics! What is her new prescription?

Use $\frac{1}{f} = \frac{1}{s_o} + \frac{1}{s_i}$ and $\frac{1}{f} = D$ for each of the two situations. Aunt Peg can see right now with $2.5 = D = \frac{1}{0.35} + \frac{1}{s_i}$, which means the image is $s_i - 10$ cm from her eye. This means the image distance from glasses sitting 2 cm from her eyes would be $s_i - 8$ cm. You want $D_{new} = \frac{1}{0.23} + \frac{1}{s_i - .08}$ so combine equations to find Aunt Peg's new prescription is $D_{new} = \frac{1}{0.23} + \left(\left(2.5 - \frac{1}{0.35}\right)^{-1} - .08\right)^{-1} = 4.0\ \text{m}^{-1}$

$\frac{\mu_0}{4\pi} = 10^{-7}\frac{N}{A^2}$

$\frac{1}{4\pi\epsilon_0} = k = 9\times10^9\frac{Nm^2}{C^2}$

mass of electron $m_e = 9.109\times10^{-31}kg$

charge of electron $q_e = 1.602\times10^{-19}C$

charge of neutron $q_n = 0\ C$

$V_{sphere} = \frac{4\pi r^3}{3}$ and $A_{sphere} = 4\pi r^2$

mass of proton $m_p = 1.673\times10^{-27}kg$

charge of proton $q_p = 1.602\times10^{-19}C$

mass of neutron $m_n = 1.675\times10^{-27}kg$