Physics 227 – Final
Tuesday, December 16, 2014, 4:00 PM - 7:00 PM
College Ave Gym Annex (A-I), College Ave Gym (J-R) and Scott Hall 135 (S-Z)

Your name sticker ⇒
with exam code

SIGN HERE

1. Use a #2 pencil to make entries on the answer sheet. Enter the following id information now, before the exam starts.
2. In the section labeled NAME (Last, First, M.I.) enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.
3. Under STUDENT # enter your 9-digit RUID Number.
4. Under CODE enter the exam code given above.
5. Enter 227 under COURSE. You do not need to write anything else on the answer sheet for now, but you may continue to read the instructions.
6. During the exam, you are allowed three 8.5 x 11 inch sheets of paper with whatever you want written on them. NO calculators, NO cell phones.
7. The exam consists of 30 multiple-choice questions. For each question mark only ONE answer on the answer sheet. There is no deduction of points for an incorrect answer. If you cannot work out an answer, you should make an educated guess.
8. If you have questions or problems during the exam, you may raise your hand and a proctor will assist you. We will provide values of physical constants that are needed. It is your responsibility to know the relevant equations.
9. A proctor will check your name sticker and your student ID sometime during the exam. Please have them ready.
10. You are not allowed to help any other student, ask for help from anyone but a proctor, change your seat without permission from a proctor or use any electronic device. Doing so will result in a zero score for the exam.
11. When you are done with the exam, hand in only this cover sheet and your answer sheet.
12. Please sign above by the name sticker to indicate that you have read and understood these instructions.
Possibly useful constants:

\[ \epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2 \]

\[ k = 1/4\pi\epsilon_0 = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \]

\[ \mu_0 = 4\pi \times 10^{-7} \text{ T} \cdot \text{m}/\text{A} = 12.57 \times 10^{-7} \text{ T} \cdot \text{m}/\text{A} \]

\[ c = \text{speed of light} = 3.00 \times 10^8 \text{ m/s} \]

\[-q_{\text{electron}} = q_{\text{proton}} = 1.602 \times 10^{-19} \text{ C} \]

\[ m_{\text{electron}} = \text{electron mass} = 9.11 \times 10^{-31} \text{ kg} \]

\[ m_{\text{proton}} = \text{proton mass} = 1.67 \times 10^{-27} \text{ kg} \]

\[ 1 \text{ eV} = 1.602 \times 10^{-19} \text{ J.} \]

Circumference of a circle = \(2\pi r\); Area of a circle is \(\pi r^2\)

Surface of a sphere = \(4\pi r^2\); Volume of a sphere = \(\frac{4}{3}\pi r^3\)

Volume of cylinder = \(\pi r^2 h\)

\[
\begin{align*}
\sin(0^\circ) &= \cos(90^\circ) = 1 \\
\sin(90^\circ) &= \cos(0^\circ) = 0 \\
\sin(30^\circ) &= \cos(60^\circ) = \frac{1}{2} \\
\sin(60^\circ) &= \cos(30^\circ) = \frac{\sqrt{3}}{2} \\
\sin(45^\circ) &= \cos(45^\circ) = \frac{\sqrt{2}}{2} \\
\tan(45^\circ) &= 1 \\
\tan(30^\circ) &= \frac{1}{\sqrt{3}} \\
\tan(60^\circ) &= \sqrt{3} \\
\tan\theta &= \frac{\sin\theta}{\cos\theta} \\
\cos\theta &= \frac{1}{\sqrt{1 + \tan^2\theta}}
\end{align*}
\]

\[
\frac{dx^n}{dx} = nx^{n-1}
\]

\[ f x^n = \frac{1}{n+1} x^{n+1} \text{ except when } n = -1 \text{. For } n = -1, \int dx/x = \ln x \]

Some metric prefixes:

\[ f = \text{femto} = 10^{-15} \]

\[ p = \text{pico} = 10^{-12} \]

\[ n = \text{nano} = 10^{-9} \]

\[ \mu = \text{micro} = 10^{-6} \]

\[ m = \text{milli} = 10^{-3} \]

\[ k = \text{kilo} = 10^3 \]

\[ M = \text{mega} = 10^6 \]

\[ G = \text{giga} = 10^9 \]
1. Two toroidal solenoids are wound around the same form so that the magnetic field of one passes through the turns of the other. Solenoid 1 has \(N_1=600\) turns and solenoid 2 has \(N_2=400\) turns. When the current in solenoid 1 is \(I_1=4\) A, the average flux through each turn of solenoid 2 is \(\Phi_2 = 4 \times 10^{-2}\) Wb. When the current in solenoid 2 is \(I_2=6\) A, what is the average flux \(\Phi_1\) through each turn of solenoid 1?

a) \(\Phi_1 = 1 \times 10^{-2}\) Wb  
b) \(\Phi_1 = 2 \times 10^{-2}\) Wb  
c) \(\Phi_1 = 4 \times 10^{-2}\) Wb  
d) \(\Phi_1 = 6 \times 10^{-2}\) Wb  
e) \(\Phi_1 = 9 \times 10^{-2}\) Wb

2. A series ac circuit contains a resistor with \(R = 1/4\) \(\Omega\), an inductor with \(L = 1/3 \times 10^{-2}\) H and a capacitor with \(C = 60\) mF that are connected to an AC voltage supply with a voltage amplitude of 10 V and angular frequency \(\omega = 100\) rad/s. What is the tangent of the phase angle, \(\tan \phi\)?

a) \(\tan \phi = 3/2\)  
b) \(\tan \phi = 4/3\)  
c) \(\tan \phi = 3/4\)  
d) \(\tan \phi = 3/13\)  
e) \(\tan \phi = 2/3\)

3. The electric field in an electromagnetic wave is given by \(\vec{E} = E_0 \sin(kz - \omega t) \hat{i}\). What is the associated magnetic field \(\vec{B}\)?

a) \(B_0 \cos(kz - \omega t) \hat{k}\)  
b) \(B_0 \sin(kx - \omega t) \hat{k}\)  
c) \(B_0 \cos(kz - \omega t) \hat{j}\)  
d) \(B_0 \sin(kx - \omega t) \hat{i}\)  
e) \(B_0 \sin(kz - \omega t) \hat{j}\)

4. A 12-\(\mu F\) capacitor \(C_1\) and a 6-\(\mu F\) capacitor \(C_2\) are connected as shown in the figure. If the charge \(Q_1 = 24\) \(\mu C\) on capacitor \(C_1\), what is the charge \(Q_2\) on capacitor \(C_2\)?

a) \(Q_2 = 6\) \(\mu C\)  
b) \(Q_2 = 12\) \(\mu C\)  
c) \(Q_2 = 24\) \(\mu C\)  
d) \(Q_2 = 36\) \(\mu C\)  
e) \(Q_2 = 48\) \(\mu C\)

5. A particle with charge \(q = -1\) C is moving in the +y-direction at 5 m/s. The magnetic field at its position is \(\vec{B} = (4\hat{i} + 3\hat{k})\) T. What is the magnetic force on the particle?

a) \(\vec{F} = (-20\hat{i} - 15\hat{k})\) N  
b) \(\vec{F} = (+15\hat{i} + 20\hat{k})\) N  
c) \(\vec{F} = (+15\hat{i} - 20\hat{k})\) N  
d) \(\vec{F} = (-15\hat{i} + 20\hat{k})\) N  
e) \(\vec{F} = (+20\hat{i} + 15\hat{k})\) N
6. You are originally given an inductor with inductance $L_1$ and current $I_1$ and potential energy $U_1$. You want to increase the potential energy stored in the inductor to $U_2 = 5U_1$. Which of the following changes would NOT increase the potential energy $U_2$ to $5U_1$?

   a) Increase the inductance by a factor of 5 and leave the current unchanged.
   b) Leave the inductance unchanged and increase the current by a factor of $\sqrt{5}$.
   c) Reduce the inductance by a factor of 5 and increase the current by a factor of 5.
   d) Leave the inductance unchanged and increase the current by a factor of 5.
   e) Reduce the inductance by a factor of 25 and increase the current by a factor of $5\sqrt{5}$.

7. What is the reactance $X_C$ of a capacitor with capacitance $C = 10 \ \mu F$ at a frequency $f = 30$ Hz?

   a) $X_C = [1/(6\pi)] \times 10^4 \ \Omega$
   b) $X_C = [1/(3)] \times 10^4 \ \Omega$
   c) $X_C = [1/(2\pi)] \times 10^4 \ \Omega$
   d) $X_C = 6\pi \times 10^{-5} \ \Omega$
   e) $X_C = 3 \times 10^{-5} \ \Omega$

8. An electromagnetic standing wave in a certain material has a frequency $f$ and a speed of propagation $v$. What is the distance $\Delta x$ between a nodal plane of $\vec{B}$ and the closest antinodal plane of $\vec{B}$?

   a) $\Delta x = v/f$
   b) $\Delta x = v/4f$
   c) $\Delta x = v/2f$
   d) $\Delta x = f/2v$
   e) $\Delta x = f/4v$

9. A 2-cm radius loop of $N = 100$ turns of wire lies in the plane of the paper. A magnetic field of $B=0.15$ T is introduced, pointing into the paper, in time $\Delta t=0.3$ s. What is the magnitude of the induced EMF and does the induced current flow clockwise or counterclockwise?

   a) $\mathcal{E} = 2\pi \times 10^{-2} \ \text{V};$ clockwise.
   b) $\mathcal{E} = 2\pi \times 10^{-4} \ \text{V};$ clockwise.
   c) $\mathcal{E} = 4\pi \times 10^{-2} \ \text{V};$ clockwise.
   d) $\mathcal{E} = 2\pi \times 10^{-2} \ \text{V};$ counterclockwise.
   e) $\mathcal{E} = 2\pi \times 10^{-4} \ \text{V};$ counterclockwise.

10. Which of the following statements is FALSE?

   a) The total electric flux through a closed surface is equal to $Q_{\text{enclosed}}/\epsilon_0$.
   b) The change in magnetic flux in a closed loop induces an EMF that opposes the change in magnetic flux.
   c) The energy flow rate (or power per unit area) in an electromagnetic wave is proportional to the product of the electric and magnetic field strengths with direction perpendicular to both.
   d) The magnetic force per unit length of two long, parallel, current-carrying conductors is repulsive if the currents are flowing in the opposite direction.
   e) The total magnetic flux through a closed surface is equal to $\mu_0 I_{\text{enclosed}}$. 

11. A coil with a self-inductance of $L=1$ H is connected in parallel to a light bulb with $R = 10$ $\Omega$ and a 5-V battery. Very roughly, how long ($\Delta t$) would the light bulb stay lit, if the battery were disconnected from the circuit? (Choose the closest answer).

   a) $\Delta t=10.0$ s
   b) $\Delta t=5.0$ s
   c) $\Delta t=0.05$ s
   d) $\Delta t=0.5$ s
   e) $\Delta t=0.001$ s
12. You are given an L-R-C circuit with given values of \( R \) and \( C \). If you double the value of \( L \), how does the new resonance curve differ from the original one?
   a) Both the peak height and the peak frequency double.
   b) The peak height will be half as great and the peak frequency will double.
   c) The peak height will not change and the peak frequency will be \( 1/\sqrt{2} \) times as great.
   d) The peak height will not change and the peak frequency will double.
   e) The peak height will not change and the peak frequency will be \( \sqrt{2} \) as great.

13. The figure displays two large parallel conducting plates of width \( w \), with a small separation \( d \) between them. A current \( I \) flows uniformly across each plate, in opposite directions. What is the strength of the magnetic field \( B \) induced between the plates?
   a) \( B = \mu_0 I/d \)
   b) \( B = \mu_0 I/w \)
   c) \( B = \mu_0 Id/w \)
   d) \( B = \mu_0 I \)
   e) \( B = \mu_0 Iwd \)

14. The figure shows the uniform magnetic field inside a long, straight solenoid. The field is directed into the plane of the drawing and is INCREASING. What is the direction of the electric force \( \vec{F} \) on a positive point charge placed at the point \( a \)?
   a) \( \vec{F} = 0 \)
   b) \( \vec{F} \) is straight up.
   c) \( \vec{F} \) is to the left.
   d) \( \vec{F} \) is to the right.
   e) \( \vec{F} \) is straight down.

15. A current \( I \) flows around a plane circular loop of radius \( r \) giving the loop a magnetic moment of magnitude \( m \). Initially, the loop is placed in a uniform magnetic field \( \vec{B} \) with an angle \( \phi \) between the direction of the field lines and the magnetic dipole moment of the loop, as shown in the figure. What is the change in potential energy \( \Delta U \) between the final configuration when the magnetic moment is aligned with \( \vec{B} \) and the initial configuration?
   a) \( \Delta U_B = -mB(1-\sin \phi) \)
   b) \( \Delta U_B = -mB \cos \phi \)
   c) \( \Delta U_B = +mB(1-\cos \phi) \)
   d) \( \Delta U_B = -mB(1-\cos \phi) \)
   e) \( \Delta U_B = -mB(1+\cos \phi) \)
16. Consider an R-L circuit (with resistance \( R \) and inductance \( L \)) with a DC voltage source, as shown in the figure. The circuit has a current \( I_0 \) when \( t < 0 \). At time \( t = 0 \) the switch is thrown, removing the DC voltage source from the circuit. The current decays to \( I(t) \) at time \( t \). At time \( t \), what is the power \( P_R(t) \) flowing into the resistor?

\[
\begin{align*}
a. & \quad P_R(t) = R I_0^2 \exp(-2t/\tau), \\
& \quad \text{where } \tau = R/L \\
b. & \quad P_R(t) = R I_0^2 \exp(-2t/\tau), \\
& \quad \text{where } \tau = L/R \\
c. & \quad P_R(t) = R I_0^2 \exp(-t/\tau), \\
& \quad \text{where } \tau = R/L \\
d. & \quad P_R(t) = R I_0^2 \exp(-t/\tau), \\
& \quad \text{where } \tau = L/R \\
e. & \quad P_R(t) = R I_0^2 \exp(-2t/\tau), \\
& \quad \text{where } \tau = L/R
\end{align*}
\]

17. You are given four transformers with the following properties for their primary \( V_p \) voltages and primary \( N_p \) and secondary \( N_s \) number of turns.

- \( V_1p=120 \text{ V}, N_1p=500 \text{ turns}, N_1s=2000 \text{ turns} \)
- \( V_2p=240 \text{ V}, N_2p=1000 \text{ turns}, N_2s=2000 \text{ turns} \)
- \( V_3p=240 \text{ V}, N_3p=1000 \text{ turns}, N_3s=500 \text{ turns} \)
- \( V_4p=480 \text{ V}, N_4p=2000 \text{ turns}, N_4s=1000 \text{ turns} \)

The current on the primary side of each transformer is \( I_{rms,p} \). Rank the \( I_{rms,s} \) secondary current for each transformer.

\[
\begin{align*}
a) & \quad I_{1rms,s} = I_{2rms,s} = I_{3rms,s} = I_{4rms,s} \\
b) & \quad I_{1rms,s} < I_{2rms,s} < I_{3rms,s} < I_{4rms,s} \\
c) & \quad I_{1rms,s} < I_{2rms,s} < I_{3rms,s} = I_{4rms,s} \\
d) & \quad I_{1rms,s} < I_{2rms,s} = I_{3rms,s} < I_{4rms,s} \\
e) & \quad I_{1rms,s} = I_{2rms,s} < I_{3rms,s} = I_{4rms,s}
\end{align*}
\]

18. In the circuit shown, what is the current \( I \) through the 2 \( \Omega \) resistor?

\[
\begin{align*}
a) & \quad I = 1.5 \text{ A} \\
b) & \quad I = 1.0 \text{ A} \\
c) & \quad I = 2.0 \text{ A} \\
d) & \quad I = 3.0 \text{ A} \\
e) & \quad I = 2.5 \text{ A}
\end{align*}
\]

19. A uniform electric field has a magnitude \( E \) and is directed in the negative \( x \) direction. The potential difference is of magnitude \( V = 300 \text{ V} \) between point \( a \) at \( x_a=0.70 \text{ m} \) and point \( b \) at \( x_b=0.85 \text{ m} \). Which of the following statements is TRUE?

\[
\begin{align*}
a) & \quad E = 2000 \text{ N/C} \text{ and the point } b \text{ is at higher potential.} \\
b) & \quad E = 2000 \text{ N/C} \text{ and the point } a \text{ is at higher potential.} \\
c) & \quad E = 200 \text{ N/C} \text{ and the point } b \text{ is at higher potential.} \\
d) & \quad E = 300 \text{ N/C} \text{ and the point } a \text{ is at higher potential.} \\
e) & \quad E = 300 \text{ N/C} \text{ and the point } b \text{ is at higher potential.}
\end{align*}
\]
20. The figure shows an electric dipole in a uniform electric field \( \vec{E} \) of magnitude \( E = 5.0 \times 10^5 \text{ N/C} \) that is directed parallel to the plane of the figure. The charges are of magnitude \( Q = 1.0 \mu \text{C} \) and are separated by a distance \( d = 1.0 \times 10^{-3} \text{ m} \). This electric dipole makes an angle \( \theta \) with the \( \vec{E} \) field as shown in the figure. What are the magnitude and direction of the torque \( \vec{\tau} \) on the electric dipole?

a) \( \vec{\tau} = 5.0 \times 10^{-4} \sin 145^\circ \text{ N-m}; \) clockwise.
b) \( \vec{\tau} = 5.0 \times 10^{-4} \cos 35^\circ \text{ N-m}; \) counterclockwise.
c) \( \vec{\tau} = 5.0 \times 10^{-4} \sin 145^\circ \text{ N-m}; \) counterclockwise.
d) \( \vec{\tau} = 5.0 \times 10^{-2} \cos 35^\circ \text{ N-m}; \) clockwise.
e) \( \vec{\tau} = 5.0 \times 10^{-2} \sin 145^\circ \text{ N-m}; \) counterclockwise.

21. A 300-V DC power supply is used to charge a 4 \( \mu \text{F} \) capacitor. After the capacitor is fully charged, it is disconnected from the power supply and connected across a 10 mH inductor. The resistance in the circuit is negligible. What is the frequency \( f \) of oscillation of the circuit?

a) \( f = 5 \times 10^3 \text{ Hz} \)
b) \( f = (5/2\pi) \times 10^3 \text{ Hz} \)
c) \( f = 10\pi \times 10^3 \text{ Hz} \)
d) \( f = 2.5 \times 10^7 \text{ Hz} \)
e) \( f = (1/8\pi) \times 10^7 \text{ Hz} \)

22. In a large room, the intensity of light is \( I \) and it is uniformly distributed throughout the room. If the room is \( L \) meters long, \( W \) meters wide, and \( H \) meters high, how much energy \( U \) is stored in the room in the form of light waves?

a) \( U = \frac{1}{2}LI^2 \)
b) \( U = \frac{I}{c} \)
c) \( U = cILWH \)
d) \( U = ILWH/c \)
e) \( U = \epsilon_0I^2LWH/2 \)

23. The electric field lines arising from the two charges \( Q_1 \) and \( Q_2 \) are shown in the figure. Point \( P_1 \) is at the midpoint of the line joining \( Q_1 \) and \( Q_2 \). Point \( P_2 \) is to the right of \( Q_2 \), as shown in the figure. Which of the following is a TRUE statement about this figure?

a. Both \( Q_1 \) and \( Q_2 \) have the same sign.
b. The electric field could be zero at \( P_2 \).
c. The electric field could be zero at \( P_1 \).
d. \( |Q_1| > |Q_2| \).
e. \( Q_1 = -Q_2 \).
24. In the figure, a very small, charged, metal sphere with charge $+Q_0$ is placed inside a thin conducting spherical shell of radius $B$ without touching it. Two gaussian spheres of radius $A$ and $C$ are used to find the net electric flux inside and outside of the shell. If the electric flux $\Phi_C$ through the outer gaussian surface is three times the electric flux $\Phi_A$ through the inner gaussian surface, what are the charges $Q_1$ on the inner and $Q_2$ on the outer surfaces of the conducting shell?

a) $Q_1 = +2Q_0$, $Q_2 = -3Q_0$

b) $Q_1 = +Q_0$, $Q_2 = -3Q_0$

c) $Q_1 = -Q_0$, $Q_2 = +2Q_0$

d) $Q_1 = -Q_0$, $Q_2 = -3Q_0$

e) $Q_1 = -Q_0$, $Q_2 = +3Q_0$

25. A dielectric-filled parallel-plate capacitor has plate area $A$, plate separation $d$ and is filled with a material with dielectric constant $K$. The capacitor is connected to a battery that creates a constant voltage $V$. The dielectric plate is now slowly pulled out of the capacitor, which remains connected to the battery. What is the energy $U$ stored in the capacitor at the moment when the capacitor is half-filled with the dielectric?

a) $U = K\epsilon_0 AV^2/d$

b) $U = (K + 1)\epsilon_0 AV^2/2d$

c) $U = K\epsilon_0 AV^2/4d$

d) $U = K\epsilon_0 AV^2/d$

e) $U = (K + 1)\epsilon_0 AV^2/4d$

26. An inductance $L$ and a resistance $R$ are connected to a source of EMF as shown in the Figure. When a switch $S_1$ is closed, a current begins to flow. Which statement is TRUE?

a) The final value of the current $i$ is directly proportional to $R/L$.

b) The final value of the current $i$ is directly proportional to $RL$.

c) The final value of the current $i$ is directly proportional to $L/R$.

d) The final value of the current $i$ is independent of $L$.

e) The final value of the current $i$ is independent of $R$.

27. A radio wave of frequency $f = 10^7$ Hz hits a perfectly absorbing planar surface that is perpendicular to the direction of propagation of the wave. The average power per unit area of the wave at the position where it is absorbed is $3 \text{ W/m}^2$. What is the radiation pressure $p_{rad}$ on the surface?

a) $p_{rad} = 1.0 \times 10^{-8} \text{ N/m}^2$

b) $p_{rad} = 2.0 \times 10^{-8} \text{ N/m}^2$

c) $p_{rad} = \frac{\pi}{2} \times 10^{-8} \text{ N/m}^2$

d) $p_{rad} = \frac{1}{3} \times 10^{-8} \text{ N/m}^2$

e) $p_{rad} = 3.0 \times 10^{-8} \text{ N/m}^2$
28. The figure displays a square with sides equal to $2a$. The charges are placed as shown in the figure. Each charge has the same magnitude $-Q$. What are the electrostatic potential $V$ and the electric field $E$ at the location marked with an “x”? Assume that the reference point for $V$ is at infinity.

a) $V = 4kQ/a; E = 0$
b) $V = -4kQ/a; E = 0$
c) $V = -4kQ/a; E = -4kQ/a^2$
d) $V = 0; E = 0$
e) $V = 0; E = -4kQ/a^2$

29. You are given two metals. Metal A has $\rho_A = 20 \times 10^{-8} \text{ } \Omega \cdot \text{m}$ with diameter $d_A = 6 \text{ mm}$. The wire of metal B has diameter $d_B = 3 \text{ mm}$. If both of the wires have the same length and resistance, what is the resititivit $\rho_B$ of Metal B?

a) $\rho_B = 10 \times 10^{-8} \text{ } \Omega \cdot \text{m}$
b) $\rho_B = 5 \times 10^{-8} \text{ } \Omega \cdot \text{m}$
c) $\rho_B = 20 \times 10^{-8} \text{ } \Omega \cdot \text{m}$
d) $\rho_B = 80 \times 10^{-8} \text{ } \Omega \cdot \text{m}$
e) $\rho_B = 40 \times 10^{-8} \text{ } \Omega \cdot \text{m}$

30. The figure shows the path of a negatively charged particle with magnitude $Q_1$, mass $m$ and velocity $v$ in the region of a uniform magnetic field with magnitude $B$. The path of this particle has radius $r_1$. If we replace the original particle with a positively charged particle with magnitude $Q_2 = 2Q_1$ and the same mass $m$ and same velocity $v$, what are the radius $r_2$ and direction of the path of the second particle?

a. $r_2 = 2r_1$ and up.
b. $r_2 = r_1$ and down.
c. $r_2 = 2r_1$ and down.
d. $r_2 = r_1/2$ and up.
e. $r_2 = r_1/2$ and down.