Physics 227 – Final Exam
Friday, May 10, 2019

Your name with exam code

Your signature

Turn off and put away ALL electronic devices NOW. NO cell phones, NO smart watches, NO calculators.

1. The exam will last from 4:00 to 7:00 PM.
   Use a #2 pencil to make entries in the circles at the bottom of the cover sheet.

2. Make sure your name and RU ID are correct on the cover page. CAREFULLY detach the cover sheet (with your name, ID and the answer circles).

3. During the exam, you may use pencils, NO calculator. and THREE 8 1/2” x 11” sheets of paper with handwritten (both sides) equations and notes.

No marks except filled in answer circles below the line, please.
4. There are 30 multiple-choice questions on the exam. For each question, mark only ONE and only one answer on the answer sheet. There is no subtraction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess.

5. Before starting the exam, make sure that your copy contains all 30 questions and the information pages. Bring your exam to the proctor if this is not the case.

6. At the end of the exam, hand in only the cover sheet. Retain the question sheets for future reference and study.

9. If you have questions or problems during the exam, you may raise your hand and a proctor will assist you. We will provide the value of physical constants that are needed. It is your responsibility to know the relevant equations.

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, show your student ID to a proctor, hand in only the cover sheet.
Possibly useful constants:
\[ \varepsilon_0 = 1/\mu_0 c^2 = 8.85 \times 10^{-12} \text{ C}^2/\text{N \cdot m}^2 \]
\[ k = 1/4\pi \varepsilon_0 = 8.99 \times 10^9 \text{ N \cdot m}^2/\text{C}^2 \]
\[ c \text{ speed of light} = 3.00 \times 10^8 \text{ m/s} \]
\[ q_{\text{electron}} = q_{\text{proton}} = 1.602 \times 10^{-19} \text{ C} \]
\[ m_{\text{electron}} = \text{electron mass} = 9.11 \times 10^{-31} \text{ kg} \]
\[ m_{\text{proton}} = \text{proton mass} = 1.67 \times 10^{-27} \text{ kg} \]
\[ \mu_0 = 4\pi \times 10^{-7} \text{ T \cdot m/A} = 12.57 \times 10^{-7} \text{ T \cdot m/A} \]
\[ 1 \text{ eV} = 1.602 \times 10^{-19} \text{ J} \]

Circumference of a circle = \(2\pi r\); area of a circle is \(\pi r^2\)
Surface area of a sphere = \(4\pi r^2\); volume of a sphere = \(\frac{4}{3} \pi r^3\)
Surface area of a cylinder = \(2\pi rh + 2\pi r^2\); volume of cylinder = \(\pi r^2h\)
\[ \sin(0^\circ) = \cos(90^\circ) = 0 \]
\[ \sin(90^\circ) = \cos(0^\circ) = 1 \]
\[ \sin(30^\circ) = \cos(60^\circ) = 1/2 \]
\[ \sin(60^\circ) = \cos(30^\circ) = \sqrt{3}/2 \]
\[ \sin(45^\circ) = \cos(45^\circ) = \sqrt{2}/2 \]
\[ \frac{d}{dx} x^n = nx^{n-1} \]

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

\[ \frac{d}{dx} \sin(ax) = a \cos(ax) \]

\[ \frac{d}{dx} \cos(ax) = -a \sin(ax) \]

\[ \int \sin(ax) dx = -\cos(ax)/a \]
\[ \int \cos(ax) dx = \sin(ax)/a \]

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. When a magnet is plunged into a coil at speed \( v \), as shown in the figure, a voltage \( V_1 \) is induced in the coil and a current flows in the circuit. If the speed at which the magnet falls is doubled, how is the induced voltage \( V_2 \) related to the original \( V_1 \)?

\[
V = -\frac{d\Phi_B}{dt} \quad \text{d/dt doubles} \implies V_2 = 2V_1
\]

- a) \( V_2 = V_1 \)
- b) \( V_2 = 2V_1 \)
- c) \( V_2 = V_1/2 \)
- d) \( V_2 = V_1/4 \)
- e) \( V_2 = 4V_1 \)

2. An \( L - R \) circuit is displayed in the figure. Initially the switch connects a resistor of resistance \( R \) and an inductor to a battery, and a current \( I_0 \) flows through the circuit. At time \( t = 0 \) the switch is thrown open with the motion indicated by the arrow, removing the battery from the circuit. At time \( t_1 \) the current in the circuit has decayed to \( I_1 \). In terms of the quantities given, what is the time constant \( \tau \) of the circuit?

\[
I_1 = I_0 e^{-t_1/\tau}
\]

- a) \( \tau = t_1 \)
- b) \( \tau = LR \)
- c) \( \tau = t_1/(I_0/I_1) \)
- d) \( \tau = t_1/(ln(I_0/I_1)) \)
- e) \( \tau = R/L \)

\[
\frac{I_0}{I_1} = e^{t_1/\tau}
\]

\[
\ln \left( \frac{I_0}{I_1} \right) = \frac{t_1}{\tau}
\]

\[
\tau = t_1/\ln \left( \frac{I_0}{I_1} \right)
\]
3. A capacitor with capacitance $C$ and an inductor with inductance $L$ are connected in parallel to an AC source. Which of the following statements about the magnitude of the current through the voltage source is TRUE?

- (a) The current through the voltage source is always larger than the sum of the magnitudes of the currents in the capacitor and inductor. **FALSE**
- (b) The current through the voltage source is always less than the sum of the magnitudes of the currents in the capacitor and inductor. **TRUE**
- (c) The current through the voltage source is small at very high frequencies. **FALSE**
- (d) The current through the voltage source is small at very low frequencies. **FALSE**
- (e) The current through the voltage source is zero when the frequency $\omega = \frac{1}{LC}$. **FALSE**

4. Which of the following statements is TRUE about an electromagnetic wave at a given point in space?

- (a) The electric and magnetic fields oscillate out of phase so that the energy density at that point alternates between electric and magnetic, with the total constant. **FALSE**
- (b) The electric and magnetic fields oscillate in phase, with the electric field pointing in the direction of the propagation of the wave. **FALSE**
- (c) The electric and magnetic fields are proportional to each other in magnitude, but are perpendicular to each other. **TRUE**
- (d) The electric field lags behind the magnetic field by 90° because it is the changing magnetic flux which produces the electric field. **FALSE**
- (e) The electric field is constant while the magnetic field oscillates at the frequency of the wave. **FALSE**

$E$ and $B$ waves oscillate in phase. And perpendicular to direction of propagation. $E = cB$
5. The electric field for a plane electromagnetic wave traveling in the +y direction is shown in the figure. Consider a point where \( \vec{E} \) is in the +z direction.

Which of the following statements is TRUE?

(a) The \( \vec{B} \) field is in the +x direction and in phase with the \( \vec{E} \) field. \( \text{TRUE} \)
(b) The \( \vec{B} \) field is in the -x direction and in phase with the \( \vec{E} \) field. \( \text{FALSE} \)
(c) The \( \vec{B} \) field is in the +x direction and one-fourth of a cycle out of phase with the \( \vec{E} \) field. \( \text{FALSE} \)
(d) The \( \vec{B} \) field is in the +z direction and in phase with the \( \vec{E} \) field. \( \text{FALSE} \)
(e) The \( \vec{B} \) field is in the +z direction and one-fourth of a cycle out of phase with the \( \vec{E} \) field. \( \text{FALSE} \)

6. When an electric dipole in a uniform electric field rotates to become more nearly aligned with the field, which of the following is TRUE?

(a) The field does positive work and the potential energy increases. \( \text{TRUE} \)
(b) The field does positive work and the potential energy decreases. \( \text{FALSE} \)
(c) The field does negative work and the potential energy increases. \( \text{FALSE} \)
(d) The field does negative work and the potential energy decreases. \( \text{FALSE} \)
(e) The field does no work. \( \mathbf{U}_E = - \mathbf{P} \cdot \mathbf{E} \)

7. Four identical resistors with resistance \( R \) are connected to an ideal battery of voltage \( V = 10 \text{ V} \) as shown in the figure. The current \( I = 0.20 \text{ A} \). What is the value of the resistance \( R \) of the resistors?

\[
R_{eq} = \frac{\frac{2R}{3} + R}{\frac{3}{3}} = \frac{5R}{3} \]
\[
R_{eq} = \frac{V}{I} = \frac{10 \text{ V}}{0.2 \text{ A}} = 50 \Omega = \frac{5R}{3} \Rightarrow R = 30 \Omega
\]
8. In an $x - y - z$-coordinate system, a plane of infinite extent with uniform surface charge density $+\sigma$ lies in the $x - y$-plane ($z=0$). Which graph best represents the $z$-component of the electric field $E$ as a function of $z$ along the $z$-axis?
\[ E = I \mathcal{E}(N \times \mathcal{B}) \cdot d\ell \]
only want magnitude = \( I \propto |\mathcal{B}| \)

Four identical vertical metal bars start at the positions shown in the figure and move at constant velocities through identical magnetic fields. The bars make electrical contact with and move along frictionless metal rods attached to light bulbs. At the instant shown, rank these four scenarios on the basis of the magnitude of the current \( I \) in the light bulb.

- a) \( I_D > I_B > I_A > I_C \)
- b) \( I_D > I_A > I_B > I_C \)
- c) \( I_A = I_D > I_B > I_C \)
- d) \( I_D = I_B > I_A > I_C \)
- e) \( I_D > I_B > I_C > I_A \)

\[ \mathbf{v}_A > \mathbf{v}_D > \mathbf{v}_B > \mathbf{v}_C \]

10. The circuit in the figure contains a capacitor of capacitance \( C \) and inductor of inductance \( L \). The resistance of all wires is considered negligible. Initially, the switch is open and the capacitor has a charge \( q_0 \). The switch is then closed at \( t = 0 \). Assume that the period of the oscillations \( T = 8.0 \) ms.

At what time \( t \) does the current in this circuit reach its maximum value for the first time?

- a) \( t = 0.0 \) ms
- b) \( t = 8.0 \) ms
- c) \( t = 6.0 \) ms
- d) \( t = 2.0 \) ms
- e) \( t = 4.0 \) ms

\[ T/4 = 8 \sqrt{\frac{\mu_0}{4}} = 2 \text{ ms}. \]
11. An AC generator supplies \( V_1 = 100 \) V to the primary coil of a transformer. The primary has 50 turns and the secondary has 500 turns. What is the secondary voltage \( V_2 \)?

\[
\begin{align*}
\text{a)} & \quad V_2 = 1000 \text{ V} \\
\text{b)} & \quad V_2 = 500 \text{ V} \\
\text{c)} & \quad V_2 = 250 \text{ V} \\
\text{d)} & \quad V_2 = 100 \text{ V} \\
\text{e)} & \quad V_2 = 10 \text{ V}
\end{align*}
\]

\[
\frac{V_2}{V_1} = \frac{\text{500}}{\text{50}} = 10
\]

\[
V_2 = 10V_1 = 1000 \text{ V}
\]

12. When an electromagnetic wave falls on a perfectly absorbing surface it exerts a force \( F_1 \) on that surface. If the surface is now replaced by a perfectly reflecting surface, what will be the force \( F_2 \) that the same wave will exert on the surface?

\[
\text{Prad (absorbing surface)} = \frac{F_1}{A} = \frac{P}{c}.
\]

\[
\text{Prad (reflective surface)} = \frac{P}{c} = 2 \frac{P}{c} \quad \text{above} \quad \text{(Surf.)}
\]

\[
F_2 = 2F_1
\]

13. The table below gives the electric flux in \( \text{N-m}^2/\text{C} \) through the ends and curved surfaces of four gaussian surfaces in the form of cylinders. (The "+" sign means "in", and the "+" sign means "in"). Rank the cylinders according to the charge \( Q \) inside, from the most negative to the most positive.

\[
\Phi_E = \Phi_{\text{left end}} = \Phi_L + \Phi_R + \Phi_C
\]

<table>
<thead>
<tr>
<th>Cylinder</th>
<th>Left End</th>
<th>Right End</th>
<th>Curved Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+2 \times 10^{-9}</td>
<td>+4 \times 10^{-9}</td>
<td>-6 \times 10^{-9}</td>
</tr>
<tr>
<td>2</td>
<td>+3 \times 10^{-9}</td>
<td>-2 \times 10^{-9}</td>
<td>+6 \times 10^{-9}</td>
</tr>
<tr>
<td>3</td>
<td>-2 \times 10^{-9}</td>
<td>-5 \times 10^{-9}</td>
<td>+3 \times 10^{-9}</td>
</tr>
<tr>
<td>4</td>
<td>+2 \times 10^{-9}</td>
<td>-5 \times 10^{-9}</td>
<td>-3 \times 10^{-9}</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
\text{a)} & \quad Q_1 < Q_2 < Q_3 < Q_4 \\
\text{b)} & \quad Q_4 < Q_3 < Q_1 < Q_2 \\
\text{c)} & \quad Q_3 < Q_1 < Q_4 < Q_2 \\
\text{d)} & \quad Q_4 < Q_3 < Q_2 < Q_1 \\
\text{e)} & \quad Q_3 < Q_4 < Q_2 < Q_1 \\
\end{align*}
\]

\[
\begin{align*}
Q_1 \propto (+2) + (+4) + (-6) = 0 \\
Q_2 \propto (+3) + (-2) + (+6) = +7 \\
Q_3 \propto (-2) + (-5) + (+3) = -4 \\
Q_4 \propto (+2) + (-5) + (-3) = -6
\end{align*}
\]

\[
Q_4 < Q_3 < Q_1 < Q_2
\]
14. A particle with charge $q = -1 \text{ C}$ is moving in the positive $+z$-direction at 5 m/s. The magnetic field at its position is $\mathbf{B} = (4\hat{i} + 3\hat{j}) \text{ T}$. What is the magnetic force on the particle?

a) $\mathbf{F} = (-20\hat{i} - 15\hat{j}) \text{ N}$

b) $\mathbf{F} = (+15\hat{i} + 20\hat{j}) \text{ N}$

c) $\mathbf{F} = (+15\hat{i} - 20\hat{j}) \text{ N}$

d) $\mathbf{F} = (-15\hat{i} + 20\hat{j}) \text{ N}$

e) $\mathbf{F} = (+20\hat{i} + 15\hat{j}) \text{ N}$

$$\mathbf{F}_x = q\nu_x B_z = (-1)(+5)(-3) = +15 \hat{i}$$

$$\mathbf{F}_y = q\nu_y B_x = (-1)(+5)(+4) = -20 \hat{j}$$

15. In the figure a circular loop of wire is in a region of a spatially uniform magnetic field. The field is directed into the plane of the figure. If the magnetic field magnitude is decreasing, which of the following statements about the induced EMF is correct?

![Diagram of a circular loop with magnetic field lines](image)

a) The induced EMF in the loop can only be counter-clockwise.

b) The induced EMF in the loop could clockwise or counter-clockwise.

c) The induced EMF in the loop is zero.

d) The induced EMF in the loop could clockwise or counter-clockwise or zero.

e) The induced EMF in the loop can only be clockwise.

**Induced EMF from induced \( \mathbf{B} \):**

- Opposes change in magnetic flux
- \( \mathbf{B} \) decreasing into the page

$\Rightarrow$ Induced into the page $\Rightarrow$ Clockwise, induced EMF
16. As shown in the figure a long solenoid with cross-sectional area $A_1$ and length $L_1$ is wound with $N_1$ turns of wire. A time-varying current $i_1$ flows through this wire. A shorter coil of cross-sectional area $A_2$ and length $L_2$ with $N_2$ turns of wire surrounds it. What is the mutual inductance $M$ of this configuration?

\[
\Phi_B = \int_B = \mu_0 N_1 I A_1
\]

\[
M = N_2 \frac{\Phi_B}{I}
\]

\[
M = \frac{\mu_0 N_1 N_2 A_1}{L_1}
\]

\[
M = \frac{\mu_0 N_1 A_1}{L_1}
\]

\[
M = \frac{\mu_0 N_1 N_2 A_1}{L_1}
\]

\[
M = \frac{\mu_0 N_1 N_2 A_1}{L_1}
\]

17. Which of the curves best describes the relationship between the magnetization and the applied B-field for a ferromagnetic material?

a) \[\begin{array}{c}
\text{M} \\
\text{B_a}
\end{array}\]

b) \[\begin{array}{c}
\text{M} \\
\text{B_a}
\end{array}\]

c) \[\begin{array}{c}
\text{M} \\
\text{B_a}
\end{array}\]

d) \[\begin{array}{c}
\text{M} \\
\text{B_a}
\end{array}\]

e) \[\begin{array}{c}
\text{M} \\
\text{B_a}
\end{array}\] with hysteresis from ferromagnet

18. In vacuum the velocity of an electromagnetic wave \[\begin{array}{c}
= \text{speed of light} \\
= \text{universal constant}
\end{array}\]

a) depends on its frequency.

b) depends on its amplitude.

c) none of the others is true.

d) depends upon its wavelength.

e) is a universal constant.
19. Which of the following statements is FALSE?

a) The algebraic sum of the potential differences in any loop must equal zero. **TRUE**

b) When two resistors are in parallel the equivalent resistance is always less than when the two resistors are in series. **TRUE**

c) The net torque on a current loop in a uniform magnetic field is always equal to zero. **FALSE** The torque is not necessarily zero.

d) For a tightly wound toroidal solenoid (toroid) with N turns, the magnetic field outside of the space enclosed by the windings is **TRUE**.

e) The resistance of a wire made from a particular conductor decreases when the cross sectional area increases. **TRUE**

20. In which of these circuits will the light bulb B be the brightest? [Assume the battery has no internal resistance.]

- **Circuit 1**
- **Circuit 2**
- **Circuit 3**

a) The light bulb B will be brightest in Circuit 2

b) The light bulb B will be brightest in Circuits 1 and 2

c) The light bulb B will be brightest in Circuits 1 and 3

d) The light bulb B will be brightest in Circuits 2 and 3

e) The light bulb B will have the same brightness in all three circuits.

21. At a certain instant the current flowing though a \( L = 5.0 \) H inductor is \( I = 3.0 \) A. If the energy in the inductor at this instant is increasing at a rate of \( dU/dt = 3.0 \) J/s, what is \( dI/dt \), the rate at which the current is changing?

\[
U = \frac{1}{2} LI^2
\]

a) \( dI/dt = 1/3 \) A/s

b) \( dI/dt = 1/5 \) A/s

c) \( dI/dt = 1/10 \) A/s

d) \( dI/dt = 1/4 \) A/s

e) \( dI/dt = 1/2 \) A/s

\[
\frac{dU}{dt} = \frac{1}{2} L (2) I \frac{dI}{dt}
\]

\[
\frac{dI}{dt} = \frac{dU}{L \frac{dI}{dt}} \Rightarrow \frac{dI}{dt} = \frac{1}{2} \frac{dU}{5H(3A)} = \frac{1}{5} A/s
\]
22. The rectangular loop of wire in the figure is being moved to the right at a constant velocity. A constant current $I$ flows in the long wire in the direction shown. What are the directions of the magnetic forces on the left-hand (L) and right-hand (R) sides of the loop?

\[ F = I L B \]

- Left wire: $F$ to the left.
- Right wire: $F$ to the right.

![Diagram with magnetic forces and induced fields]

- $B_{\text{from wire}}$ (induced)
- $B_{\text{from wire}}$
- $I_{\text{induced}}$
- $I_{\text{induced}}$

a) The magnetic force on L is to the left; the magnetic force on R is to the left.
b) The magnetic force on L is to the left; the magnetic force on R is to the right.
c) The magnetic force on L is to the right; the magnetic force on R is to the left.
d) The magnetic force on L is to the right; the magnetic force on R is to the right.
e) The magnetic force on L is zero; the magnetic force on R is zero.
23. 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?

![Electrical Circuit Diagram](image)

Final value of current $i$ is $E/R$, independent of $L$.

- 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 $R$.

24. The figure describes a phasor analysis of a parallel AC circuit containing a resistor, a capacitor, and an inductor. The voltage across each of these elements of the circuit is the same, represented by the vector labeled $V_0$. Which vectors represent the currents in the resistor $I_R$, the capacitor ($I_C$), and the inductor $I_L$?

- For resistor, $I_R$ in phase with $V$.
- For capacitor, $I_C$ leads $V_0$.
- For inductor, $I_L$ lags the voltage.

![Phasor Diagram](image)

- a) $I_R = I_1$, $I_C = I_2$, $I_L = I_3$
- b) $I_R = I_1$, $I_C = I_3$, $I_L = I_4$
- c) $I_R = I_1$, $I_C = I_4$, $I_L = I_2$
- d) $I_R = I_1$, $I_C = I_2$, $I_L = I_4$
- e) $I_R = I_1$, $I_C = I_3$, $I_L = I_1$

- $I_R = I_1$, $I_C = I_2$, and $I_L = I_4$.
25. A long solenoid of length \( L \) has a magnetic field \( B \) in its interior. If the solenoid coil carries current \( I \), what is the number of turns \( N \) in the coil?

\[
\begin{align*}
&\text{a) } N = \frac{BL}{(\mu_0 I)} \\
&\text{b) } N = \frac{BL}{I} \\
&\text{c) } N = \frac{B}{(\mu_0 I)} \\
&\text{d) } N = \frac{\mu_0 B}{I} \\
&\text{e) } N = \frac{\mu_0 B L}{I}
\end{align*}
\]

26. The capacitors in the network shown in the figure all have a capacitance of \( C = 4.0 \, \mu\text{F} \). What is the equivalent capacitance, \( C_{ab} \) of this capacitor network?

\[
\begin{align*}
\frac{1}{C_{eq}} &= \frac{1}{C} + \frac{2}{3C} = \frac{5}{3C} \\
C_{eq} &= \frac{3C}{5} = \frac{3(4)}{5} = 2.4 \, \mu\text{F}
\end{align*}
\]

27. A metal ring 2-cm in radius is placed between the north and south poles of large magnets with the plane of its area perpendicular to the magnetic field. These magnets produce an initial uniform magnetic field of \( B_0 = 1 \, \text{T} \) between them. The magnets are gradually pulled apart, causing this field to remain uniform but decrease steadily at 0.2 T/s. What is the magnitude of the electric field \( E \) induced in the ring?

\[
\begin{align*}
&\text{a) } E = 1 \times 10^{-2} \, \text{V/m} \\
&\text{b) } E = 2 \times 10^{-2} \, \text{V/m} \\
&\text{c) } E = 4 \times 10^{-3} \, \text{V/m} \\
&\text{d) } E = 2 \times 10^{-3} \, \text{V/m} \\
&\text{e) } E = 1 \times 10^{-3} \, \text{V/m}
\end{align*}
\]

\[
E = \frac{2 \times 10^{-3}}{\text{V/m}}
\]

28. A standing electromagnetic wave in a certain material has a frequency of \( 3 \times 10^{10} \, \text{Hz} \). The nodal planes of magnetic field \( \vec{B} \) are a distance 2.0 mm apart. What is the speed \( v \) of the electromagnetic wave in this medium?

\[
\begin{align*}
&\text{a) } v = 6.0 \times 10^7 \, \text{m/s} \\
&\text{b) } v = 3.0 \times 10^7 \, \text{m/s} \\
&\text{c) } v = 6.0 \times 10^6 \, \text{m/s} \\
&\text{d) } v = 12.0 \times 10^7 \, \text{m/s} \\
&\text{e) } v = 12.0 \times 10^8 \, \text{m/s}
\end{align*}
\]
29. Consider the circuit in the figure. $\varepsilon = 10 \text{ V}$, $R = 150 \text{ } \Omega$, $C = 5 \mu\text{F}$. The capacitor is initially uncharged. Just after the switch is closed, what is the current $I$ through the resistor?

\[ V = IR \]
\[ \Rightarrow I = \frac{10U}{150 \Omega} = \frac{1}{15} \text{ A} \]

a) $I = 1.0 \text{ A}$  
b) $I = 5.0 \text{ A}$  
c) $I = 0 \text{ A}$  
d) $I = 15 \text{ A}$  
e) $I = 1/15 \text{ A}$

30. An assembly of two point charges consists of a charge $+q$ at $x = -a$ and a charge of $-q$ at $x = +a$. The potential energy of this configuration is $U_1$. A third $+q$ point charge is brought in from $y = \infty$ along the $y$-axis to make an equilateral triangle. What is the potential energy $U_2$ of this final configuration?

\[ U_1 = -\frac{kq^2}{2a} \]

a) $U_2 = U_1$  
b) $U_2 = \frac{1}{2}U_1$  
c) $U_2 = 2U_1$  
d) $U_2 = \frac{3}{2}U_1$  
e) $U_2 = \frac{2}{3}U_1$

\[ U_2 = \frac{kq^2}{2a} - \frac{kq^2}{2a} - \frac{kq^2}{2a} \]
\[ = -\frac{kq^2}{2a} = U_1 \]