SHOW YOUR WORK

PRINT NAME _______________

HONOR PLEDGE: I pledge my honor that I have neither given nor received improper aid on this exam. I further pledge that, if I have reason to suspect that the Code has been violated, I have taken or will take action as specified in the Honor Code.

SIGNATURE ____________________________
\( \epsilon_o = 8.85 \times 10^{-12} \text{ C}^2 / \text{N} \cdot \text{m}^2 \)
\( 1 \text{eV} = 1.6 \times 10^{-19} \text{J} \)
\( \mu_o / 4\pi = 10^{-7} \text{ T} \cdot \text{m} / \text{A} \)

\( q(\text{proton}) = -q(\text{electron}) = 1.602 \times 10^{-19} \text{ C} \)

\( m(\text{electron}) = 9.11 \times 10^{-31} \text{ kg} \)
\( m(\text{proton}) = 1.672 \times 10^{-27} \text{ kg} \)

\[
F = \frac{Qq\hat{r}}{4\pi \epsilon_o r^2}
\]

\[
E = \frac{Q\hat{r}}{4\pi \epsilon_o r^2}
\]

\[
\oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q_{\text{inside}}}{\epsilon_o}
\]

\( U = QV \)

\( V_B - V_A = -\int_A^B \mathbf{E} \cdot d\mathbf{s} \)

\[
V = \frac{Q}{4\pi \epsilon_o r}
\]

\( Q = CV \)

\[
i(t) = \frac{E}{R} (1 - e^{-\frac{t}{\tau}}), \quad \tau = \frac{L}{R}
\]

\( \text{EMF} = -L \frac{di}{dt} \)

\( \text{EMF} = -N \frac{d\phi_B}{dt} \)

\[
\Phi_B = \oint_S \mathbf{B} \cdot d\mathbf{A}
\]

\[
\mathbf{F} = q\mathbf{v} \times \mathbf{B}
\]

\[
d\mathbf{F} = I d\mathbf{s} \times \mathbf{B}
\]

\[
U_B = \frac{1}{2} Li^2
\]

\[
p = \frac{U}{c}
\]

\[
n = \frac{c}{v}
\]

\[
n_1 \sin \theta_1 = n_2 \sin \theta_2
\]

1u = 931.494 MeV/c^2

1ev = 1.6 \times 10^{-19} \text{J} \)

\( h = h / 2\pi = 1.054 \times 10^{-34} \text{ J} \cdot \text{s} \)

\( h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s} \)

\( c = 2.997 \times 10^8 \text{ m/s} \)

\[
F = qE
\]

\[
\Phi_E = \int_s \mathbf{E} \cdot d\mathbf{A}
\]

\( u = IA \)

\( \bar{\tau} = \mu x \bar{B} \)

\[
B = \frac{\mu_o I}{2\pi r}
\]

\[
B = \mu_o \frac{N I}{L}
\]

\[
\oint \mathbf{B} \cdot d\mathbf{s} = \mu_o I
\]

\[V = IR
\]

\[P = VI = I^2 R = \frac{V^2}{R}
\]

\[R = \frac{\rho \ell}{A}
\]

\( Q(t) = CV((1 - e^{-t/\tau}), \quad \tau = RC
\)

\[
d\mathbf{B} = \frac{\mu_o I d\mathbf{s} \times \hat{r}}{4\pi \tau^2}
\]

\( \Delta V = B \ell v \)

\[S_{av} = \frac{E_{max}B_{max}}{2\mu_o} = \frac{E^2_{max}}{2\mu_o c} = \frac{c}{2\mu_o} B^2_{max}
\]

\[n = \frac{\lambda_o}{\lambda_n}
\]
\[ M = \frac{h'}{h} = -\frac{q}{p} \]
\[ \frac{n_1 + n_2}{p} = \frac{n_2 - n_1}{q} = \frac{R}{R} \]
\[ I = I_o \cos^2 \theta \]
\[ S = \frac{1}{\mu_o} E \times B \]
\[ E_{\text{photon}} = pc = hf = \frac{hc}{\lambda} \]
\[ d \sin \theta = m\lambda \quad (m = 0, \pm 1, \pm 2, \ldots) \]
\[ d \sin \theta = (m + \frac{1}{2})\lambda \quad (m = 0, \pm 1, \pm 2, \ldots) \]
\[ \lambda_n = \frac{\lambda}{n} \]
\[ 2nt = (m + \frac{1}{2})\lambda \quad (m = 0, 1, 2, \ldots) \]
\[ 2nt = m\lambda \quad (m = 0, 1, 2, \ldots) \]
\[ \sin \theta = \frac{m\lambda}{a} \quad (m = \pm 1, \pm 2, \pm 3, \ldots) \]
\[ d \sin \theta = m\lambda \quad (m = 0, 1, 2, 3, \ldots) \]
\[ T_{1/2} = \frac{0.693}{\lambda} \]
\[ \frac{1}{p} + \frac{1}{q} = \frac{2}{R} = \frac{1}{f} \]
\[ \frac{1}{p} + \frac{1}{q} = \frac{1}{f} \]
\[ \frac{E}{B} = c \]
\[ P = \frac{S}{c} \]
\[ K_{\text{max}} = hf - \phi \]
\[ \lambda' - \lambda_0 = \frac{h}{m_c} (1 - \cos \theta) \]
\[ \Delta x \Delta p_x \geq \frac{\hbar}{2} \]
\[ \psi(x) = A \sin \frac{(n\pi x)}{L} \quad (n = 1, 2, 3, \ldots) \]
\[ \lambda_{\text{d}} = \frac{h}{p} \]
\[ E_n = \left( \frac{h^2}{8mL^2} \right) n^2 \quad (n = 1, 2, 3, \ldots) \]
\[ \theta_{\text{min.}} = \frac{1.22\lambda}{D} \]
MULTIPLE CHOICE (CHOOSE CLOSEST ANSWER)

1. A charge $q$ is located inside a spherical surface of radius $r$. What happens to the electric flux if the sphere is replaced by a cube of side $r$?
   a. It changes by a factor of $4/3 \pi$
   b. It changes by a factor of $\pi$
   c. It changes by a factor of $4\pi$
   d. It changes by a factor of $3/2\pi$
   e. It remains the same.

2. A $7.96 \times 10^{-5}$ C charge is distributed uniformly on a wire 125 m long. What is the linear charge density in C/m?
   a. $3.14 \times 10^{-5}$
   b. $6.37 \times 10^{-5}$
   c. $5.69 \times 10^{-5}$
   d. 0.995
   e. $9.2 \times 10^{-5}$

   $\lambda = \frac{Q}{L} = \frac{7.96 \times 10^{-7} \text{C}}{125 \text{m}} = 6.37 \times 10^{-5} \frac{\text{C}}{\text{m}}$

3. Two capacitors are placed in series. Their capacitances are 6 µF and 3 µF. What is their total capacitance in µF?
   a. 9
   b. 5
   c. 12
   d. 2
   e. 3

   \[ \frac{1}{C} = \frac{1}{6} + \frac{1}{3} = \frac{2}{6} + \frac{1}{6} = \frac{3}{6} \]

   \[ C = \frac{6}{3} = 2 \mu\text{F} \]
4. A 150 watt light bulb is plugged into a 120 volt circuit. What current in A flows through the bulb?

- a. 10000
- b. 0.8
- c. 1.25
- d. 0.08
- e. 0.125

\[ P = I \cdot U \quad \therefore \quad I = \frac{P}{U} = \frac{150 \text{ VA}}{120 \text{ V}} = 1.25 \text{ A} \]

5. A solenoid carries a constant current. How does the magnetic field inside the coil change if the length of the coil remains the same and the number of turns is doubled?

- a. It is doubled.
- b. It is cut in half.
- c. It stays the same.
- d. There is no magnetic field inside.
- e. It reverses.

\[ B = \mu_0 n I = \mu_0 \frac{N}{L} I \]

\[ \text{If } N \to 2N \quad \text{then} \]

\[ B \to B' = \mu_0 \frac{2N}{L} I = 2B \]

6. A long solenoid (radius = 3.0 cm, 2500 turns per meter) carries a current given by \( I = 0.30 \sin(200\pi t) \) A, where \( t \) is measured in s. When \( t = 5.0 \text{ ms} \), what is the magnitude of the induced electric field in V/m at a point which is 2.0 cm from the axis of the solenoid?

- a. \( 7.3 \times 10^{-3} \)
- b. \( 6.4 \times 10^{-3} \)
- c. \( 6.9 \times 10^{-3} \)
- d. \( 5.9 \times 10^{-3} \)
- e. \( 13.3 \times 10^{-3} \)

\[ E = \oint_C \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt} \]

\[ \text{Let:} \quad \oint_C \vec{E} \cdot d\vec{s} = E \oint_C ds = E2\pi r \]

\[ \text{Right:} \quad B = \mu_0 n I \quad \text{Enclosed by} \quad \oint_C \]

\[ \frac{d\Phi_B}{dt} = \frac{d}{dt} (B \cdot A) = \pi r^2 \frac{dI}{dt} = \pi r^2 \mu_0 n \frac{dI}{dt} \]

\[ E = \mu_0 n \frac{dI}{dt} \quad \text{and} \quad \frac{dI}{dt} \bigg|_{t=5\times10^{-3}} = 60\pi \cdot \cos(200\pi t) = -60\pi \]

\[ E(t=5\text{ms}) = \frac{\mu_0 n r}{2} \frac{dI}{dt} \bigg|_{t=5\text{ms}} = \frac{\mu_0 n r}{2} \cdot 60\pi = 5.92 \times 10^{-2} \text{V/m} \]
7. What is the radiation pressure in N/m² on a perfect absorber if the electromagnetic flux is 1000 W/m²?

a. $2.53 \times 10^6$

b. $6.91 \times 10^6$

c. $4.29 \times 10^6$

d. $6.67 \times 10^6$

e. $3.33 \times 10^6$

$$P = \frac{\phi}{c} = \frac{1000 \text{ W/m}^2}{3 \times 10^8 \text{ m/s}} = 3.33 \times 10^{-6} \text{ N/m}^2$$

$$[P] = \frac{W/\text{m}^2}{\text{W/s}} = \frac{5/5}{5} = \frac{NW}{m^2} = \frac{N}{m^2}$$

8. If the ratio of the wavelength of light in medium 1 to that in medium 2 is 1:2, what is the ratio of the frequencies?

a. 1:1

b. 1:2

c. 3:1

d. 1:3

e. 2:1

The frequency of light is not affected by the change of the medium!

9. A magnifying glass has a convex lens of focal length 15 cm. What distance from the lens is the image if the object is 5 cm in front of the lens?

a. 7.5

b. 8.1

c. 7.2

d. 7.8

e. 8.2

$$\frac{1}{P} + \frac{1}{Q} = \frac{1}{F}$$

$$\frac{1}{Q} = \frac{1}{F} - \frac{1}{P} = \frac{1}{15} - \frac{1}{5} = \frac{1}{15} - \frac{3}{15} = -\frac{2}{15}$$

$$Q = -\frac{15}{2} = -7.5 \text{ cm}$$

distance from the lens is $|Q| = 7.5 \text{ cm}$
10. Two slits separated by 0.1 mm are illuminated with green light (λ = 540 nm). Calculate the distance in cm from the central bright region to the fifth bright fringe if the screen is 1 m away.

\[ \Delta s = d \cdot \sin \theta = m \cdot \lambda \]

\[ 5\text{th bright fringe} \Rightarrow m = 5 \]

\[ \sin \theta = \frac{5 \lambda}{d} \approx \tan \theta = \frac{x}{D} \]

\[ x = 5 \lambda \cdot \frac{D}{d} = 0.007 \Rightarrow m = 2.7 \text{ cm} \]

11. Heisenberg's uncertainty principle states that it is fundamentally impossible to make simultaneous measurements, with infinite accuracy, of a particle's position and its

a. wavelength.
b. work function.
c. momentum.
d. terminal velocity.
e. quantum number.

\[ \Delta x \cdot \Delta p_x \geq \frac{\hbar}{2} \]

12. When the principle quantum number is 2, the magnetic orbital quantum number can be

a. -1, 0 or 0 
b. -1, 1 or 2 
c. 1, 3 or 0 
d. 1, 1 or -2 
e. -1, 0 or 1

\[ n = 2 \]

\[ l = 0, 1, \ldots, n-1 \rightarrow l \text{ can be } 0 \text{ or } 1 \]

\[ m = -l, -l+1, \ldots, l-1, l \rightarrow \text{ if } l = 0 \Rightarrow m = 0 \]

if \( l = 1 \)

then \( m = -1, 0, 1 \)

So \[ m \text{ can be } -1, 0, 1 \]
13. All isotopes of an element have the same
   a. atomic number.
   b. atomic mass.
   c. neutrons.
   d. neutrons plus electrons.
   e. neutrons plus protons.

14. Find the binding energy in MeV of carbon -12.

   \[ A \rightarrow ^{12} C : \frac{Z}{2} = 6 \]
   \[ N = A - Z = 12 - 6 = 6 \]

   Assume:
   \[ m_C = 11.996706 \text{ u} \]
   \[ m_p = 1.007276 \text{ u} \]
   \[ m_n = 1.008665 \text{ u} \]
   \[ u = 1.66 \times 10^{-27} \text{ kg} \]

   \[ B E = (Z \cdot m_p + N \cdot m_n - M_0) \cdot c^2 \]
   \[ = \left[ 6 \left( m_p + m_n \right) - m_C \right] \cdot c^2 \]
   \[ = 0.098949 \text{ u} \times 1.6 \times 10^{-27} \cdot \frac{m_n}{m} \cdot \left( 3 \times 10^8 \text{ m/s} \right)^2 \]
   \[ = 1.48 \times 10^{-11} \text{ J} = 92.4 \text{ MeV} \]

15. The isotope, tritium, has a half-life of 12.3 years. Assume we have 10 kg of the substance. How much tritium in kg will be left after 30 years?

   \[ N = N_0 \cdot e^{-\lambda t} \rightarrow M = M_0 \cdot e^{-\lambda t} \]
   \[ \lambda = \frac{\ln 2}{T_{1/2}} \]
   \[ M = 10 \text{ kg} \cdot e^{-\frac{\ln 2}{12.3} \cdot 30 \text{ yr}} = 10 \text{ kg} \cdot e^{-1.69} \]
   \[ = 0.184 \cdot 10 \text{ kg} = 1.84 \text{ kg} \]
16. Which force is mediated by bosons?
   - weak force.
   - electromagnetic force.
   - gravitational force.
   - strong force.
   - all of the above.

17. Particles that interact through the strong force are called
   - leptons.
   - hadrons.
   - neutrinos.
   - muons.
   - electrons.

18. The four forces, in order of relative strength (strongest to weakest) are
   - strong, gravitation, electromagnetic, weak.
   - electromagnetic, strong, gravitation, weak.
   - strong, electromagnetic, weak, gravitation.
   - weak, strong, electromagnetic, gravitation.
   - strong, gravitation, weak, electromagnetic.