\( \varepsilon_0 = 8.85 \times 10^{-12} \, \text{C}^2 / \text{N} \cdot \text{m}^2 \)
\( \mu_0 = 4\pi \times 10^{-7} \, \text{T} \cdot \text{m} / \text{A} \)
\( c = 2.998 \times 10^8 \, \text{m} / \text{s} \)
\( q(\text{proton}) = -q(\text{electron}) = 1.602 \times 10^{-19} \, \text{C} \)

\( m(\text{electron}) = 9.11 \times 10^{-31} \, \text{kg} \)
\( m(\text{proton}) = 1.67 \times 10^{-27} \, \text{kg} \)
\( P(\text{sun}) = 3.9 \times 10^{26} \, \text{W} \)
\( R(\text{earth} - \text{sun}) = 1.5 \times 10^{11} \, \text{m} \)
\( R(\text{earth}) = 6.4 \times 10^6 \, \text{m} \)

\[ \mathbf{F} = -\frac{q \hat{r}}{4\pi \varepsilon_0 r^2} \]
\[ \mathbf{F} = q \mathbf{E} \]
\[ \mathbf{E} = \frac{Q \hat{r}}{4\pi \varepsilon_0 r^2} \]
\[ \Phi_E = \oint \mathbf{E} \cdot d\mathbf{A} \]
\[ \Phi_B = \oint \mathbf{B} \cdot d\mathbf{A} \]
\[ \oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q_{\text{inside}}}{\varepsilon_0} \]
\[ U = QV \]
\[ V_B - V_A = \int_A^B \mathbf{E} \cdot d\mathbf{s} \]
\[ V = \frac{Q}{4\pi \varepsilon_0 r} \]
\[ u_B = \frac{1}{2} \varepsilon_0 E^2 \]
\[ I = \frac{\Delta Q}{\Delta t} \]
\[ \mathbf{J} = q \mathbf{v} \]
\[ \mathbf{J} = \frac{\mathbf{E}}{\rho} \]
\[ \rho = \rho_0 [1 + \alpha (T - T_0)] \]

\[ \mathbf{v}_D = \frac{q \tau}{m} \mathbf{E} \]
\[ R = \frac{\rho}{A} \]
\[ P = I V = I^2 R = \frac{V^2}{R} \]
\[ \mathbf{F} = q \mathbf{v} \times \mathbf{B} \]
\[ F = \frac{mv^2}{R} \]
\[ \mathbf{dF} = \mathbf{dl} \times \mathbf{B} \]
\[ \mathbf{B} = \mathbf{\mu}_0 \mathbf{l} \]
\[ \mathbf{\tau} = \mathbf{\mu} \times \mathbf{B} \]
\[ \oint \mathbf{B} \cdot d\mathbf{A} = \mathbf{\mu}_0 I_{\text{inside}} + \mathbf{\mu}_0 \varepsilon_0 \frac{d\Phi_E}{dt} \]
\[ B = \frac{\mu_0 I}{2\pi R} \]
\[ B = \mu_0 n l \]
\[ \mathbf{\varepsilon} = -\frac{d\Phi_B}{dt} \]
\[ \mathbf{\varepsilon} = \oint \mathbf{E} \cdot d\mathbf{A} \]
\[ \mathbf{\varepsilon} = \frac{d\Phi}{dt} \]
\[ \mathbf{u}_B = \frac{1}{2} \frac{B^2}{\mu_0} \]
\[ c = \frac{1}{\mathbf{u}_B} \]
\[ \mathbf{E}_c = c \]
\[ B_c = \frac{1}{\frac{1}{2} \frac{\mu_0}{\mathbf{B}_c}} \]
\[ S = \mathbf{u}_{\text{total}} c = \frac{1}{2} c \left( \varepsilon_0 E^2 + \frac{1}{\mu_0} B^2 \right) \]
\[ \mathbf{u}_{\text{total}} = \frac{1}{2} \varepsilon_0 E^2 \]
\[ \bar{u} = \bar{u} = \frac{S}{c} \]
\[ l = l_0 \cos^2 \theta \]
1. (7 points) In a lecture demonstration a permanent magnet inserted into a coil of wire induced a current in the wire. When was the current largest?
(a) Before the magnet was inserted into the coil.
(b) While the magnet was entering the coil.
(c) When the magnetic flux through the coil reached its largest value?

2. (7 points) As shown below, a square loop of wire is moved into a magnetic field from above. What is the direction of the current induced in the wire?

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

(a) Counterclockwise (as shown)?  (b) Clockwise (opposite shown)?

3. (7 points) As shown below, a long solenoid has an area \( A = 0.1 \, \text{m}^2 \) and a magnetic field which oscillates with time at 60 Hz, so that \( B = 0.1 \sin(120\pi t) \) T.

![Diagram of a long solenoid](image)

What is the emf induced in the coil around the solenoid if the coil has an area \( A' = 0.2 \, \text{m}^2 \) and 20 turns?
(a) \( 4.8\pi \cos(120\pi t) \) V
(b) \( 48\pi \cos(120\pi t) \) V
(c) \( 24\pi \cos(120\pi t) \) V
(d) \( 48\pi \sin(120\pi t) \) V

(7 points) In a lecture demonstration a radiometer illuminated by a strong light was observed to rotate rapidly. The direction of rotation was such that
(a) the paddles whose silver sides faced the light moved in the direction of the light.
(b) the paddles whose black sides faced the light moved in the direction of the light.

5. (7 points) The Serbs in Kosovo are operating a transmitter to direct the attack on an ethnic Albanian village. To find the transmitter, the NATO troops use a radio direction finder consisting of a loop of wire in which the oscillating magnetic field of the radio waves induces an emf. The signal is maximum when the loop is oriented so that the magnetic flux through the loop is maximum. The maximum signal occurs when
(a) the area of the loop faces toward the transmitter.
(b) the edge of the loop points toward the transmitter.

6. (7 points) A high-power laser in the Nova project at Livermore National Laboratory is focused to produce an intensity \( \bar{S} = 10^{22} \text{ W/m}^2 \). What is the peak electric field in the laser beam?
(a) \( 10^6 \text{ V/m} \)  
(b) \( 10^{12} \text{ V/m} \)  
(c) \( 10^{16} \text{ V/m} \)  
(d) \( 10^{24} \text{ V/m} \)

7. (7 points) A long solenoid has a length \( L = 1 \text{ m} \), a radius \( r = 100 \text{ mm} \), and a total of \( N = 1000 \) turns through which a current \( I = 1 \text{ A} \) flows. What is the energy of the magnetic field in the solenoid?

(a) 20 nJ  
(b) 20 \( \mu \text{J} \)  
(c) 20 mJ  
(d) 20 J  
(e) 20 kJ

8. (7 points) A polarized laser beam is blocked by a polaroid sheet oriented with its direction of polarization normal to that of the laser. A second polaroid sheet is inserted between the laser and the first sheet with its direction of polarization oriented at an angle 20 degrees from the first polarizer. What is the fraction of the light coming through compared with that of the laser?
(a) 0\%  
(b) 10\%  
(c) 34\%  
(d) 88\%  
(d) 94\%

9. (7 points) The cosmic background radiation left over from the "Big Bang" at the beginning of the universe has an energy density \( u = 4.0 \times 10^{-14} \text{ J/m}^3 \). What is the corresponding mass density of the radiation?
(a) \( 4 \times 10^{-31} \text{ kg/m}^3 \)  
(b) \( 1 \times 10^{-22} \text{ kg/m}^3 \)  
(c) \( 4 \times 10^3 \text{ kg/m}^3 \)

10. (7 points) In an electromagnetic wave, the electric and magnetic fields are
(a) parallel and in phase
(b) parallel and out of phase
(c) perpendicular and in phase
(d) perpendicular and out of phase

11. (15 points) An electric field of 300 V/m is confined to the area inside the circle \( r = 10 \text{ cm} \), and is directed into the page.
(a) If the field is increasing at the rate $20 \text{ V/m-s}$, what is the magnitude of the magnetic field at the point indicated on the circle of radius $R = 15 \text{ cm}$?

\[
\oint B \cdot dl = 2\pi R \oint dE = \mu_0 \epsilon_0 \frac{d}{dt} \oint E = \mu_0 \epsilon_0 \pi R^2 \frac{dE}{dt}
\]

\[
B = \frac{\mu_0 \epsilon_0 \pi R^2}{2\pi R} \frac{dE}{dt} = \frac{2 \times 10^{-7} \times 9 \times 10^{-12} \times (0.1)^2}{2 \times 0.15} \times (-20)
\]

\[
= -7.5 \times 10^{-18} \text{T}
\]

(b) Is the vector shown for $B$ pointing in the right direction? \textbf{No}

12. (15 points) We want to do some solar sailing out near the orbit of Mars, a distance of $2 \times 10^{11} \text{ m}$ from the sun. We use an aluminized (reflective) mylar sail (like a "space blanket" or a helium balloon) having a mass of $10^{-3} \text{ kg/m}^2$.

(a) What is the intensity of the solar radiation at this distance from the sun?

\[
\pi R^2 S = P_0
\]

\[
S = \frac{P_0}{4\pi R^2} = \frac{3.9 \times 10^{26}}{4\pi \times (2 \times 10^{11})^2} = 776 \text{ W/m}^2
\]

(b) If the sail is oriented normal to the sun's rays, what is the radiation pressure on the sail?

\[
P = \frac{S}{c} = \frac{776}{3 \times 10^8} = 2.6 \times 10^{-6} \text{ N/m}^2
\]

(c) What is the acceleration of the sail caused by the solar radiation pressure?

\[
a = \frac{P}{\sigma} = \frac{2.6 \times 10^{-6}}{10^{-3}} = 2.6 \times 10^{-3} \text{ m/s}^2
\]

I pledge that I have neither given nor received help on this quiz.

__________________________
Signature