Physics 122 Final Exam December 18, 2013 7:15 to 9:15 pm

Constants and equations for final exam. You may detach this page if you wish.

Coulomb’s Law constant

\[ k = 8.99 \times 10^9 \text{ N m}^2/\text{C}^2 \]

Permittivity of free space

\[ \varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N m}^2 \]

Charge of one electron

\[ -e = -1.60 \times 10^{-19} \text{ C} \]

Mass of one electron

\[ m_e = 9.11 \times 10^{-31} \text{ kg} \]

Magnetic permeability of free space

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

Speed of light in vacuum

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

Coulomb’s law

\[ F = k \frac{Q_1 Q_2}{r^2} \]

Electric field

\[ \vec{F} = q\vec{E} \] - definition of \( E \)

\[ E = k \frac{Q}{r^2} \] - point charge

\[ E = \frac{V}{d} \] – capacitor, constant field

Electric Potential

\[ PE = qV \] - potential energy of a charge in electric field

\[ V = k \frac{Q}{r} \] - potential of a point charge

\[ \vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 \ldots \] - sum of point-like charges

\[ V = V_1 + V_2 + V_3 + \ldots \]

System of charges

Electric Flux, Gauss’s Law

For uniform field \( \Phi_E = \vec{E} \cdot \vec{A} \) - electric flux; \( \vec{A} \) - area vector, equal to area, pointing perpendicular to area

\[ \Phi_E = \int \vec{E} \cdot d\vec{A} \]

\[ \Phi_E > 0 \] – outflux, \( \Phi_E < 0 \) – influx,

\[ \Phi_E = \frac{Q}{\varepsilon_0}, Q \] – enclosed charge

Electric current

Definition: \( I = \Delta Q/\Delta t \)

\[ V = I R \] – Ohms law

Power: \( P = IV \)

Resistance: \( R = \rho l/A \)

Series connection:

\[ R_{eq} = R_1 + R_2 + R_3 \]

\[ V = V_1 + V_2 + V_3 \]

\[ I = I_1 = I_2 = I_3 \]

Parallel connection:

\[ \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \]

\[ V = V_1 = V_2 = V_3 \]

\[ I = I_1 + I_2 + I_3 \]
**Capacitor**

$$Q = CV \quad \text{definition of capacitance}$$

Energy stored:

$$U = \frac{QV}{2} = \frac{CV^2}{2} = \frac{Q^2}{2C}$$

Parallel plates with dielectric K:

$$C = K\varepsilon_0 \frac{A}{d}$$

**Magnetic field**

- \( B = \frac{\mu_0 I}{2\pi r} \) - magnetic field of a current (1st right hand rule: thumb along the current, fingers curled in the direction of the magnetic field); \( B = K_B \mu \ln n \) – magnetic field in solenoid, \( n = N/l \)
- \( F = BIL \sin \theta \); \( F = qvB \sin \theta \); \( a = v^2/r \) – centripetal acceleration (2nd right hand rule: fingers along the current, bend in the direction of the magnetic field, thumb shows the force)
- \( \tau = rF \sin \theta \); \( \mu = NAI \); \( \vec{\tau} = \vec{\mu} \times \vec{B} \)

\[ \oint Bdl = \mu_0 I_{net} \quad \text{Ampère’s law}; \quad d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{l} \times \vec{r}}{r^2} \quad \text{- Biot-Savart law.} \]

**Induced emf**

Magnetic flux: \( \Phi = BA \cos \theta \)

Faraday’s Law: \( \varepsilon = -N\frac{d\Phi}{dt} \)

Transformer: \( V_s / V_p = N_s / N_p \)

\( V_s I_s = V_p I_p \)

**AC circuits**

Current:

\( I(t) = I_0 \cos(2\pi ft) \)

Voltage:

\( V(t) = V_0 \cos(2\pi ft + \varphi) \)

RMS and peak:

\( I_{rms} = I_0 / \sqrt{2} \)

\( V_{rms} = V_0 / \sqrt{2} \)

<table>
<thead>
<tr>
<th>Resistor R</th>
<th>( V = IR )</th>
<th>( V_{rms} = I_{rms} R )</th>
<th>( I, V ) – in phase: ( \varphi = 0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitor</td>
<td>( dV / dt = I / C )</td>
<td>( V_{rms} = I_{rms} X_C )</td>
<td>( X_C = 1 / (2\pi C) )</td>
</tr>
<tr>
<td>Inductor</td>
<td>( V = LdI / dt )</td>
<td>( V_{rms} = I_{rms} X_L )</td>
<td>( X_L = 2\pi L )</td>
</tr>
</tbody>
</table>

Impedance:

\( Z = \sqrt{R^2 + (X_L - X_C)^2} \)

\( V_{rms} = I_{rms} Z \)

Phase angle:

\( \tan \varphi = \frac{X_L - X_C}{R} \)

Power factor = \( \cos \varphi \)

Power dissipated:

\( P = I_{rms}^2 R \)

Resonance:

\( X_L = X_C \)

\( f_0 = \frac{1}{2\pi \sqrt{LC}} \)

**EM waves**

Displacement current:

\( I_D = \varepsilon_0 A \frac{dE}{dt} \)

Wave:

\( v = f\lambda \quad \text{EM wave in vacuum} \)

**Trigonometry review**

\( \sin \theta = \frac{opp}{hyp} \), \( \cos \theta = \frac{adj}{hyp} \), \( \tan \theta = \frac{opp}{adj} \)

Pythagorean theorem:

\( \text{hyp}^2 = \text{opp}^2 + \text{adj}^2 \)