PHYSICS 2B QUIZ 7 WINTER QUARTER 2010
PROF. HIRSCH MARCH 8, 2010

Formulas:

$\sin 30^\circ = \cos 60^\circ = 1/2, \quad \cos 30^\circ = \sin 60^\circ = \sqrt{3}/2, \quad \sin 45^\circ = \cos 45^\circ = \sqrt{2}/2$

$F = k\frac{q_1 q_2}{r^2}$ Coulomb's law ; $k = 9\times 10^9 \mathrm{N\cdot m^2/C^2}$; $\vec{F}_{12} = \frac{kq_1q_2}{|\vec{r}_2 - \vec{r}_1|^3}(\vec{r}_2 - \vec{r}_1)$

Electric field due to charge q at distance r: $\vec{E} = \frac{kq}{r^2}\hat{r}$; Force on charge Q: $\vec{F} = Q\vec{E}$

Electric field of dipole: along dipole axis / perpendicular: $E = \frac{2kp}{x^3}$ / $E = \frac{kp}{y^3}$ (p=qd)

Energy of and torque on dipole in E-field: $U = -\vec{p}\cdot\vec{E}$, $\vec{\tau} = \vec{p}\times\vec{E}$

Linear, surface, volume charge density : $dq = \lambda\, ds$, $dq = \sigma\, dA$, $dq = \rho\, dV$

Electric field of infinite: line of charge: $E = \frac{2k\lambda}{r}$; sheet of charge: $E = 2\pi k\sigma = \sigma/(2\varepsilon_0)$

Gauss law : $\Phi = \oint \vec{E}\cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$; Φ = electric flux ; $k = \frac{1}{4\pi\varepsilon_0}$; $\varepsilon_0 = 8.85\times 10^{-12} C^2/Nm^2$

$U_B - U_A = \Delta U_{AB} = -W_{AB} = -\int_A^B \vec{F}\cdot d\vec{l} = -\int_A^B q\vec{E}\cdot d\vec{l} = q\Delta V_{AB} = q(V_B - V_A)$ V=N/C

$V = \frac{kq}{r}$; $V = \int \frac{kdq}{r}$; $V = \frac{kp\cos\theta}{r^2}$ (dipole) ; $E_l = -\frac{\partial V}{\partial l}$; $\vec{E} = -\vec{\nabla}V$

Electrostatic energy: $U = k\frac{q_1q_2}{r}$; Capacitors: $Q = CV$; with dielectric: $C = \kappa C_0$; $\varepsilon_0 = 8.85 pF/m$

$C = \frac{\varepsilon_0 A}{d}$ parallel plates ; $C = \frac{2\pi\varepsilon_0 L}{\ln(b/a)}$ cylindrical ; $C = 4\pi\varepsilon_0\frac{ab}{b-a}$ spherical

Energy stored in capacitor: $U = \frac{Q^2}{2C} = \frac{1}{2}QV = \frac{1}{2}CV^2$; $U = \int dv\, u_E$; $u_E = \frac{1}{2}\varepsilon_0 E^2$

Capacitors in parallel: $C = C_1 + C_2$; in series: $C = C_1C_2/(C_1 + C_2)$

Elementary charge: $e = 1.6\times 10^{-19} C$

$I = \frac{dq}{dt} = \int \vec{J}\cdot d\vec{A}$; $\vec{J} = ne\vec{v}_d$; $v_d = \frac{eE\tau}{m}$; $\rho = \frac{m}{ne^2\tau}$; $R = \rho\frac{\ell}{A}$; $\vec{E} = \rho\vec{J}$, $\vec{J} = \sigma\vec{E}$

$V = IR$; $P = VI = I^2R = V^2/R$; $P_{emf} = \varepsilon I$; $R_{eq} = R_1 + R_2$ (series) ; $R_{eq}^{-1} = R_1^{-1} + R_2^{-1}$ (parallel)

Charging capacitor: $Q(t) = C\varepsilon(1 - e^{-t/RC})$; Discharging capacitor: $Q(t) = Q_0 e^{-t/RC}$

Force on moving charge: $\vec{F} = q(\vec{E} + \vec{v}\times\vec{B})$; force on wire: $d\vec{F} = Id\vec{\ell}\times\vec{B}$

Circular motion: $a = \frac{v^2}{r}$; radius $r = \frac{mv}{qB}$; period $T = \frac{2\pi\,\mathrm{m}}{\mathrm{qB}}$

Magnetic dipole: $\vec{\mu} = I\vec{A}$; torque: $\vec{\tau} = \vec{\mu}\times\vec{B}$; energy: $U = -\vec{\mu}\cdot\vec{B}$

Biot-Savart law : $d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{\ell}\times\hat{r}}{r^2}$; $\mu_0 = 4\pi\times 10^{-7}\frac{N}{A^2}$; Ampere's law : $\oint \vec{B}\cdot d\vec{\ell} = \mu_0 I_{enc}$

Long wire: $B = \frac{\mu_0 I}{2\pi r}$; loop, along axis: $B = \frac{\mu_0 I a^2}{2(a^2 + z^2)^{3/2}}$; dipole: $\vec{B} = \frac{\mu_0}{2\pi}\frac{\vec{\mu}}{x^3}$

solenoid: $B = \mu_0 In$; toroid: $B = \frac{\mu_0 NI}{2\pi r}$; Gauss law for magnetism: $\oint \vec{B}\cdot d\vec{A} = 0$

Faraday law : $\varepsilon = -\frac{d\Phi_B}{dt} = \oint \vec{E}\cdot d\vec{s}$; $\Phi_B = \int \vec{B}\cdot d\vec{A}$ magnetic flux

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Mutual inductance: $M = \frac{\Phi_2}{I_1} = \frac{\Phi_1}{I_2}$; $\varepsilon_2 = -M\frac{dI_1}{dt}$; $\varepsilon_1 = -M\frac{dI_2}{dt}$

Self-inductance: $L = \frac{\Phi_B}{I}$; $\varepsilon_L = -L\frac{dI}{dt}$; $L = \mu_0 n^2 A\ell$ for solenoid

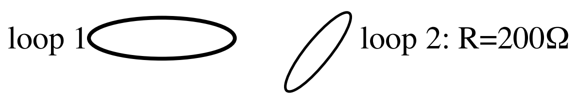
Magnetic energy: $U_B = \frac{1}{2}LI^2$; $u_B = \frac{B^2}{2\mu_0}$

RL circuit: $I = \frac{\varepsilon}{R}(1 - e^{-t/\tau_L})$ (rise) ; $I = I_0 e^{-t/\tau_L}$ (decay) ; $\tau_L = L/R$

LC oscillations: $q(t) = q_p\cos(\omega_0 t)$; $I(t) = -\omega_0 q_p \sin(\omega_0 t)$; $\omega_0 = \frac{1}{\sqrt{LC}}$

There are 8 problems. You get 1 point for correct answer, 0 points for incorrect answers, 0.2 points for no answer (up to 5 non-answers). This is Test Form A

Problems 1 and 2

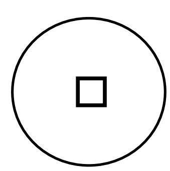


The mutual inductance of the two loops shown is 2H. Loop 2 has resistance 200Ω. At time t=0, a current is supplied to loop 1 that increases at a constant rate in the time interval t=0 to t=10s. At time t=0.5s, the induced current in loop 2 is 1mA (=10^{-3}A).

Problem 1: At time t=2s, the induced current in loop 2 is
(a) 2mA ; (b) 4mA ; (c) 0.5mA ; (d) 1mA ; (e) 8mA

Problem 2: the current supplied to loop 1 at time t=1s is
(a) 1mA ; (b) 1A ; (c) 0.1A ; (d) 2mA ; (e) 0.2A

Problems 3 and 4

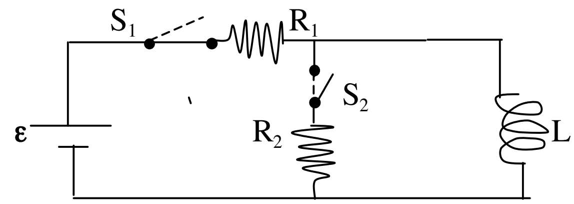


The round loop has radius 1m and resistance 0.1Ω. The small square loop is centered at the center of the round loop and has side length 0.1m. You may assume that 0.1m is much smaller than 1m.
A current is supplied to the small square loop that increases at a constant rate, it is 0 at time t=0 and 100A at time t=1s. A current will be induced in the round loop.

Problem 3: The mutual inductance of this arrangement is
(a) $2\pi\times10^{-9}$H ; (b) $\pi\times10^{-9}$H ; (c) $4\pi\times10^{-8}$H ; (d) $0.5\pi\times10^{-8}$H ; (e) 2×10^{-9}H

Problem 4: The current induced in the round loop at time t=0.5s is
(a) 50A ; (b) $\pi\times10^{-7}$A ; (c) 0.1A ; (d) 2×10^{-8}A ; (e) $2\pi\times10^{-6}$A

Problems 5 and 6

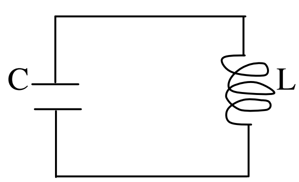


In the circuit shown, R_1=1Ω, R_2=2Ω, L=1H. The switch S_1 has been closed for a long time and the switch S_2 has been open for a long time. The emf of the battery is $\varepsilon = 1$V. Then, the switch S_2 is closed while the switch S_1 remains closed. Call t=0 the time when this occurs.

Problem 5: the current flowing through R_2 at time t=1s, i.e. 1s after the switch S_2 was closed, is
(a) 0A ; (b) 0.61A ; (c) 1A ; (d) 0.55A ; (e) 0.33A

Problem 6: then, at time t=10s (i.e. 10s after the switch S_2 was closed), switch S_1 is opened (the switch S_2 remains closed). The current flowing through R_2 at time t=11s, i.e. 1s after the switch S_1 was opened, is
(a) 0A ; (b) 0.61A ; (c) 0.20A ; (d) 0.05A ; (e) 0.14A

Problems 7 and 8



In the LC circuit shown, the charge in the capacitor is 4C at time t=0 and the current in the inductor is 0. The charge in the capacitor starts decreasing and reaches zero at time t=3s. The value of L is 2mH.

Problem 7: what is the current in the inductor at time t=3s?
(a) 2.6A ; (b) 1.4A ; (c) 2.1A ; (d) 3.2A ; (e) 0.8A

Problem 8: what is the energy stored in the capacitor at t=0?
(a) 1.1mJ ; (b) 2.2mJ ; (c) 3.3mJ ; (d) 4.4mJ ; (e) 5.5mJ