Kuwait University **Physics Department**

Physics 122
Midterm Exam II (Semester I)
December 11, 2005 (12.30- 2:00 p.m.)

Name: ………………………… Student No: ………………..

Instructors: Drs. Kokay, Rakhshani, and Sharma

(Fundamental Constants)

$k = \frac{1}{4\pi\varepsilon_o} = 9.0 \times 10^9 \mathrm{N\cdot m^2 / C^2}$ (Coulomb constant)

$\varepsilon_o = 8.85 \times 10^{-12}\ \mathrm{C^2 / (N\cdot m^2)}$ (Permittivity of free space)

$e = +1.60 \times 10^{-19}$ C (Elementary unit of charge)

$N_A = 6.022\times 10^{23}$ (Avogadro's number)

$g = 9.8\ \mathrm{m/s^2}$ (Acceleration due to gravity)

$m_e = 9.11 \times 10^{-31}$ kg (Electron mass)

$m_p = 1.67 \times 10^{-27}$ kg (Proton mass)

Prefixes of units

$m = 10^{-3}$ $\mu = 10^{-6}$ $n = 10^{-9}$ $p = 10^{-12}$
$k = 10^{3}$ $M = 10^{6}$ $G = 10^{9}$ $T = 10^{12}$

For use by Instructors only

Prob.	1	2	3	4	5	6	7	8	9	10	Total
Marks											

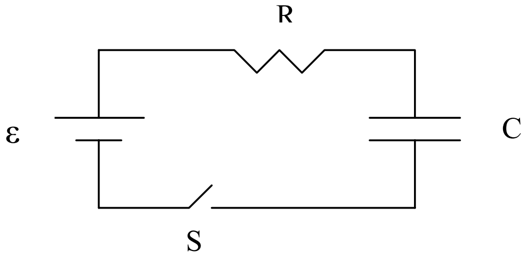
1. What is the maximum instantaneous power dissipated in a 800 W hair dryer connected to a 240 V a.c. power source?

   a. 400 W
   b. 565 W
   c. 800 W
   d. 1130 W
   e. 1600 W

$$
\begin{aligned}
\overline{P} &= V_{rms} \cdot I_{rms} \\
I_{rms} &= \frac{\overline{P}}{V_{rms}} = \frac{800}{240} = 3.33\,\mathrm{A} \\
I_o &= \sqrt{2}\, I_{rms} \\
V_o &= \sqrt{2}\, V_{rms} \\
P_{peak} &= I_o V_o = 2 I_{rms} V_{rms} = 2\overline{P} \\
&= 1600\ \mathrm{W}
\end{aligned}
$$

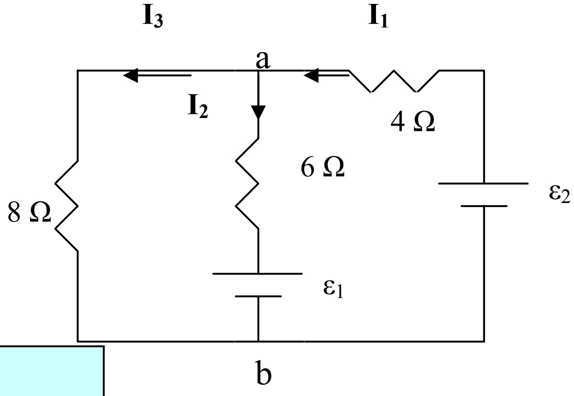
2. At 3 s after the switch S is closed, the voltage at the capacitor becomes 0.4 times the battery voltage. What is the power dissipated in resistor R at this instant of time? Given, $\varepsilon = 10$ V, $C = 10\ \mu F$.

   a. 41 μW
   b. 61 μW
   c. 71 μW
   d. 81 μW
   e. other



$$
\begin{aligned}
Q &= C\varepsilon\,(1-e^{-t/\tau}) \\
V_c &= \frac{Q}{C} = \varepsilon\,(1-e^{-t/\tau}) \\
0.4\,\varepsilon &= \varepsilon\,(1-e^{-t/\tau}) \\
0.4 &= 1-e^{-t/\tau} \\
e^{-t/t} &= 0.6 \qquad \Rightarrow \qquad -t/\tau = ln(0.6) \\
\tau &= \frac{-t}{ln(0.6)} = \frac{-3}{ln(0.6)} = 5.87\,\mathrm{s} = RC \\
R &= \frac{5.87}{10\times10^{-6}} = 5.87\times10^{5}\,\Omega \\
V_R &= \varepsilon\, e^{-t/t} = 10\times0.6 = 6\,\mathrm{V} \\
P &= \frac{V_R^2}{R} = 6.1\times10^{-5}\ \mathrm{W} = 61\,\mu\mathrm{W}
\end{aligned}
$$

3. In the circuit shown, what is potential difference V_{ab}? Given, $\varepsilon_1 = 4$ V and $\varepsilon_2 = 12$ V.



a. 4.0 V
b. 1.2 V
c. 5.2 V
d. 6.8 V
e. 8.0 V

$$\text{Loop Rule}: I_1 + I_2 = I_3 \qquad (1)$$

$$\text{Left loop}: 8I_3 - 6I_2 = 4 \qquad (2)$$

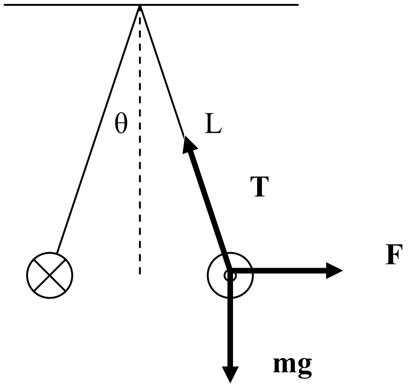
$$\text{Outer loop}: 8I_3 + 4I_1 = 12 \qquad (3)$$

$$\text{Solving (1), (2) and (3) gives, } I_2 = \frac{6}{13}\ \text{A}$$

$$V_a - 6I_2 - \varepsilon_1 = V_b$$

$$V_{ab} = V_a - V_b = 6I_2 + \varepsilon_1 = 6.\frac{6}{13} + 4 = 6.8\ \text{V}$$

4. Two identical wires of mass per unit length of 10 g/m hang on two strings as shown in the figure. The wires carry equal currents but in opposite directions and are separated by an angle θ = 6°. What is the magnitude of the current I? Given, L = 50 cm.



a. 51 A
b. 62 A
c. 73 A
d. 84 A
e. other

$$T\sin\theta = F \qquad T\cos\theta = mg$$

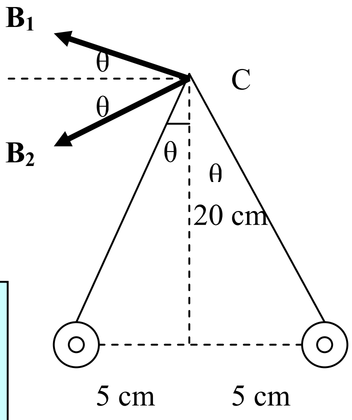
$$\Rightarrow \quad F = mg\tan\theta$$

$$\frac{\mu_o I^2 \ell}{2\pi d} = mg\tan\theta, \qquad \text{where } d = 2.L\sin\theta$$

$$I^2 = \frac{m}{\ell}\ \frac{.g\tan\theta .\ 2\pi\,(2L\sin\theta)}{4\pi\times10^{-7}}, \qquad \frac{m}{\ell} = 10\,\text{g/m} = 10^{-2}\ \text{Kg/m}$$

$$I = 73\,\text{A}$$

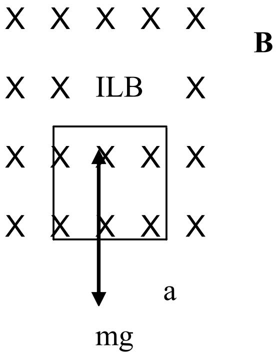
5. Two wires carrying equal currents I = 4 A are placed as shown in the figure. What is the resultant magnetic field at the point C?



a. 3.5 μT
b. 5.0 μT
c. 7.5 μT
d. 9.0 μT
e. other

$$B_1 = B_2 = B = \frac{\mu_o I}{2\pi r}$$
$$r = \sqrt{20^2 + 5^2} = 20.6 \text{ cm}$$
$$B_{net} = 2B\cos\theta$$
$$= 2B.\frac{20}{20.6}$$
$$= 7.5\times10^{-6} \text{ T}$$
$$= 7.5 \ \mu\text{T}$$

6. A square coil (sides a = 12 cm) having a total resistance of 4.5 mΩ is placed perpendicular to a uniform magnetic field B = 60 mT with its lower edge at the boundary of the field. When set free, the coil starts moving with a constant velocity of 5 m/s. What is the mass of the coil?



a. 1.2 g
b. 2.3 g
c. 3.5 g
d. 5.9 g
e. other

$$mg = ILB$$
$$\text{and } I = \frac{\varepsilon}{R} = \frac{BLv}{R}$$
$$\therefore \ mg = \frac{B^2L^2v}{R}$$
$$m = \frac{B^2L^2v}{gR} = 5.9\times10^{-3} \text{ kg}$$
$$= 5.9 \text{ g}$$

7. A circular coil of diameter 26 cm consists of 30 turns. A uniform magnetic field perpendicular to the plane of the coil changes from a value of 0.40 T in one direction to a value of 0.40 T in another direction during a period of 100 ms. How much energy is produced in the coil if the total resistance of the coil is 12.0 Ω?

   a. 0.3 J
   b. 1.4 J
   c. 2.0 J
   d. 2.4 J
   e. other

$$\begin{aligned}
\varepsilon &= \frac{\Delta\varphi}{\Delta t} = \frac{\Delta(BA\cos 0^\circ)}{\Delta t} \\
&= A\frac{\Delta B}{\Delta t} \\
&= \frac{\pi d^2}{4} \cdot \frac{(0.40-(-0.40))}{100\times10^{-3}} \\
&= 12.74\,\mathrm{V} \\
P &= \frac{\varepsilon^2}{R} \\
E &= P.t = \frac{\varepsilon^2}{R}\;.\,t \cong 1.4\,\mathrm{J}
\end{aligned}$$

8. A sample of ^{226}Ra decays through emission of α-particles to the ground state of its daughter nucleus. The half-life of the ^{226}Ra is 1600 yrs. If the sample contains 10 g of ^{226}Ra, how much energy will be supplied to the environment by the α-decay in a period of 10 years? Given, M(^{226}Ra) = 226.025402 u, M(^{222}Rn) = 222.017571 u, and M(^{4}He) = 4.002602 u.

   a. 90 MJ
   b. 120 MJ
   c. 150 MJ
   d. 200 MJ
   e. 225 MJ

$$\begin{aligned}
10\,\mathrm{g}\ \ \mathrm{Ra} &\equiv \frac{6.02\times10^{22}}{226}\times 10\ \text{atoms} \\
&\equiv 2.6637\times10^{22}\quad \text{atoms} \\
N &= N_o\,e^{-\lambda t} \\
&= 2.6637\times10^{22}\ e^{-\frac{0.693\times10}{1600}} \\
&= 2.6522\ \times10^{22}\ \text{atoms (nuclei)}
\end{aligned}$$

$$\text{No.of nuclei decayed} = N - N_o = \ 1.151\times10^{20}$$

$$\begin{aligned}
Q_\alpha &= \left[M\left(^{226}\mathrm{Ra}\right) - M\left(^{222}\mathrm{Rn}\right) - M\left(^{4}\mathrm{He}\right)\right]c^2 \\
&= \ 4.871\ \mathrm{MeV}
\end{aligned}$$

$$\begin{aligned}
\text{Total energy supplied} &= (N - N_o)Q_\alpha \\
&= 5.607\times10^{20}\ \mathrm{MeV} \\
&= 5.607\times10^{20}\times10^{6}\ \times1.6\times10^{-19}\ \mathrm{J} \\
&= 90\times10^{6}\ \ \mathrm{J} = 90\ \ \mathrm{MJ}
\end{aligned}$$

9. The binding energy of the last neutron in a nucleus of ^{15}N is 10.83 MeV. What is the binding energy per nucleon of ^{15}N? Given M(^{14}N) = 14.003074 u, M(n) = 1.008665 u, M(^{1}H) = 1.007825 u.

a. 6.7 MeV
b. 7.7 MeV
c. 8.0 MeV
d. 8.3 MeV
e. zero

Binding energy of the last neutron in ^{15}N:

$$\text{B.E.(n)} = \left[M\left({}^{15}N\right) - M\left({}^{14}N\right) - M(n)\right]c^2$$

$$\frac{-10.83}{931.5} = M\left({}^{15}N\right) - 14.003074 - 1.007825 \text{ u}$$

$$M\,({}^{15}N) = 15.0001086 \text{ u}$$

$$\text{B.E.}({}^{15}N) = \Delta M.c^2$$

$$= \left[7 \times M\left({}^{1}H\right) + 8 \times M(n) - M\left({}^{15}N\right)\right]c^2$$

$$= 115.5 \text{ MeV}$$

$$\frac{\text{B.E.}}{A} = \frac{115.5}{15} = 7.7 \text{ MeV/nucleon}$$

10. The isotope ${}^{15}_{8}\mathrm{O}$ decays through emission of a position (β^{+}). The maximum energy of the positron emitted is 1.732 MeV. What is the mass of the daughter nucleus? Given, M(^{15}O) = 15.003065 u, and M(e) = 0.0005486 u.

a. 14.984356 u
b. 14.997678 u
c. 14.953214 u
d. 15.000108 u
e. 15.012034 u

$$Q_{\beta^{+}} = \left[M\left({}^{15}O\right) - M\left({}^{15}N\right) - 2M(e)\right]c^2$$

$$\frac{1.732}{931.5} = M({}^{15}O) - M\left({}^{15}N\right) - 2M(e)$$

$$= 15.003065 - M({}^{15}N) - 2 \times 0.0005486$$

$$M({}^{15}N) = 15.000108 \text{ u}$$