Physics II Final Examination

Department of Physics
PHYS102 - Physics II
Final Examination
Spring 2015-16
(June 2, 2016)

Name & Surname: Solution
Number: 
Group: 
Signature: 

1. The exam includes 4 questions.
2. You are not allowed to use any source of information.
3. All electronic devices are forbidden to be used during the exam.
4. Your mobile phone must be turned off before the exam starts.
5. Calculator is allowed.
6. Duration of the exam is 90-minutes.

Good Luck

<table>
<thead>
<tr>
<th>P1(10)</th>
<th>P2(15)</th>
<th>P3(15)</th>
<th>P4(15)</th>
<th>Total(55)</th>
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\[ \Delta S = \int \frac{dQ}{T} \]
\[ \sigma = \frac{W}{q_U} \]
\[ Q_{\text{gained}} + Q_{\text{lost}} = 0 \]
\[ \int \vec{E} \cdot d\vec{A} = \frac{q_{\text{enc}}}{\varepsilon_0} \]
\[ \Delta V_{12} = - \int_1^2 \vec{B} \cdot d\vec{s} \]
\[ |\vec{p}_B| = \frac{\mu_0 I_z}{2\pi} \]
\[ \vec{p}_B = \frac{1}{e} \int d\vec{q} \times \vec{B} \]
\[ Q = mc\Delta T \]
\[ \vec{B} = \frac{\mu_0 I}{4\pi} \int \frac{d\vec{s} \times \vec{r}}{r^2} \]
\[ \frac{\mu}{c} \int \frac{d\vec{B} \cdot d\vec{s} = \mu_0 I_{\text{enc}} }{E} \]
\[ \mu_0 = 4\pi \times 10^{-7} \text{ T.m/A} \]
\[ \varepsilon_W = 4186 \frac{J}{kg \cdot ^\circ C} \]
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P1)

a) A cup holding 125 g of hot water at 100°C cools down to the room temperature, 20°C.
   i) What is the change in entropy of the water? (2 points)
   ii) What is the change in entropy of the room? (2 points)
   iii) Is the second law of thermodynamics satisfied? Why? (2 points)
       (Hint: Neglect the specific heat of the cup and any change in temperature of the room.)

b) Find the maximum efficiency of an engine that absorbs energy from a hot reservoir at 545°C and exhausts (loses) energy to a cold reservoir at 185°C. (4 points)

\[ \Delta S_w = \int \frac{dQ}{T} = m_w c_w \int \frac{dT}{T} = m_w c_w \ln \left( \frac{T_2}{T_1} \right) = 0.125 \times 4186 \ln \left( \frac{293}{373} \right) = -12.6.3 \frac{J}{K} \]

\[ \Delta S_L = \int \frac{dQ}{T} = \int \frac{dQ}{T} = \frac{1}{293} \int dQ = \frac{1}{293} Q_{	ext{Total}} = \frac{1}{293} (-Q_{	ext{lost}}) \]

\[ \Delta S_L = -\frac{1}{293} \left( m_w c_w (293 - 100) \right) = \frac{80 \times 0.125 \times 4186}{293} = 142.9 \frac{J}{K} \]

\[ \Delta S_{\text{Total}} = \Delta S_w + \Delta S_L = 16.6 > 0 \]

So the Second Law is satisfied.

\[ e_{\max} = e_c = 1 - \frac{T_2}{T_1} = 1 - \frac{185 + 293}{545 + 293} = 0.44 = 44\% \]
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P2) An electric charge $Q$ is uniformly distributed throughout a non-conducting solid sphere of radius $a$. Determine the electric field at points:

i) inside the sphere. (5 points)
ii) and outside the sphere. (5 points)
iii) What is the potential difference between the center of the sphere and a point on the surface of the sphere? (5 points)

\[
\int \vec{E} \cdot d\vec{A} = \frac{Q}{4\pi\varepsilon_0} \Rightarrow \vec{E} \parallel \vec{A} \quad \text{and} \quad \int \vec{E} \cdot d\vec{A} = \text{const.}
\]

\[
\vec{E} = \frac{Q}{4\pi\varepsilon_0 r^2} \quad \text{and} \quad |\vec{E}| = \frac{Q}{4\pi\varepsilon_0 r^2}
\]

\[
\int \vec{E} \cdot d\vec{A} = \frac{Q}{\varepsilon_0} \Rightarrow |\vec{E}| = \frac{Q}{4\pi\varepsilon_0 r^2} \Rightarrow 1\vec{E} \cdot d\vec{A} = \frac{Q}{4\pi\varepsilon_0 r^2}
\]

\[
\nabla \cdot \vec{E} \cdot d\vec{A} = \frac{Q}{4\pi\varepsilon_0 a^3} \Rightarrow (\frac{Q}{4\pi\varepsilon_0 a^3})_A
\]

\[
\nabla \cdot \vec{E} \cdot d\vec{A} = \frac{Q}{8\pi\varepsilon_0 a}
\]

\[
\nabla \cdot \vec{E} = \frac{Q}{8\pi\varepsilon_0 a} \quad \text{and} \quad d^2 = dr^2
\]
P3) A circular wire of radius $R$ carries a current $I$ in the counterclockwise direction and lies on $xy$-plane with the center $C$ at the origin. What magnetic field $\vec{B}$ (magnitude and direction) does the current produce at the center $C$. (Hint: Use Biot-Savart's law) (15 points)

\[ \frac{\vec{B}}{c} = \frac{\mu_0 I}{4\pi} \int_{\text{circle}} \frac{d\vec{s} \times \hat{r}}{r^2} = \frac{\mu_0 I}{4\pi} \int_0^{2\pi} \frac{R d\theta}{R^2} (+\hat{k}) \]

\[ \vec{B}_c = \frac{\mu_0 I}{4\pi R} \hat{k} (2\pi) = \frac{\mu_0 I}{2\pi R} \hat{k} \]
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P4) Three long straight wires are perpendicular to the page, and are placed at the corners of an equilateral triangle of edge length \( a = 5 \text{cm} \) as shown in the figure. Wire number 1 and 2 each carries a 2.0 \( A \) current out of the page while the wire number 3 carries a 4.0 \( A \) current into the page. Determine the force vector exerted on 6.0 \( \text{m} \) length of wire number 2 due to the magnetic field set up by the other two wires. (15 points)

\[
\vec{F}_2 = \vec{F}_{12} + \vec{F}_{32}
\]

\[
\vec{F}_{12} = \frac{\mu_0 I_1 I_2 (\hat{i})}{2 \pi a} l
\]

\[
\vec{F}_{32} = \frac{\mu_0 I_3 I_2 (60 \hat{i} + 50 \hat{j})}{2 \pi a} l
\]

\[
\vec{F}_{12} = \frac{\mu_0 I_1 I_2}{2 \pi a} \left[ -I_1 \hat{i} + I_2 \left( \frac{1}{2} \hat{j} + \frac{1}{3} \hat{k} \right) \right] l
\]

\[
\vec{F}_{32} = \frac{\mu_0 I_3 I_2}{2 \pi a} \left( \hat{i} \left( \frac{I_1}{2} - I_1 \right) - \hat{j} \frac{\sqrt{3}}{2} \right) l
\]

\[
\vec{F}_2 = \frac{4 \pi \times 10^{-7}}{2 \pi \times 1 \times 10^{-2} \hat{i}} \left[ I_2 \left( \frac{4}{3} - 2 \right) - \frac{\sqrt{3}}{2} (4) \right] l
\]

\[
\vec{F}_2 = \frac{4}{5} \times 10^{-5} (-12 \hat{\sqrt{3}} \hat{j}) = 16.6 \times 10^{-5} \hat{\sqrt{3}} \hat{j} \text{ N}
\]