# P161 Final Part 2 - Solutions
## Spring 2009

① (D)

② Heat given up by metal container plus water in container equals heat used to melt ice cube plus heat it to final temperature, ie

$$m_{metal} C_{metal} (T_i - T_f) + m_{water} C_{water} (T_i - T_f)$$

$$= m_{ice} L_{ice} + m_{ice} (T_f - T_{ice})$$

Solve for $C_{metal} = 2360 \frac{J}{kg \cdot K}$ (B)

③ (B) It has 5 degrees of freedom = 3 translational + 1 rotational + 1 vibrational

④ $W = \int P dV = P \Delta V$ for $P =$ constant

$W = 120 \text{ kPa} (0.12 \text{ m}^3 - 0.23 \text{ m}^3) = -13 \text{ kJ}$ (B)

⑤ For a Carnot heat engine

$e = 1 - \frac{T_c}{T_H}$. If it wastes 35.0%, it's efficiency is $1 - 0.350 = 0.650$, so $\frac{T_c}{T_H} = 0.350$

$T_H = T_c / 0.350 = \frac{(15°C + 273°C)}{0.35} = 823 K = 550°C$ (C)

(6) $\vec{F} = k\frac{q_1 q_2}{r^2}\hat{r}$ so $q_1 q_2 = -\frac{Fr^2}{k}$ (attractive force, so $q_1 q_2 < 0$)

(a) $q_1 q_2 = -4.32\times10^{-10}\,C^2$

Also
(b) $q_{Total} = -24\,\mu C = q_1 + q_2$, so we have 2 equations with 2 unknowns. Substitute from (a) $q_1 = -\frac{4.32\times10^{-10}\,C^2}{q_2}$ into (b) to get:

$$q_2^2 + (24\times10^{-6}\,C)q_2 - 4.32\times10^{-10}\,C^2 = 0$$

whose solutions are $q_2 = (\underline{12\,\mu C}, \text{ or } -36\,\mu C)$ (A)

(7) From Gauss' law for a line charge

$E = \frac{\lambda}{2\pi\epsilon_0 r}$. Hence to have double the electric field, you need to be $\underline{1/2 \text{ the distance}}$ (E)

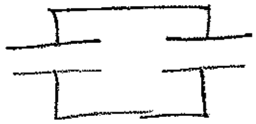
(8) Electric potential is additive, so

$$0 = V(y) = V_{Q_1} + V_{Q_2} = \frac{q_1}{4\pi\epsilon_0 y} + \frac{q_2}{4\pi\epsilon_0\sqrt{y^2+(0.8m)^2}}$$

Solve for $\underline{y = 0.69\,m}$ (B)

(9) Initially $\begin{pmatrix} q_1^i = VC_1 = 2\times10^{-4}C \\ q_2^i = VC_2 = 5\times10^{-4}C \end{pmatrix}$ Connect with opposite polarity;

on top plates $q_{Total} = +2\times10^{-4}c - 5\times10^{-4}c$



(a) $q_1^f + q_2^f = -3\times10^{-4}C$

But the final voltage is same across both

(b) $V^f = \frac{q_1^f}{C_1} = \frac{q_2^f}{C_2}$ or $q_1^f = \frac{C_1}{C_2}q_2^f = \frac{2}{5}q_2^f$

Use (a) + (b) to solve for $q_{1,2}^f$, Then get $\underline{V^f = 42.9V}$ (C)

(10) $P = I^2 R$. The resistance does not change, but if $I = I_0/2 \Rightarrow P = P_0/4 = \frac{60W}{4} = 15W$ (C)

(11) $V_{16\Omega} = V_{8\Omega}$ or $I_{16\Omega} * (16\Omega) = I_{8\Omega} * (8\Omega)$

So $I_{16\Omega} = I_{8\Omega}\left(\frac{8\Omega}{16\Omega}\right) = 0.25A$

The total current thru the parallel $16\Omega + 8\Omega$ is:

$$I_{Top} = I_{8\Omega} + I_{16\Omega} = 0.75A$$

This current also goes thru the $20\Omega$, so the total potential across the top is

$$V_{Top} = I_{Top}(R^{top}_{equiv.}), \text{ where } R^{top}_{equiv.} = \frac{76}{3}\,\Omega$$

$$= (0.75A)\left(\frac{76}{3}\Omega\right) = 19V$$

This is also the potential across both the $6\Omega + 2\Omega$,

$$V_{Top} = V_{bottom} = I_{2\Omega} * (2\Omega)$$

$$\text{So } I_{2\Omega} = \frac{V_{Top}}{2\Omega} = \frac{19V}{2\Omega} = 9.5A \quad \text{(D)}$$

(12) If no deflection $\vec{F}_{mag} = -\vec{F}_{elec.}$

$$q\vec{v} \times \vec{B} = -q\vec{E}$$

or $\vec{E} = vB(-\hat{j}) = -76\,kV/m\,\hat{j}$ (E)

(13) (C)

(14) (A)

(15) (C)