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General Physics II, Midterm 3
PHYS10400, Class year 100
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SN:___________________, Name:________________

Solutions:

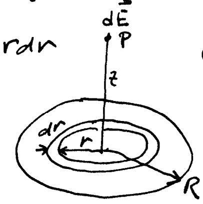
1. (a) The charge will evenly distributed on the surface of the sphere, since the sphere is a conductor, charges will repel one another. As a result, the charges will spread evenly on surface. (b) Follow (a) the charge densith will be $\dfrac{Q}{4\pi R^2}$

2.

(a) Electric field for a charged disk

$dq = \sigma dA = \sigma 2\pi r dr$

σ = charge density



$$dE = \frac{z\sigma 2\pi r dr}{4\pi\epsilon_0 (z^2+r^2)^{3/2}}$$

$$= \frac{\sigma z}{4\epsilon_0}\frac{2r dr}{(z^2+r^2)^{3/2}}$$

$$E = \int_{r=0}^{r=R} dE = \frac{\sigma z}{4\epsilon_0}\int_0^R \frac{2r dr}{(z^2+r^2)^{3/2}}$$

$$= \frac{\sigma z}{4\epsilon_0}\left[\frac{(z^2+r^2)^{-1/2}}{-1/2}\right]_0^R = \frac{\sigma}{2\epsilon_0}\left[1 - \frac{z}{\sqrt{z^2+R^2}}\right]$$

(b) ① When $R \to \infty$, $E \to \frac{\sigma}{2\epsilon_0}$ just like a big plane with uniform charge density

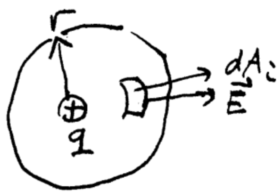
② When $z \to \infty$, $E \to 0$, similar to the case of point charge at infinite far away.

3.

(a) Gauss law — the relation between the net electric flux through a closed surface and the charge enclosed by the surface

i.e. $\Phi_E = \frac{q}{\epsilon_0}$. Φ_E = the electric flux

(b) Take a point charge for example



$\vec{E} \cdot dA_i = E \Delta A_i$

$$\Phi_E = \oint E \cdot dA = \oint E dA = E \oint dA$$

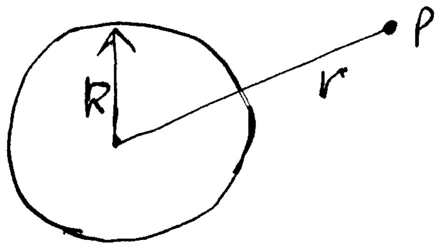
$$\vec{E} = k_e \frac{q}{r^2}$$

$$\therefore \Phi_E = k_e \frac{q}{r^2} \cdot 4\pi r^2 = 4\pi \frac{1}{4\pi\epsilon_0} q \qquad \therefore \Phi_E = \frac{q}{\epsilon_0}$$

4.

4

(a) Outside the sphere



$\Phi_E = \oint E \cdot dA = E \oint dA$

$= E \cdot 4\pi r^2 = \frac{q}{\epsilon_0}$

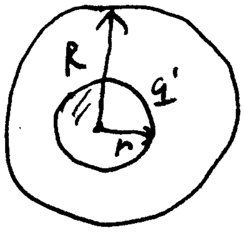
$\therefore E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$. (for $r > R$), just like a point charge

$E \propto \frac{1}{r^2}$

(b) Inside the sphere, $r < R$

Since this is a non-Conductor

$q'_{in} = \rho V' = \rho \cdot \frac{4}{3}\pi r^3$



$\vec{E} \cdot \vec{A} = \Phi_E \cdot E_0 \frac{q_{in}}{4\pi\epsilon_0 r^2} = \frac{\rho(\frac{4}{3}\pi r^3)}{4\pi\epsilon_0 r^2}$

$\therefore \vec{E} = \frac{\rho}{3\epsilon_0} \vec{r}$, $\therefore E \propto r$

5.

(a) Entropy : definition $dS = \frac{dQ_r}{T}$

: Entropy is a measure of disorder

: (There are many ways to describe)

: etc.

(b) In a Carnot cycle. The total change in entropy in one full cycle is $\Delta S = \Delta S_h + \Delta S_c$

$$= \frac{|Q_h|}{T_h} - \frac{|Q_c|}{T_c}$$

But $\frac{|Q_c|}{|Q_h|} = \frac{T_c}{T_h}$

$\therefore$ $\Delta S = 0$ in a Carnot cycle

(c) Since $\Delta S \geq 0$ in all thermal dynamic systems. $\Delta S = 0$ means a Carnot cycle is the most efficient engine, that is, it will transfer all energy to work

(d) $m_c c \Delta T_c = -m_h c \Delta T_h$

$m_c (T_f - T_c) = -m_h (T_f - T_h)$ $\quad T_f \equiv$ final temperature

$$\rightarrow T_f = \frac{m_c T_c + m_h T_h}{m_c + m_h}$$

(e) $$\Delta S = \int_c \frac{dQ_c}{T} + \int_h \frac{dQ_h}{T} = m_c \int_{T_c}^{T_f} \frac{dT}{T} + m_h \int_{T_h}^{T_f} \frac{dT}{T}$$

$$= m_c \ln\left(\frac{T_f}{T_c}\right) + m_h \ln\left(\frac{T_f}{T_h}\right)$$