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General Physics II, Midterm 2
PHYS10400, Class year 102-2
04-24-2014

SN:_______________, Name:________________

ABSOLUTELY NO CHEATING!

Please write the answers on the blank space or on the back of this paper to save resources.

1.

(a)

(a)

$$e \equiv \frac{W_{carnot}}{|Q_h|} = \frac{|Q_h|-|Q_c|}{|Q_h|} = 1 - \frac{|Q_c|}{|Q_h|}$$

In a Carnot cycle, $\Delta E_{in} = 0$ (path $A \to B$)

$\therefore |Q_h| = |-W_{AB}|$, $W_{AB} \equiv$ work done between $A \to B$

$A \to B$, $|Q_h| = |-W_{AB}| = nRT_h \ln\left(\frac{V_B}{V_A}\right)$ absorb energy

$C \to D$, $|Q_c| = |-W_{CD}| = nRT_c \ln\left(\frac{V_C}{V_D}\right)$

$$\therefore \frac{|Q_c|}{|Q_h|} = \frac{T_c}{T_h} \cdot \frac{\ln\left(\frac{V_C}{V_D}\right)}{\ln\left(\frac{V_B}{V_A}\right)} \quad \text{—— ①}$$

But $P_i V_i^{\gamma} = P_f V_f^{\gamma} \longrightarrow T_i V_i^{\gamma-1} = T_f V_f^{\gamma-1}$

$$\left.\begin{array}{ll} B \to C & T_h V_B^{\gamma-1} = T_c V_C^{\gamma-1} \\ D \to A & T_h V_A^{\gamma-1} = T_c V_D^{\gamma-1} \end{array}\right\} \Rightarrow \left(\frac{V_B}{V_A}\right)^{\gamma-1} = \left(\frac{V_C}{V_D}\right)^{\gamma-1}$$

$$\therefore \frac{V_B}{V_A} = \frac{V_C}{V_D} \quad \text{—— ②}$$

From ① and ② $\frac{|Q_c|}{|Q_h|} = \frac{T_c}{T_h}$

$$\Rightarrow e_{carnot} = 1 - \frac{|Q_c|}{|Q_h|} = 1 - \frac{T_c}{T_h} \ast.$$

(b)

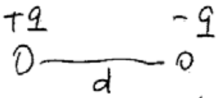
(b) $\Delta S = \Delta S_h + \Delta S_c$

$$= \frac{|Q_h|}{T_h} - \frac{|Q_c|}{T_c} \quad \text{But } \frac{|Q_c|}{|Q_h|} = \frac{T_c}{T_h} \text{ as in (a)}$$

$= 0$ That's why Carnot engine is a perfect engine

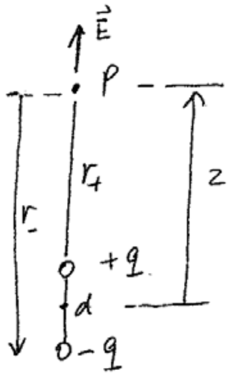
2.
(a)

③ dipole —



z

two charges separated by a distance, have Oppositive sign are called electric dipole



$$\vec{E} = \vec{E}_{(+)} + \vec{E}_{(-)} = \text{electric field @ pt. P.}$$

$$= \frac{1}{4\pi\epsilon_0}\left[\frac{q}{r_+^2} - \frac{q}{r_-^2}\right]$$

$$= \frac{q}{4\pi\epsilon_0}\left[\frac{1}{[z-\frac{1}{2}d]^2} - \frac{1}{[z+\frac{1}{2}d]^2}\right]$$

$$= \frac{q}{4\pi\epsilon_0 z^2}\left[\left(1-\frac{d}{2z}\right)^{-2} - \left(1+\frac{d}{2z}\right)^{-2}\right], \quad z \gg d. \ \frac{d}{2z} \ll 1$$

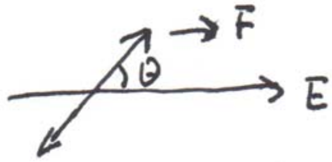
$$= \frac{q}{4\pi\epsilon_0 z^2}\left[\left(1+\frac{2d}{2z(1!)} + \cdots\right) - \left(1-\frac{2d}{2z(1!)} + \cdots\right)\right]$$

$$\doteq \frac{q}{4\pi\epsilon_0 z^2} \frac{2d}{z}$$

$$= \frac{1}{2\pi\epsilon_0} \frac{qd}{z^3}$$

$$= \frac{1}{2\pi\epsilon_0} \frac{\vec{P}}{z^3} \qquad P \equiv qd = \text{electric dipole moment.}$$

(b) in page 23-8



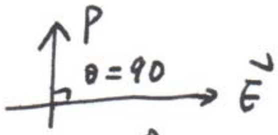
$$\tau = \frac{F}{2} d \sin\theta + F \frac{d}{2} \sin\theta = F d \sin\theta$$

$$= qEd\sin\theta = pE\sin\theta$$

in general $\tau = \vec{p} \times \vec{E} = -pE\sin\theta$

(negative torque)

(c)



$$U = -W = -\int_{90^\circ}^{\theta} \tau \, d\theta = -\int_{90^\circ}^{\theta} -pE\sin\theta \, d\theta$$

$$= -p \cdot E\cos\theta = -\vec{p} \cdot \vec{E}$$

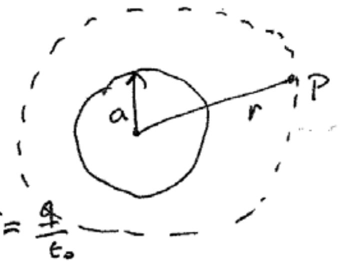
$$\therefore W = \vec{p} \cdot \vec{E}$$

3.

② A spherically symmetric charge distribution

②-1 : A point outside the sphere

Pick a Gaussian surface bigger than the surface

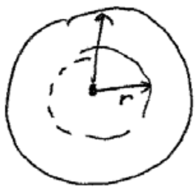


$$\Phi_E = \oint E \cdot dA = E \oint dA = E \cdot 4\pi r^2 = \frac{q}{\epsilon_0}$$

$$E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2} = k_e \frac{q}{r^2} \quad (r > a)$$

②-2 . A point ~~and~~ inside the sphere.

Pick a Gaussian surface as shown



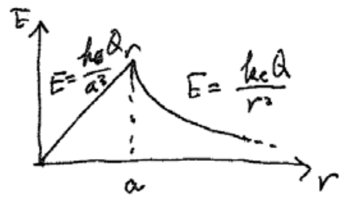
$$q_{in} = \rho V' = \rho \cdot \frac{4}{3}\pi r^3$$

$$\Phi_E = \oint E\, dA = E \oint dA = E(4\pi r^2) = \frac{q_{in}}{\epsilon_0}$$

$$E = \frac{q_{in}}{4\pi\epsilon_0 r^2} = \frac{\rho(\frac{4}{3}\pi r^3)}{4\pi\epsilon_0 r^2} = \frac{\rho}{3\epsilon_0} r$$

$$\rho = Q \Big/ \tfrac{4}{3}\pi a^3$$

$$\therefore E = \frac{Qr}{4\pi\epsilon_0 a^3} = k_e \frac{Q}{a^3} r , \quad (r < a)$$



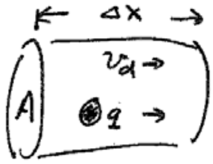
4.

(a) (b)

$n \equiv$ number of moble charge per unit volume

$$\Delta Q = (nA\,\Delta x)\,q$$

$$= (nA\,\underbrace{v_d\,\Delta t}_{})\,q$$



$$I_{av} = \frac{\Delta Q}{\Delta t} = n\,q\,v_d\,A$$

$q \equiv$ Charge on each carrier

v_d = Carrier speed

= drift speed

v_d = drift speed.

Example 27.1, page 834

Volume of one mole of Copper $V = \frac{m}{\rho} = \frac{63.5\ g}{8.95\ g/cm^3} = 7.09\ cm^3$

$$n = \frac{6.02\times10^{23}\ \text{electrons}}{7.09\ cm^3}\left(\frac{1\times10^6\ cm^3}{1\ m^3}\right) = 8.49\times10^{28}\ \text{electrons}/m^3$$

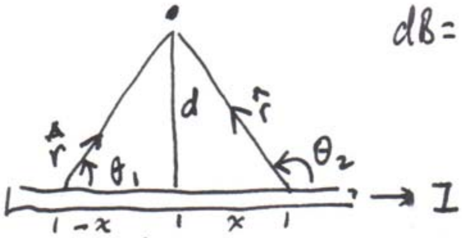
— each Copper atom contribut one free electro

$$v_d = \frac{I^{\text{given}}}{nqA_{\text{given}}} = \frac{10\ C/s}{(8.49\times10^{28}\ e/m^3)(1.6\times10^{-19}\ C)(3.31\times10^{-6}\ m^2)}$$

$$= 2.22\times10^{-4}\ m/s$$

(c). Vd describe the speed of electons in the conductor. When light ~~switched on~~ switched on, the electric field that drives the electrons travels through the conductor with a speed close to that of light. So light tunns on instantaneously.

5



$$dB = \frac{\mu_0 I}{4\pi} \frac{\vec{ds} \times \hat{r}}{r^2}$$

$\vec{ds} \times \hat{r} = |\vec{ds} \times \hat{r}|\,\hat{k}$. $\hat{k} \equiv$ the direction of the magnetic field

$= (ds \sin\theta)\,\hat{k}$

$= (dx \sin\theta)\,\hat{k}$

$\vec{dB} = (dB)\,\hat{k}$, in this case . the magnetic field is pointing out of the paper.

$$= \frac{\mu_0 I}{4\pi} \frac{dx \sin\theta}{r^2}$$

$$r = \frac{a}{\sin\theta} = a \csc\theta$$

$$x = -a \cot\theta$$

$$dx = a \csc^2\theta$$

$$\therefore dB = \frac{\mu_0 I}{4\pi} \frac{d \csc^2\theta \sin\theta\, d\theta}{d^2 \csc^2\theta}$$

(a) $B = \frac{\mu_0 I}{4\pi} \int_{\theta_1}^{\theta_2} \sin\theta\, d\theta = \frac{\mu_0 I}{4\pi} (\cos\theta_1 - \cos\theta_2)$

— for finite size wire θ_1 and θ_2 are as indicated in the figure

(b) for infinite long wire.

$\theta_1 = 0$. $\theta_2 = 180°$

Plug in the above equation

$B = \frac{\mu_0 I}{2\pi d}$. → You can also calculate using ~~Gauss~~ Ampere's law it will be alot easier