LECTURE 10

1 kg water at 0°C + 1 kg water at 100°C. Compute ΔS.

$$dQ = mc\,dT$$

$$\Delta S = S_2 - S_1 = \int_1^2 \frac{dQ}{T}$$

$$= \int_{T_1}^{T_2} \frac{mc\,dT}{T}$$

$$= mc \ln\left(\frac{T_2}{T_1}\right)$$

$$= (1\,kg)(4190\,J/kg \cdot K)\left(\ln \frac{373}{273}\right)$$

$$= 1.31 \times 10^3\,J/K$$

For a Carnot cycle

$$\frac{|Q_C|}{|Q_H|} = \frac{T_C}{T_H}$$

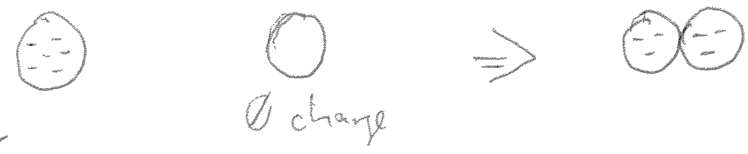
or $$\frac{Q_H}{T_H} + \frac{Q_C}{T_C} = 0$$

$$\Delta S_H + \Delta S_C = 0$$ True for ANY cyclic process.

Coulomb's Observations

1. For point charges (very small charged bodies), the electric force is proportional to $\frac{1}{r^2}$.

2. The electric force between 2 point charges depends on the quantity of charge of each body.



→ the forces exerted on each other proportional to the product of 2 charges.

Coulomb's Law

$$F \propto \frac{|q_1 q_2|}{r^2}, \quad F = k\frac{|q_1 q_2|}{r^2}$$

$$k = 8.988 \times 10^9 \ N \cdot m^2/C^2$$

$$= (10^{-7} N \cdot s^2/C^2)\, c^2$$

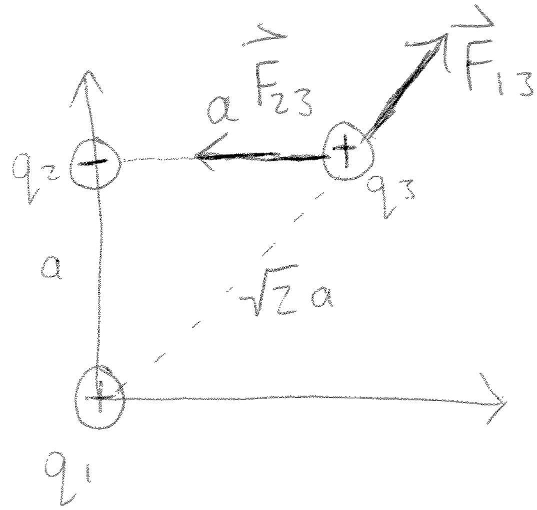
← speed of light

$$= \frac{1}{4\pi\epsilon_0}$$

ϵ_0 – permittivity of free space

$$\epsilon_0 = 8.854 \times 10^{-12} \ C^2/N \cdot m^2$$

Newton's 3rd law is obeyed!



Force on q_3

Given $q_1 = q_3 = 5.0\,\mu C$

$q_2 = -2.0\,\mu C$

$a = 0.10\,m$.

$$F_{23} = \frac{k|q_2||q_3|}{a^2} = \frac{\left(9.0\times10^9\ \frac{N\cdot m^2}{C^2}\right)|q_2||q_3|}{(0.10\,m)^2}$$

$$= 9.0\,N$$

$$F_{13} = \frac{k|q_1||q_3|}{(\sqrt{2a})^2} = 11.0\,N$$

$F_{13x} = (\cos 45)(F_{13}) = 7.9\,N$

$F_{13y} = (\sin 45)(F_{13}) = 7.9\,N$

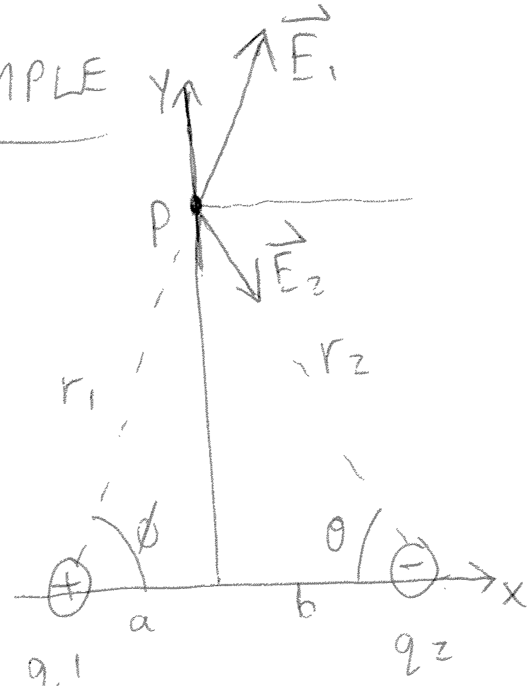
$\vec{F}_{3x} = \vec{F}_{23x} + \vec{F}_{13x} = (9.0N)(-\hat{i}) + (7.9N)(\hat{i})$

$= -(1.1N)\hat{i}$

$\vec{F}_{3y} = \vec{F}_{13y} = (7.9\,N)\hat{j}$

$\vec{F}_3 = (-1.1\hat{i} + 7.9\hat{j})\,N$

EXAMPLE



E @ P from q_1

Magnitudes

$$E_1 = \frac{k|q_1|}{r_1^2} = \frac{k|q_1|}{a^2+y^2}$$

$$E_2 = \frac{k|q_2|}{r_2^2} = \frac{k|q_2|}{b^2+y^2}$$

Vectors

$$\vec{E}_1 = \frac{k|q_1|}{a^2+y^2}\cos\phi\,\hat{i} + \frac{k|q_1|}{a^2+y^2}\sin\phi\,\hat{j}$$

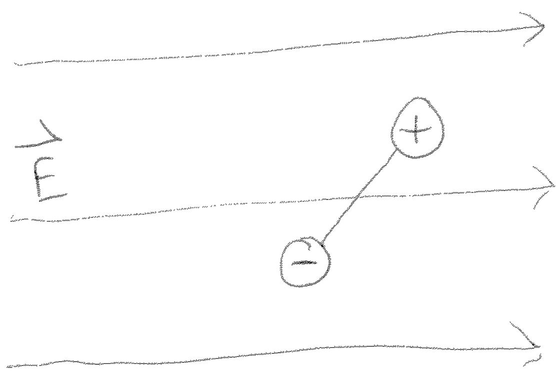
$$\vec{E}_2 = \frac{k|q_2|}{b^2+y^2}\cos\theta\,\hat{i} - \frac{k|q_2|}{b^2+y^2}\sin\theta\,\hat{j}$$

$$E_x = E_{1x} + E_{2x} = \frac{k|q_1|}{a^2+y^2}\cos\phi + \frac{k|q_2|}{b^2+y^2}\cos\theta$$

$E_y = E_{1y} + E_{2y}$

$$= \frac{k|q_1|}{a^2+y^2}\sin\phi - \frac{k|q_2|}{b^2+y^2}\sin\theta$$

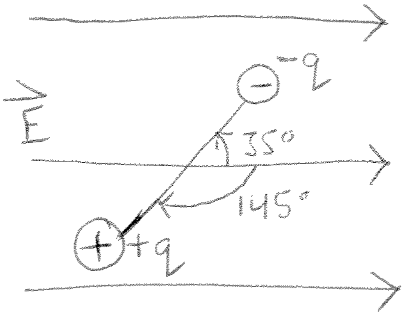
$|q_1| = |q_2|$ Dipole



Net force?

$= 0$

EXAMPLE



$|\vec{E}| = 5.0 \times 10^5$ N/C

$|q| = 1.6 \times 10^{-19}$ C

$d = 0.125$ nm

Find: a) Net force exerted by the field on the dipole.

b) The magnitude and direction of the dipole moment.

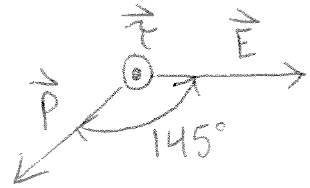
c) The magnitude and direction of the torque

d) The potential energy of the system in the direction shown.

a) Field is uniform. Dipole has equal and opposite charges. The total force is zero.

b) $p = qd = (1.6 \times 10^{-19}\ \text{C})(0.125 \times 10^{-9}\ \text{m})$

$= 2.0 \times 10^{-29}\ \text{C}\cdot\text{m}$



c) $\tau = pE\sin\phi = (2.0 \times 10^{-29}\ \text{C})(5.0 \times 10^5\ \text{N/C})(\sin 145°)$

$= 5.7 \times 10^{-24}\ \text{N}\cdot\text{m}$

$\vec{\tau}$ is out of page and rotation is therefore counter-clockwise.

d) $U = -pE\cos\phi = -(2.0 \times 10^{-29}\ \text{C}\cdot\text{m})(5.0 \times 10^5\ \text{N/C})(\cos 145°)$

$= 8.2 \times 10^{-24}$ J