Whoa! back to our course

Coulomb's Law

Fundamental Remember This !!

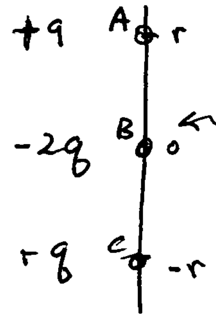
$$\vec{F}_{12} = k \frac{q_1 q_2}{r_{12}^2} \hat{r}$$

$k \equiv \frac{1}{4\pi \epsilon_0} = 8.99 \times 10^{9} \frac{N \cdot m^2}{C^2}$

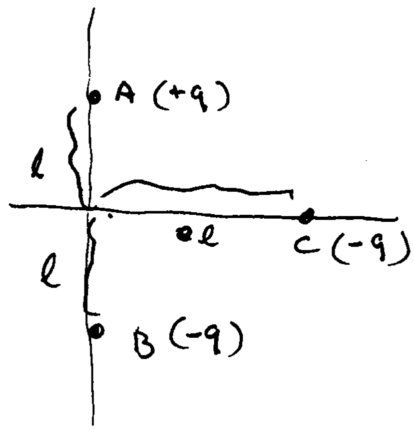
$\epsilon_0 \equiv$ Permittivity of free space

$\epsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{N \cdot m^2}$

Vector equation : superposition holds

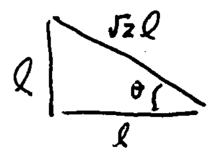


Net force is zero on charge b

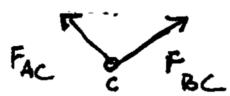


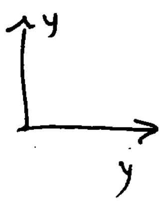
Skip

Do this example



$\sin\theta = \frac{l}{\sqrt{2}\, l} = \frac{1}{\sqrt{2}}$





symmetry

$\sum F_x : \quad (F_{AC})_x + (F_{BC})_x = 0$

$\sum F_y : \quad |\vec{F}_{AC}| \sin\theta + |\vec{F}_{BC}| \sin\theta$

$= |\vec{F}_{AC}| \frac{1}{\sqrt{2}} + |\vec{F}_{BC}| \frac{1}{\sqrt{2}}$

$= \frac{2}{\sqrt{2}} \frac{k(q)(q)}{(\sqrt{2}\, l)^2} \hat{y}$ up in y

q_1 → field → q_2

Field vs. action at a distance

↳ if q_1 moves ... change in field propagates at c
field disturbance

Electric field

electric field strength $\vec{E}$ defined as

Fundamental ⇒ Remember this

$$\vec{E} = \vec{F}/q_0$$

where q_0 is some positive test charge.

$\vec{F}$ is $\vec{F}$ due to electrostatic force on q_0

Electric field lines – lines of force

useful for visualizing problems

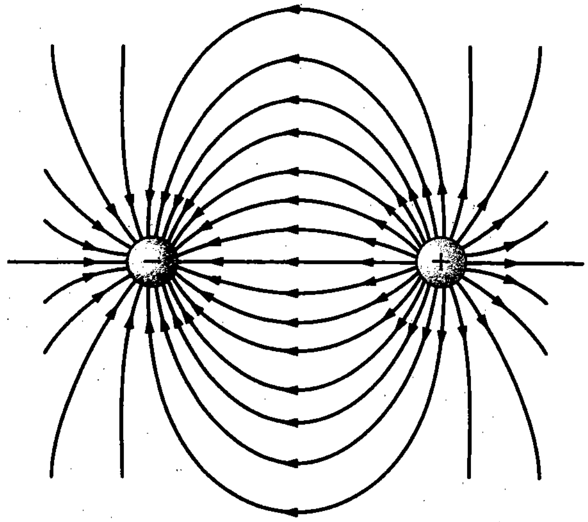
- Tangent to line of force gives $\vec{E}$ (direction only) at that point
- Start on ⊕ charge or ∞
- End on ⊖ charge or ∞
- density of lines ∝ magnitude of $\vec{E}$
- lines never cross

Transparency 2

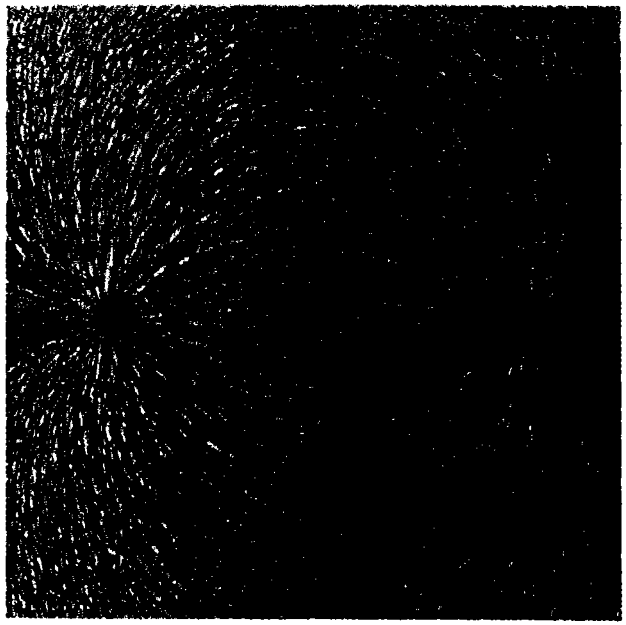
Figure 22-19, page 673, Figure 22-20, page 673

Electric field lines for an electric dipole (top) and for two point charges +2q and -q (bottom)

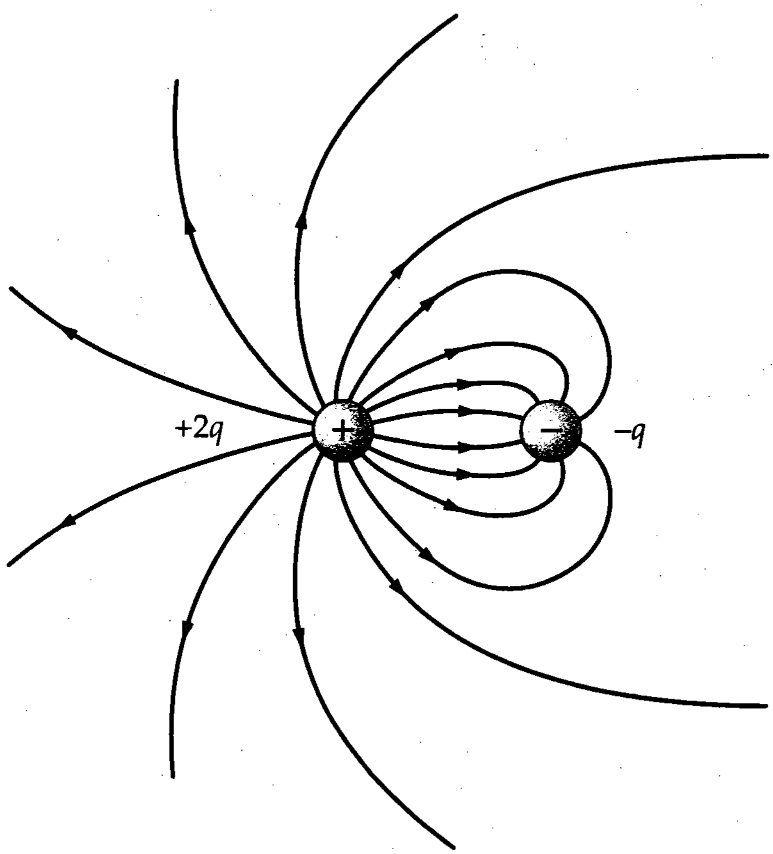
Tipler: **Physics for Scientists and Engineers 4/e**



(*a*)

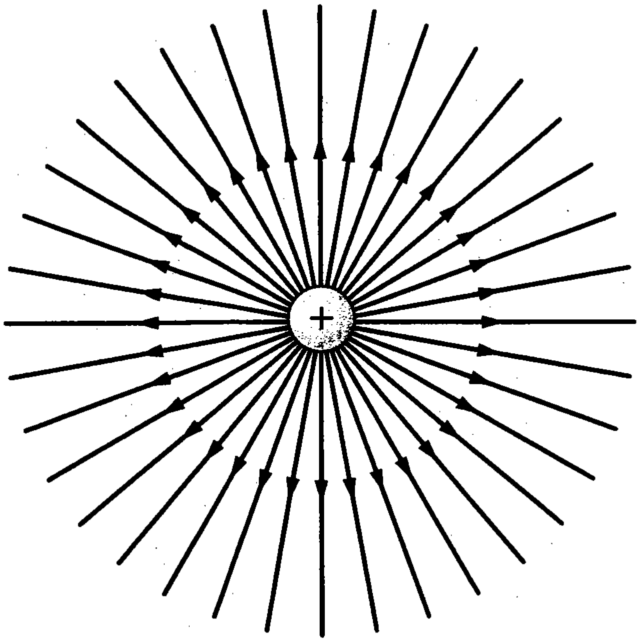


(*b*)

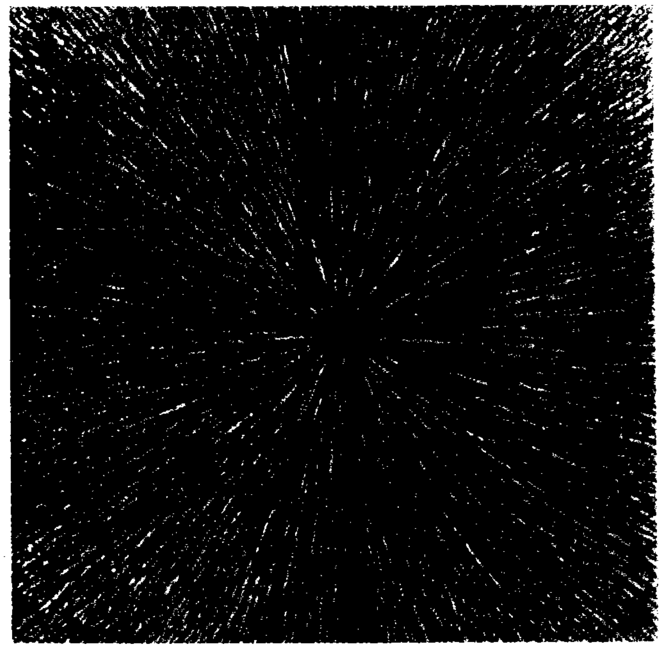


Transparency 1
Figure 22-17, page 672; Figure 22-18, page 672
Electric field lines for one positive point charge (top) and for two positive point charges (bottom)

Tipler: **Physics for Scientists and Engineers 4/e**



(*a*)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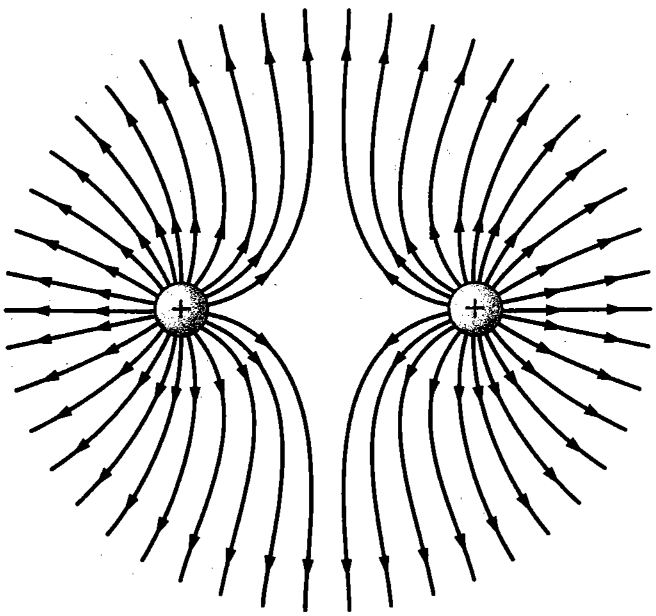
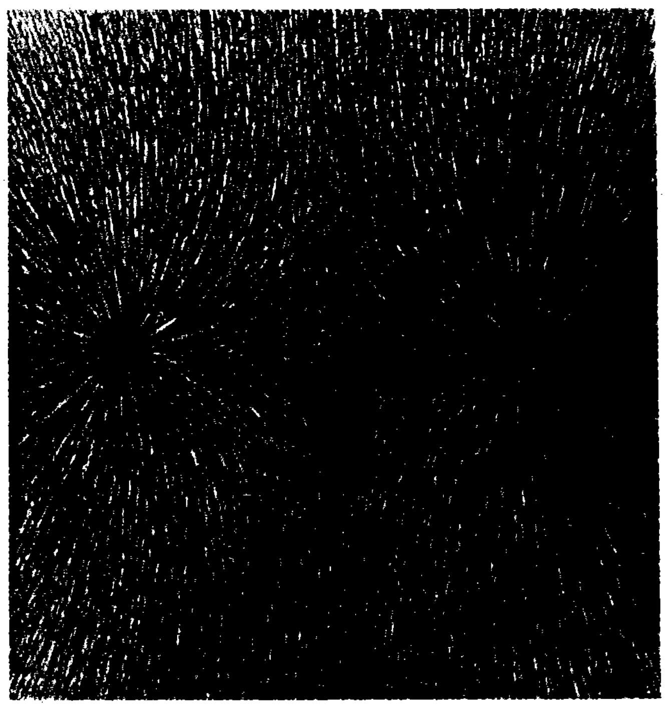


(*a*)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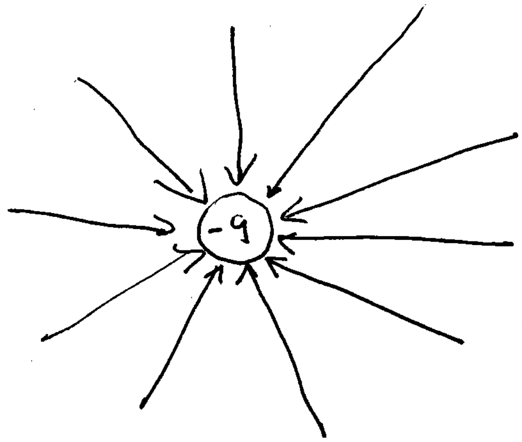
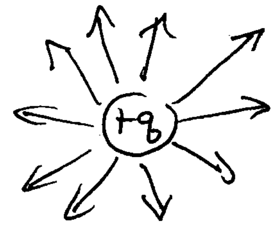
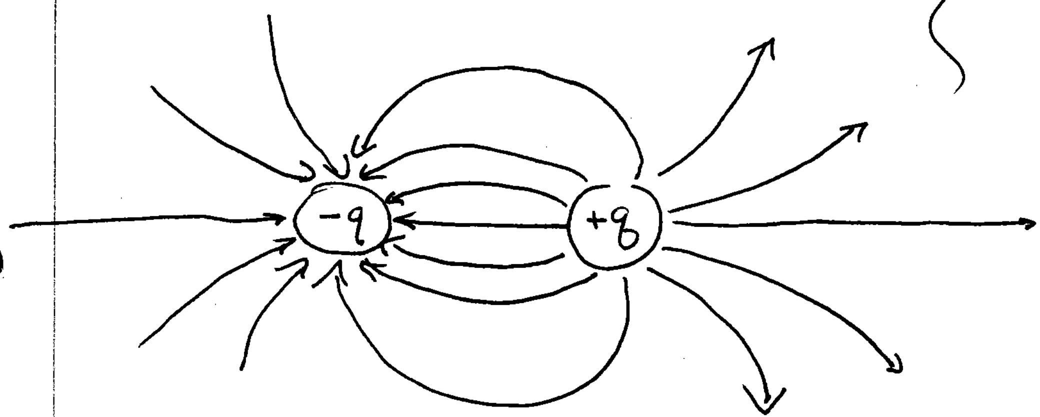
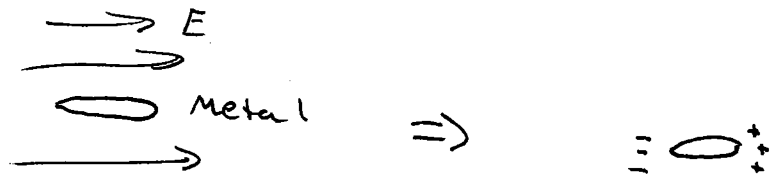








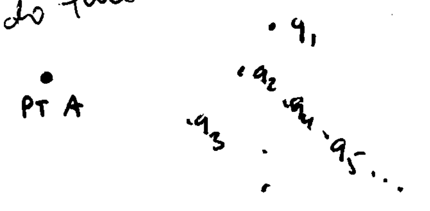
little dipole

orients in field due to torque

⇒ TRANSparency for lines of force

Calculation of The electric Field from Coulombs Law

→ How do I do this



$$\vec{E}_A = \sum \frac{\vec{F}_{iA}}{q_0} = \sum \frac{k\, q_i\, q_0\, \hat{r}_{iA}}{r_{iA}^2} \Big/ q_0$$

$$= \sum \frac{k\, q_i\, \hat{r}_{iA}}{r_{iA}^2}$$

Electric Field

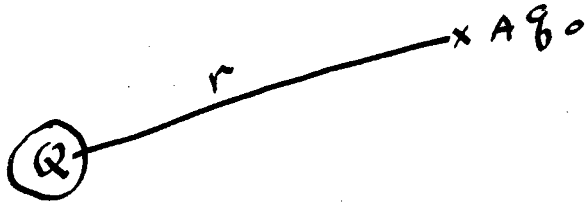
$\vec{E} = \vec{F}/q$ at a point A Vector

$\vec{F}_{\text{on } q \text{ at pt A}} = q\vec{E}$

If you know $\vec{E}$ thruout space you know $\vec{F}$ on charged particles

Electrostatics boils down to determining $\vec{E}$

$\vec{E}$ surrounding point charge



Place q_0 at pt A a distance r from Q

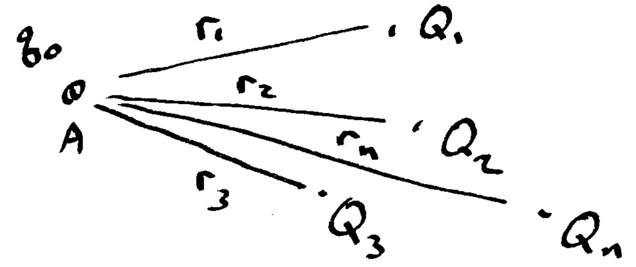
$$\vec{F} = \frac{k q_0 Q}{r^2}\hat{r}$$

$$\vec{E} = \frac{\vec{F}}{q_0} = \frac{kQ}{r^2}\hat{r}$$

radially away from Q if Q is +

radially toward Q if Q is −

→ Electric field strength falls off as $\frac{1}{r^2}$



at point A
What is $\vec{E}_A$ for a distribution of discrete point charges

$$\vec{F}_{\text{on test charge}} = \frac{kQ_1 q_0 \hat{r}_1}{r_1^2} + \frac{kQ_2 q_0 \hat{r}_2}{r_2^2} \dots + \frac{kQ_n q_0 \hat{r}_n}{r_n^2}$$

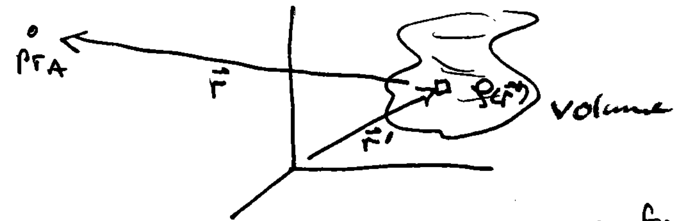
vector sum

$$\vec{E} = \frac{\vec{F}}{q_0} = \frac{kQ_1}{r_1^2}\hat{r}_1 + \frac{kQ_2}{r_2^2}\hat{r}_2 + \dots + \frac{kQ_n}{r_n^2}\hat{r}_n$$

overall $\vec{E}$ is vector sum ~~all~~ of all the individual E fields

⇒ Principle of Superposition!

go to Continuous charge distribution



dq is fn of $\vec{r}'$

$$d\vec{E} = \frac{k\,dq}{r^2}\hat{r} = \frac{k\,dq(\vec{r}')}{r^2}\hat{r}$$

⇒ what is dE due to little dq

$dq = \rho\, dV$ volume charge

$dq = \sigma\, dA$ surface charge

$dq = \lambda\, dL$ line charge

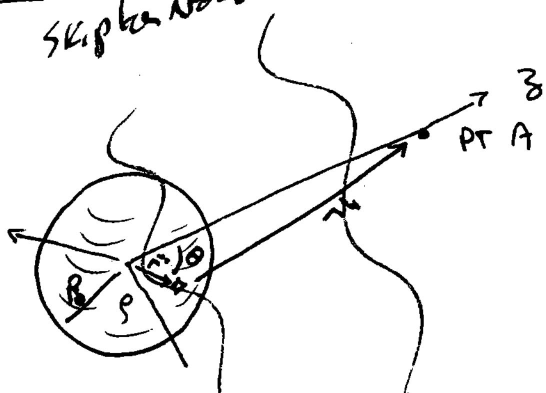
$$E = \int \frac{k\,dq}{r^2}\hat{r} \qquad E = \int_{vol} \frac{k\,dq(\vec{r}')}{r^2}\hat{r}$$

$$= \int_{vol} \frac{k\,\rho(r')\,\hat{r}\,dv}{r^2}$$

NOTE r can change as r' changes in integral

Example

skip for now



Calculate $\vec{E}$ along $\hat{z}$ axis outside of a uniform Spherical charge dist.

uniform spherical distribution

$$\rho = \frac{Q_{TOT}}{\frac{4}{3}\pi R^3}$$