FIELDS = region of space where an OBJECT experiences a FORCE

GRAVITATION

* NEWTON's LAW OF GRAVITATION:

gravitational constant

$$F_{grav} = \frac{G m_1 m_2}{r^2}$$

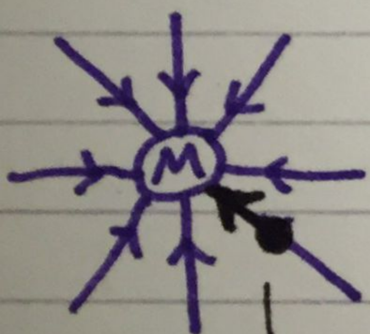
gravitational force of attraction

"force between 2 masses is $\propto$ to product of masses and $\frac{1}{\propto}$ to square of distance between the masses"

r — distance between CENTRE of the two objects

* GRAVITATIONAL FIELD LINES

= lines that indicate direction of the gravitational force that would act on a $\underbrace{\text{test mass}}_{}$ placed in the field



test mass

mass small enough not to affect shape of field with own gravity

* The force follows an INVERSE SQUARE LAW

* g & DENSITY

$g = \frac{F}{m}$ (force per unit mass)

$$= \frac{\frac{G\cancel{M_1}M_2}{r^2}}{\cancel{M_1}} = \frac{GM_2}{r^2}$$

— mass of planet

if ρ = constant...

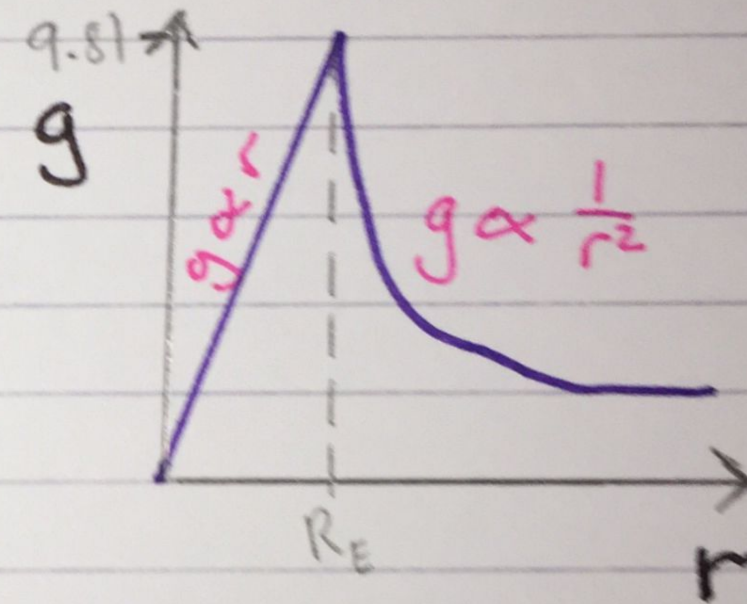
$m = \rho V$ $V = \frac{4}{3}\pi r^3$

$m = \frac{4}{3}\rho\pi r^3$ $\therefore$ $g = \frac{\frac{4}{3}G\rho\pi \cancel{r^3}}{\cancel{r^2}}$

$\therefore$ $g = \frac{4}{3}G\rho\pi r$

→ as ρ = constant (below planet's surface):

$$g \propto r$$



→ above planet's surface:

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

* SATELLITE MOTION

→ KEPLER's THIRD LAW: $T^2 \propto r^3$

orbital period — T

r — orbital radius

$$F_{cent} = \frac{mv^2}{r} \qquad F_{grav} = \frac{GMm}{r^2} \qquad v = \frac{2\pi r}{T}$$

$$\frac{GM\cancel{m}}{r^2} = \frac{\cancel{m}v^2}{r}$$

$$\frac{GM}{r^2} = \frac{v^2}{r}$$

$$\frac{GM}{r} = v^2$$

$$GM = rV^2$$

$$GM = r\,\frac{4\pi^2 r^2}{T^2}$$

$$GM = \frac{4\pi^2 r^3}{T^2}$$

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

$$T^2 = \left(\frac{4\pi^2}{GM}\right) r^3$$

∴ for a LOW POLAR ORBIT SATELLITE:

$$T = \sqrt{\left(\frac{4\pi^2}{GM}\right) r^3}$$

T = 90 minutes

→ GEO-STATIONARY SATELLITES

$$T = 24 \text{ hours}$$

→ centripetal acceleration of satellites is the gravitational field strength at that point so SATELLITES ARE IN FREEFALL

$$g = \frac{GM}{r^2} = \frac{v^2}{r}$$

* GRAVITATIONAL POTENTIAL ENERGY (E_p)

→ close to Earth's surface, GPE:

$$\Delta E_p = mg\Delta h$$

→ further from surface of the Earth:

$$E_p = -\frac{GMm}{r}$$

→ E_p is always NEGATIVE

- work must be done to move mass towards infinity AGAINST attraction of other mass
- gravity is always attractive

* GRAVITATIONAL POTENTIAL (V)

= amount of GPE an object will have per unit mass, at a point in a gravitational field

$$V = \frac{E_p}{m} = -\frac{GM}{r} \quad (J\,kg^{-1})$$

(= work done per unit mass in moving a mass from infinity to that point in the field.)

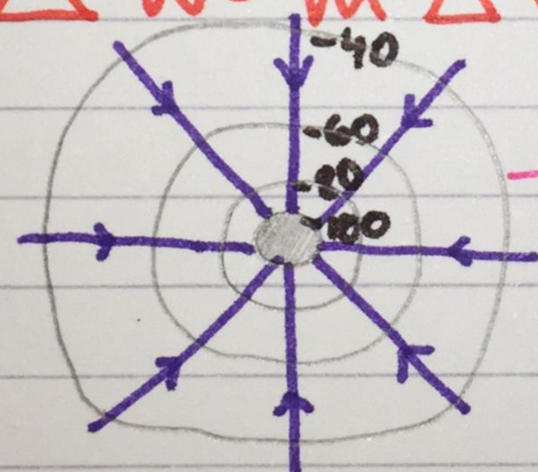
* WORK DONE AGAINST GRAVITY

(raising objects above surface of planets)

work done = GPE gained

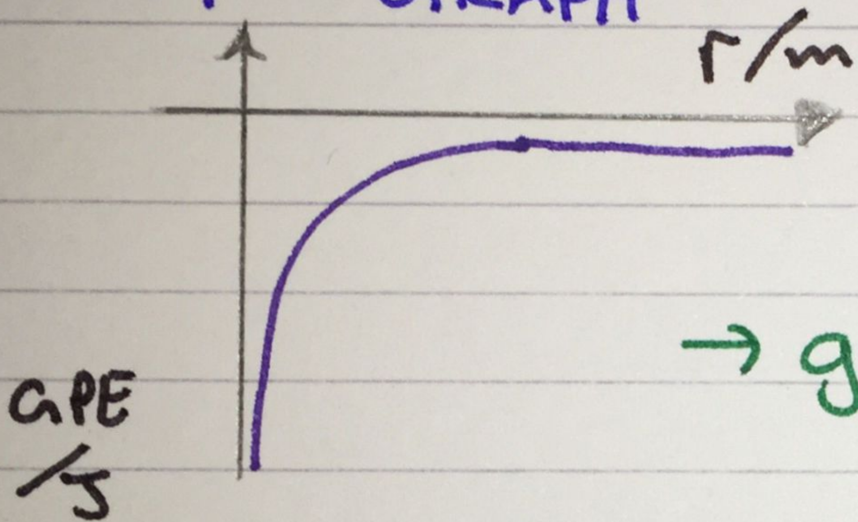
$$\Delta W = \Delta E_p$$

$$\Delta W = m \Delta V$$



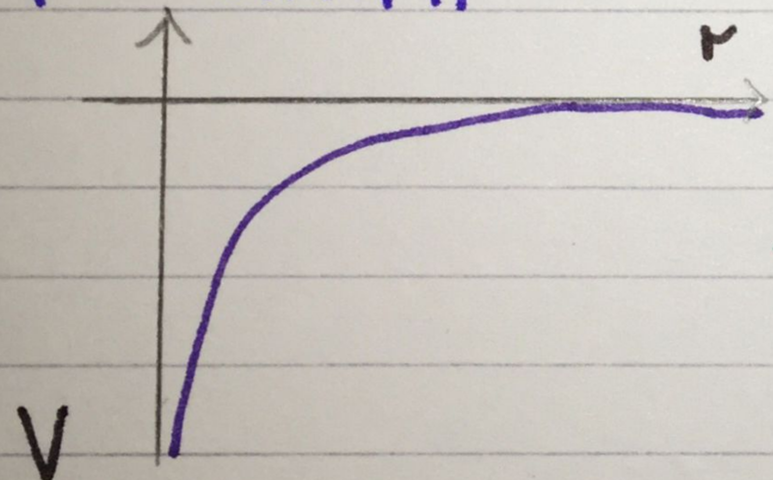
— equipotentials

* GPE - r GRAPH



→ gradient = F_{grav}

* V - r GRAPH



→ gradient = g

*ESCAPE VELOCITY = velocity at which an object must be projected in order to completely escape gravitational field of the planet

GPE gained = KE lost

$$\frac{GMm}{r} = \frac{1}{2} m v_{esc}^2$$

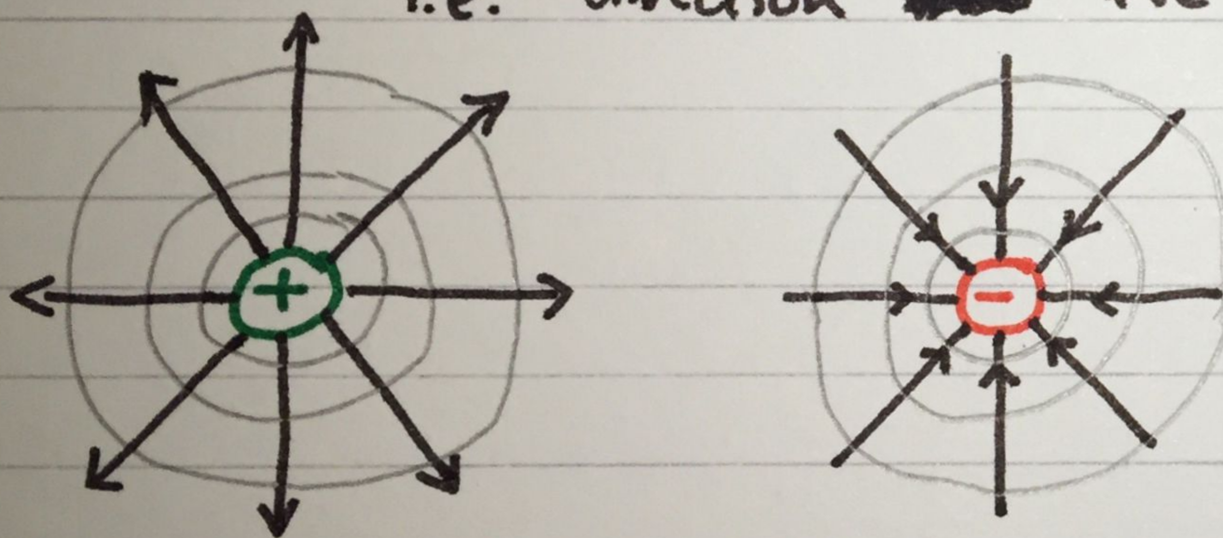
$$v_{esc} = \sqrt{\frac{2GM}{r}}$$

ELECTRIC FIELDS

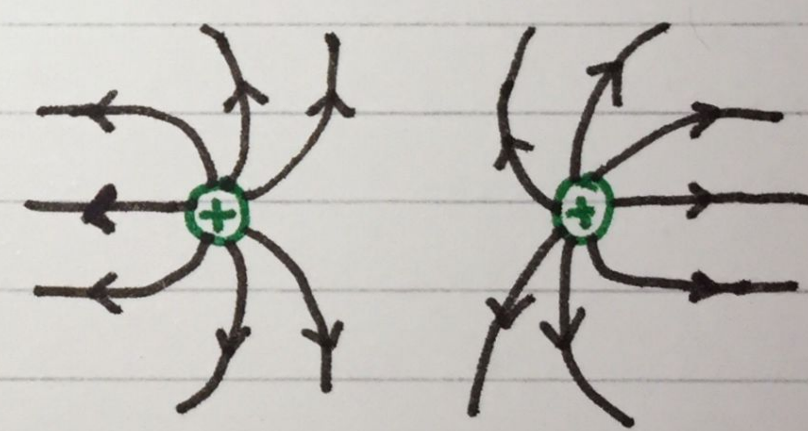
* DIRECTION OF AN ELECTRIC FIELD

= direction force would be experienced by a positive charge

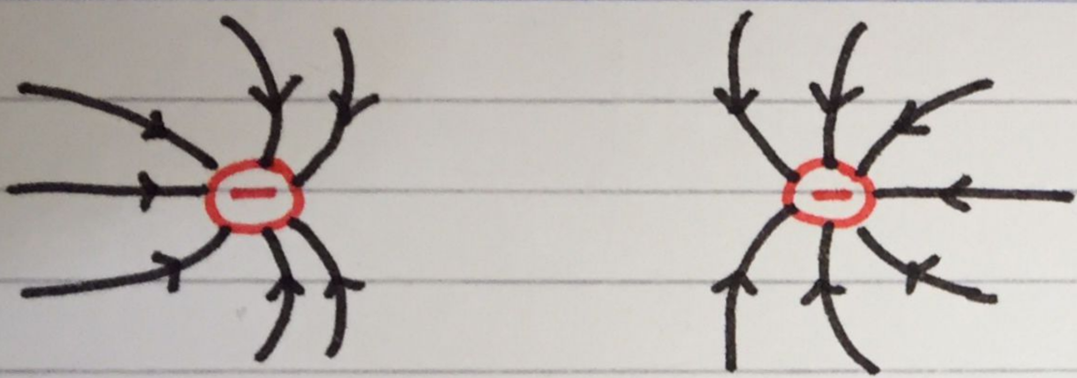
i.e. direction +ve charge would move in



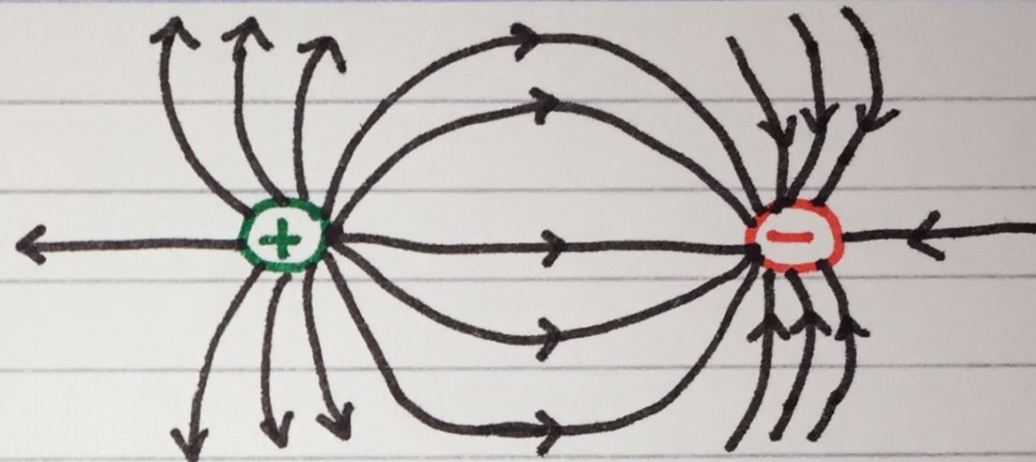
electric field from an isolated +ve / -ve charge



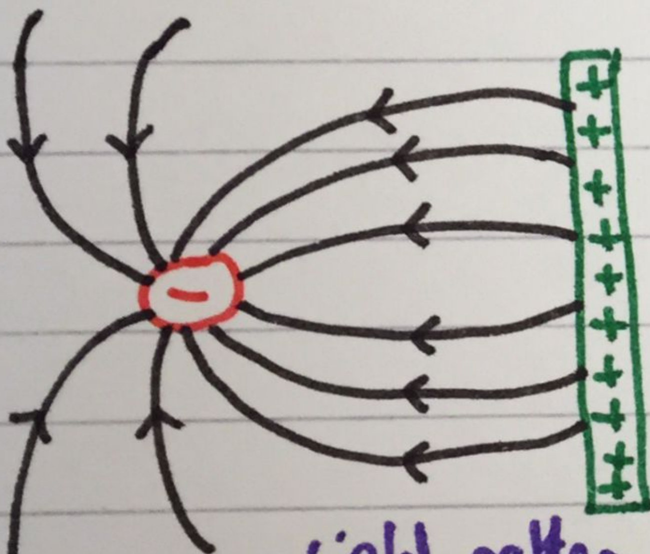
two positive point charges

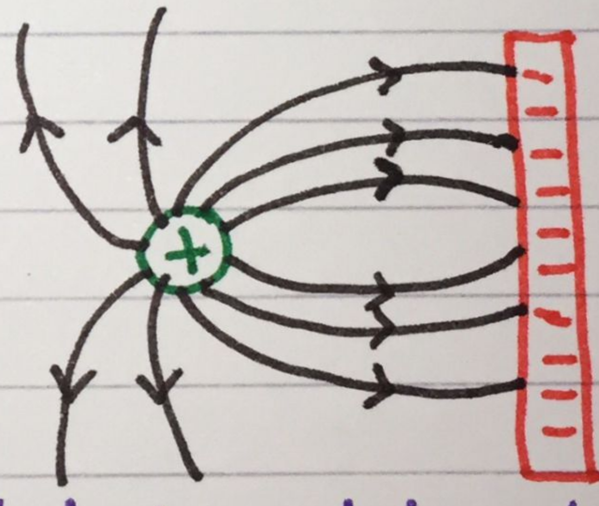


two negative point charges

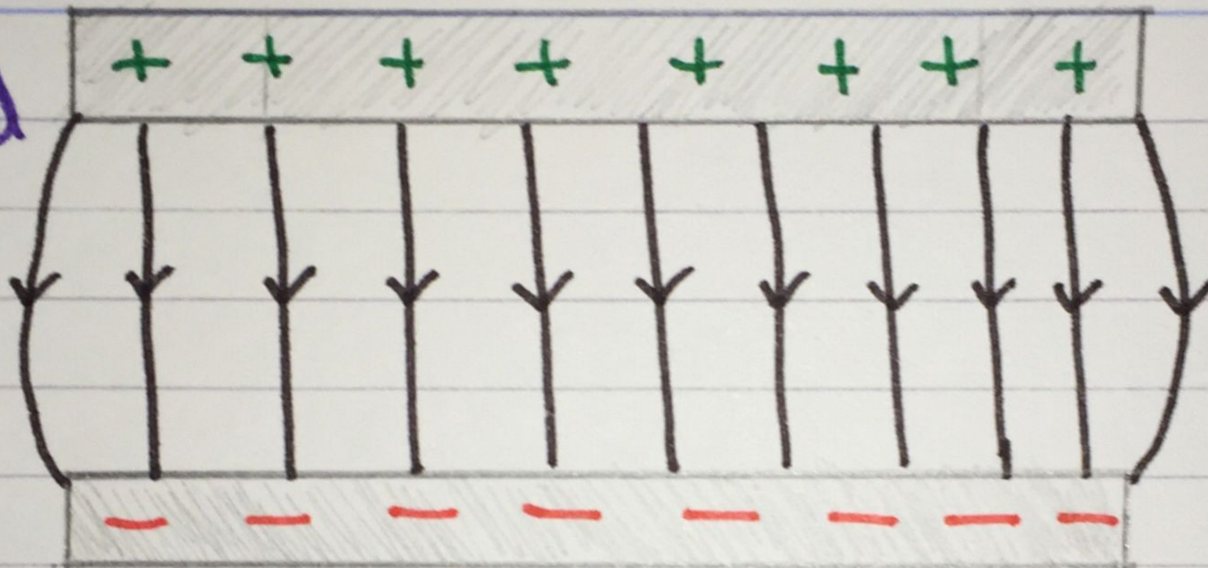


two unlike point charges





field pattern of a pointed electrode and plane electrode two parallel plates



"force between two point charges is $\propto$ to product of charges and $\frac{1}{\propto}$ to square of distance between the charges"

*** COULOMB'S LAW** $\Rightarrow$

constant of proportionality — k

$$F = \frac{k\,Q_1\,Q_2}{r^2} = \frac{1}{4\pi\varepsilon_0}\,\frac{Q_1\,Q_2}{r^2}$$

$$\boxed{\begin{array}{l} Q_1 = |Q_1| \\ Q_2 = |Q_2| \end{array}}$$

$k =$ [redacted]$^{9}\ Nm^2C^{-2} = \dfrac{1}{4\pi\varepsilon_0}$

8.99×10^9

* ELECTRIC FIELD STRENGTH (E)

= force experienced by a positive test charge of 1 C

$$E = \frac{F}{q}$$

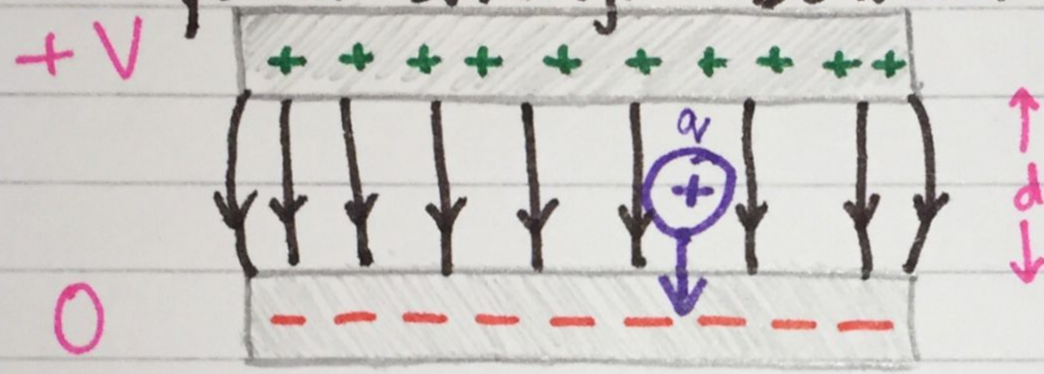
$$E = \frac{\frac{k Q_1 \cancel{Q_2}}{r^2}}{\cancel{Q_2}} = \frac{k Q}{r^2} \Rightarrow E = \frac{Q}{4\pi \varepsilon_0 r^2}$$

electric field strength a distance r from point charge Q

this is for a RADIAL FIELD

→ for a UNIFORM FIELD:

i.e. field strength between 2 parallel plates.



$$E = \frac{F}{Q} \qquad W = F\,d \Rightarrow W = VQ$$

$$Fd = VQ$$

$$F = \frac{W}{d}$$

$$E = \frac{\frac{VQ}{d}}{Q} = \frac{V}{d}$$

Vm^{-1} — $E = \dfrac{V}{d}$ — volts, — m

* SHUTTLING BALL EXPERIMENT

→ able to calculate charge on ball if you know current and time of travel of ball between plates

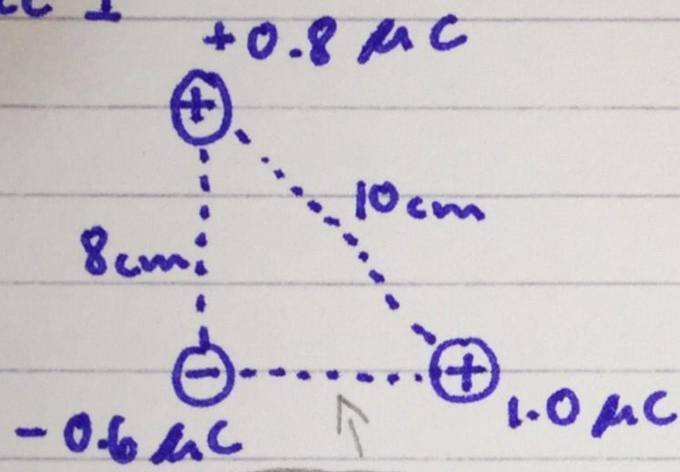
→ current = rate at which ball carries charge across gap

→ ball shuttles backwards and forwards between plates because when it touches the plate it becomes charged and is attracted to opposite plate

→ and when it touches this plate it becomes oppositely charged and attracted to first plate

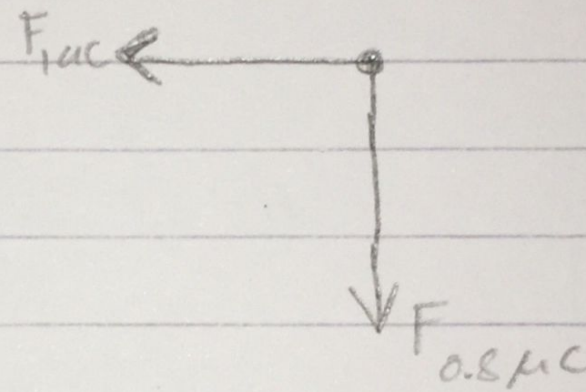
→ $Q = It$ to calculate charge

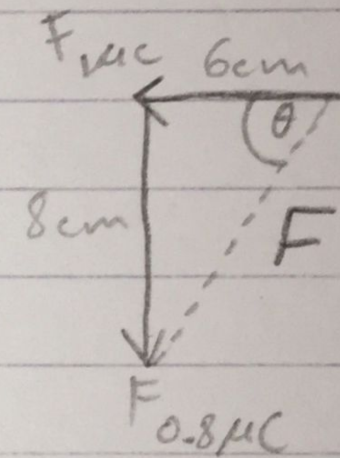
*** EXAMPLE 1**



$\sqrt{10^2-8^2} = 6cm$

$$F = \frac{kQ_1Q_2}{r^2}$$





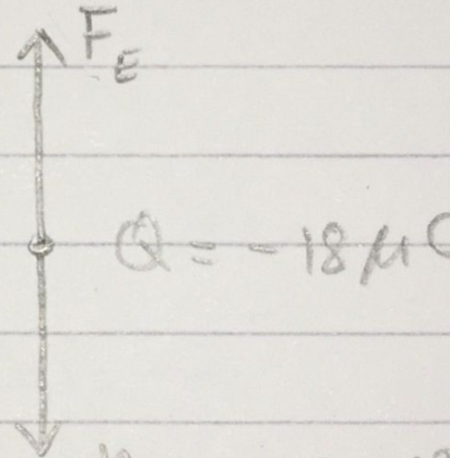
$$F_{1\mu C} = \frac{(8.99\times10^9)(0.6\times10^{-6})(1.0\times10^{-6})}{(0.06)^2} = 1.50N$$

$$F_{0.8\mu C} = \frac{(8.99\times10^9)(0.6\times10^{-6})(0.8\times10^{-6})}{(0.08)^2} = 0.674N$$

$F = \sqrt{1.5^2 + 0.674^2} = 1.6N$ $\quad \theta = \tan^{-1}\left(\frac{0.674}{1.5}\right) = 24°$

* EXAMPLE 2

- a tiny ball ($m = 0.012\,kg$) carries charge of $-18\,\mu C$. What electric field is needed to cause ball to float above ground?



$$E = \frac{F}{Q}$$

$$mg = 0.012 \times 9.81 = 0.11772\,N$$

$$F_E = 0.11772\,N$$

$$E = \frac{0.11772}{-18 \times 10^{-6}} = -6540\,N\,C^{-1}$$

down

$$= 6540\,N\,C^{-1}$$

up

* ELECTRICAL POTENTIAL (V)

= work done per unit positive charge when a positive test charge is moved from infinity to that position

V [redacted] $= \frac{E_p}{Q} = \frac{Q}{4\pi\varepsilon_0 r}$

→ it can be considered as VOLTAGE (JC^{-1})

so... $E_p = QV$

* E – r GRAPH

→ area under = ΔV