show an understanding of the concept of an electric field as an example of a field of force and define electric field strength as force per unit positive charge

Electric Field

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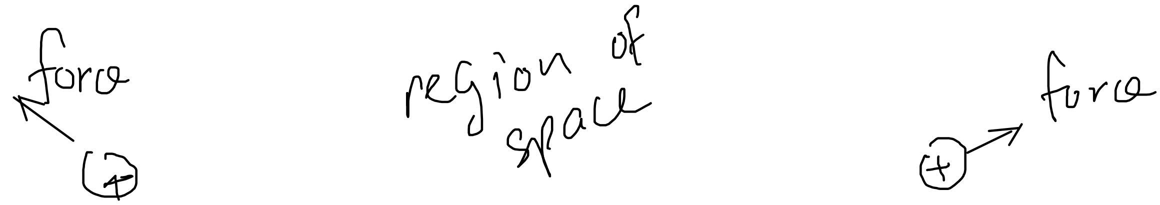

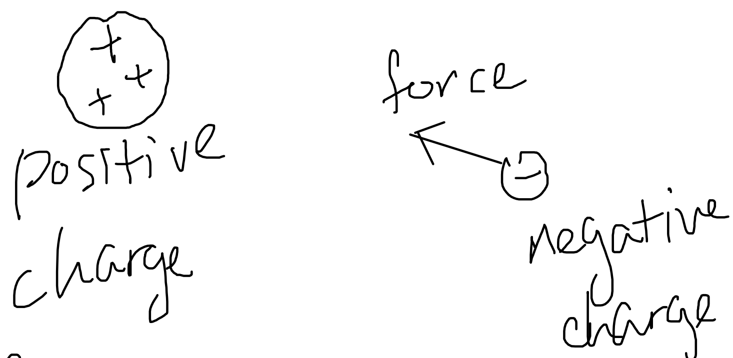

Electric field - a region of space in what an electric force acts.

Unit of charge = Coulomb (C)

e.g. Find the force per Coulomb at B due to the field from A.

force per coulomb at B = $\frac{3N}{0.5C}$ = 6 N/C

Electric field strength - force per unit charge (at a point in an electric field)

Electric Field Lines

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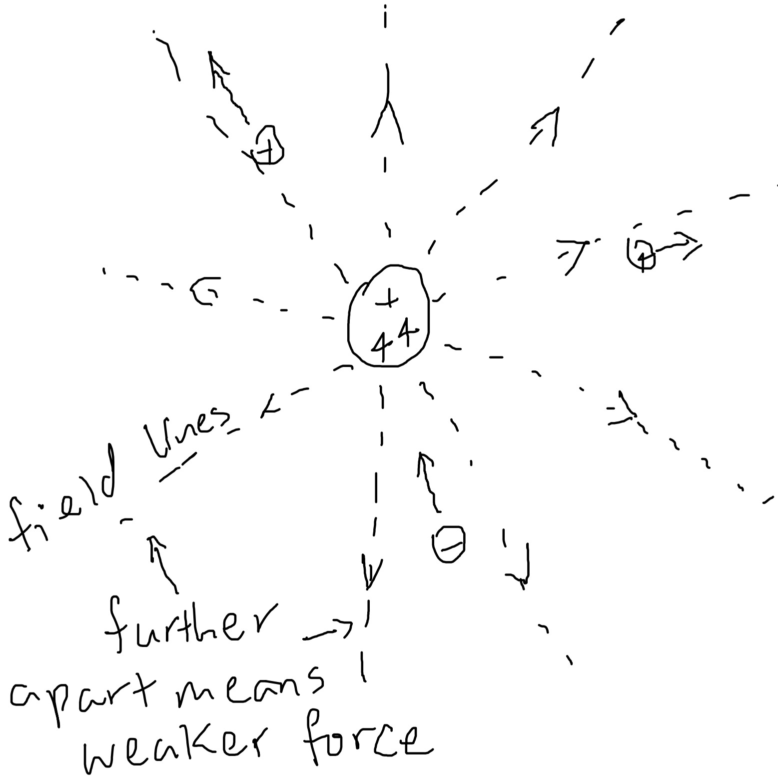
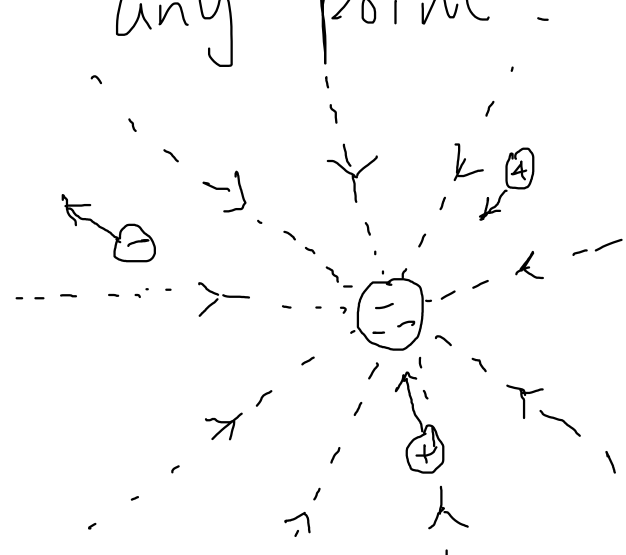
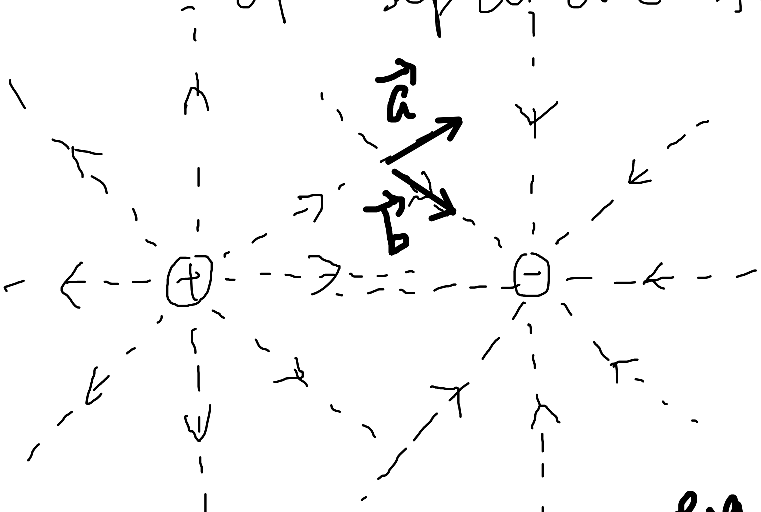


Dashed lines show direction of force if we put a +ve charge at any point



Combined field of 2 charges = vector sum (at each point) of separate fields



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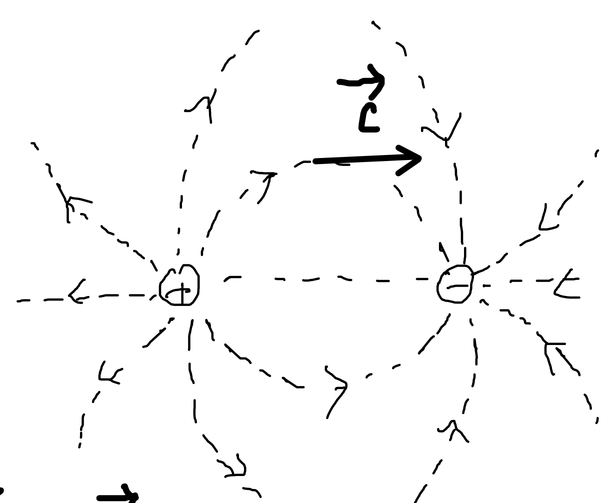

e.g. $\vec{a} + \vec{b} = \vec{c}$

recall and use Coulomb's law in the form F = Q_1 Q_2/4 π ε_0 r^2 for the force between two point charges in free space or air

Coulomb's law

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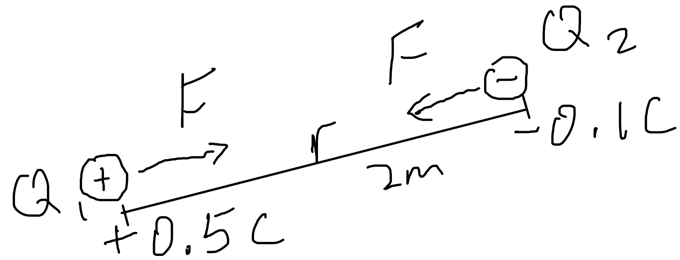
e.g.



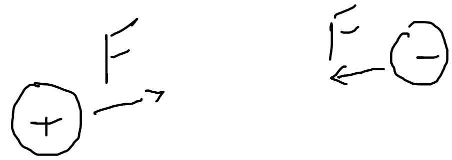
What is the force of attraction?

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2} = \frac{0.5\times0.1}{4\pi\times(8.85\times10^{-12})\times 2^2}$$

Coulomb's law — permittivity — = ____ N

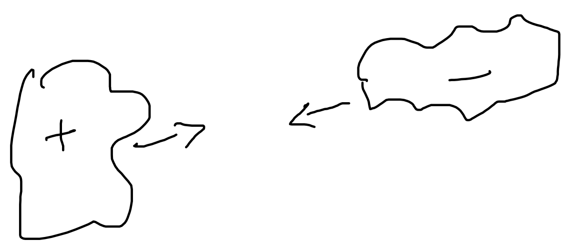
Charges

✓ spheres



✓ points

X irregular



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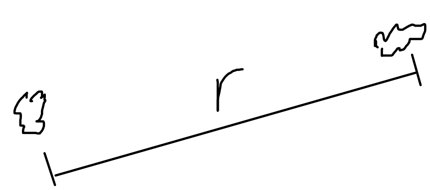

recall and use $E = Q/4\pi\varepsilon_0 r^2$ for the field strength of a point charge in free space or air

Electric Field Strength

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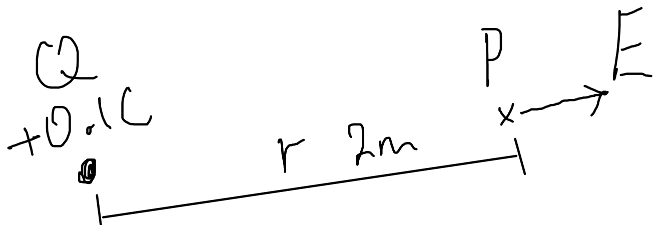
e.g.



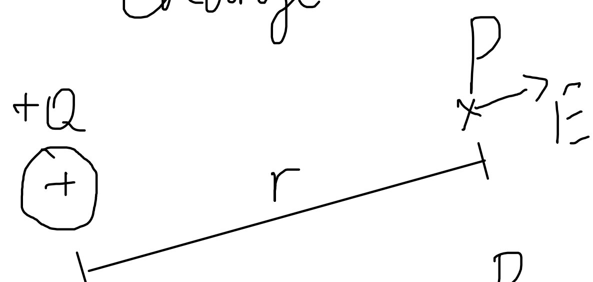
Find the electric field strength at P.

$$E = \frac{Q}{4\pi\varepsilon_0 r^2} = \frac{0.1}{4\pi(8.85\times10^{-12})\times 2^2}$$

Electric field strength $=$ ____ N/C

Charge

$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ Sphere



$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ point

$E \neq \frac{Q}{4\pi\varepsilon_0 r^2}$ irregular

$E \approx \frac{Q}{4\pi\varepsilon_0 r^2}$ size $\ll$ r

calculate the field strength of the uniform field between charged parallel plates in terms of potential difference and separation

Parallel Plate

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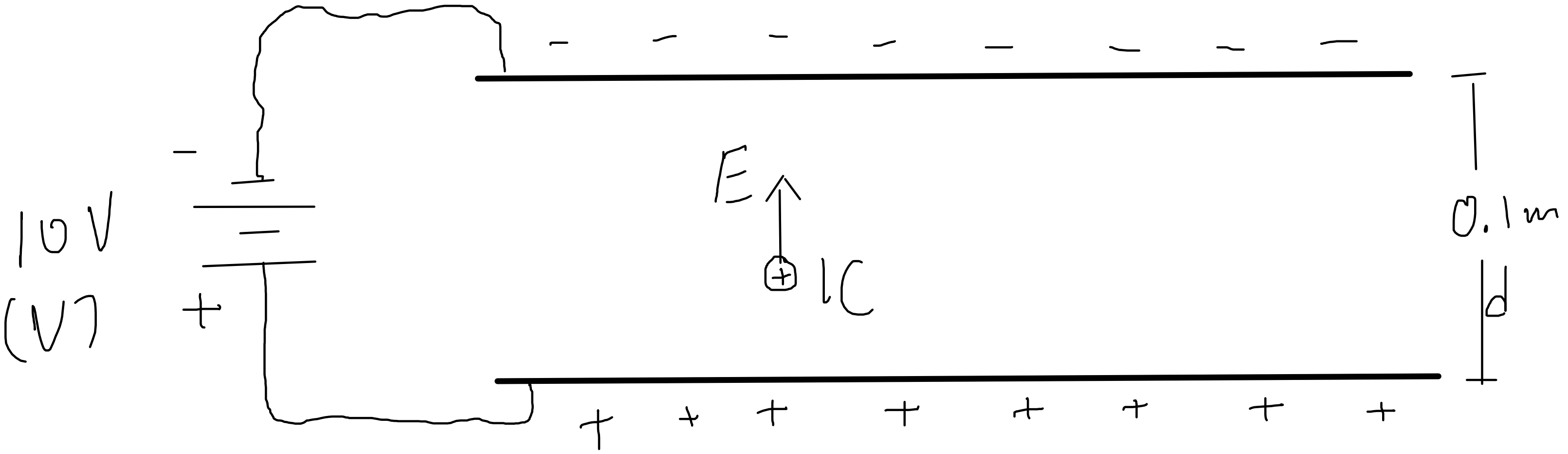
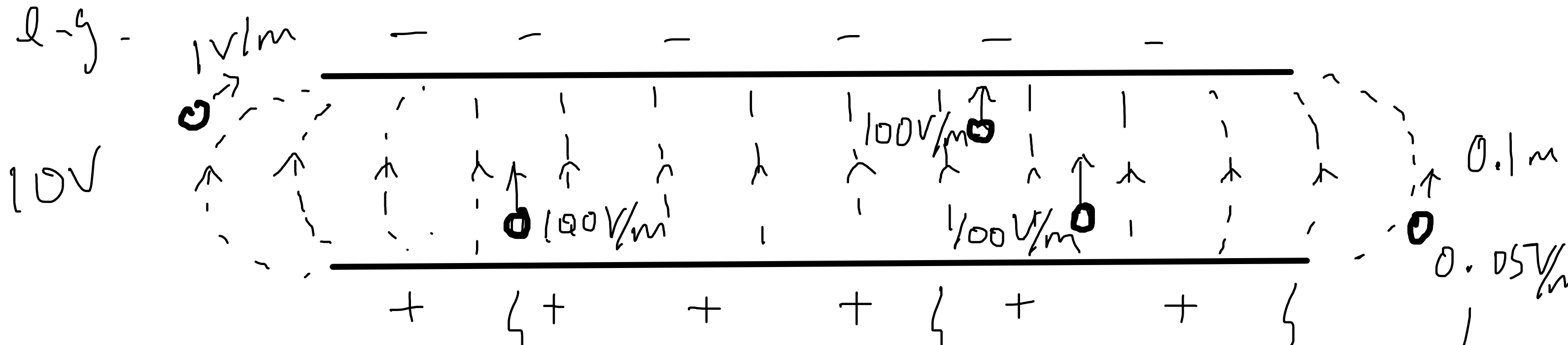


e.g. What force acts on the 1C between these 2 plates?

$$\boxed{E = \frac{V}{d}} = \frac{10}{0.1} = 100 \text{ V/m (or N/C)}$$

Electric field strength between // plates.



$E = \frac{V}{d}$ $E = \frac{V}{d}$ $E \approx \frac{V}{d}$ (edge) $E \neq \frac{V}{d}$ (outside)

| Uniform = Same mag., dirn |

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Uniform Electric Field

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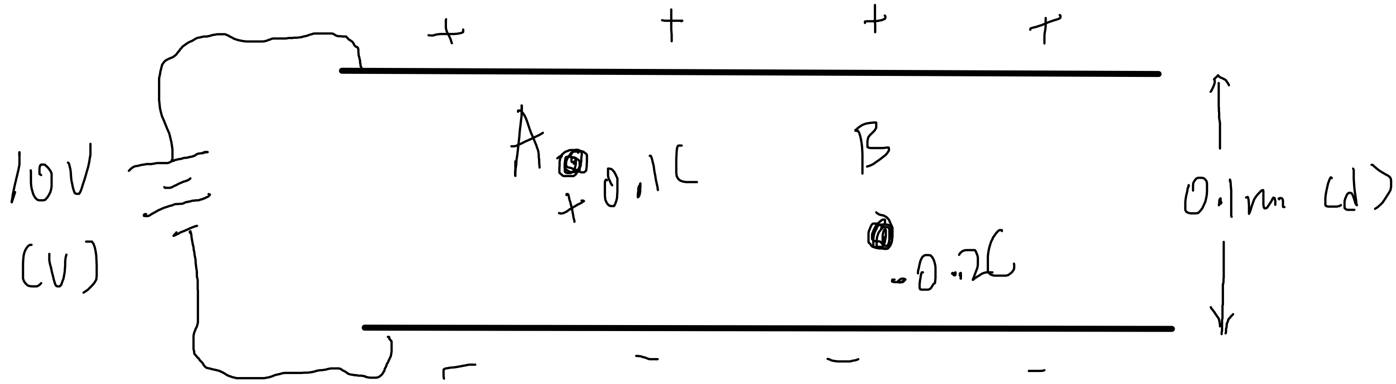

e.g. find the magnitudes and directions of the forces on A and B.

A: +ve. - Repelled by +ve plate on top.
- Attracted by -ve plate below.
- ∴ force direction ↓

Electric field strength

$$E = \frac{V}{d} = \frac{10}{0.1} = 100 \text{ V/m}$$

Force magnitude, $F = qE = 0.1 \times 100 = 10\text{ N}$

B: -ve. ∴ force direction ↑

magnitude, $F = qE = 0.2 \times 100$
$= 20\text{ N}$.

Charged Partcle in // Plates

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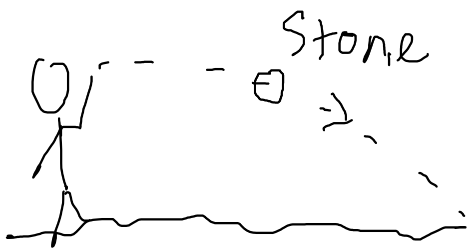
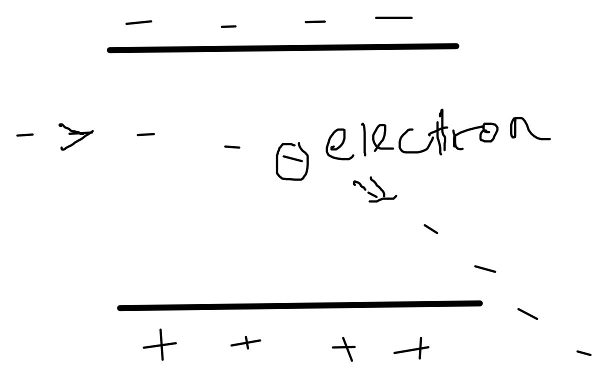
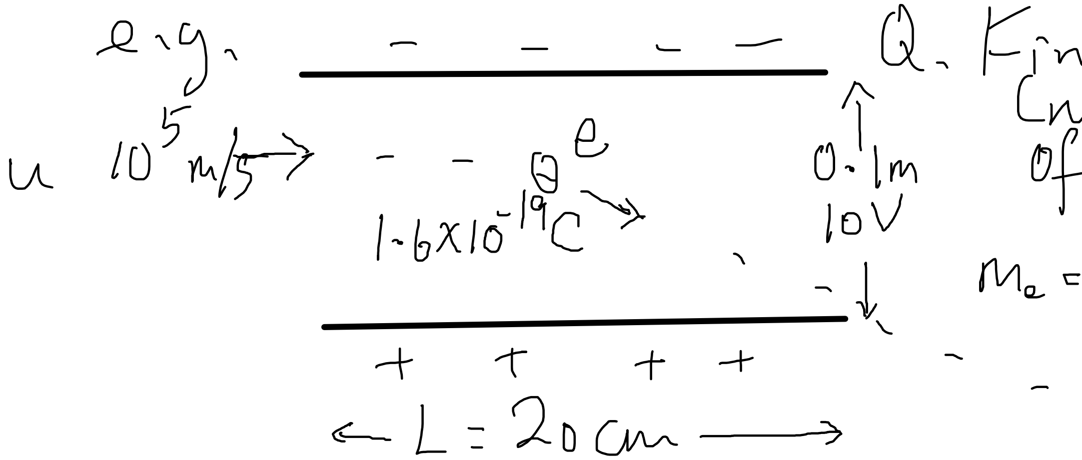




Similar curves - both uniform fields

e.g.



Q. Find acceleration (mag., dirn) of e^-.

$m_e = 9.1 \times 10^{-31}$ kg

A. Force, $F = qE = q\frac{V}{d}$

acceleration, mag. $a = \frac{F}{m_e} = \frac{qV}{m_e d}$

$$a = \frac{1.6 \times 10^{-19} \times 10}{9.1 \times 10^{-31} \times 0.1} = \_\_\_\_ \text{ m/s}^2$$

dirn ↓ because F ↓.

Q. How long to go thru' // plates?

$$t = \frac{L}{u} = \frac{0.20}{10^5} = \_\_\_\_ \text{ s}.$$

define potential at a point in terms of the work done in bringing unit positive charge from infinity to the point

Electric Potential Energy

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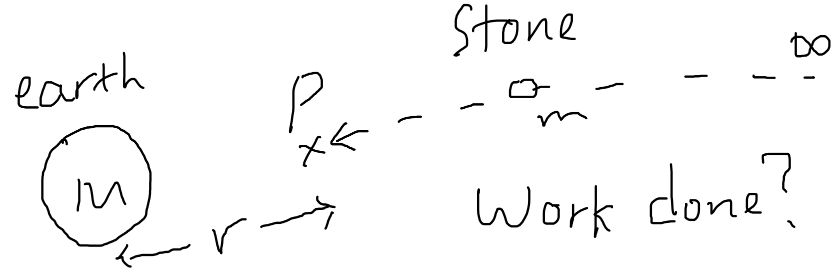
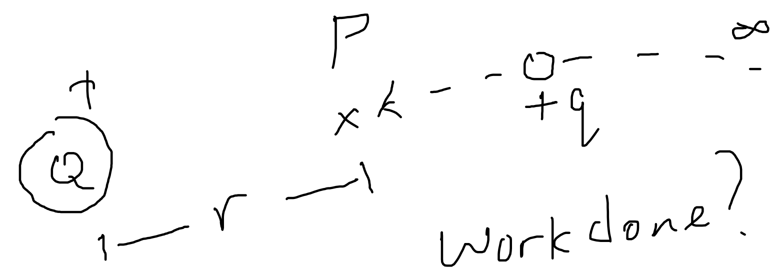
Gravitational PE

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



Electric PE

$$U = +\frac{Qq}{4\pi\varepsilon_0 r}$$



Difference from gravity:

- charges have signs →

Signs	PE
same	+ve
opposite	-ve

- but need not change formula (Q, q incl. signs)

$$\text{Potential} = \frac{PE}{\text{charge}} \rightarrow V = \frac{Q}{4\pi\varepsilon_0 r}$$

*** Potential at a point (P) = Work done in bringing unit charge from infinity (∞) to that point. (P).

state that the field strength of the field at a point is numerically equal to the potential gradient at that point

Potential Gradient

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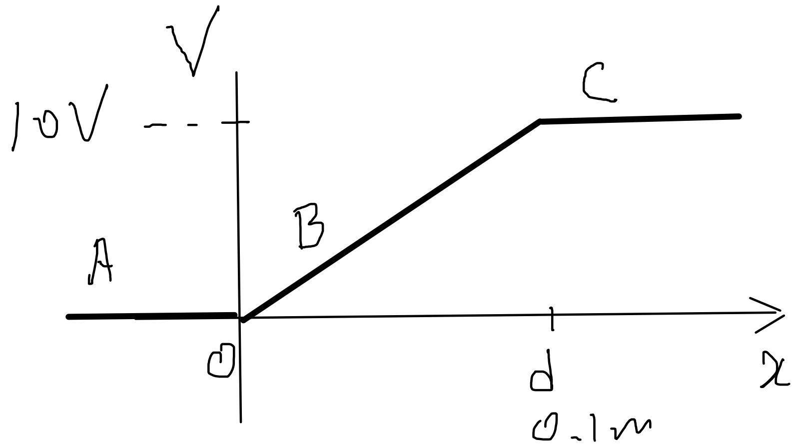

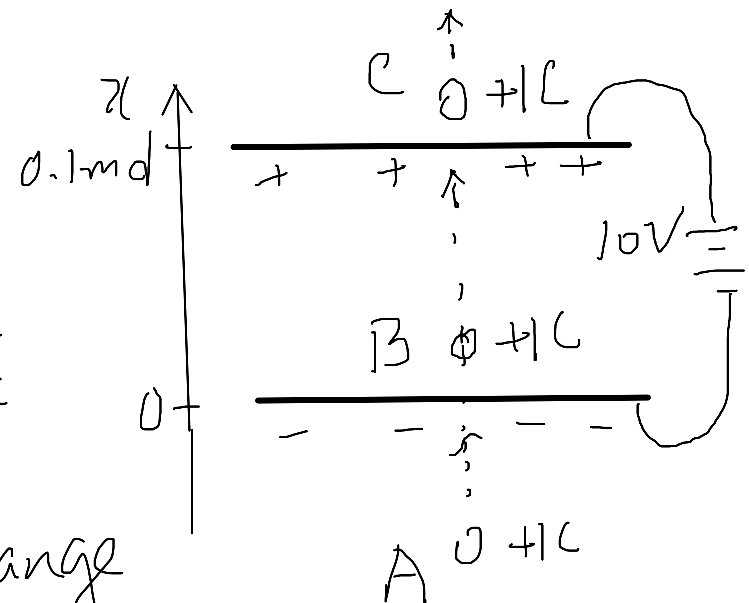

At A, C - no change

∵ no work done

∵ no force

∵ forces cancel ∵ +, - plates on same side.

At B, V ↑ - because work done against electric force

Straight line - ∵ $W = Fs$ and F const. ∵ uniform field.

Gradient at B $= \frac{V}{d} = E$, electric field strength

∴ **E = - potential gradient**

↑ -ve ∵ field → lower potential

e.g. just let go +ve charge, move → lower V.

use the equation V = Q/4 π ε_0 r for the potential in the field of a point charge

Point Charge Potential

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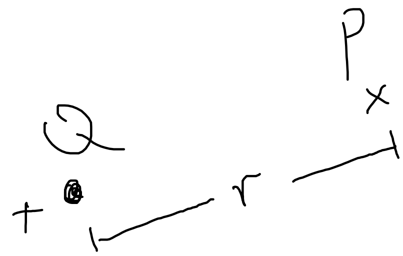
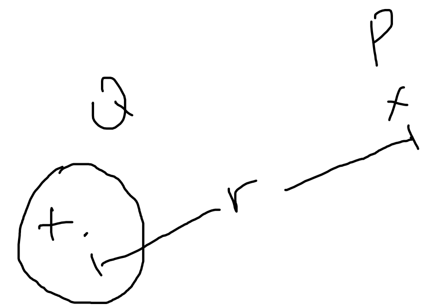
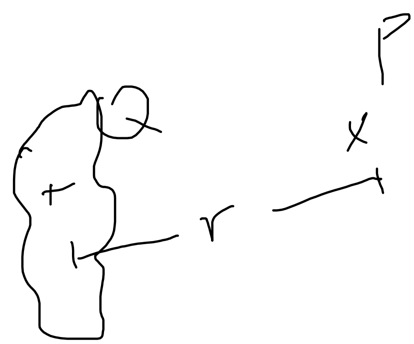
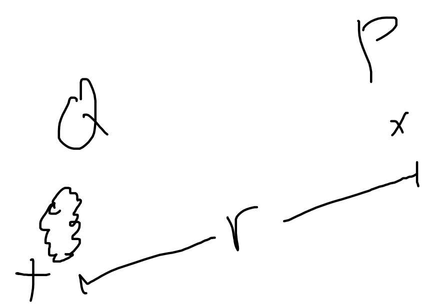
Potential	Charge	
$V = \frac{Q}{4\pi\varepsilon_0 r}$	point	
$V = \frac{Q}{4\pi\varepsilon_0 r}$	Spherical	
$V \neq \frac{Q}{4\pi\varepsilon_0 r}$	irregular	
$V \approx \frac{Q}{4\pi\varepsilon_0 r}$	small	

(Q can be -ve. Just include sign when substituting.)