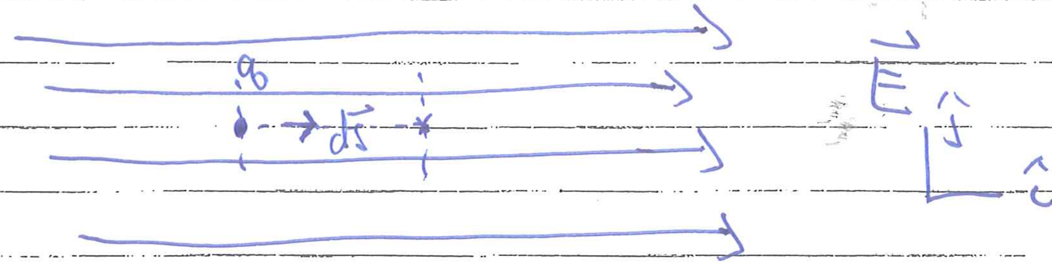
"Clean-up" w/ Wed. short class ☺

Ch. 23



$\underbrace{\text{"Natural" forces}}_{\vec{F}_{electric} = q\vec{E}}$ move things $\underbrace{\text{"downhill"}}_{\text{to lower } P.E._{electric}}$.

If q is a +10 C charge and $\vec{E} = 25\hat{i}$ N/C, what is the work done by $\vec{F}_E$ in moving the charge 5 meters? (in $+\hat{i}$ direction)

$$W = \int \vec{F}\cdot d\vec{s} = \int (q\vec{E})\cdot(dx\,\hat{i}) = \int_0^5 250\,\hat{i}\cdot(dx\,\hat{i})$$

$$= \underbrace{250\int_0^5 dx}_{5}\ \underbrace{\hat{i}\cdot\hat{i}}_{|\hat{i}||\hat{i}|\cos(0) = 1*1*1} = \underline{+1250 \text{ joules}}$$

Aside: In general, $d\vec{s} = dx\,\hat{i} + dy\,\hat{j} + dz\,\hat{k}$

Did the PE_E increase or decrease for this charge as it moved the 5 meters? Decrease.

Same questions, but let $q = -10$ C.

$$\Rightarrow W = \ldots = \int_0^5 (-250\,\hat{i}\cdot(dx\,\hat{i})) = \underline{-1250 \text{ J}}$$

INCREASE in PE_E

END EXAM #1 MATERIAL

Recall: "Conservative Forces" ⇒ have an associated P.E.

"Conservative Forces": VECTOR description of the interaction

P.E.: Scalar description of interaction

Two equivalent "paradigms".

$$\vec{F} = -\underbrace{\nabla}_{\text{"gradient"}} P.E.(x,y,z)$$

$$\vec{F} = -\frac{\partial}{\partial x} P.E.\,\hat{i} - \frac{\partial}{\partial y} P.E.\,\hat{j} - \frac{\partial}{\partial z} P.E.\,\hat{k}$$

partial derivative

Ex Given: $PE(x,y,z) = 4z^3x + 7y + 8$

$$\vec{F} = -\underbrace{\left(4z^3\frac{\partial}{\partial x}(x) + 7y\frac{\partial}{\partial x}(1) + \frac{\partial}{\partial x}(8)\right)}_{4z^3}\hat{i}$$

$$-7\hat{j} - 12z^2x\,\hat{k}$$

Hey,

$$\underset{q\vec{E}}{\vec{F}} = -\nabla P.E._{electric}$$

$$q\vec{E} = -\nabla PE_E$$

* $$\vec{E} = -\nabla \underbrace{\left(\frac{PE_E}{q}\right)}_{\text{Voltage (a definition!)}}$$

$\therefore \Delta PE_E = q\Delta V$ ☆

SEE HANDOUT

* $$\vec{E} = -\nabla V \qquad (V)$$

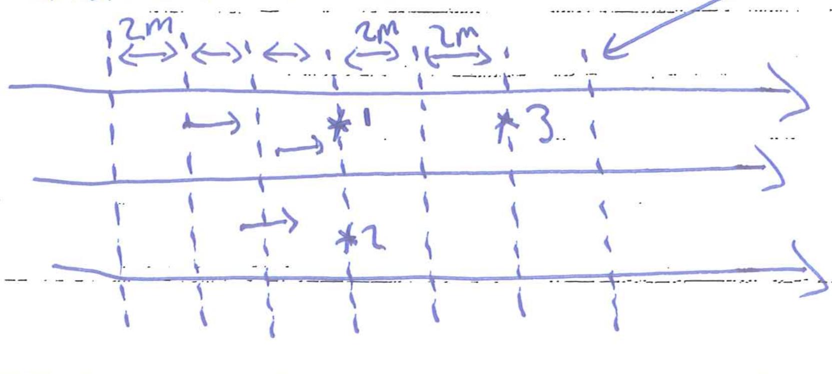
$\boxed{\text{OR}}$ $$-\int \vec{E}\cdot d\vec{s} = \Delta V$$ ☆

Physically: We have a "disturbed" space.
Can characterize that disturbance with an electric field, $\vec{E}$ (VECTOR)

$\boxed{\text{OR}}$

can characterize that disturbance with a SCALAR field, Voltage.

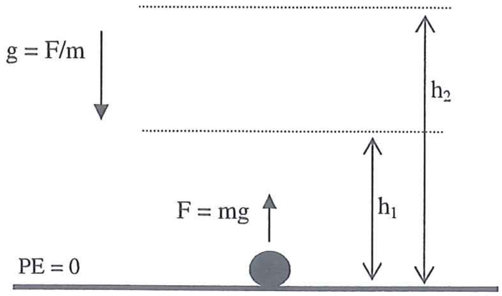
Ex. Consider a uniform $\vec{E}$. "equipotential surface" Constant Voltage.

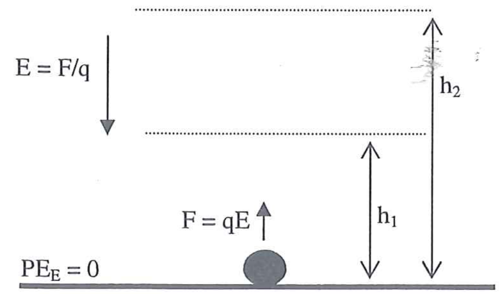


$\vec{E} = 10\hat{i}\ \frac{N}{C}$

Electric Potential (Voltage)

taken from "Physics, A Laboratory Textbook", 2nd ed., Carr & Simon, 1984





Zero gravitational PE is shown	Zero electrical PE is shown (PE_E)
The magnitude of the gravitational field is the force per unit mass	The magnitude of the electric field is the force per unit charge
The direction of the gravitational field is the direction the test mass will go if released	The direction of the electric field is the direction that a test charge will go if released
To lift the test mass in the uniform gravitational field (w\o acceleration), a force = mg must be applied.	To lift the test charge in the uniform electric field (w\o acceleration), a force = qE must be applied.
The work needed to lift the mass to h_1 and h_2, respectively, is just the gravitational PE at these levels $W_1 = Fh_1 = mgh_1 = PE_1$ $W_2 = Fh_2 = mgh_2 = PE_2$	The work needed to lift the charge to h_1 and h_2, respectively, is just the electrical PE at these levels $W_1 = Fh_1 = qEh_1 = PE_{E\ 1}$ $W_2 = Fh_2 = qEh_2 = PE_{E\ 2}$
The amount of work needed to go from level 1 to level 2 is just the change in PE $W_{1\to 2} = mg\Delta h = \Delta PE$	The amount of work needed to go from level 1 to level 2 is just the change in PE_E $W_{1\to 2} = qE\Delta h = \Delta PE_E$
Investigators seeking to find the work done in going from 1 to 2 will get different answers, depending on the mass they use. Can resolve this problem by defining Gravitational Potential Difference (no instrument exist to measure). $G_{12} = W_{1\to 2}/m = g\Delta h = \Delta PE/m$	Investigators seeking to find the work done in going from 1 to 2 will get different answers, depending on the charge they use. Can resolve this problem by defining Electrical Potential Difference (Voltage! measured with a voltmeter) $\boxed{V_{12} = W_{1\to 2}/q = E\Delta h = \Delta PE_E/q}$
Gravitational field strength can now be determined by $g = G_{12}/\Delta h$	Electric field strength can now be determined by $E = V_{12}/\Delta h$

What is the voltage between points 1 and 2?

$$\Delta V = -\int_1^2 \vec{E}\cdot \underbrace{d\vec{s}}_{(-dy\,\hat{j})} = -\int_1^2 (10\hat{i})\cdot(-dy\,\hat{j}) = 0$$

Between points 1 and 3?

$$\Delta V = -\int_{pt.1}^{pt.3} \vec{E}\cdot d\vec{s} = -\int_{point\,1}^{point\,3} (10\hat{i})\cdot(dx\,\hat{i})$$

$$= -10\underbrace{\int_{pt1}^{pt3} dx}_{4} = -40 \text{ volts} \quad \Big\| \quad \frac{Nm}{C}$$

?

Electric Field OR Voltage

Force OR Energy

NEWTON — 1800's Work/Energy

Coulomb

Alternative ways to characterize the interaction between two objects.

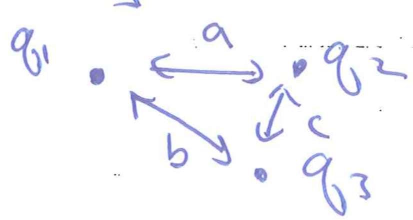
Recall: $\left|\vec{E}_{\substack{pt\\charge}}\right| = \frac{k|q|}{r^2}$ radial in or out $\boxed{\text{FORCE}}$

$V_{\substack{pt.\\charge}} = \frac{kq}{r}$ Keep sign on q.

$PE_{electric} = \frac{kq_1q_2}{r}$ Keep sign on q.

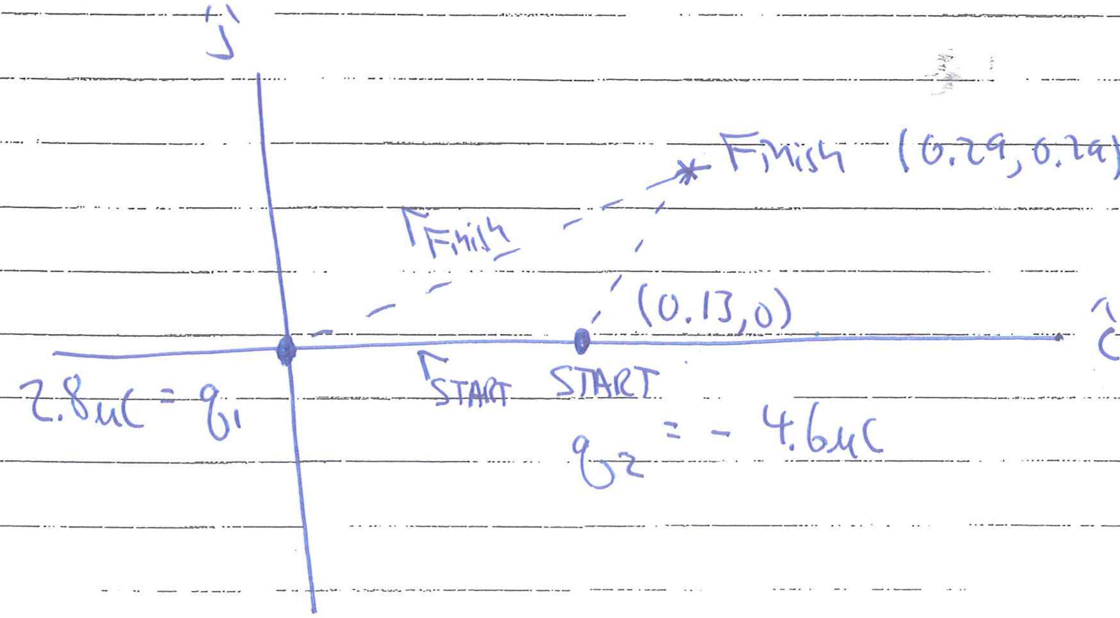
$\left|\vec{F}\right| = \frac{k|q_1||q_2|}{r^2}$ opposites attract likes repel.

EX) What is the P.E. associated with the following collection of charges?



$PE_{system} = \frac{kq_1q_2}{a} + \frac{kq_1q_3}{b} + \frac{kq_2q_3}{c}$

HW 23.1



Work done $\Rightarrow$ $\Delta P.E._{electric}$

$PE_{START} = \dfrac{kq_1q_2}{r_{start}}$ $PE_{FINISH} = \dfrac{kq_1q_2}{r_{Finish}}$

KEEP SIGNS ON CHARGES.

$\Delta PE = PE_{Finish} - PE_{START} = \sim$

WORK DONE.

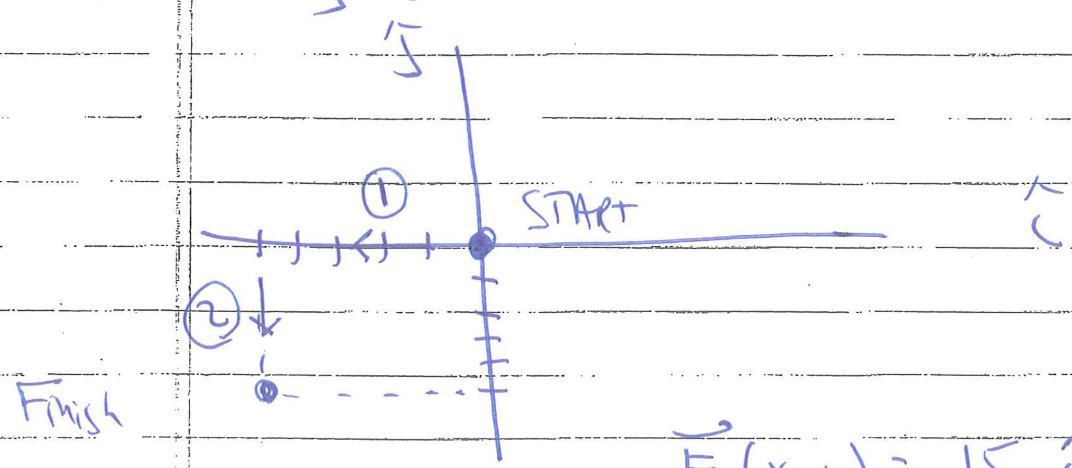
OR

$W = \int \vec{F} \cdot d\vec{s}$

$\vec{F} = q_2 \vec{E}_1$

$\vec{E}_1 = \dfrac{k|q_1|}{r_1^2}$

Something Similar:



$\vec{E}(x,y) = 15\,\hat{i}$

A 5C charge is carried from the origin to the point (-5,-5). What is the work done by the electric force on the charge. What is its change in $PE_{electric}$?

$$W = \int \vec{F}\cdot d\vec{s} = \int_{①} \vec{F}\cdot d\vec{s} + \int_{②} \vec{F}\cdot d\vec{s}$$

Conservative!!
Choose any path ☺

$$= \int_{0\,①}^{-5} (5*15\hat{i})\cdot(dx\,\hat{i}) + \underbrace{\int_{0\,②}^{-5} (5*15\hat{i})\cdot(dy\,\hat{j})}_{0}$$

$$= 75\,(x)\Big|_0^{-5} = -375 \text{ joules}$$

Answer.

Has $PE_{electric}$ increased or decreased?