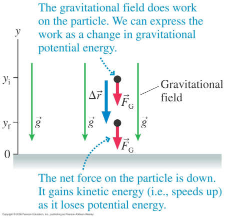


- We could define a gravitational field in much the same way we have defined the electric field:

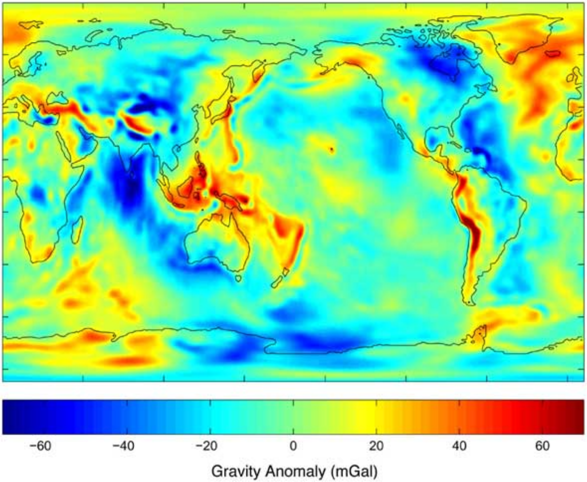
$$\vec{E} = \frac{\vec{F}_{on\ q}}{q}, \ \vec{g} = \frac{\vec{F}_{on\ m}}{m}$$

(note that m/s^2 = N/kg)

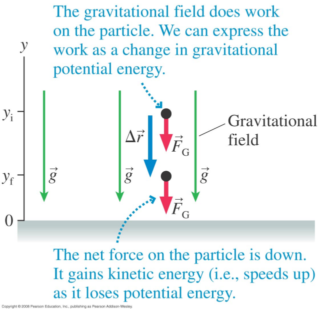
- The gravitational field near the earth is nearly uniform ($\approx$ 9.8 N/kg) much like the electric field in a capacitor.

A Uniform Gravitational Field

Small variations in $\vec{g}$ on the earth's surface are of interest.
`http://www.physlink.com/news/072403GraceGravityField.cfm`



A Uniform Gravitational Field



- The work done by gravity on a falling particle is

$$W_{grav} = F_G \Delta r \cos 0^\circ = mgy_i - mgy_f$$

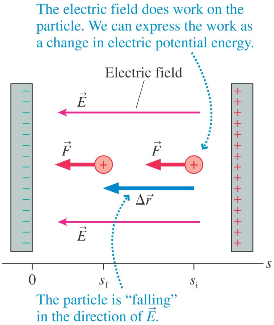
- We can turn this into potential energy by

$$\Delta U_{grav} = -W_{grav} = mgy_f - mgy_i$$

- If we define U_0 as the potential energy at $y = 0$ we get

$$U_{grav} = U_0 + mgy$$

A Uniform Electric Field



- The gravitational field near the earth always points towards the earth, in a capacitor the electric field always points towards the negative plate.
- Instead of y, define s towards the positive plate from $s = 0$ at the negative plate. A positive particle "falls" towards $s = 0$.
- The work is

$$W_{elec} = F_e \Delta r \cos 0^\circ = qEs_i - qEs_f$$

- We can turn this into potential energy by

$$\Delta U_{elec} = -W_{elec} = qEs_f - qEs_i$$

- Again we can write:

$$U_{elec} = U_0 + qEs$$

The Potential Energy of Point Charges (29.2)

- We now come back to the force between two point charges. Again, we will use Coulomb's law. This time we are seeking potential energy for a system of two charges.
- As two like charges repel each other the force between them decreases. So, we need the integral form of our work equation

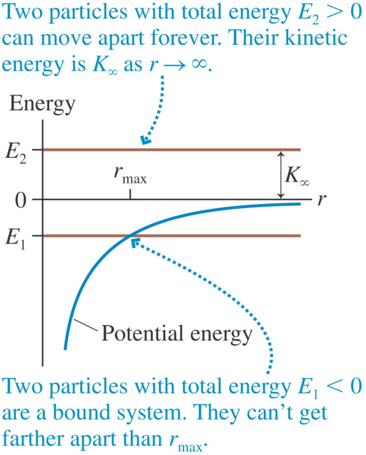
$$W_{elec} = \int_{x_i}^{x_f} F_{1\ on\ 2} dx = \int_{x_i}^{x_f} \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{x^2} dx = -\frac{q_1 q_2}{4\pi\epsilon_0} \left(\frac{1}{x_f} - \frac{1}{x_i} \right)$$

- The change in potential energy is $-W_{elec}$ and, if we set $U_0 = 0$ then

$$U_{elec} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{x}$$

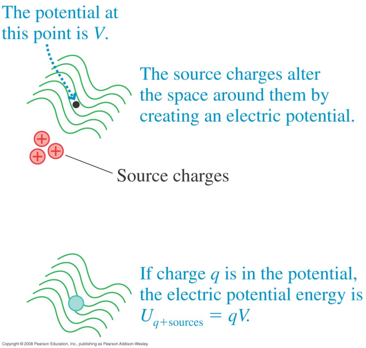
- This also works for two opposite charges and for charged spheres.
- For multiple charges just add the potentials of every pair.

The Zero of Potential Energy



- The zero of gravitational potential energy is the center of the earth...or the surface if you cannot make it to the center.
- If you put two charges really close together the force becomes really large, maybe a more sensible zero is $r = \infty$ rather than $r = 0$.
- If we define U_0 as the value at infinity then our U_{elec} is just the "amount of interaction" (ie. it is relative to zero).
- The tricky bit is that now we have negative potential energies.

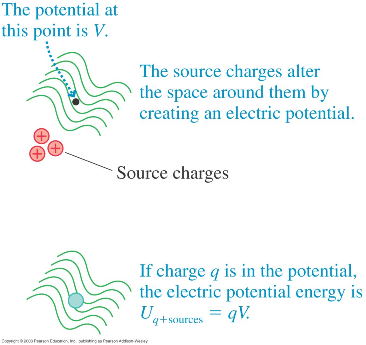
The Electric Potential (29.4)



- We introduced the concept of electric field to solve our "action at a distance" problem. A charge alters the space around it and other charges interact with the field.
- Where is the energy stored in electric potential energy?
- We will treat the potential energy in much the same way we treated the field:

$$\begin{aligned} \textit{force on } q &= [\textit{charge } q] \times [\textit{alteration of space by source charge}] \\ \textit{potential } E &= [\textit{charge } q] \times [\textit{potential interaction of source charge}] \end{aligned}$$

The Electric Potential (29.4)



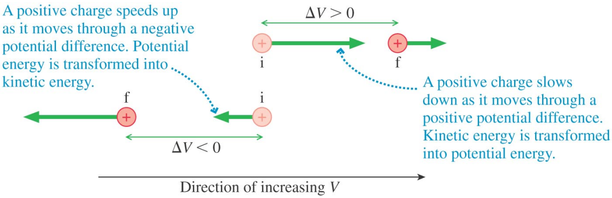
- How do we define this electric potential? It is

$$V \equiv \frac{U_{q+sources}}{q}$$

- Like for $\vec{E}$, the value of V is independent of the test charge q. The source charge makes the potential regardless of other charges.
- The unit of electric potential is J/C or Volts (V).

What Good is Electric Potential?

- Electric potential depends only on source charges and their geometry.
- If we know the electric potential in a region of space we know the interaction energy of any charged particle in that region ($U = qV$).
- So, it can be highly useful to calculate the potential.
- If a charged particle moves through a potential difference ($\Delta V = V_f - V_i$) it will accelerate.



What Good is Electric Potential?

- If a particle moves through potential difference ΔV the potential energy changes like

$$\Delta U = q\Delta V$$

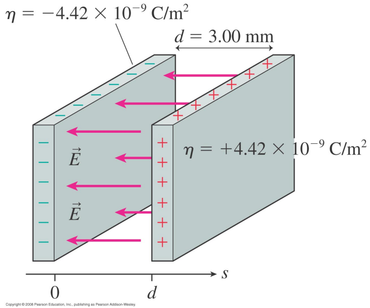
- Conservation of energy gives

$$\begin{aligned} \Delta K + q\Delta V &= 0 \\ K_f + qV_f &= K_i + qV_i \end{aligned}$$

- Conservation of energy will be a useful tool in the problems we solve in the coming weeks.

The Electric Potential Inside a Parallel Plate Capacitor (29.5)

The Phys141 text uses σ instead of η for surface charge density



- Electric field inside this capacitor:

$$|E| = \frac{\eta}{\epsilon_0} = 500 \text{ N/C}$$

- We already know that the electric potential energy is

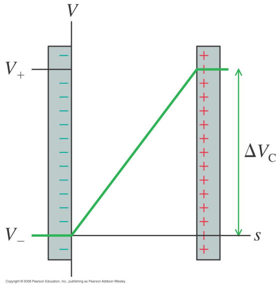
$$U_{elec} = qEs$$

where s is the distance from the negative electrode.

- The potential is then

$$V = \frac{U_{elec}}{q} = Es$$

The Electric Potential Inside a Parallel Plate Capacitor



- Electric potential increases linearly from the negative plate towards the positive.
- If we define the negative plate as $V_- = 0$, then $V_+ = Ed$ and the potential difference is

$$\Delta V_C = V_+ - V_- = Ed$$

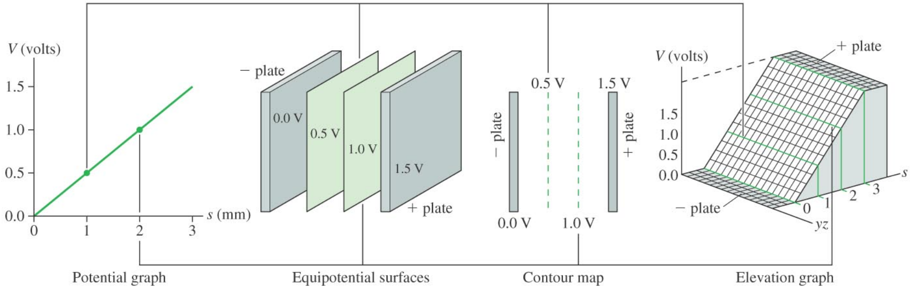
- In this example we have

$$\Delta V_C = (500N/C)(0.0030m) = 1.5V$$

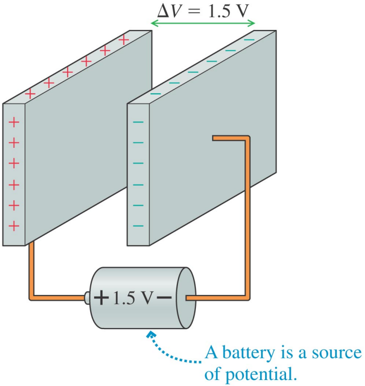
  This is the voltage across the capacitor.
- It is useful to express the field in terms of the potential

$$E = \frac{\Delta V_C}{d}$$

Graphs, Equipotential Surfaces, Contour Maps, and Elevation Graphs



Making a Capacitor with a Certain Potential Difference



A battery is a source of potential.

The Negative Plate does not have to be Zero