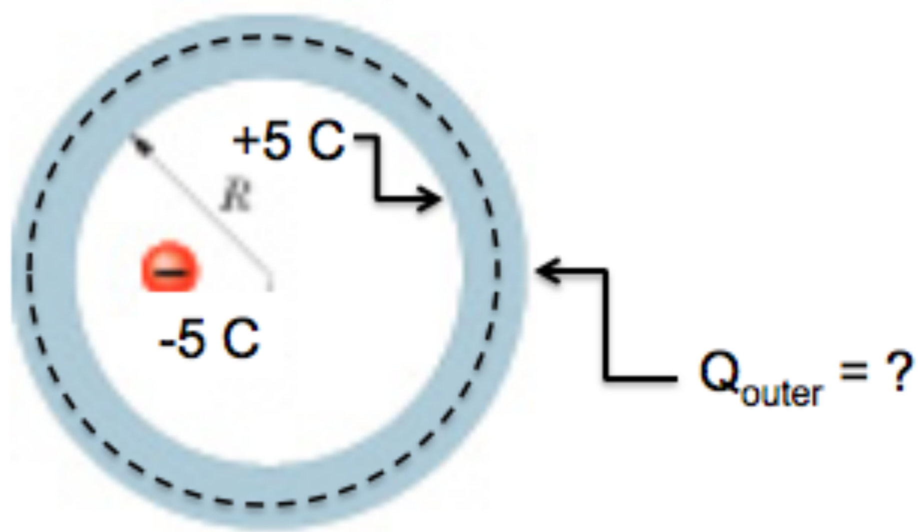
PHY294H

- Professor: Joey Huston
- email:huston@msu.edu
- office: BPS3230
- Homework will be with Mastering Physics (and an average of 1 hand-written problem per week)
  - **2nd MP assignment due Wed Jan. 27; second hand-written problem (27.51) as well**
  - **Added problem 28.68 for 3rd MP assignment due Wed Feb. 3 as a hand-in problem**
  - **Help-room hours: 12:40-2:40 Tues; 3:00-4:00 PM Friday**
- Quizzes by iclicker (sometimes hand-written)
- Course website: www.pa.msu.edu/~huston/phy294h/index.html
  - lectures will be posted frequently, mostly every day if I can remember to do so

iClicker question

A point charge of -5.0 C is off-center inside an electrically **neutral** spherical metal shell. What is the induced charge on the **outer surface** of the shell?

A. 0 C
B. +5 C
C. -5 C
D. +10 C
E. -10 C



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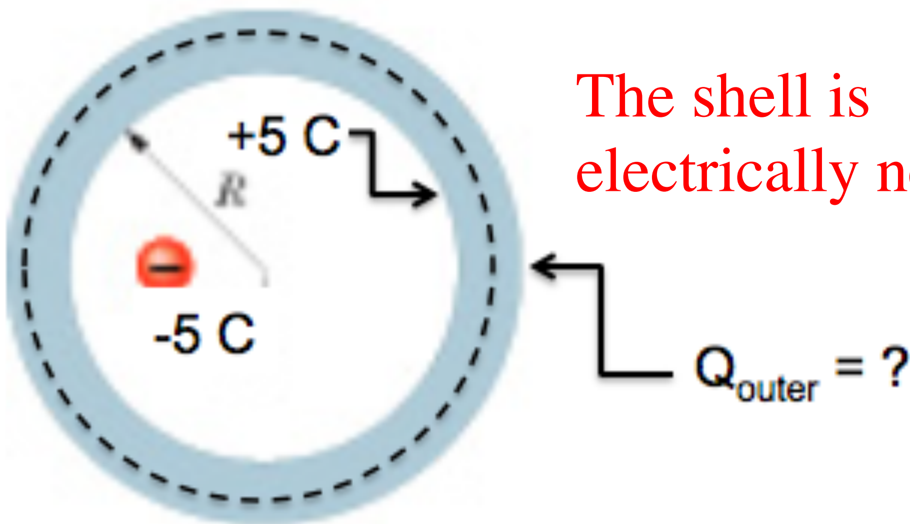
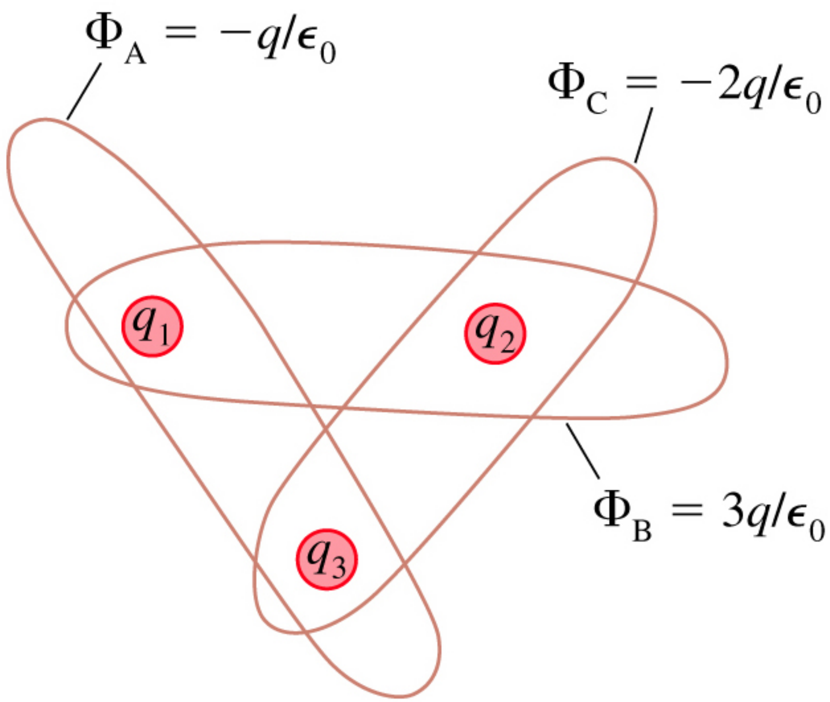


The shell is electrically neutral.

Problem

- Given the fluxes through the Gaussian surfaces, what are the values of the charges q_1, q_2 and q_3?



Step back: how well do we know Gauss' and Coulomb's law

- Gauss' law is equivalent to Coulomb's law only because Coulomb's law is an inverse square law
- How well is Coulomb's law/ Gauss' law known?

- Joseph Priestly knew that there is no gravitational field within a spherically symmetric mass distribution and speculated that a similar behavior of the gravitational and electric force laws would explain a charged cork ball placed inside the a charged metal container is not attracted to the walls of the container
  - this effect was first seen by Benjamin Franklin who told Priestly
- This is related to the styrofoam chips in the aluminum container on top of the van de Graf not feeling any electric field

Deviations from inverse square law

- John Robison did experimental tests in 1769 of the distance behavior of the forces between charges
- Robison expressed the uncertainties in his result as a deviation from Coulomb's law
  - $F \alpha 1/r^{2+/-\delta}$

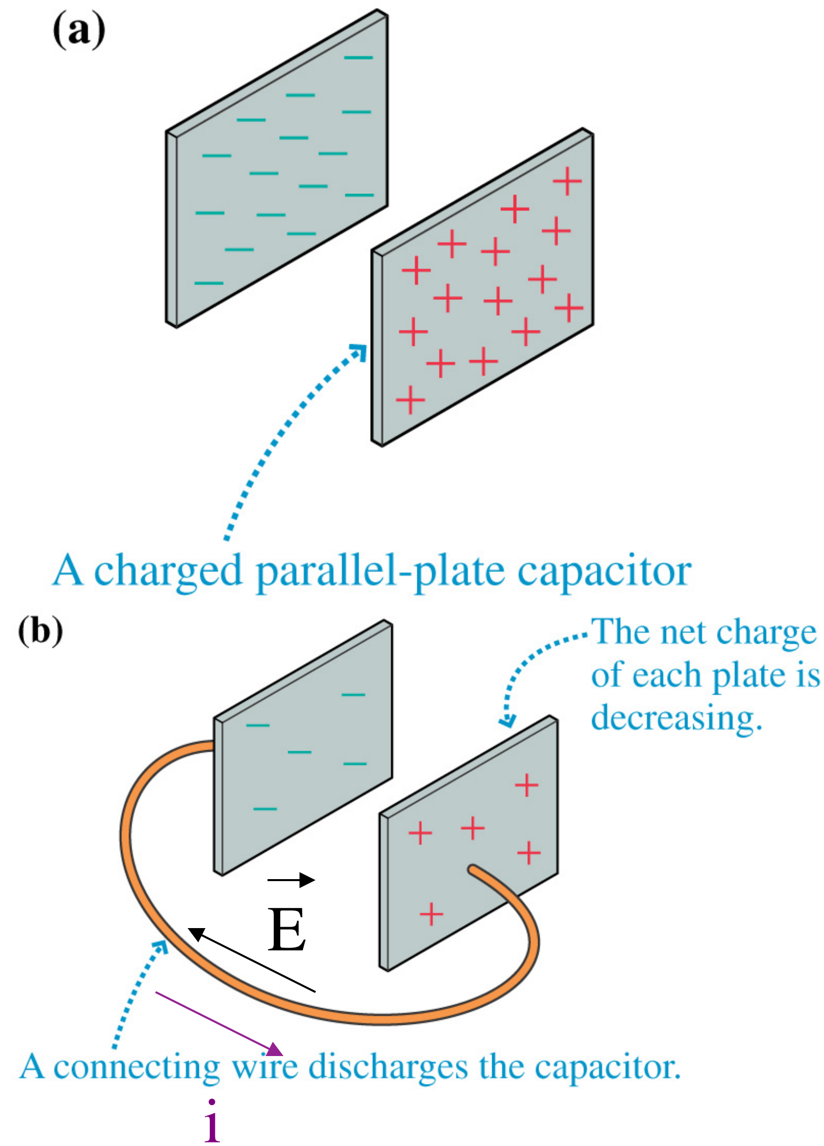
Constraints on δ have improved

Investigator	Date	Maximum δ
Robison	1769	0.06
Cavendish	1773	0.02
Coulomb	1785	0.10
Maxwell	1873	5×10^{-5}
Plimpton and Lawler	1936	2×10^{-9}
Williams, Fawler and Hill	1971	3×10^{-16}

Now verified to better than 1 part per billion from atomic scale to galactic scale.

Creating an electrical current

- Suppose I have a parallel plate capacitor in which I have equal and opposite charges on two separated plates
- If I connect the two plates by a conductor, then I know that the excess electrons will flow from the negative plate to the positive plate
- That would constitute an electrical current
- Why are the electrons moving from to the + plate?
  - there's an electric field in the conducting wire
  - the electric field provides the electrons with their motivation to move in a particular direction…but not very fast
- …and now for something completely different



Next chaper:Electric potential

- We've discussed the similarities before between the force between two charges and the force between two masses

$$\vec{F} = \frac{q_1 q_2}{r^2}\hat{r}$$

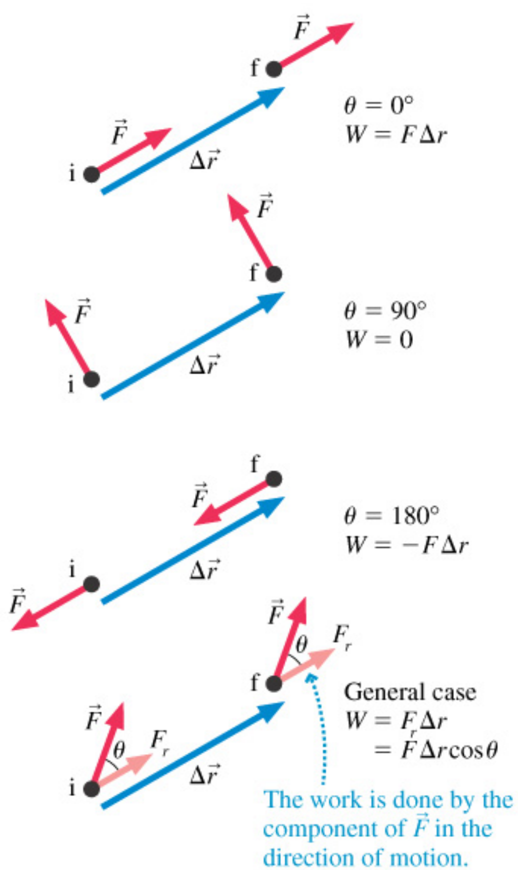
$$\vec{F} = -G\frac{m_1 m_2}{r^2}\hat{r}$$

- Any force that is a function of position only is a conservative force which means that we can associate a potential energy with it
  - $E_{mech} = K + U$
  - $\Delta E_{mech} = \Delta K + \Delta U$

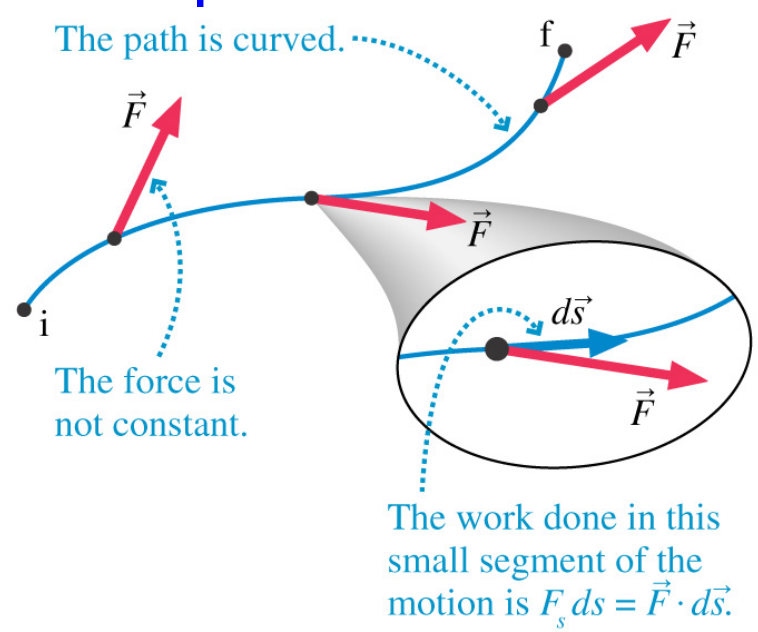
- $K = \Sigma K_i = \Sigma 1/2 m_i v_i^2$
  - sum of all kinetic energies in problem
- U = interaction energy of the system = potential energy
- Most often talk about change in potential energy due to work performed by conservative force
  - $\Delta U = U_f - U_i = - W_{force}$

Work

- Work that a constant force does is
  - $W = \vec{F} \cdot \Delta\vec{r} = F \Delta r \cos\theta$



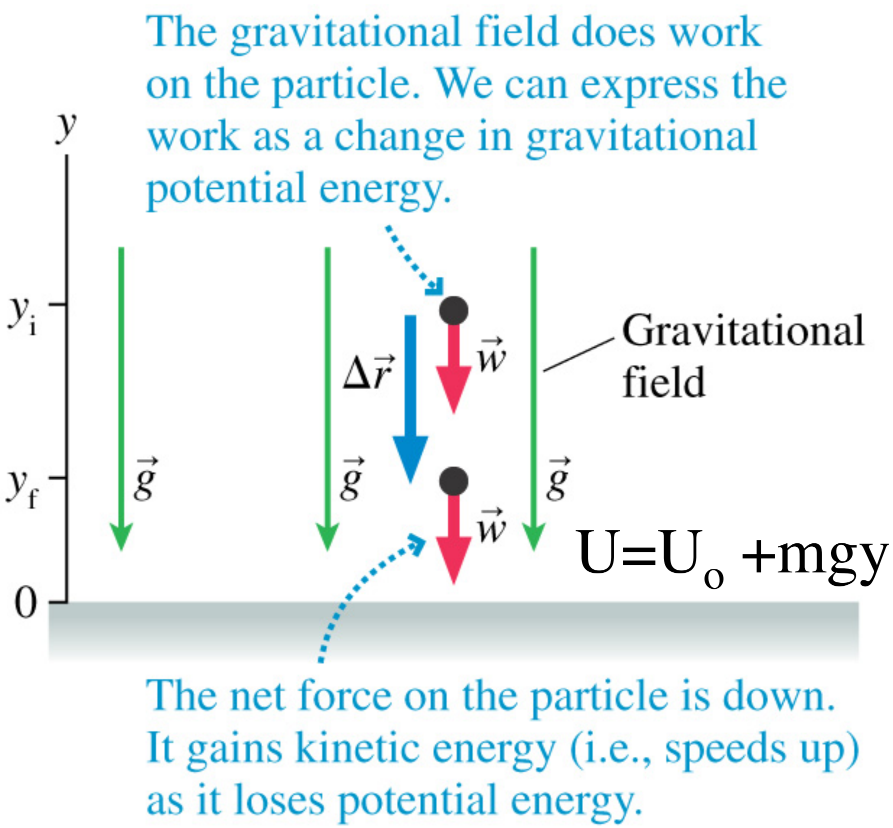
- If $\vec{F}$ or $\Delta\vec{r}$ is not constant, then have to integrate $\vec{F} \cdot d\vec{s}$ over the path travelled



…for a conservative force, the work performed is independent of the path

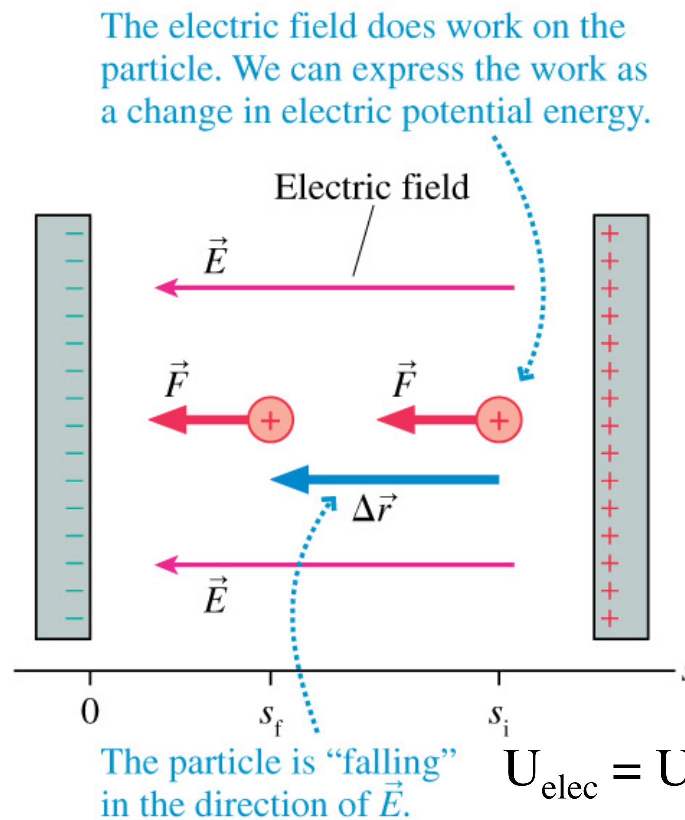
Uniform fields

- $W_{grav} = mg\ \Delta r \cos 0^o = mgy_i - mgy_f$
- $\Delta U_{grav} = U_f - U_i = -W_{grav} = mgy_f - mgy_i$



$U = U_o + mgy$

- $W_{elec} = F\Delta r \cos 0^o = qEs_i - qEs_f$
- $\Delta U_{elec} = U_f - U_i = -W_{elec} = qEs_f - qEs_i$



$U_{elec} = U_o + qEs$

Work

- Work that a constant force does is
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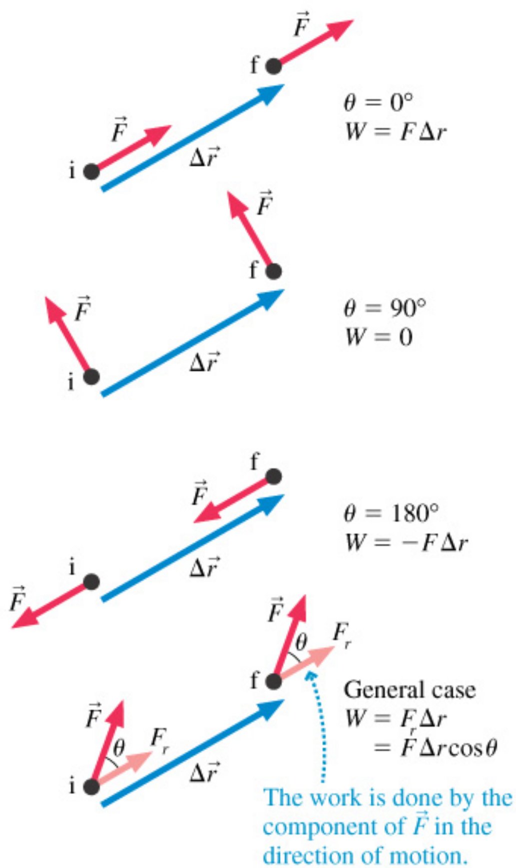

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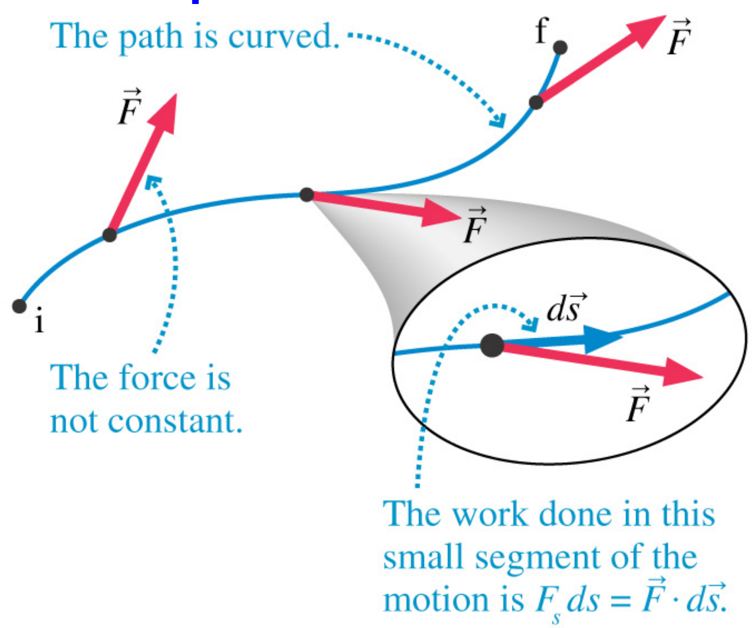
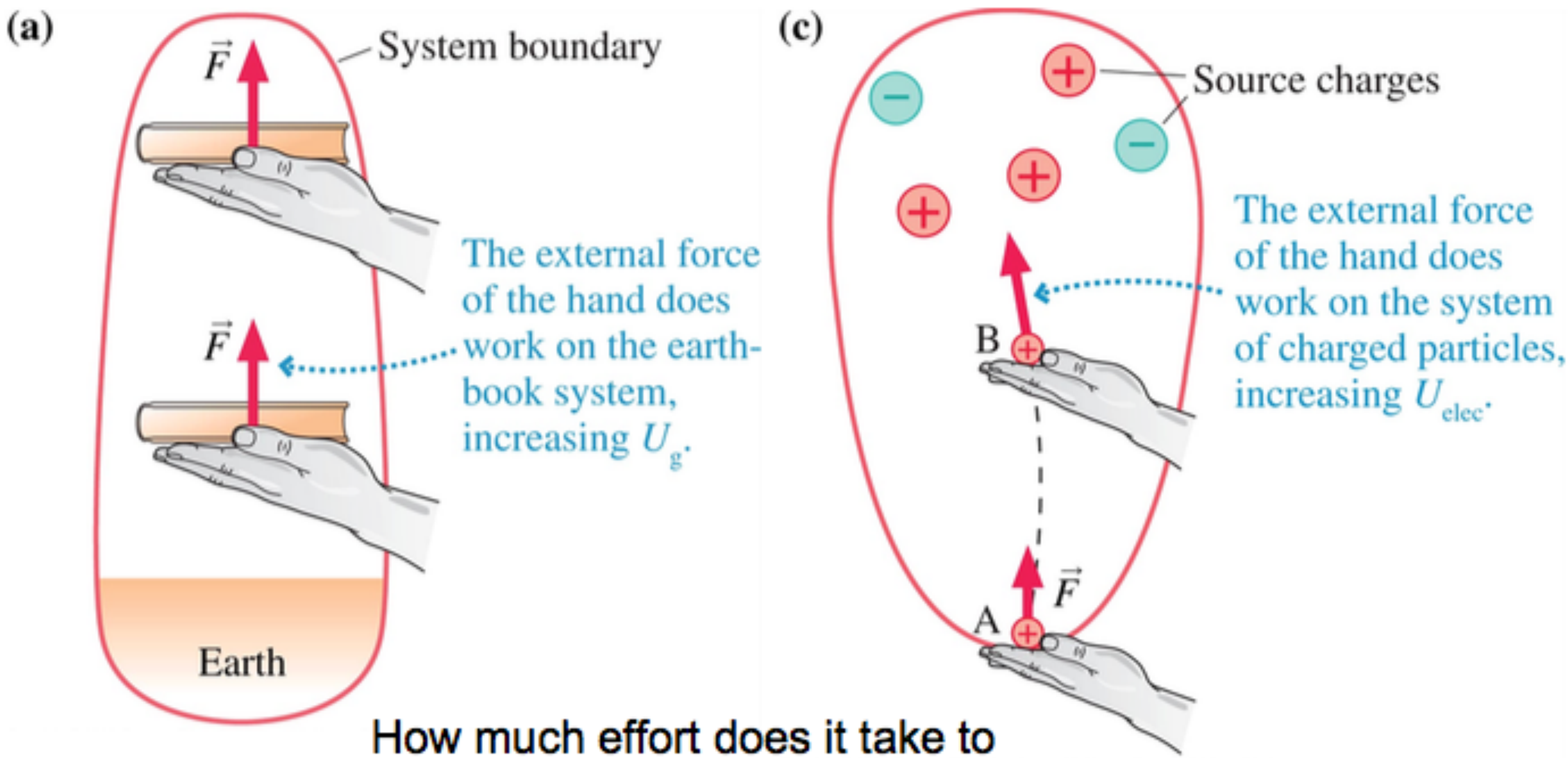


…for a conservative force, the work performed is independent of the path

Potential energy



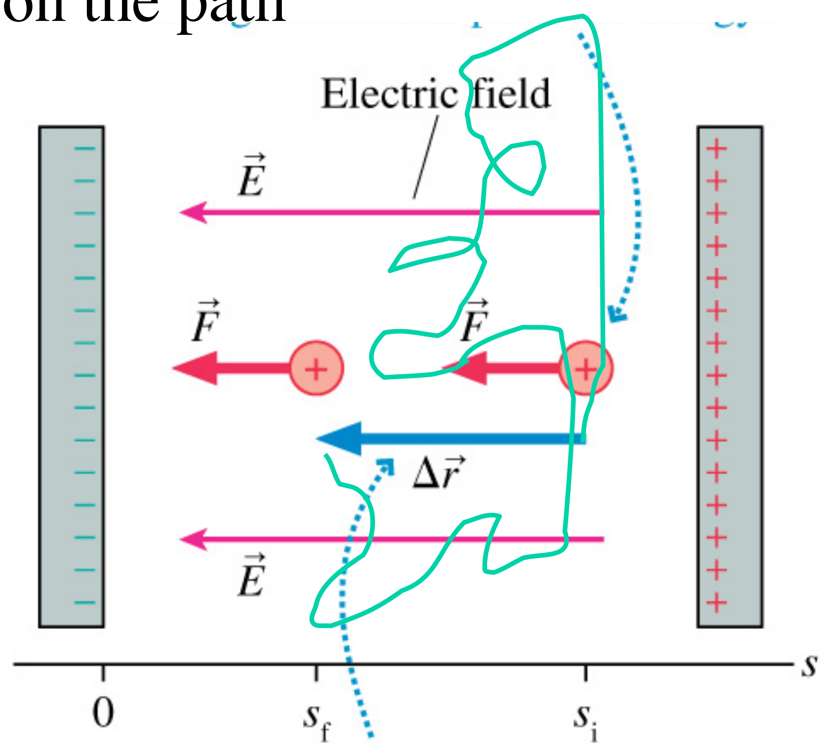
How much effort does it take to move the charge from A to B?

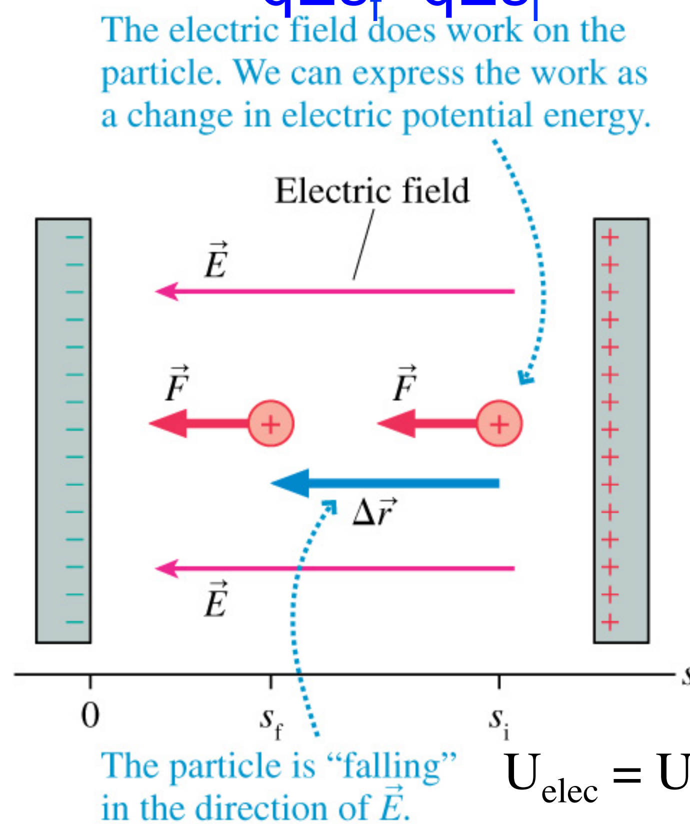
Hard (repulsive): U increases,
Easy (attractive): U decreases

Uniform fields

Note that the work done by the E field, and thus the change in potential energy does not depend on the path

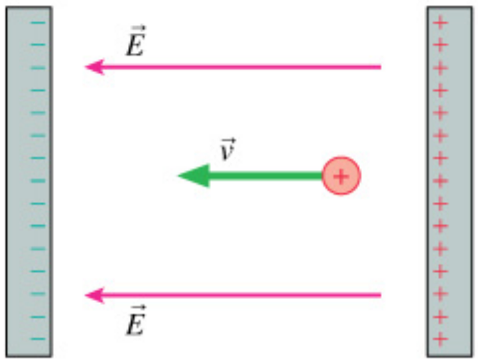
- $W_{elec} = F\Delta r \cos 0^o$
  $= qEs_i - qEs_f$
- $\Delta U_{elec} = U_f - U_i = -W_{elec}$
  $= qEs_f - qEs_i$



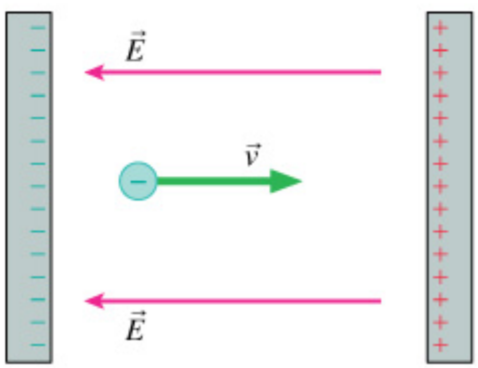


$U_{elec} = U_o + qEs$

Uniform fields



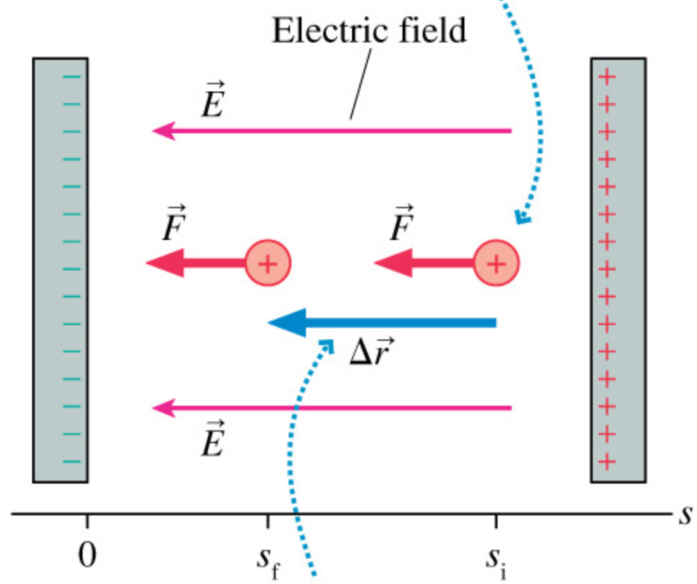
The potential energy of a positive charge decreases in the direction of $\vec{E}$. The charge gains kinetic energy as it moves toward the negative plate.



The potential energy of a negative charge decreases in the direction opposite to $\vec{E}$. The charge gains kinetic energy as it moves away from the negative plate.

- $W_{elec} = F\Delta r \cos 0^o$
  $= qEs_i - qEs_f$
- $\Delta U_{elec} = U_f - U_i = -W_{elec}$
  $= qEs_f - qEs_i$

The electric field does work on the particle. We can express the work as a change in electric potential energy.

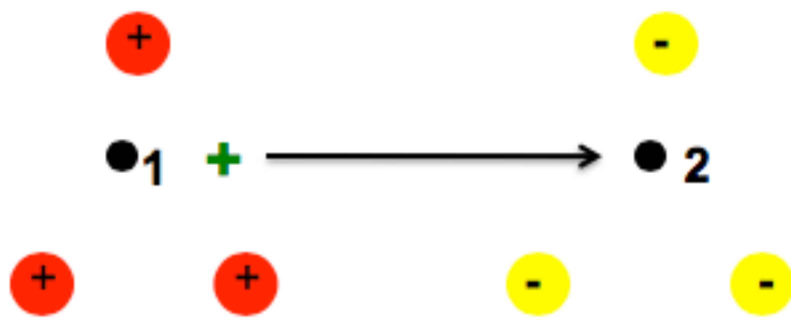


The particle is "falling" in the direction of $\vec{E}$.

$U_{elec} = U_o + qEs$

iclicker question

As you move a positive (+) charge from point 1 to point 2 its electric potential energy (U)



A. Decreases
B. Increases
C. Stays the same
D. Not enough info

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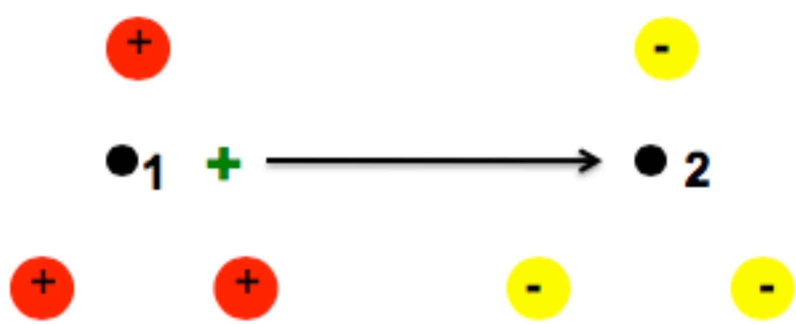
As you move a positive (+) charge from point 1 to point 2 its electric potential energy (U)



A. Decreases

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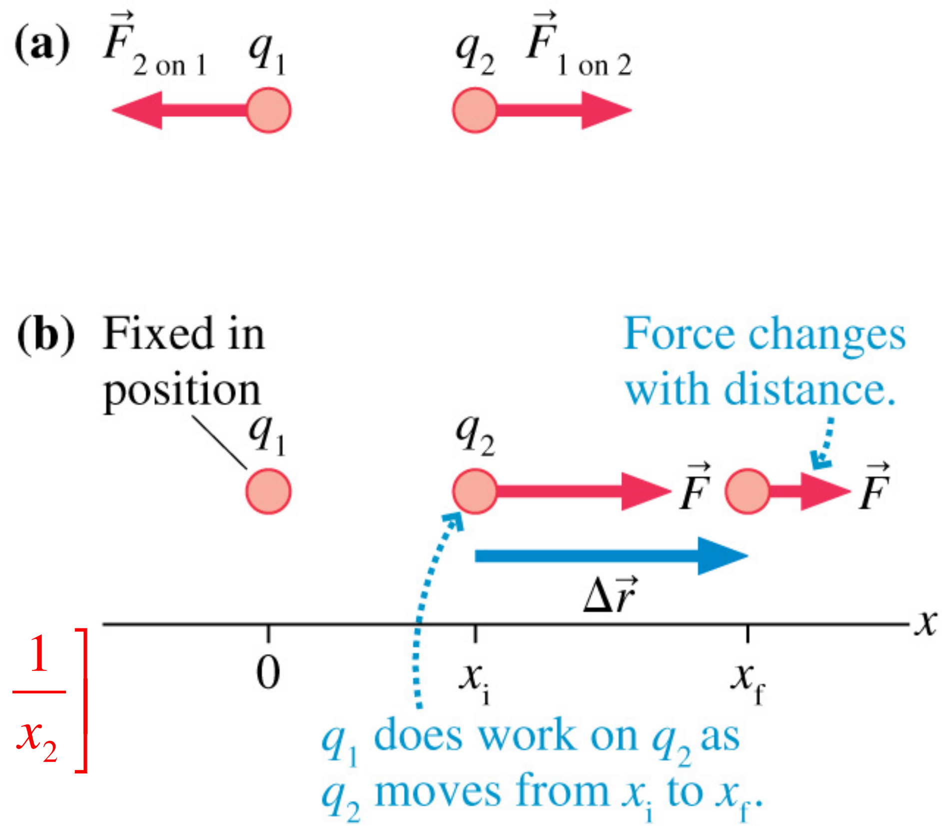
Potential energy of point charges

- First, let me calculate the work done by charge 1 on charge 2 while charge 2 moves from point x_1 to point x_2



$$W_{elec} = \int_{x1}^{x2} \vec{F}_{1on2} \bullet \vec{d}x$$

$$W_{elec} = \frac{q_1 q_2}{4\pi\varepsilon_o} \int_{x1}^{x2} \frac{1}{x^2} dx$$

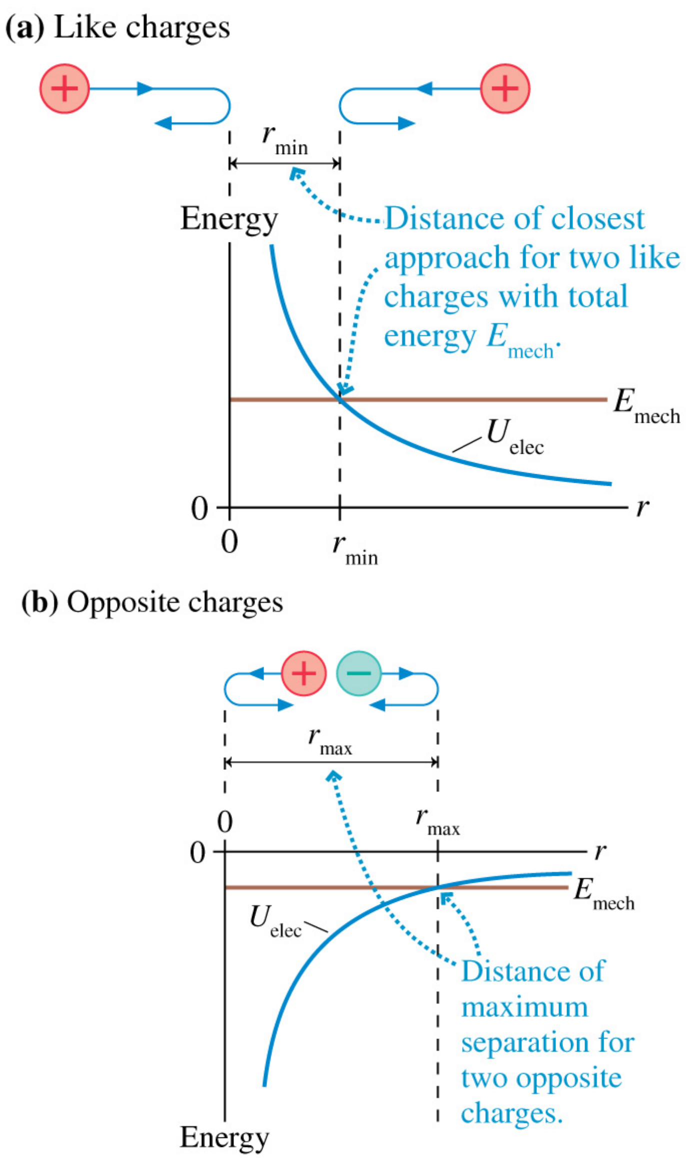
$$W_{elec} = \frac{q_1 q_2}{4\pi\varepsilon_o} \left(-\frac{1}{x} \right)_{x1}^{x2} = \frac{q_1 q_2}{4\pi\varepsilon_o} \left[\frac{1}{x_1} - \frac{1}{x_2} \right]$$

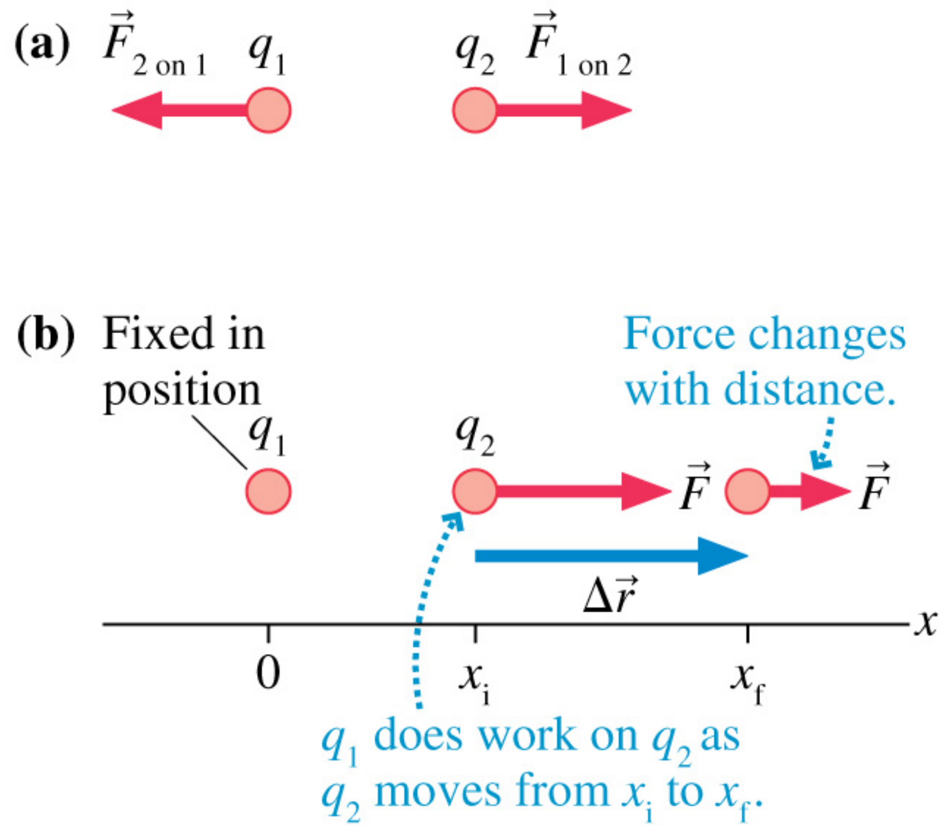
$$\Delta U_{elec} = U_f - U_i = -W_{i \to f} = \frac{q_1 q_2}{4\pi\varepsilon_o} \left[\frac{1}{x_2} - \frac{1}{x_1} \right]$$

use r instead of x. Set U_{inf}=0

$$U_{\text{elec}} = \frac{K q_1 q_2}{r} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r} \quad \text{(two point charges)}$$

Potential energy of point charges





$$U_{elec} = \frac{Kq_1q_2}{r} = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r} \quad \text{(two point charges)}$$

Note that the potential energy between any two point charges is zero at infinite separation

iclicker question

Rank in order, from largest to smallest, the potential energies U_a to U_d of these 4 pairs of charges. Each + symbol represents the same amount of charge.

$$U_{elec} = \frac{Kq_1q_2}{r}$$

A. $U_a = U_b > U_c = U_d$
B. $U_b = U_d > U_a = U_c$
C. $U_a = U_c > U_b = U_d$
D. $U_d > U_c > U_b > U_a$
E. $U_d > U_b = U_c > U_a$

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