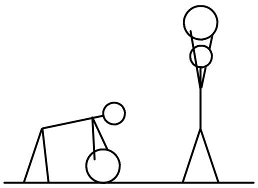
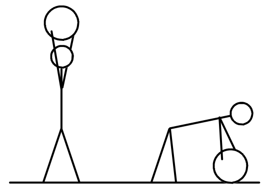
PreAP Electrostatics 11

Let's remember the difference between + and − work.



When Slim Jim lifts up an object, the force and distance are both positive, so Fd = +W and the object gains PE. Here's another way to look at it: if Jim moves the ball opposite the way it wants to move, it gains PE.



When Slim Jim lowers the object back to the ground, the force is still + but the distance is −, so Fd = −W and the object loses PE. OR the object is moving the way it wants to move, so it loses PE.

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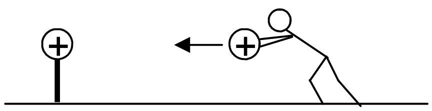
1. Imagine a fixed + charge (meaning it CANNOT MOVE). Slim Jim pushes a moveable positive charge toward the fixed charge. Assume right is the + direction.



Fixed + charge

A. Are the charges attracting or repelling each other?
B. Is Slim Jim's force positive or negative?
C. Is the distance the object is moving + or −?
D. Is the work done on the charge + or −?
E. Is the object gaining or losing PE?

1A: repelling
1B: − (pushing)
1C: −
1D: +
(− times − = +)
1E: gaining

Notice that the object is gaining potential energy because it is moved "against its will". Think of it like compressing a spring: pushing like charges together stores energy. Also, the force on the right + charge increases as it gets closer to the fixed charge giving it more possible kinetic energy when released.

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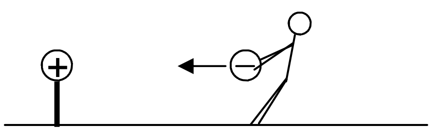
2. Now Slim Jim slowly moves a negative charge toward the fixed charge. Notice he has to hold it back.



Fixed + charge

A. Are the charges attracting or repelling each other?
B. Is Slim Jim's force positive or negative?
C. Is the distance the object is moved + or −?
D. Is the work done on the charge + or −?
E. Is the object gaining or losing PE?

2A: attracting
2B: + (pulling)
2C: − (left)
2D: −
(+ time − = −)
2E: losing

Since the negative charge is moving the way it wants to move, it is losing potential energy. Using the spring idea, again, the spring would be pulling and Jim is slowly relaxing the spring, decreasing its PE.

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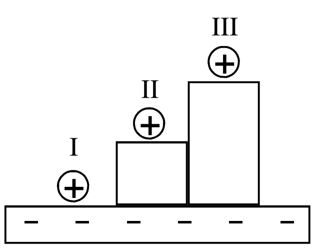
3. Three equal positive charges are at different positions above a negatively charged plate. All three charges are at rest.



A. If released, which charge will have the most kinetic energy (and therefore the greatest velocity) when it hits the plate?
B. So, which object has the most PE?
C. Which POSITION, then, has the greatest electric potential (voltage)?
D. Which charge has the least amount of PE?
E. So, if the charge is moved CLOSER to the negative plate (from III to II) does the charge gain or lose PE?

3A: charge III: it falls farthest distance.
3B: charge III
3C: position III
3D: charge I (no PE)
3E: lose

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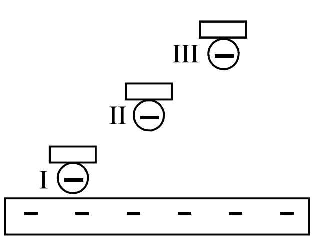
4. Now the positive charges are replaced with negative charges. This time, though, the charges have to be held down with brackets, since they are repelled by the plate.



A. Which charge feels the most repulsion from the negative plate?
B. If released, which charge will have the most possible kinetic energy (and therefore the greatest velocity)?
C. So, which object has the most PE?
D. Remembering that electric potential (voltage) is defined by a positive charge, which POSITION has the greatest electric potential (voltage)?
E. Which charge has the least amount of PE?
F. So, if the charge is moved CLOSER to the negative plate (from III to II) does the charge gain or lose PE?

4A: charge I: closest to the plate.
4B: charge I
4C: charge I
4D: position III (where a + charge has more PE)
4E: III: least force
4F: gain.

$$F_e = k_c \frac{|q_1 q_2|}{r^2} \qquad E = k_c \frac{q_1}{r^2} \qquad PE = k_c \frac{q_1 q_2}{r} \qquad V = k_c \frac{q_1}{r}$$

6μC 12cm 4μC
⊕ ⊕

5. Two charges are placed as shown. Calculate the electric potential energy between them.

5. 1.8 J (solution below)

6μC 6cm 4μC
⊕ ⊕

6. The right charge is then moved half the way to the left charge. Calculate the electric potential energy between them.

6. 3.6 J (since r is on bottom, halving r doubles PE).

Notice, moving the + charges closer increases their PE, just as we saw on the front page.

Now for some math to help us understand an important concept.

7. Pretend we have a +1C and a −1C charge. Leave the k in your answer.

   A. Calculate the potential energy if they are separated by 1 m.

   B. Calculate the potential energy if they are separated by 100 m.

   C. Calculate the potential energy if they are separated by 1,000,000 m.

   D. Calculate the potential energy if they are separated by infinity.

7A: k(1)(−1)/1 = −k joules

7B: k(1)(−1)/100 = −0.01k joules (100 times smaller)

7C: k(1)(−1)/(1E6) = −(1E−6)k joules, which is REALLY small.

7D: 0 joules.

This is why we define 0 at infinity. It is the same for PE, V, F, and E, since they all have r's on the bottom.

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8. Calculate the potential energy between the positive and negative charges shown below.

3μC 4mm 4μC
⊖ ⊕

8. −27 J

PE is negative because you had to hold back the charge (do negative work) as you moved it to this position from infinity, where PE is defined as 0J.

$$PE = \frac{(9E9)(6E-6)(4E-6)}{12E-2}$$

$$= \left(\frac{9(6)4}{12}\right)\left(\frac{10^{9}10^{-6}10^{-6}}{10^{-2}}\right) = \left(\frac{9(24)}{12}\right)\left(\frac{10^{9-12}}{10^{-2}}\right)$$

$$= \left(\frac{9(2)}{1}\right)\left(\frac{10^{-3}10^{+2}}{1}\right) = 18(10^{-1}) = 1.8(10^{1})(10^{-1})$$

$$= 1.8(10^{0}) = 1.8(1) = 1.8\,J$$