Physics 131- Fundamentals of Physics for Biologists I

Professor: Arpita Upadhyaya

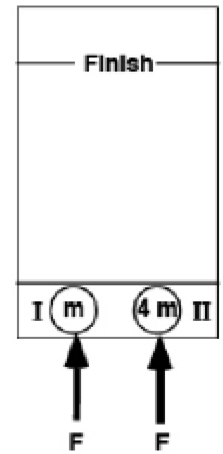
Energy

Chemical bonding

Intermolecular Interactions

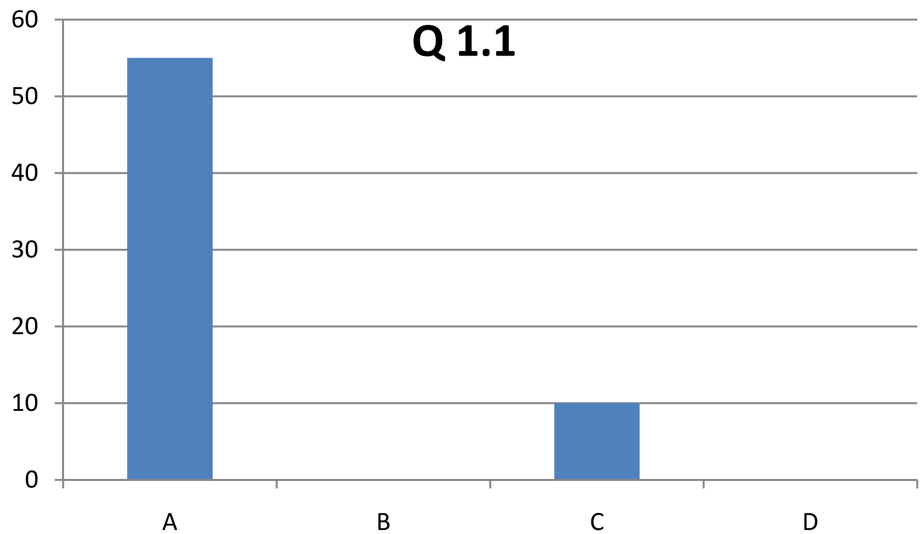
Quiz 11

Q1. (6 pts) The diagram at the right depicts two pucks on a frictionless table. Puck II is much more massive than puck I. Starting from rest, the pucks are pushed across the table by two equal forces.



Which puck reaches the finish line first?

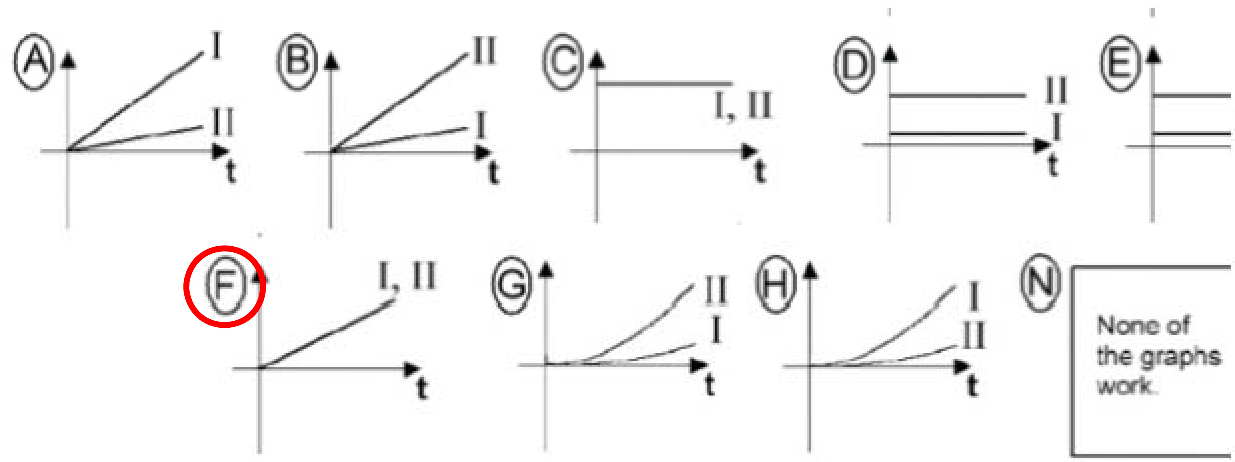
- A. Puck I
- B. Puck II
- C. Both reach at the same time
- D. Not enough information

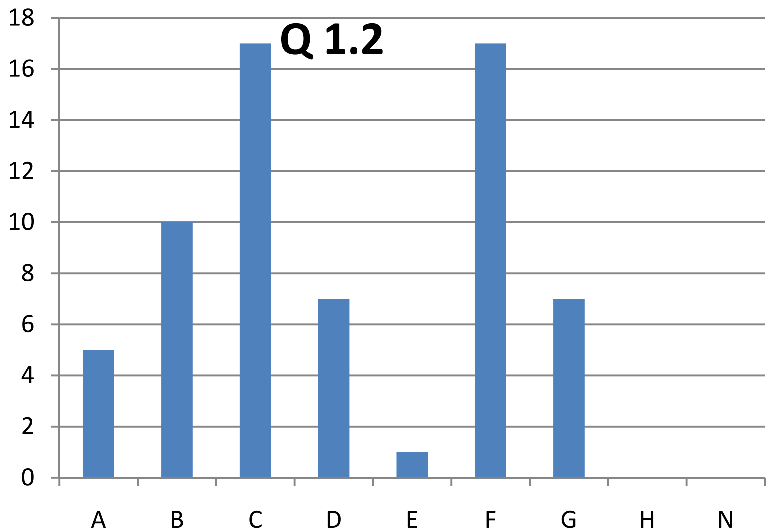


Below are shown a set of time graphs.

1.2 Which graph might show the **momentum** of the two pucks? (2 pts)

1.3 Which graph might show the **kinetic energy** of the two pucks? (2 pts)



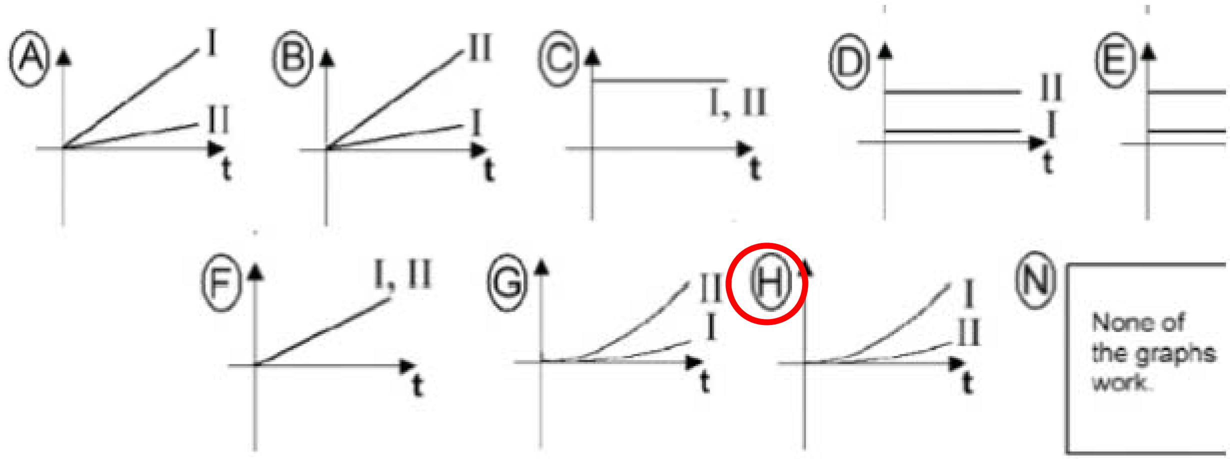


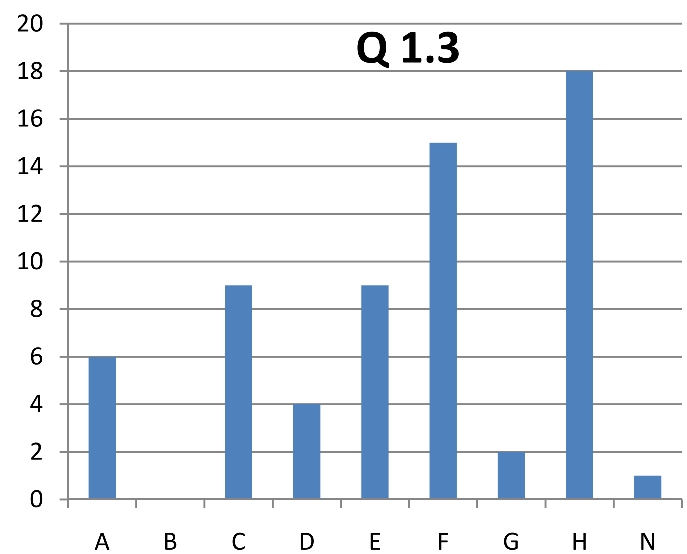
- *Graph momentum*
- Same force, more time for puck II to cross finish line…but these are plots vs. time, not position!
- $a_I = F/m \quad a_{II} = F/M$
- $v_I = Ft/m \quad v_{II} = Ft/M$
- $mv_I = Ft = Mv_{II}$
- Graph F

Below are shown a set of time graphs.

1.2 Which graph might show the **momentum** of the two pucks? (2 pts)

1.3 Which graph might show the **kinetic energy** of the two pucks? (2 pts)

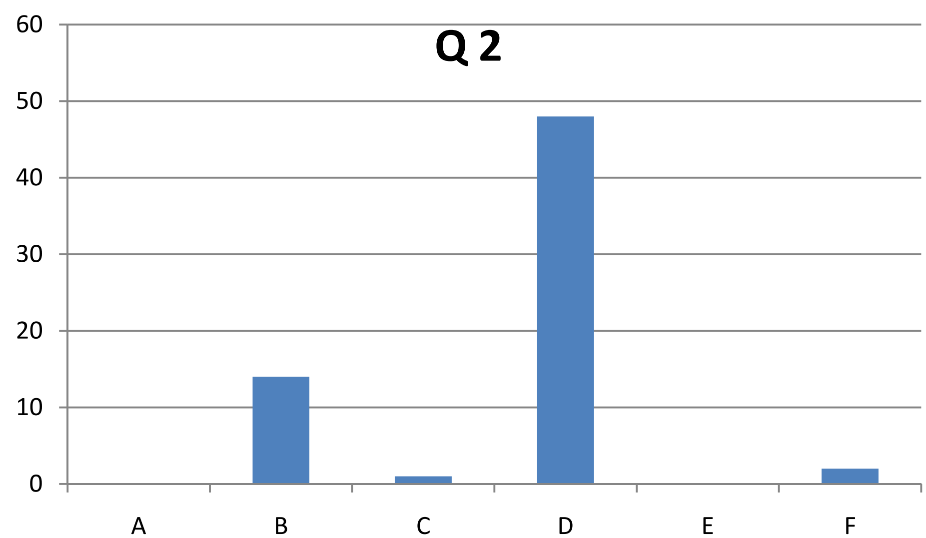




- *Graph kinetic energy?*
- Same momentum as a function of time means…
- $p_I = p_{II}$ so $(p_I)^2 = (p_{II})^2$
- $(p_I)^2/2m > (p_{II})^2/2M$
- $KE_I > KE_{II}$
- Graph H

Q2. (2 pts) A cart on an air track is moving at 1 m/s when the air is suddenly turned off. The cart comes to rest after traveling 1 m. The experiment is repeated but now the cart is traveling at 2 m/s when the air is turned off. How far does the cart travel before coming to rest?

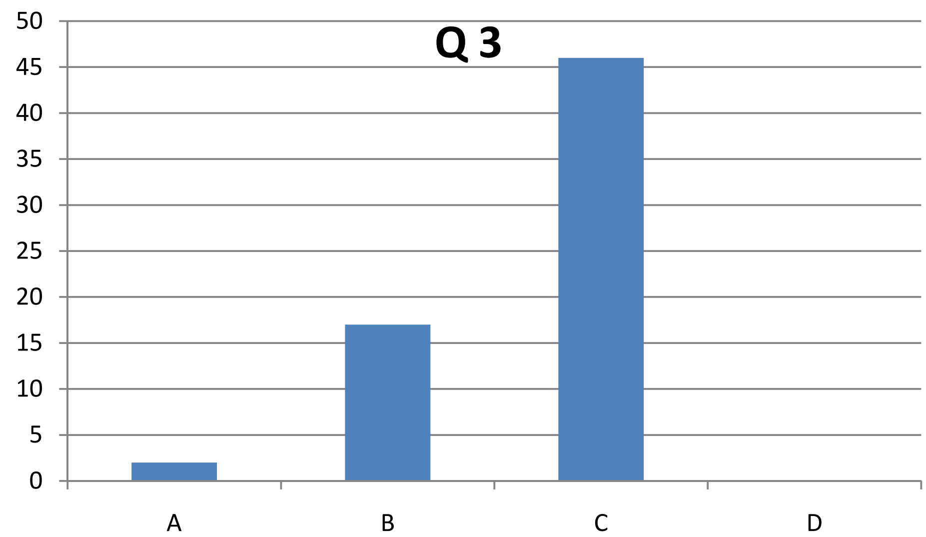
A. 1 m
B. 2 m
C. 3 m
D. 4 m
E. 5 m
F. Not enough information to tell



Q3. (2 pts) Two test charges are brought separately into the vicinity of a charge $+Q$. First, test charge $+q$ is brought to point A which is a distance r from $+Q$. Next, $+q$ is removed and a test charge $+2q$ is brought to point B which is a distance $2r$ from $+Q$.

Compared with the electrostatic potential energy of the pair of charges in case A, the PE in case B is

A. greater
B. smaller
C. the same
D. not enough information



Foothold ideas: Kinetic Energy and Work

- Newton's laws tell us how velocity changes. The Work-Energy theorem tells us how speed (independent of direction) changes.
- Kinetic energy = $\frac{1}{2}mv^2$
- Work done by a force = $F_x \Delta x$ or $F_{\parallel} \Delta r$ (part of force parallel to displacement)
- Work-energy theorem: $\Delta(\frac{1}{2}mv^2) = F_{\parallel}^{net} \Delta r$

Foothold ideas: Potential Energy

- For some forces work only depends on the change in position. Then the work done can be written

$$\vec{F} \cdot \Delta\vec{r} = -\Delta U$$

U is called a *potential energy*.

- For gravity, $U_{gravity} = mgh$

  For a spring, $U_{spring} = \frac{1}{2} kx^2$

  For electric force, $U_{electric} = k_C Q_1 Q_2 / r_{12}$

Foothold ideas: Conservation of Mechanical Energy

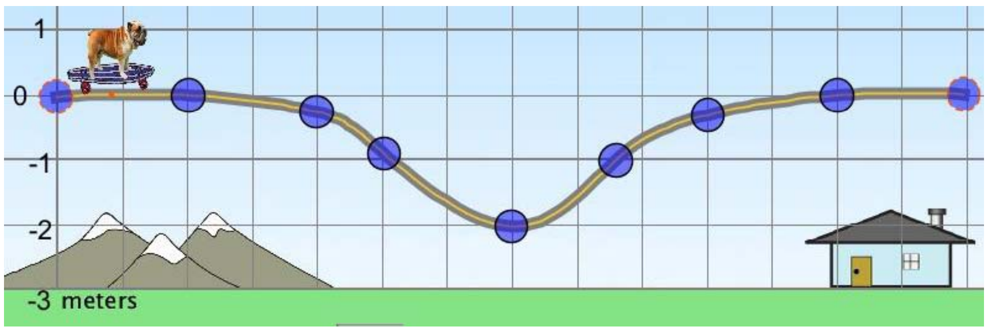
- Mechanical energy
  - The mechanical energy of a system of objects is conserved if resistive forces can be ignored.

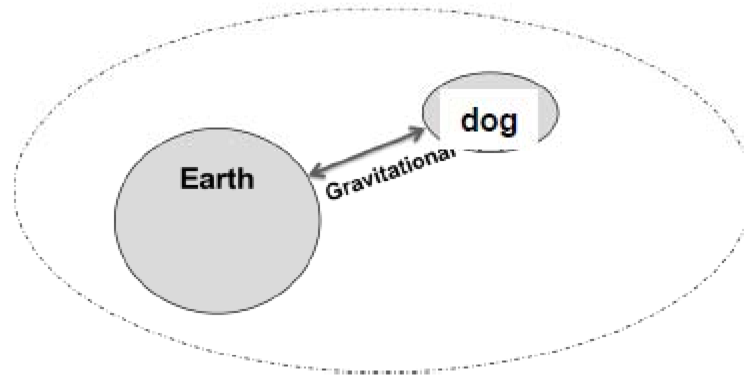
$$\Delta\left(KE + PE\right) = 0$$

$$KE_{initial} + PE_{initial} = KE_{final} + PE_{final}$$

- Thermal energy
  - Resistive forces transform coherent energy of motion (energy associated with a net momentum) into *thermal energy* (energy associated with internal chaotic motions and no net momentum)

Energy skate park

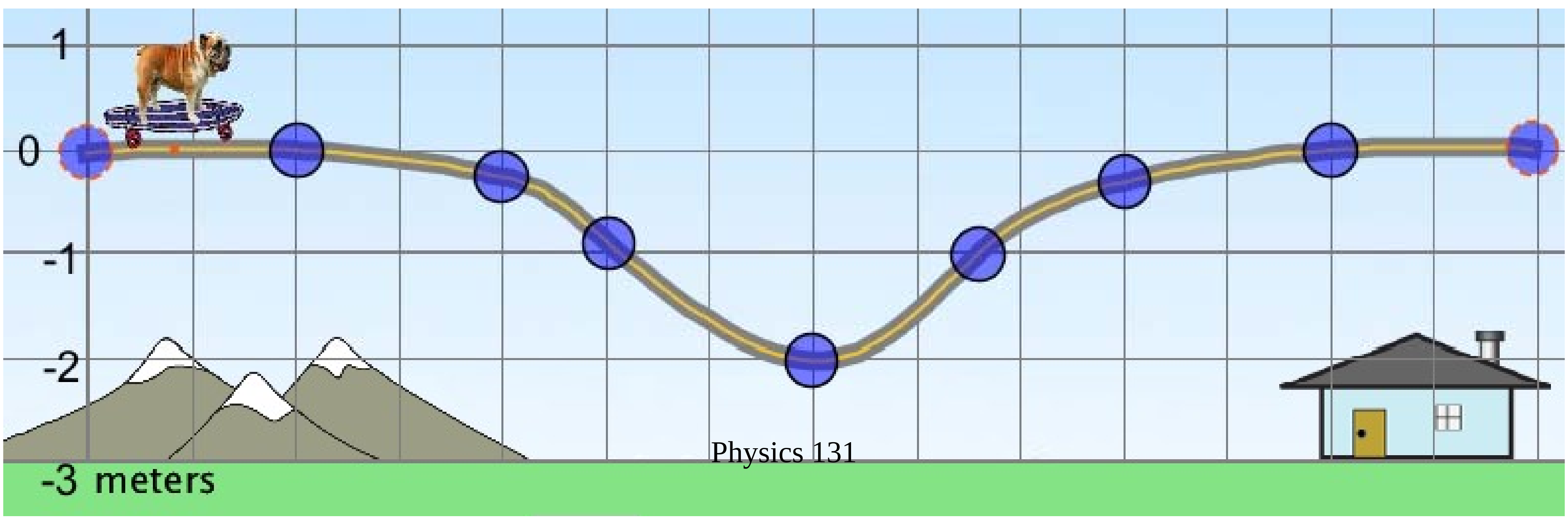




http://phet.colorado.edu/en/simulation/energy-skate-park

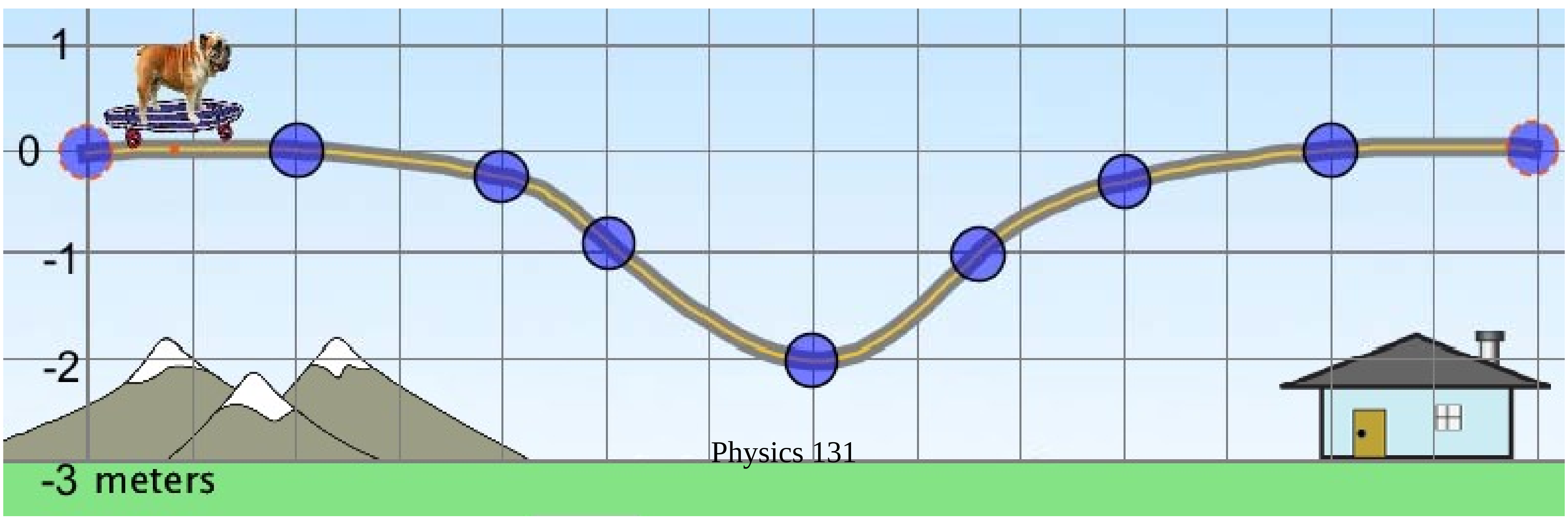
A bulldog on a skateboard is moving very slowly when he encounters a 2 m dip. How fast will be be going when he is at the bottom of the dip? The bulldog and skateboard combined have a mass of 20 kg. Friction and air drag can be ignored.

1. Very slowly
2. About 2 m/s
3. About 6 m/s
4. You can’t tell from the information given.



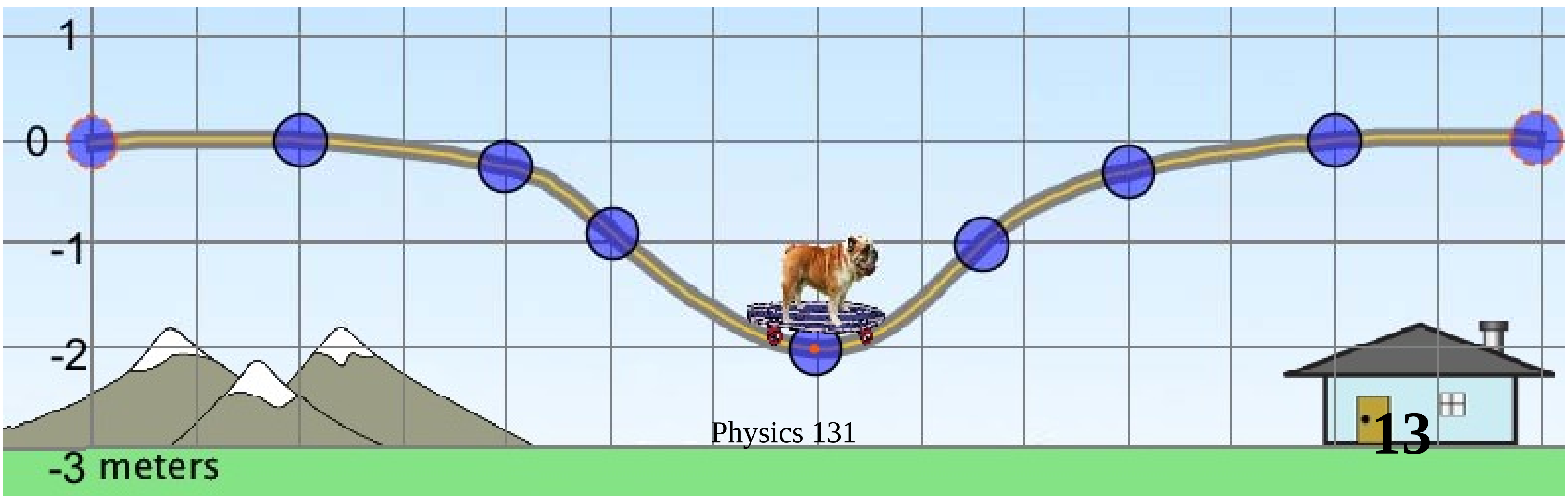
A bulldog on a skateboard is moving very slowly when he encounters a 2 m dip. The bulldog and skateboard combined have a mass of 20 kg. What is their total mechanical energy?

1. Almost zero
2. About 200 Joules
3. About 600 Joules
4. You can't tell from the information given.



A bulldog on a skateboard is sitting at the bottom of a 2 m dip. How much KE do you have to give them so they will roll out of the dip? The bulldog and skateboard combined have a mass of 20 kg. Friction and air drag can be ignored.

1. None
2. (circled) About 400 Joules
3. About 600 Joules
4. You can't tell from the information given.



Moving to molecules

- Apply our Newtonian framework and results to atoms and molecules.
- See what goes over directly,
  what we have to add.
- Can we integrate what we know about atoms and molecules from chemistry with the physics we have learned?

Foothold ideas:
Energies between charge clusters

- Atoms and molecules are made up of charges.
- The potential energy between two charges is

$$U_{12}^{elec} = \frac{k_C Q_1 Q_2}{r_{12}}$$

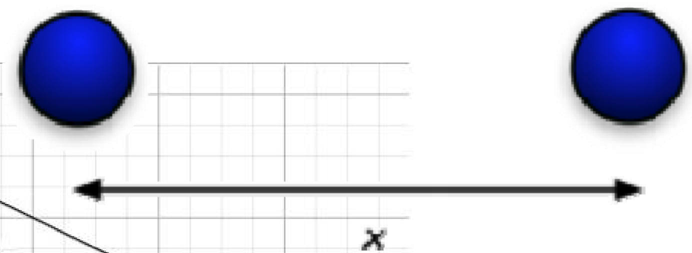
No vectors!

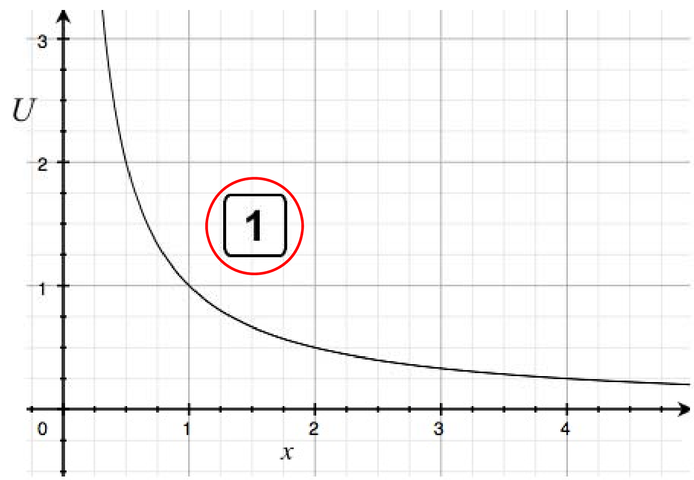
- The potential energy between many charges is

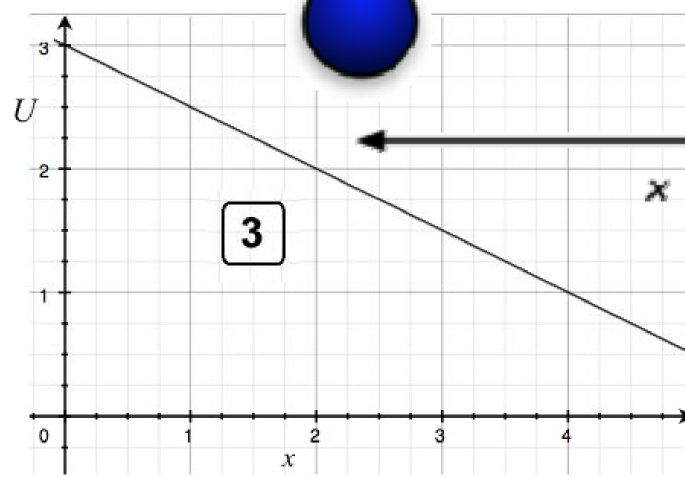
$$U_{12\ldots N}^{elec} = \sum_{i<j=1}^{N} \frac{k_C Q_i Q_j}{r_{ij}}$$

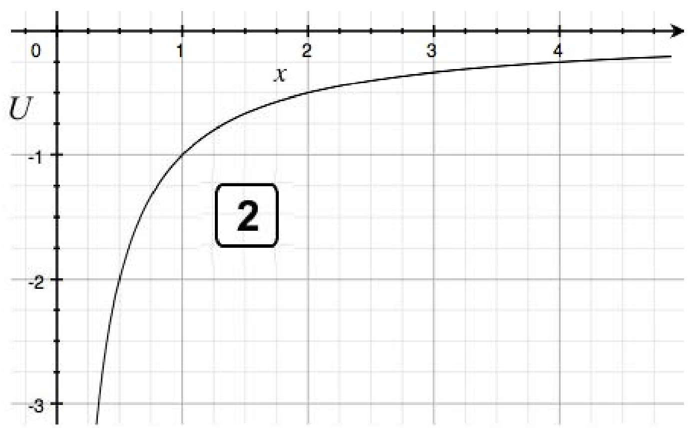
Just add up all pairs!

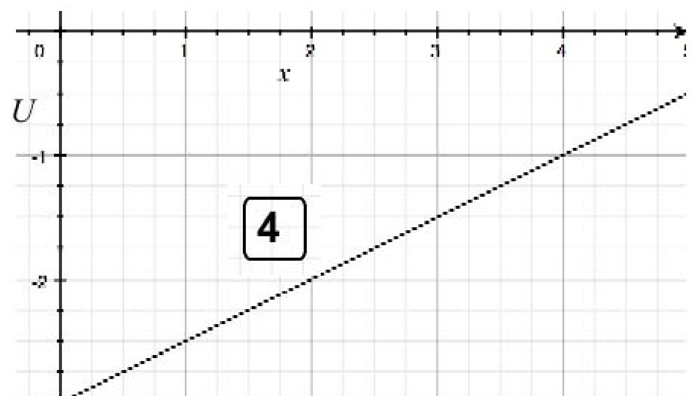
What does the electric potential energy between two identical charges look like?





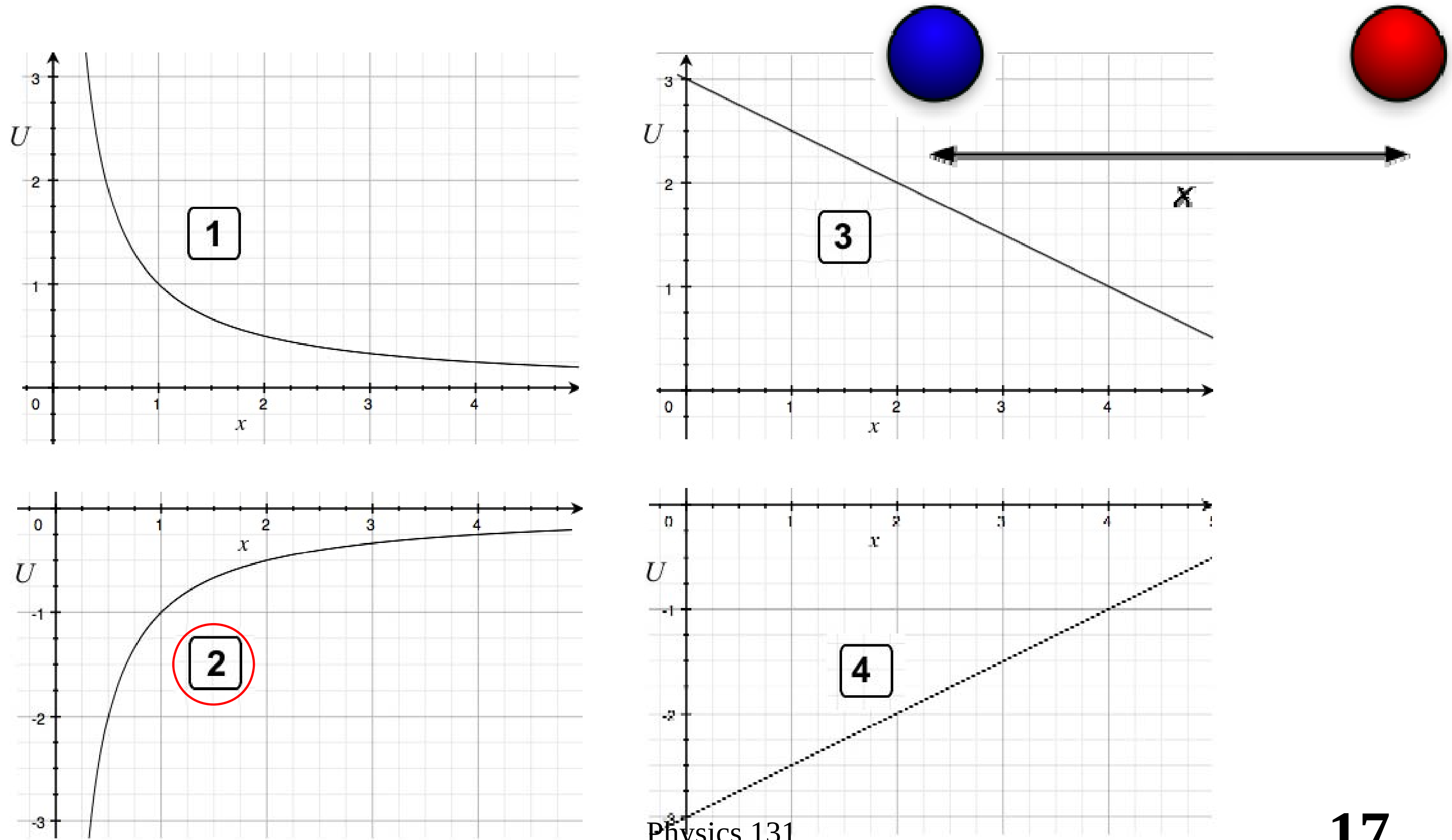






5. None of the above

What does the electric potential energy between two opposite charges look like?



5. None of the above

When a positive (test) charge is released from rest near a fixed positive (source) charge what happens to the electric potential energy of the test charge?

1. It will increase because the test charge will move towards the source charge.
2. It will decrease because the test charge will move away from the source charge.
3. It will increase because the test charge will move away from the source charge.
4. It will decrease because the test charge will move towards the source charge.
5. It will remain constant because the test charge remains at rest.
6. There is not enough information to tell.

When a negative (test) charge is released from rest near a fixed positive (source) charge what happens to the electric potential energy of the test charge?

1. It will increase because the test charge will move towards the source charge.
2. It will decrease because the test charge will move away from the source charge.
3. It will increase because the test charge will move away from the source charge.
4. It will decrease because the test charge will move towards the source charge.
5. It will remain constant because the test charge remains at rest.
6. There is not enough information to tell.

Foothold Ideas: Conservation of Mechanical Energy

- Total of kinetic plus potential energy are conserved if resistive forces can be ignored

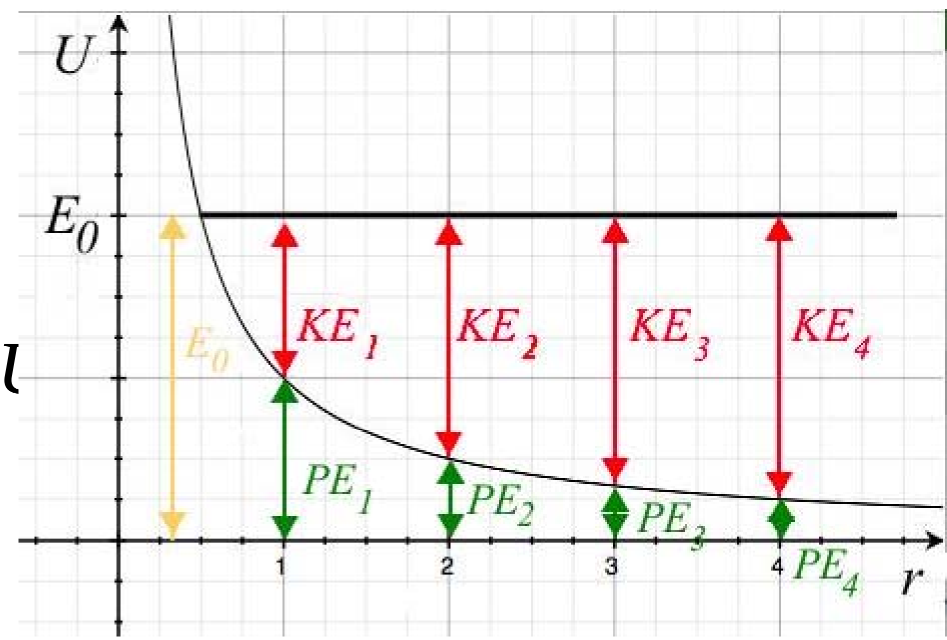
Mathematical Representation

$$\Delta(\tfrac{1}{2}mv^2) = \Delta U$$

$$\Delta(\tfrac{1}{2}mv^2 + U) = 0$$

$$\tfrac{1}{2}mv^2_{initial} + U_{initial} = \tfrac{1}{2}mv^2_{final} + U$$

Graphical Representation



Foothold ideas: Forces from PE

- For conservative forces, PE can be defined by

$$\vec{F} \cdot \Delta \vec{r} = -\Delta U$$

- If you know *U*, the force can be obtained from it via

$$F_{\parallel}^{type} = -\frac{\Delta U_{type}}{\Delta r} = -\frac{dU_{type}}{dr}$$

- In more than 1D need to use the *gradient*

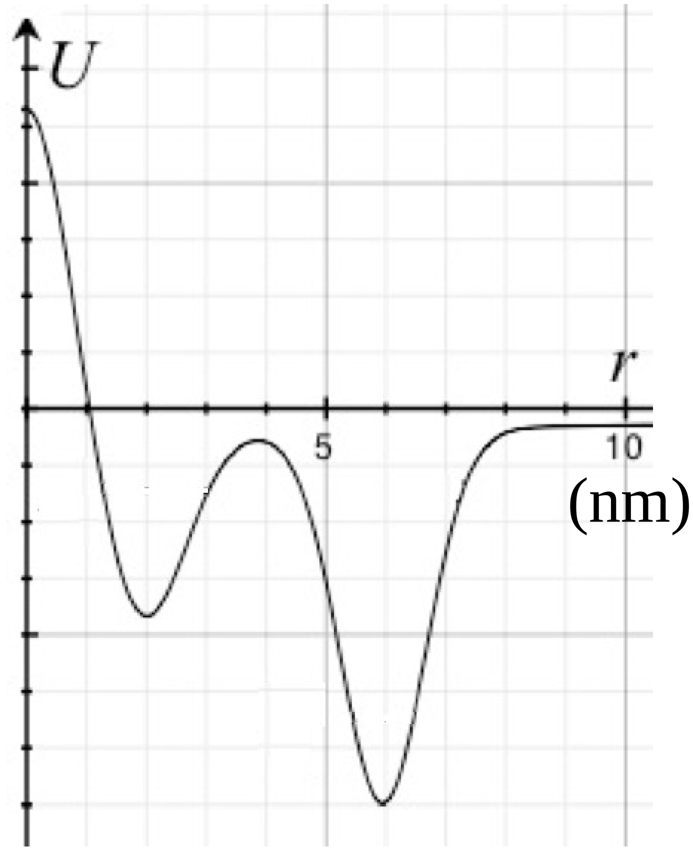
$$\vec{F}^{type} = -\left(\frac{\partial U_{type}}{\partial x}\hat{i} + \frac{\partial U_{type}}{\partial y}\hat{j} + \frac{\partial U_{type}}{\partial z}\hat{k} \right) = -\vec{\nabla} U_{type}$$

- The force always points <u>down</u> the PE hill.

The figure below shows the interaction potential between two molecules (along a particular orientation of the two molecules). The units are in nm (r) and eV (*U*).

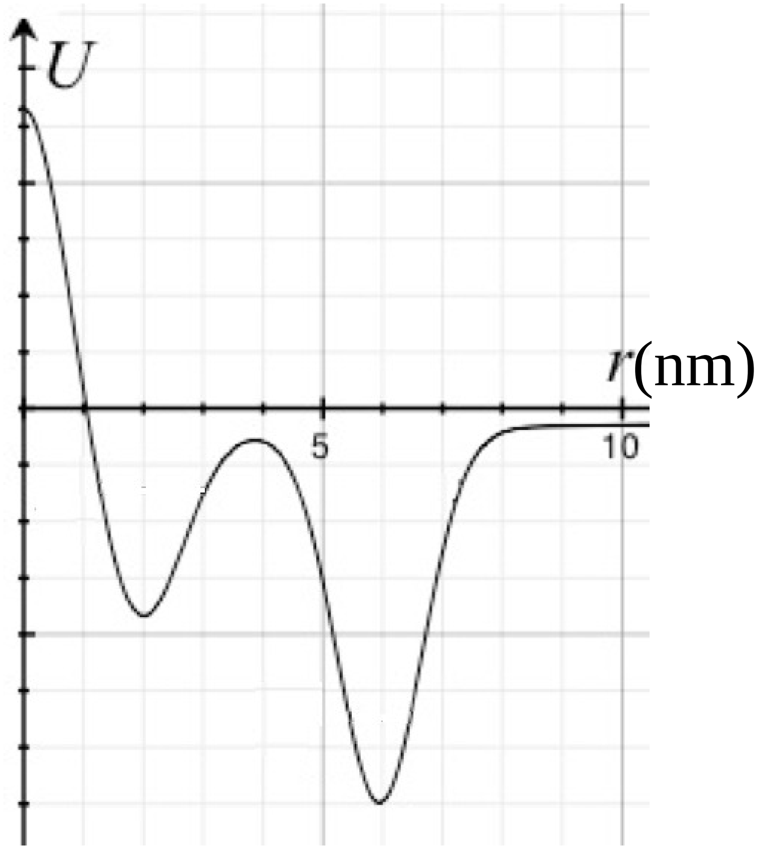
When the molecules are separated by 7 nm the force between them is

1. Attractive
2. Repulsive
3. Zero
4. Cannot be determined from the figure.



The figure below shows the interaction potential between two molecules (along a particular orientation of the two molecules). The units are in nm (r) and eV (*U*).

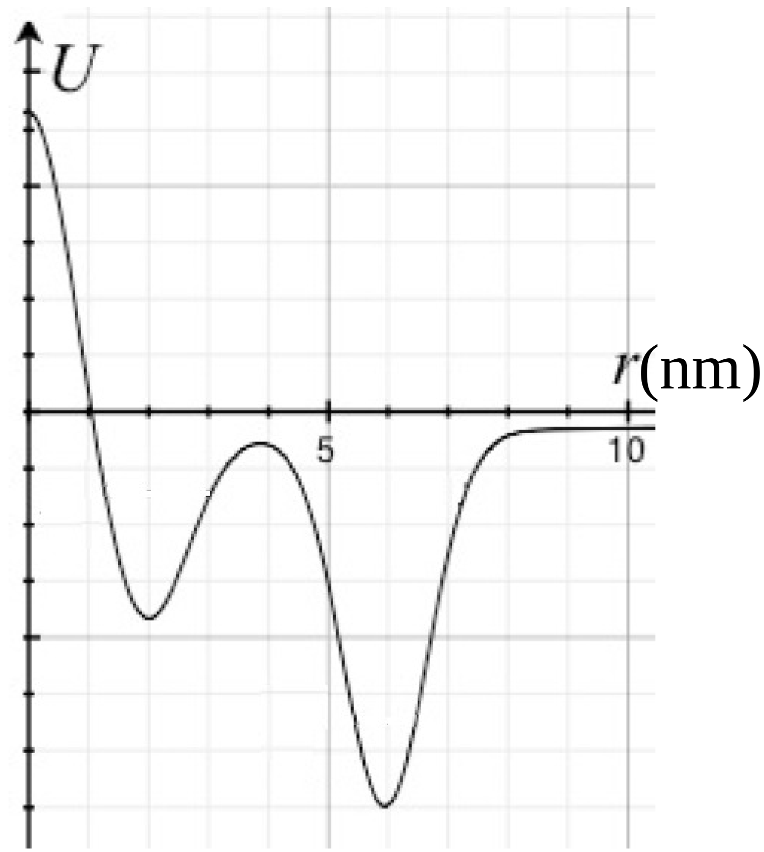
When the molecules are separated by 2 nm the force between them is



1. Attractive
2. Repulsive
3. Zero
4. Cannot be determined from the figure.

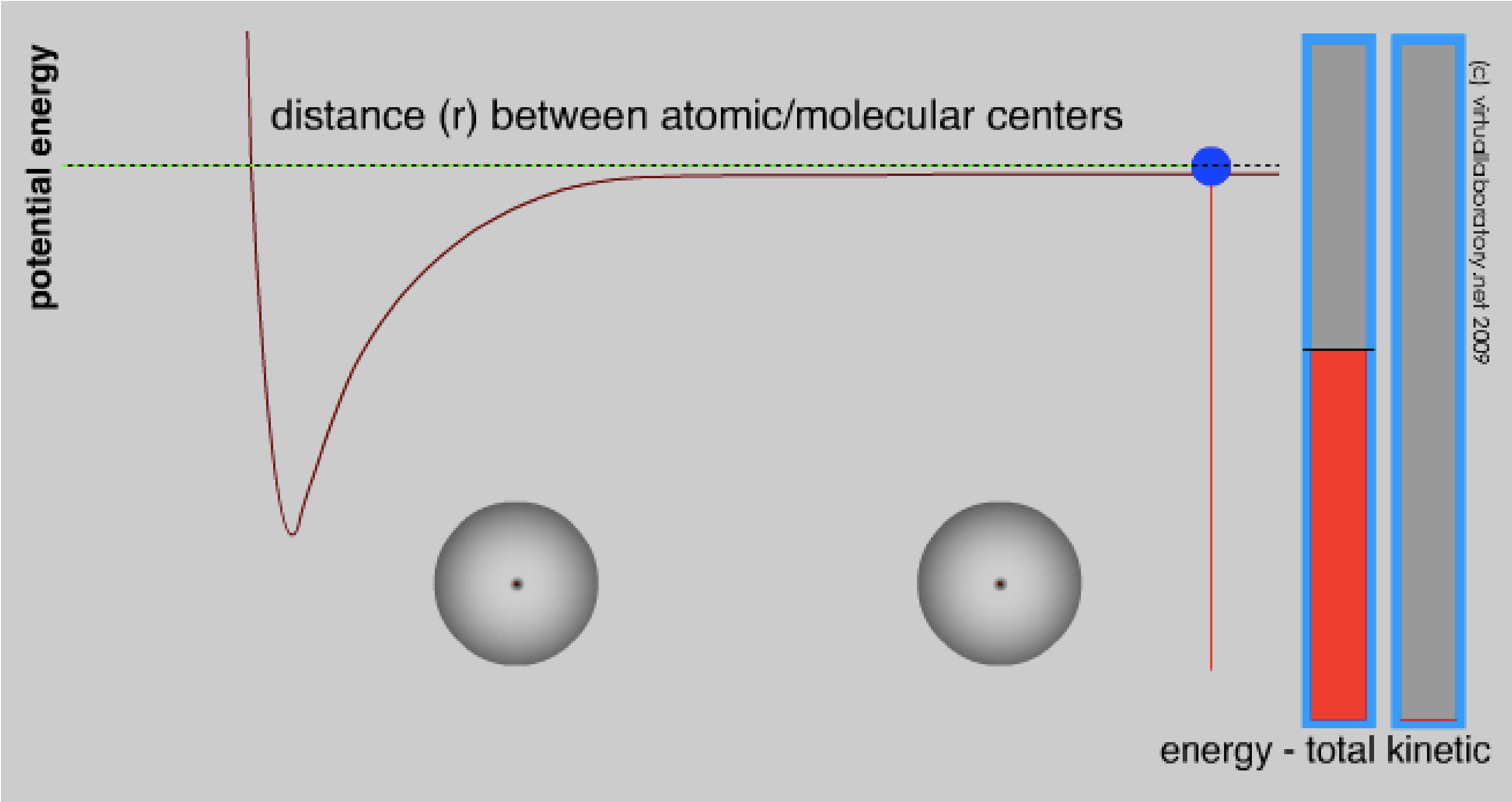
The figure below shows the interaction potential between two molecules (along a particular orientation of the two molecules). The units are in nm (r) and eV (*U*).

When the molecules are separated by 0.5 nm the force between them is



1. Attractive
2. Repulsive
3. Zero
4. Cannot be determined from the figure.

Molecular forces



http://besocratic.colorado.edu/CLUE-Chemistry/activities/LondonDispersionForce/1.2-interactions-0.html