Physics 131- Fundamentals of Physics for Biologists I

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Quiz 11

Energy

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: $\Delta(\frac{1}{2}mv^2) = F_{\parallel}^{net} \Delta r$

Momentum vs. energy

- If we are changing the motion of two interacting objects so the momentum of each change in the same way, it might be useful to look at the KE in terms of that momentum.
- Suppose each starts with 0 momentum and they move as a result of each other's forces.

$$\vec{p}_A = \Delta\vec{p}_A = -\Delta\vec{p}_B = -\vec{p}_B$$

$$KE_A = \tfrac{1}{2} m_A v_A^2 = \tfrac{1}{2}\frac{\left(m_A^2 v_A^2\right)}{m_A} = \frac{p_A^2}{2m_A}$$

$$KE_B = \tfrac{1}{2} m_B v_B^2 = \tfrac{1}{2}\frac{\left(m_B^2 v_B^2\right)}{m_B} = \frac{p_B^2}{2m_B}$$

If each object gets the same momentum, which has bigger KE?

1. The object with the bigger m.
2. The object with the smaller m.
3. The have the same KE.

s. energy

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Foothold ideas: Potential Energy

- For some forces between objects (gravity, electricity, springs) the work only depends of the change in relative position of the objects. Such forces are called <u>*conservative*</u>.
- For these forces the work done by them can be written

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

- *U* is called a *potential energy* and can be considered an <u>*energy of place belonging to the two objects that can be exchanged with KE.*</u>

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 laws

- Momentum
  - The momentum of a system of objects is conserved IF the external forces acting on them cancel.

$$\Delta\left(\sum_{n=1}^{N}\vec{p}_n^{\,initial}\right)=0$$

$$\sum_{n=1}^{N}\vec{p}_n^{\,initial}=\sum_{n=1}^{N}\vec{p}_n^{\,final}$$

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

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

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

Foothold ideas: Conservation of Mechanical Energy

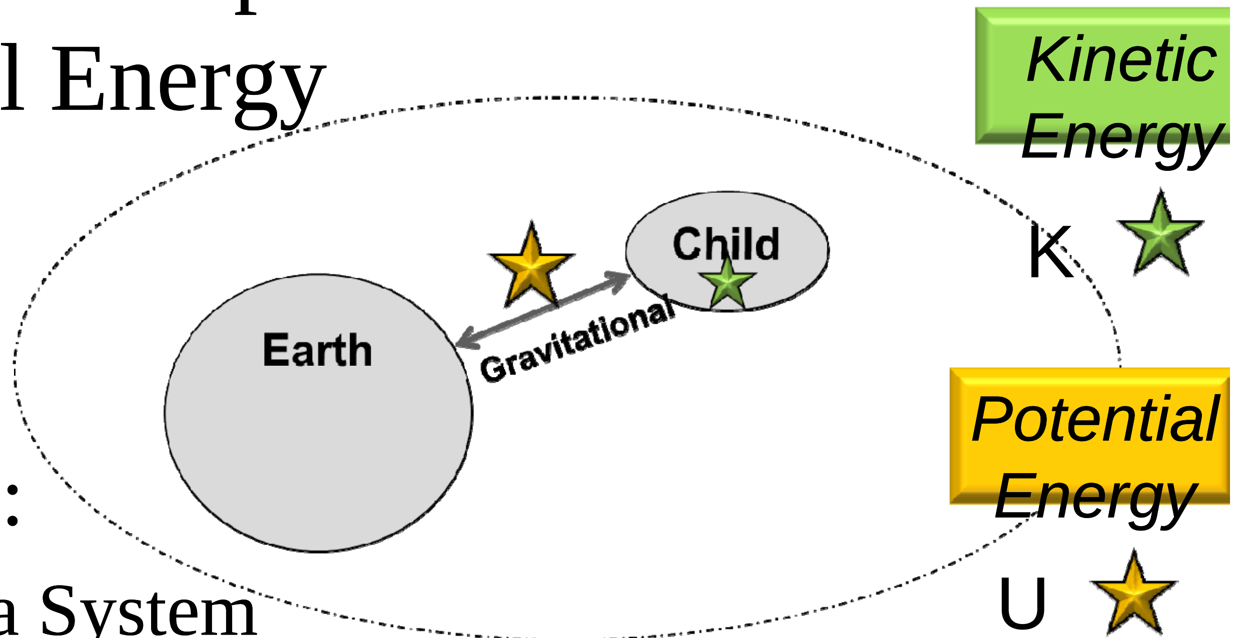
- Mechanical energy
  - The mechanical energy of a system of objects is conserved if resistive forces can be ignored.

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

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

- 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)

Foothold Principle: Potential Energy



Potential energy U:

- Internal energy of a System
- Related to interactions (forces) within the System
- Can turn into kinetic energy (or other energy) when the objects in the system move
- Stored in INTERACTION (line between objects)
- **The object that moves more gets/supplies more of the potential energy!**

Power

- An interesting question about work and energy is the rate at which energy is changed or work is done. This is called *power*.

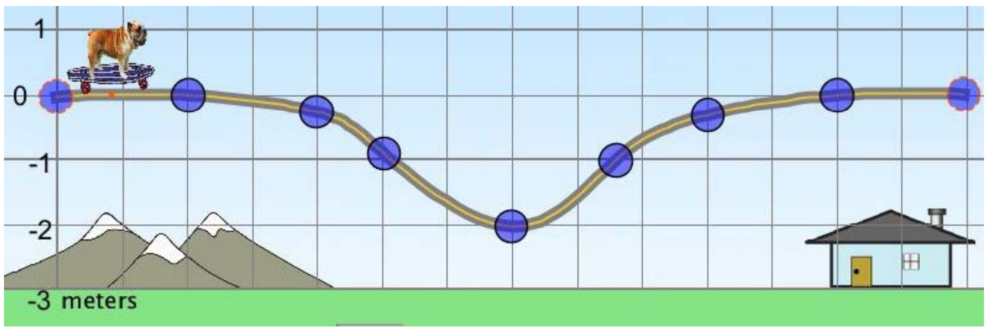
$$\text{Power} = \frac{\text{Energy change}}{\text{time to make the change}}$$

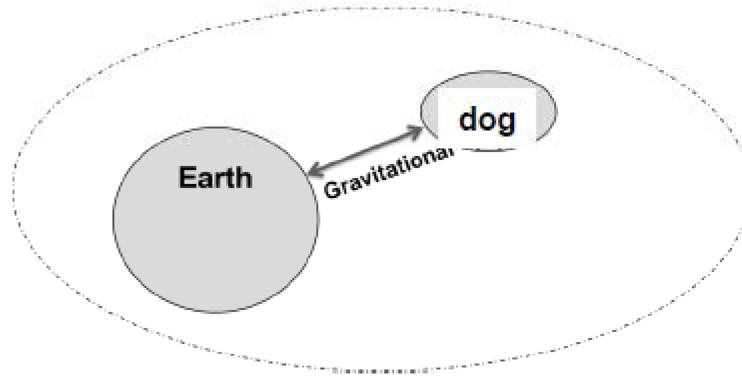
$$= \frac{\Delta W}{\Delta t} = \vec{F}^{\,net} \cdot \frac{\Delta \vec{r}}{\Delta t} = \vec{F}^{\,net} \cdot \vec{v} \quad \text{(for mechanical work)}$$

- Unit of power

1 Joule/sec = 1 Watt

Energy skate park

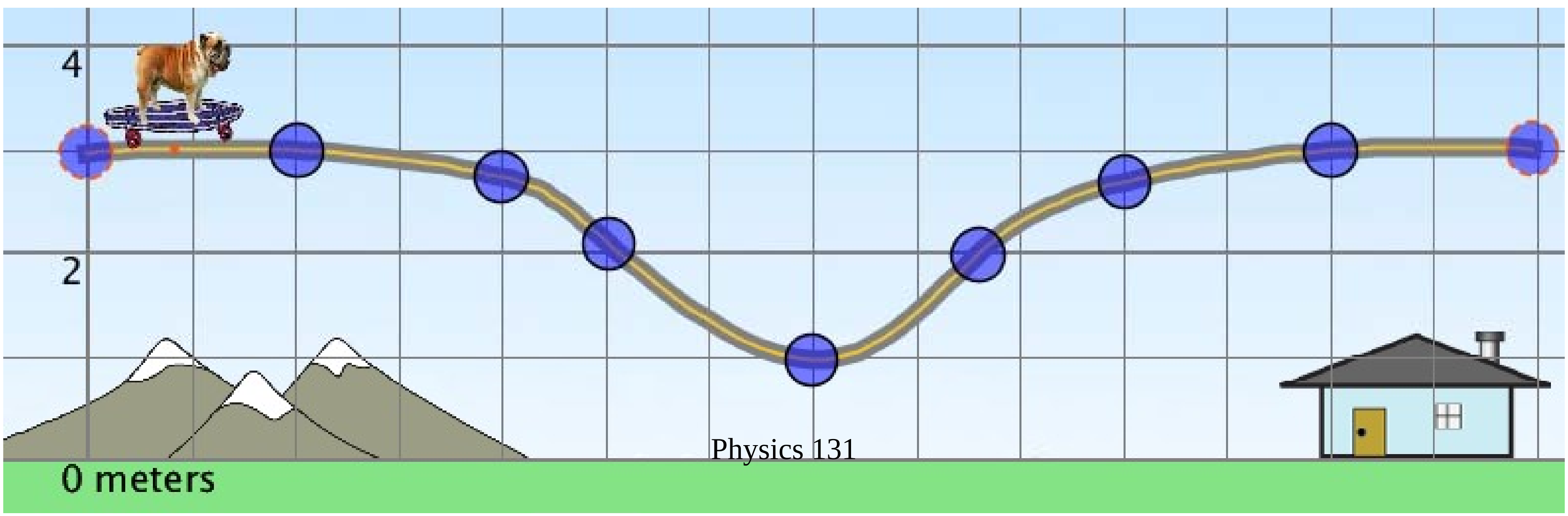




http://phet.colorado.edu/en/simulation/energy-skate-park

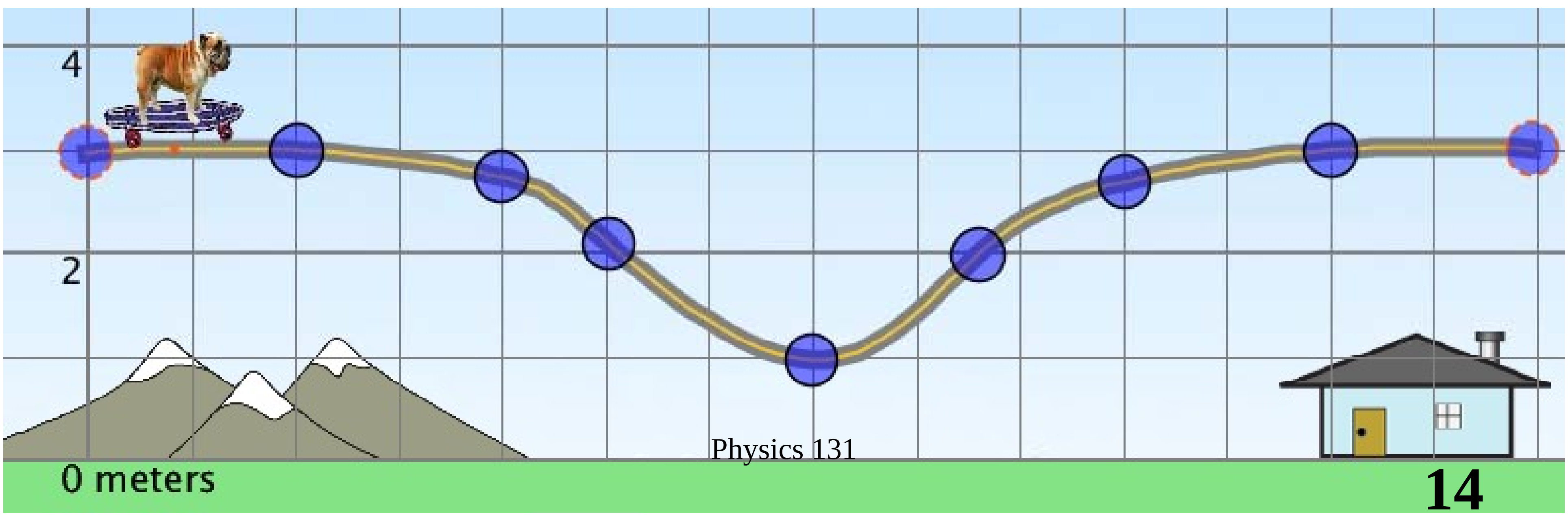
A bulldog on a skateboard is moving very slowly when he encounters a 2 m dip. How fast will be be going when he is at the bottom of the dip? The bulldog and skateboard combined have a mass of 20 kg. Friction and air drag can be ignored.

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



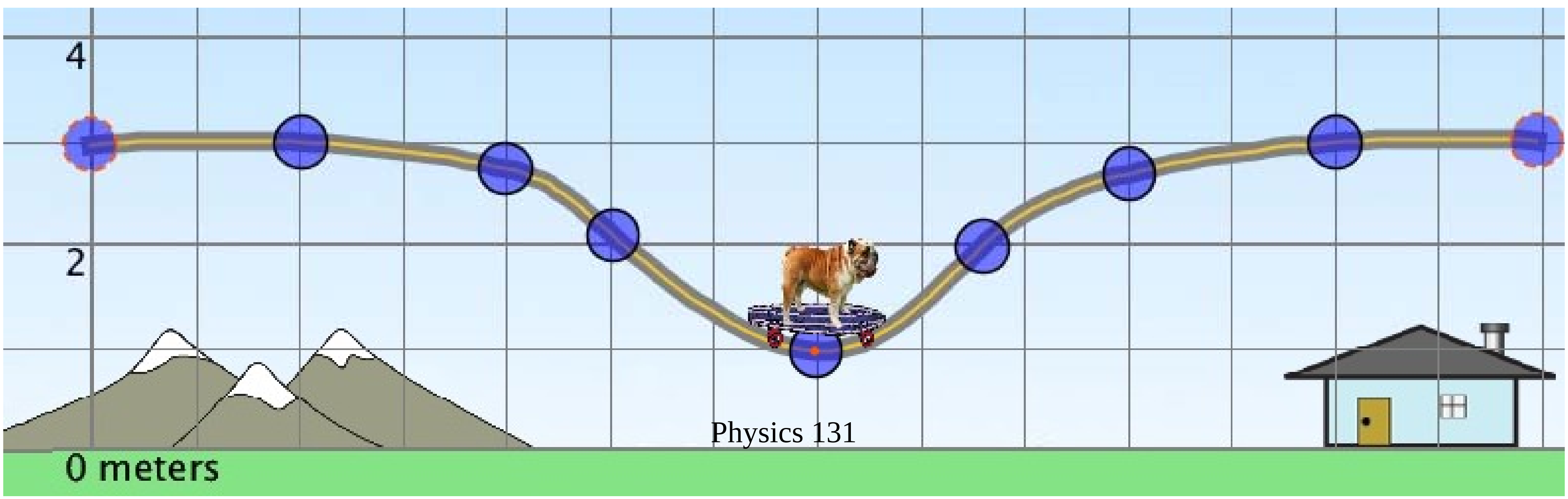
A bulldog on a skateboard is moving very slowly when he encounters a 2 m dip. The bulldog and skateboard combined have a mass of 20 kg. What is their total mechanical energy?

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



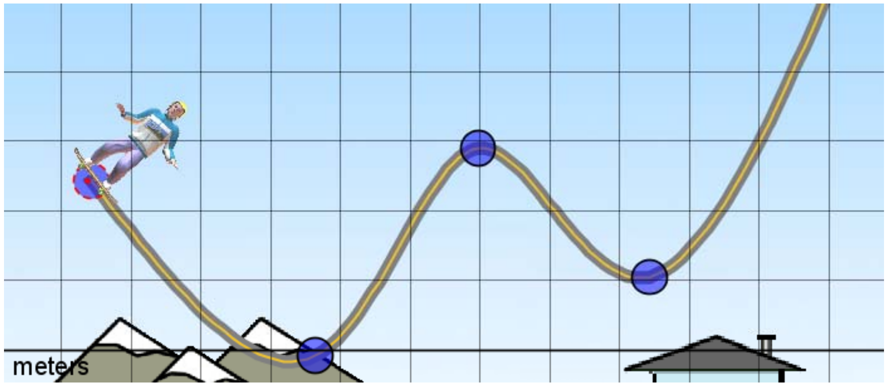
A bulldog on a skateboard is sitting at the bottom of a 2 m dip. How much KE do you have to give them so they will roll out of the dip? The bulldog and skateboard combined have a mass of 20 kg. Friction and air drag can be ignored.

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



Do you think the Skater will make it over the first hump?

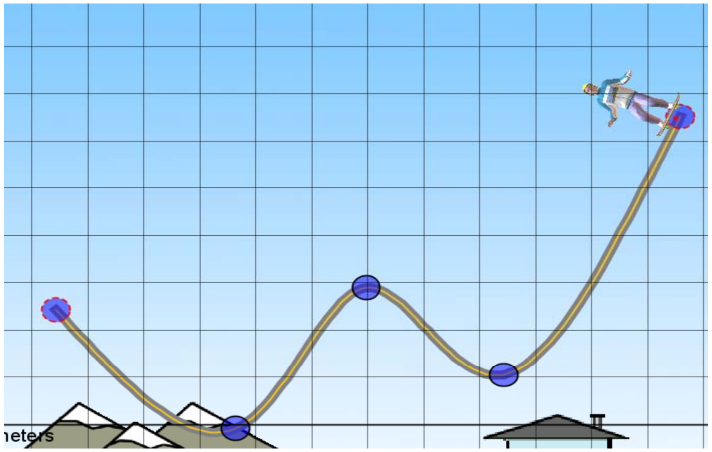
(No friction on the track)



A. No, because his potential energy will be converted to thermal energy
B. No, because he doesn't have enough potential energy
C. Yes, because all of his potential energy will be converted to kinetic energy
D. Yes, because some of his energy will be potential and some kinetic

Do you think the Skater will make it over the first hump?

(No friction on the track)



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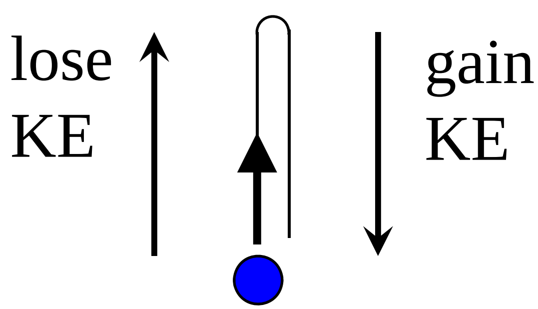
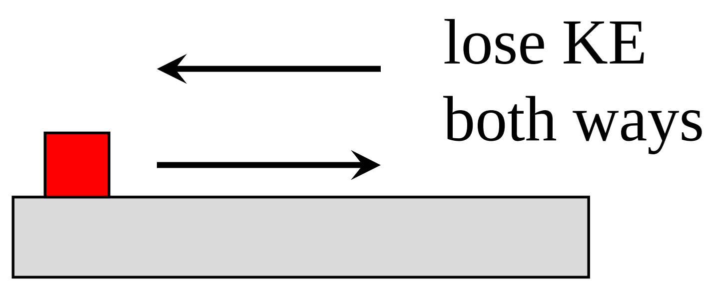
Conservative forces

- Forces (like gravity or springs) are conservative if when the force takes KE away, you can get it back when you go back to where you started.
- If the kinetic energy that a force takes away <u>can't</u> be restored by going back to where you started it is called non-conservative.
- Compare gravity and friction:



Gravity: Conservative



Friction: Non-Conservative

Foothold Ideas:
Conservation of Mechanical Energy

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

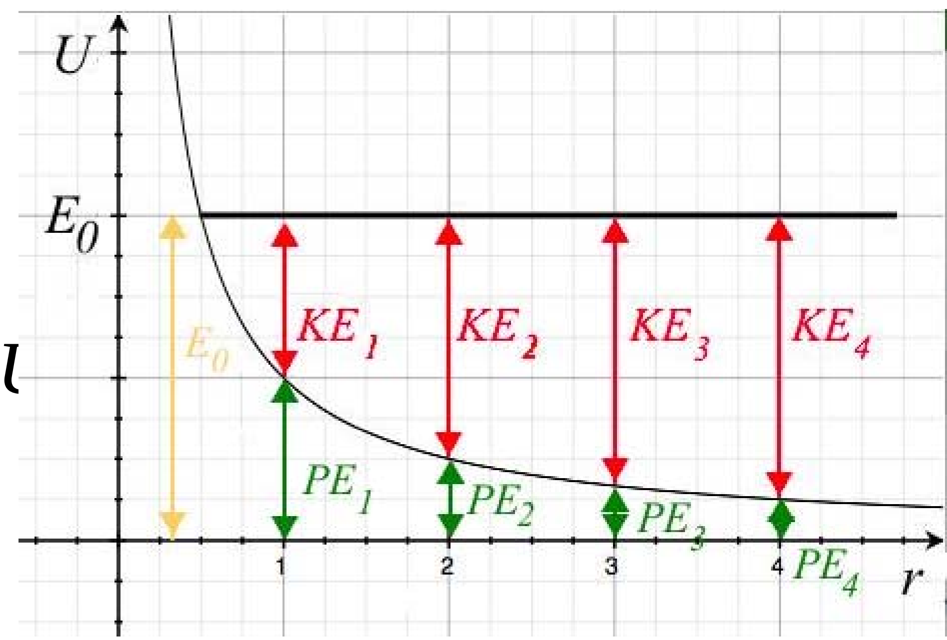
Mathematical Representation

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

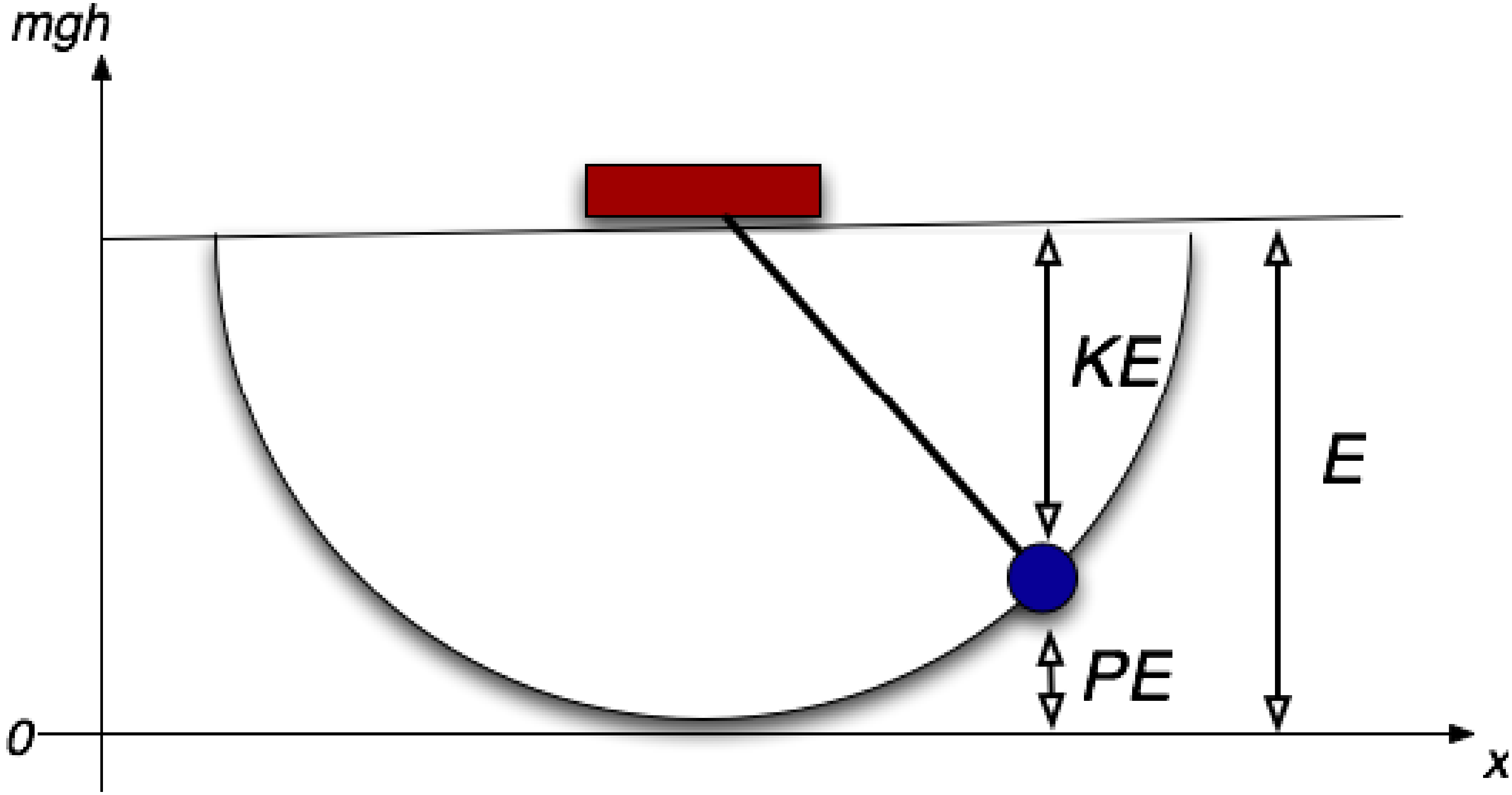
$$\Delta(\tfrac{1}{2}mv^2 + U) = 0$$

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

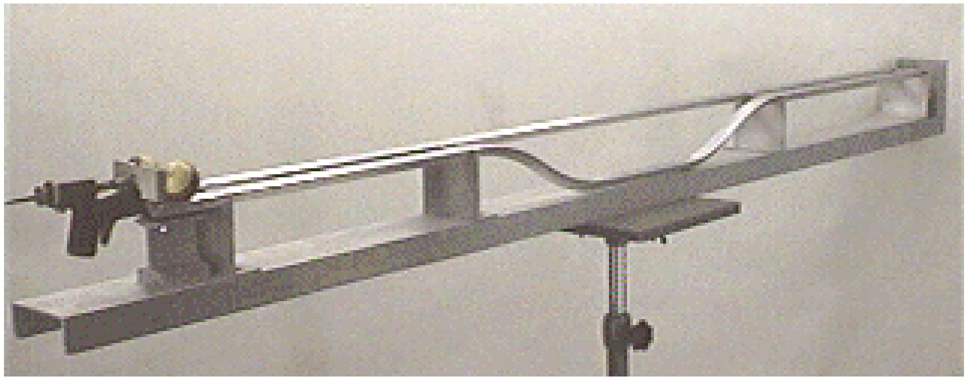
Graphical Representation



If we swing a pendulum, can we tell where it will stop from the PE curve?



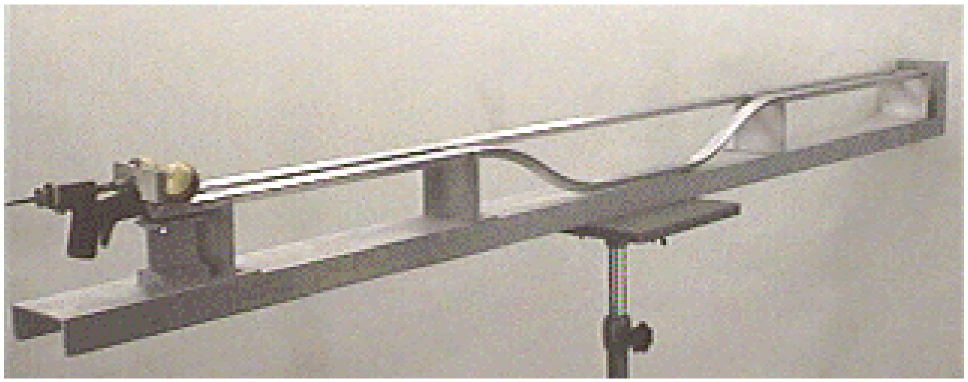
Both balls are launched at the same speed.
Which one moves faster at the end?



1. The one on the straight track.
2. The one on the dipped track.
3. They have the same speed.

Due to energy conservation

Both balls are launched at the same speed. Which one gets to the end first?



1. The one on the straight track.
2. The one on the dipped track.
3. They are the same.

Movie and explanation: http://lecdem.physics.umd.edu/question-of-the-week-archive/101-qotw-001-with-answer.html

Whiteboard, TA & LA