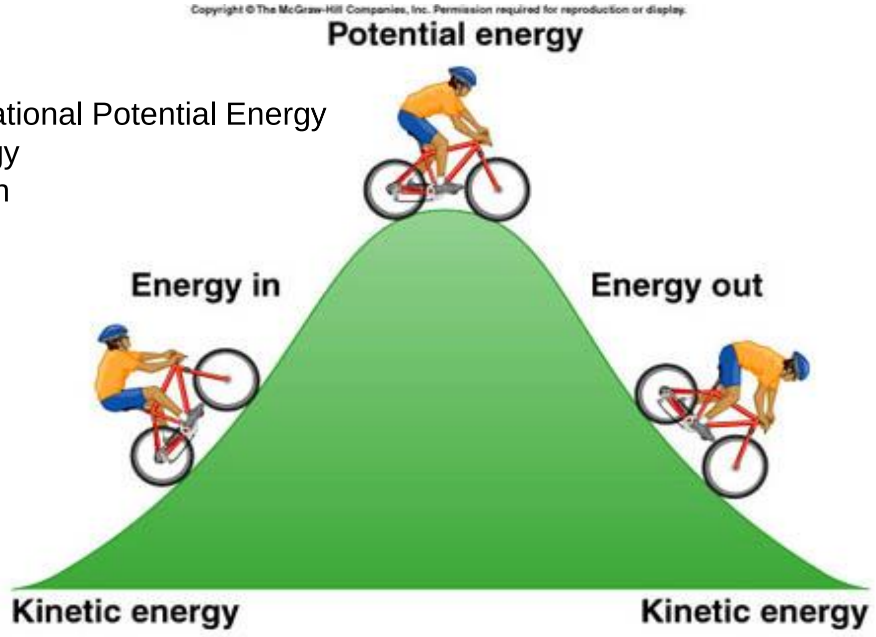
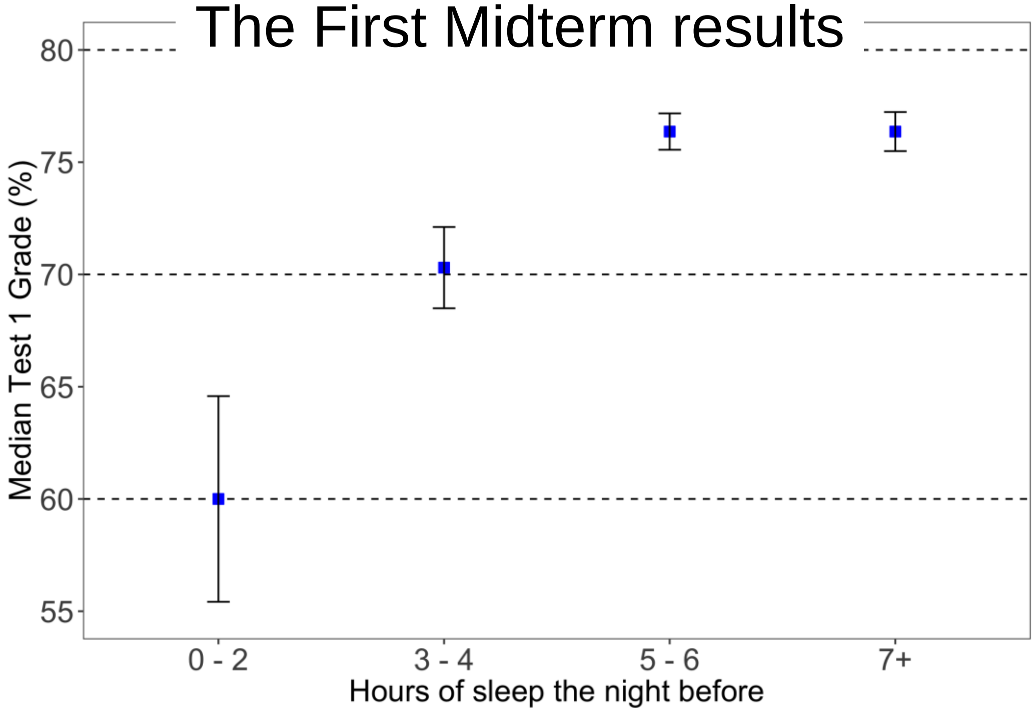
PHY131H1F - Hour 20

Today:

7.3 Kinetic Energy, Gravitational Potential Energy
7.4 Elastic Potential Energy
7.5 Work of Sliding Friction



The First Midterm results



Practicals Reminder

- Practical Week 7: from next Tuesday. Oct. 30 to Nov.12
- Please print and complete the Pre-Test Question (ideally under midterm-like conditions), and bring it with you to Practical – this is available on Quercus, or even on my Lecture Notes web-site

Learning Catalytics Thoughts from last time…

- *“would the format of the coming test be the same?”*
- **Harlow answer:** Yes! Same scratch card, same mix of multiple choice and a written answer, same rules for aid sheet and calculator.

- *“Will you post lecture slides?”*
- **Harlow answer:** Yup! Pre and Post – Pre I will try to post the day before I teach, if possible

- *“Do you expect us to read the textbook before class - in other words, will we be spending the majority of the class doing difficult problems that require prior knowledge?”*
- **Harlow answer:** If it were me, I would definitely read the textbook before coming to class. I go kind of fast, and some people are more visual learners.

Learning Catalytics Thoughts from last time…

- *“What is the difference between change in momentum and impulse?”*
- **Harlow answer:** Nothing. Those are equal to each other. But I guess one you write as $\Delta\vec{p}$ and the other you write as $\vec{J}$.

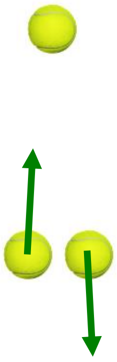
- *“up to what chapter will be covered on the midterm?”*
- **Harlow answer:** The Nov.13 midterm will cover chapters 5, 6 and 7. But, necessarily, it will also implicitly cover chapters 1-4, as physics is a subject which builds upon itself.

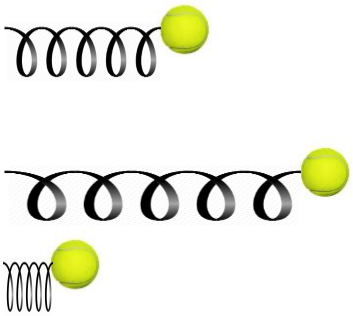
- *“Does the Physics department have a cutoff? Im trying to get into it as my major and Im uncertain if Ill be qualified.”*
- **Harlow answer:** Nope. Physics is a “Type I” program, meaning no restrictions.

Conservative Forces

$E_i + W = E_f$

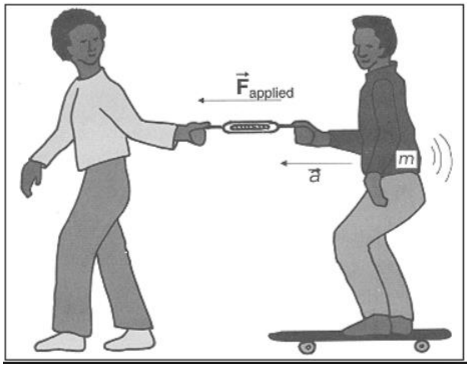
- A **conservative force** stores any work done against it, and can “give back” the stored work as kinetic energy.
- For a conservative force, the work done in moving between two points is independent of the path.
- Two examples: Gravity and Spring Force
- Also in PHY132 you will learn about the Electric Force, which is conservative.





Nonconservative Forces

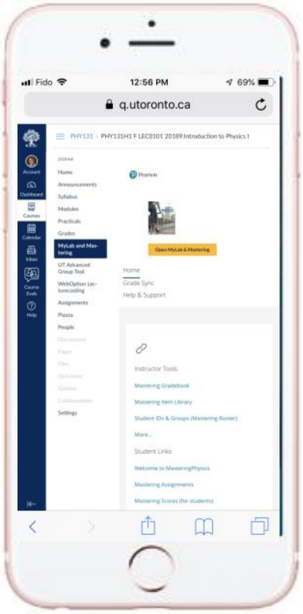
- A **nonconservative force** does not store work done against it, the work done may depend on path, and the work done going around a closed path need not be zero.
- Nonconservative forces include:
  - Sliding Friction
  - Pushing force of a human or animal
  - Automobile engine

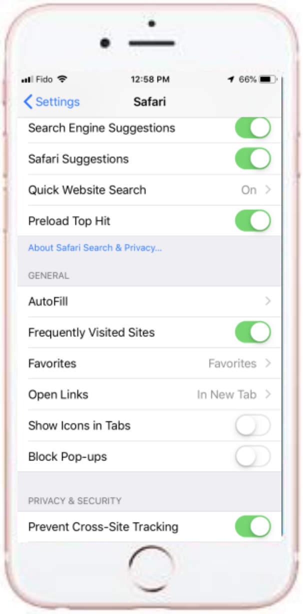


Open MyLab & Mastering

Learning Catalytics Tip

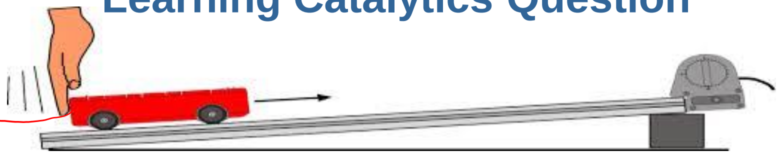
- You **can** use your phone, but **don't** use the "Canvas Student" App! (It doesn't work.)
- You have to use a browser app, like Safari or Google Chrome or Firefox, and type "q.utoronto.ca" as the address.
- Also, you have to turn off the "Block Pop-ups" for your browser. (Or it doesn't work.)
- For my iPhone I went to Settings → scroll down to Safari, and then **un**click "Block Pop-ups".
- Then it works!





Search Engine Suggestions ☑
Safari Suggestions ☑
Quick Website Search On
Preload Top Hit ☑
About Safari Search & Privacy...
GENERAL
AutoFill
Frequently Visited Sites ☑
Favorites Favorites
Open Links In New Tab
Show Icons in Tabs ☐
Block Pop-ups ☐
PRIVACY & SECURITY
Prevent Cross-Site Tracking ☑

Learning Catalytics Question



0

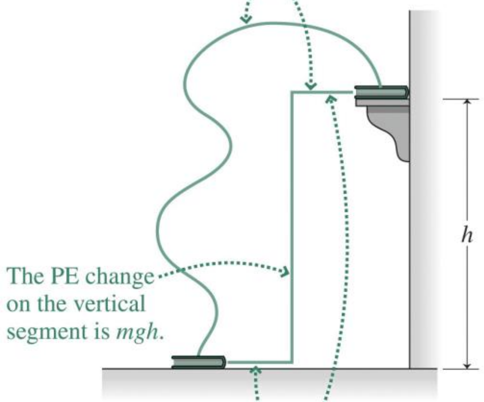
A cart rolls up a frictionless incline. It starts with speed v_i, but stops near the top ($v_f = 0$). As it rolls up the ramp, its kinetic energy is transformed to

A. stopping energy.
[✓ B.] gravitational potential energy.
C. energy of motion.
D. internal thermal energy.
E. energy of rest.

Initial Final

$K + U_g = K + U_g$

Gravitational Potential Energy



The potential energy (PE) change is the same along either path, but it's calculated more easily for the straight path.

The PE change on the vertical segment is *mgh*.

There's no PE change on the horizontal segments.

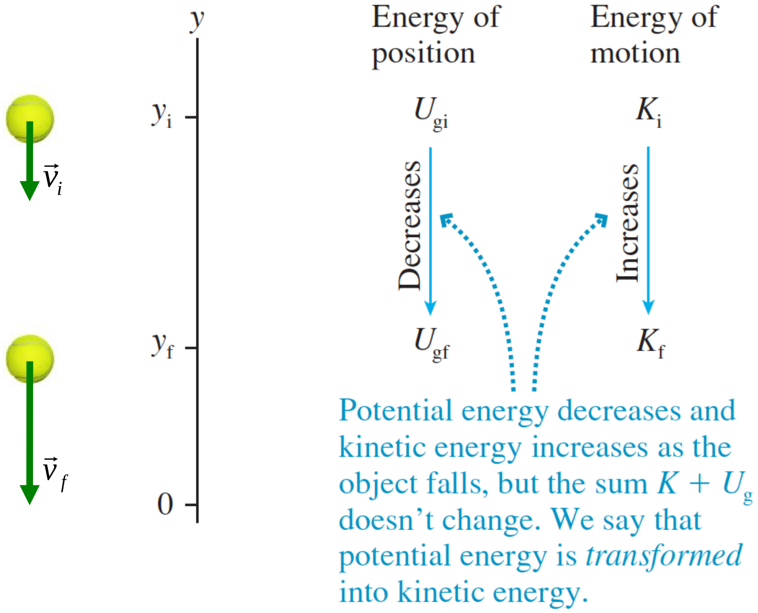
Gravitational Potential Energy

- **Gravitational potential energy** stores the work done against gravity:

$$\Delta U = mg\ \Delta y$$

  - Gravitational potential energy increases linearly with height y.
  - This reflects the *constant* gravitational force near Earth's surface.

Another way of looking at freefall:



Potential energy decreases and kinetic energy increases as the object falls, but the sum $K + U_g$ doesn't change. We say that potential energy is *transformed* into kinetic energy.

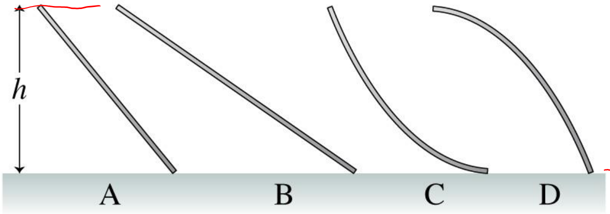
Learning Catalytics Question

A small mass slides down the four frictionless slides A–D. Each has the same height, and the mass always starts from rest. Rank in order, from largest to smallest, its speeds v_A to v_D at the bottom.

Initial

$y_i = h$

$v_i = 0$



$y_f = 0$

- A. $v_C > v_A = v_B > v_D$
- B. $v_C > v_B > v_A > v_D$
- C. $v_D > v_A > v_B > v_C$
- [✓ D.] $v_A = v_B = v_C = v_D$
- E. $v_D > v_A = v_B > v_C$

v_f

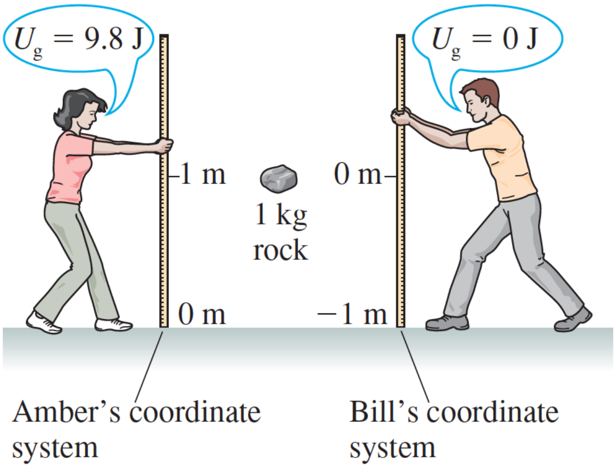
Initial Final

— □ = □ —

$mgh = \frac{1}{2} m v_f^2$

NOTE: The Zero of Potential Energy

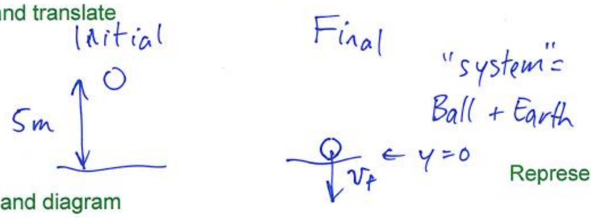
- You can place the origin of your coordinate system, and thus the "zero of potential energy," wherever you choose and be assured of getting the correct answer to a problem.
- The reason is that only ΔU_g has physical significance, not U_g itself.



[go to Doc-Cam notes]

Ch.7 Example. I hold a ball at a distance of 5 m above the ground and release it from rest. How fast is it going just before it hits the ground?

Sketch and translate

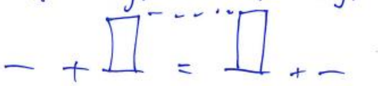


"system" = Ball + Earth

Represent mathematically

Simplify and diagram

$$K_i + U_{gi} = K_f + U_{gf}$$



$$\cancel{m}gy_i = \frac{1}{2}\cancel{m}v_f^2$$

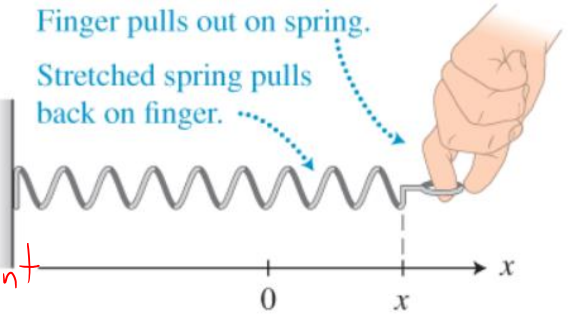
$$2gy_i = v_f^2$$

Solve and Evaluate

$$v_f = \sqrt{2gy_i} = \sqrt{2(9.8)5} = 9.9\ \text{m/s}$$

This is speed after ~1 second of falling... seems reasonable

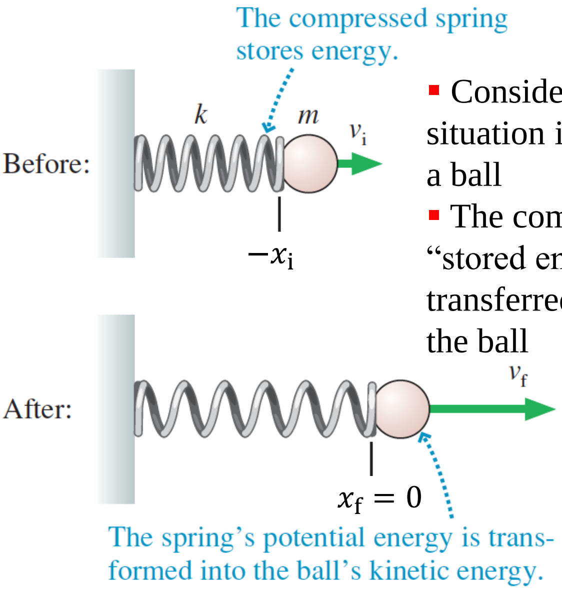
Elastic Potential Energy



- What is the work done when an Object stretches a Spring, originally at equilibrium, out to a distance x?

spring constant

  - Work = Force × distance
  - Hooke's Law for a spring is: $F_{\text{O on S}} = \boxed{k}x$
  - Work should be (kx) × distance $= kx^2$
  - But keep in mind that the force the object exerts actually starts at zero (at spring equilibrium) and then increases to kx, so the average is half.
  - Therefore, the correct equation for the work done is $W = \frac{1}{2}kx^2$
  - The work done on the spring is equal to the energy you put into that spring – this is a form of Potential Energy



The compressed spring stores energy.

The spring's potential energy is transformed into the ball's kinetic energy.

Elastic Potential Energy

- Consider a before-and-after situation in which a spring launches a ball
- The compressed spring has "stored energy," which is then transferred to the kinetic energy of the ball

- We define the **elastic potential energy** U_s of a spring to be:

$$U_s = \frac{1}{2}kx^2$$

Learning Catalytics Question

A spring-loaded gun shoots a plastic ball with a speed of 4 m/s. If the spring is compressed twice as far, the ball's speed will be

A. 1 m/s.
B. 2 m/s.
C. 4 m/s.
[✓ D. 8 m/s.]
E. 16 m/s.

Initial Final

$U_{si} + K_i = U_{sf} + K_f$

$\cancel{\frac{1}{2}}kx^2 + 0 = 0 + \cancel{\frac{1}{2}}mv_f^2$

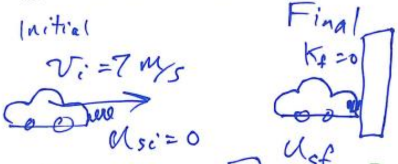
$kx^2 = mv^2$

$v_f = \sqrt{\frac{m}{k}}\ x$

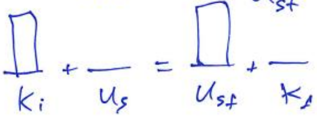
[go to Doc-Cam notes]

Ch.7 Example. A moving car has 40,000 J of kinetic energy while moving at a speed of 7.0 m/s. A spring-loaded automobile bumper compresses 0.30 m when the car hits a wall and stops. What can you learn about the bumper's spring using this information?

Sketch and translate



Simplify and diagram



Represent mathematically

$$\underbrace{\frac{1}{2}mv_i^2} = \frac{1}{2}kx_f^2$$

$x_f = 0.3$ m $\quad K_i = 4\times10^4$ J

solve for k

Solve and Evaluate

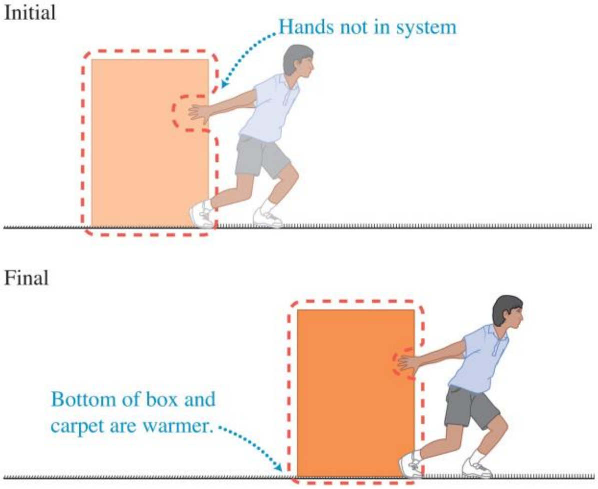
$$K_i = \frac{1}{2}kx_f^2$$

$$\frac{2K_i}{x_f^2} = k = \frac{2(4\times10^4)}{(0.3)^2}$$

$$\boxed{k = 8.9\times10^5 \ N/m}$$

Internal energy

- If a object slides on a surface, the surfaces in contact can become warmer.
- Structural changes in an object can occur when an external force is applied.
- The energy associated with both temperature and structure is called internal energy (symbol U_{int}).



Learning Catalytics Question

A car starts with speed v_i, but the driver puts on the brakes and the car slows to a stop. As the car is slowing down, its kinetic energy is transformed to

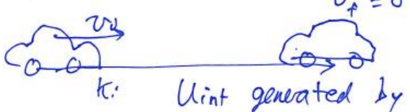
A. stopping energy.
B. gravitational potential energy.
C. energy of motion.
[✓ D.] internal thermal energy.
E. energy of rest.

[go to Doc-Cam notes]

Ch.7 Example. A driver slams on the brakes, locks all four wheels, and the car skids 18 m on a horizontal road. The coefficient of sliding friction between the wheels and the road is $\mu_k = 0.80$. How fast was the car going before slamming on the brakes?

Sketch and translate

Initial



U_{int} generated by $f_k = \mu_k n$.

Simplify and diagram

$\uparrow n$ $\downarrow mg$

$a_y = 0$

$(F_{net})_y = n - mg = 0$

$n = mg$

$f_k = \mu_k mg$

$U_{int} = |W_f| = \mu_k mgd$

Represent mathematically

$K_i = U_{int\,f}$

$\frac{1}{2}\cancel{m}v_i^2 = \mu_k \cancel{m}gd$

Solve for v_i

Solve and Evaluate

$v_i = \sqrt{2\mu_k gd} = \sqrt{2(0.8)(9.8)18}$

$\boxed{v_i = 17\,m/s} \sim 60\,\frac{km}{hr}$.

typical car speed.

Learning Catalytics Question

A child is sliding down a playground slide at ***constant speed***.
While sliding, the energy transformation is

A. $U_\mathrm{g} \rightarrow K$
[✓ B.] $U_\mathrm{g} \rightarrow U_\mathrm{int}$
C. $K \rightarrow U_\mathrm{g}$
D. $K \rightarrow U_\mathrm{int}$
E. There is no transformation because energy is conserved.