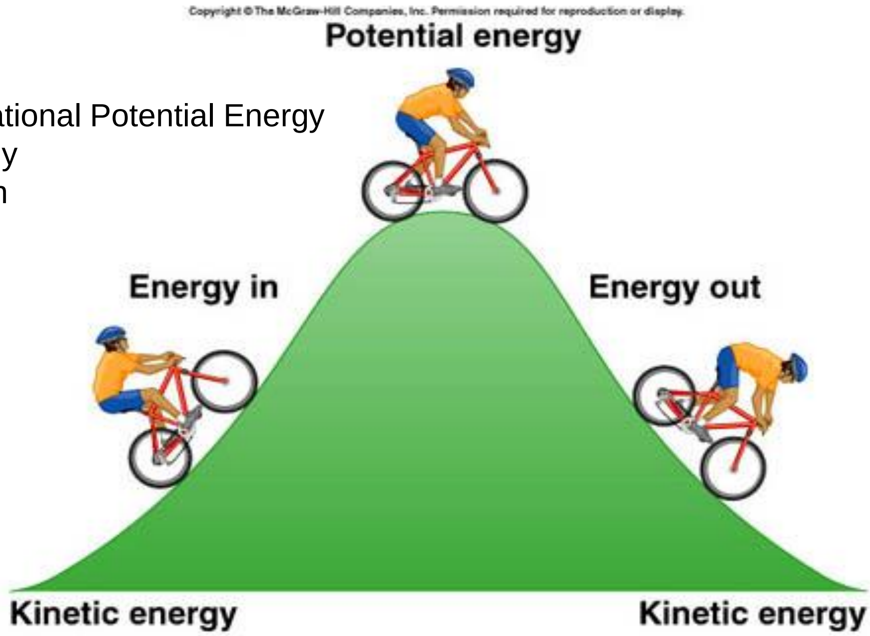
# PHY131H1F - Class 20

**Today:**

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

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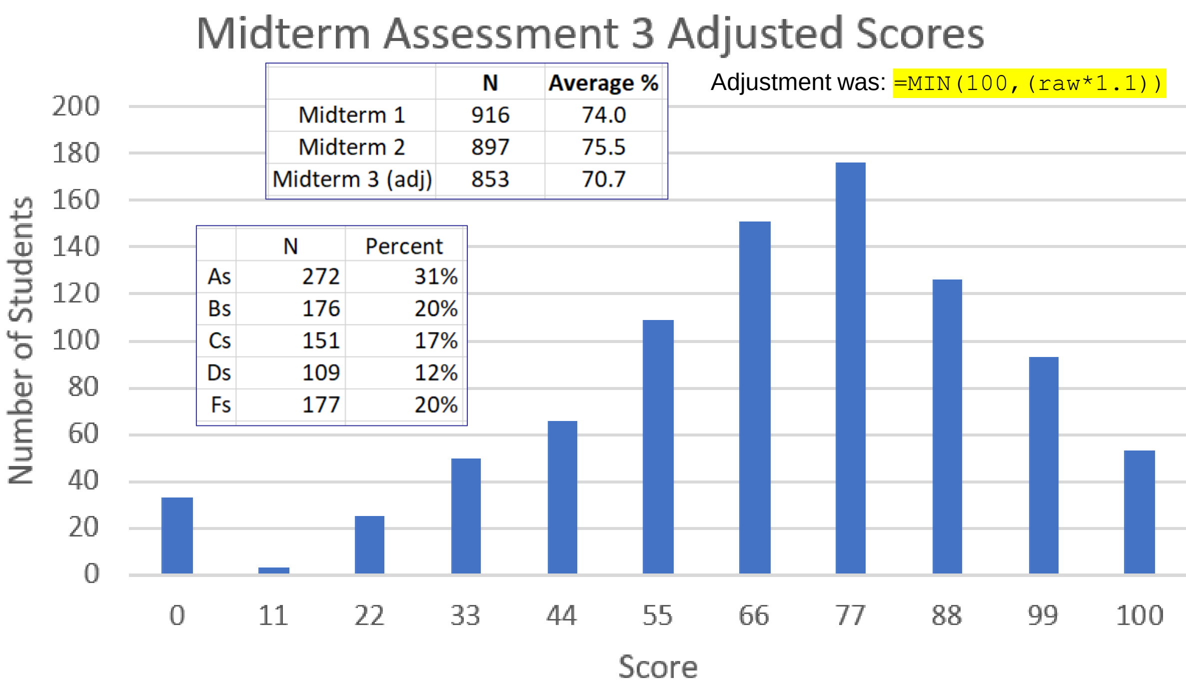


| | N | Average % |
|---|---|---|
| Midterm 1 | 916 | 74.0 |
| Midterm 2 | 897 | 75.5 |
| Midterm 3 (adj) | 853 | 70.7 |

Adjustment was: `=MIN(100,(raw*1.1))`

| | N | Percent |
|---|---|---|
| As | 272 | 31% |
| Bs | 176 | 20% |
| Cs | 151 | 17% |
| Ds | 109 | 12% |
| Fs | 177 | 20% |

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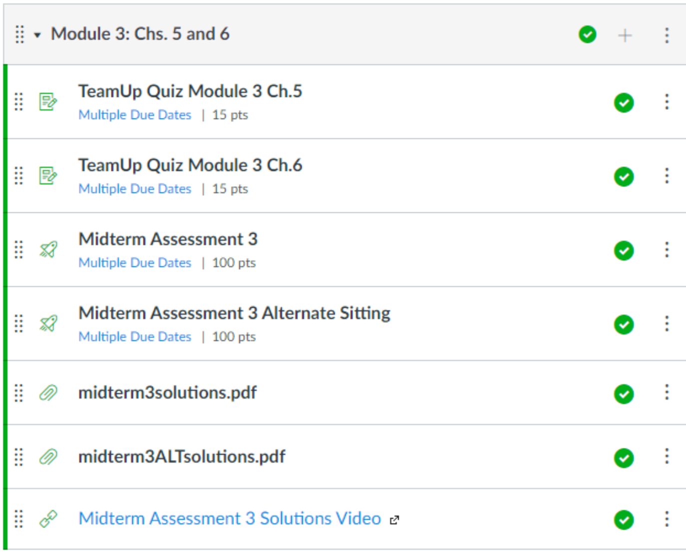
# Solutions Video Is Posted




- 17 minute Youtube video with carefully drawn out solutions is posted on Quercus.
- Written solutions with reasoning also posted.
- Written solutions only are posted for the alternate sitting (no video)
- Today, let's continue with Chapter 7. I'm happy to discuss the test after class today or during office hours, or by email.

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## Generalized work-energy principle:

- The sum of the initial energies of a system plus the work done on the system by external forces equals the sum of the final energies of the system:

$$E_{\mathrm{i}} + W = E_{\mathrm{f}}$$

- This is similar to $E_{\mathrm{i}} = E_{\mathrm{f}}$, except now you can have **Work, *W***: positive or negative energy added by outside nonconservative forces.

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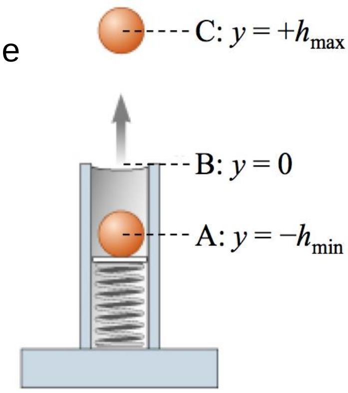
## Example

A spring-loaded toy gun is used to shoot a ball of mass $m$ straight up in the air. The spring has spring constant $k$. The ball has speed $v_B$ at point B.

- The Spring has potential energy $U_s$, and the ball/earth system has gravitational potential energy $U_g$, and the ball has kinetic energy $K$. The energy conservation equation is:

$$E_i + W = E_f$$

$$U_{si} + U_{gi} + K_i + W = U_{sf} + U_{gf} + K_f$$




- Here $W$ is the work done by forces that don't have a potential energy associated with them, like a hand pushing or sliding friction with the floor.
- In this example, we assume $W = 0$.

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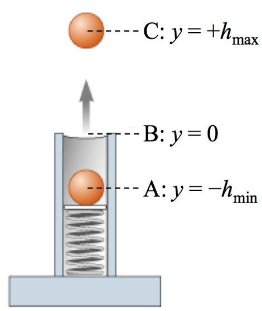
### Energy Bar Charts

A spring-loaded toy gun is used to shoot a ball of mass $m$ straight up in the air.
The spring has spring constant $k$.
The ball has speed $v_B$ at point B.

Consider time A to time B.




$$U_{sA} + U_{gA} + K_A + W = U_{sB} + U_{gB} + K_B$$

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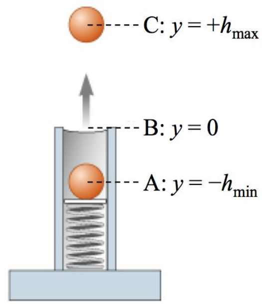
## Energy Bar Charts

A spring-loaded toy gun is used to shoot a ball of mass *m* straight up in the air.
The spring has spring constant *k*.
The ball has speed $v_B$ at point B.




Consider time B to time C.

$$U_{sB} + U_{gB} + K_B + W = U_{sC} + U_{gC} + K_C$$

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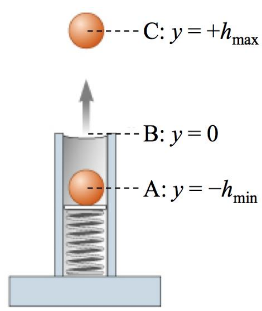
## Energy Bar Charts

A spring-loaded toy gun is used to shoot a ball of mass *m* straight up in the air.
The spring has spring constant *k*.
The ball has speed $v_B$ at point B.




Or, if you want, you can even skip B and consider time A to time C!

$$U_{sA} + U_{gA} + K_A + W = U_{sC} + U_{gC} + K_C$$

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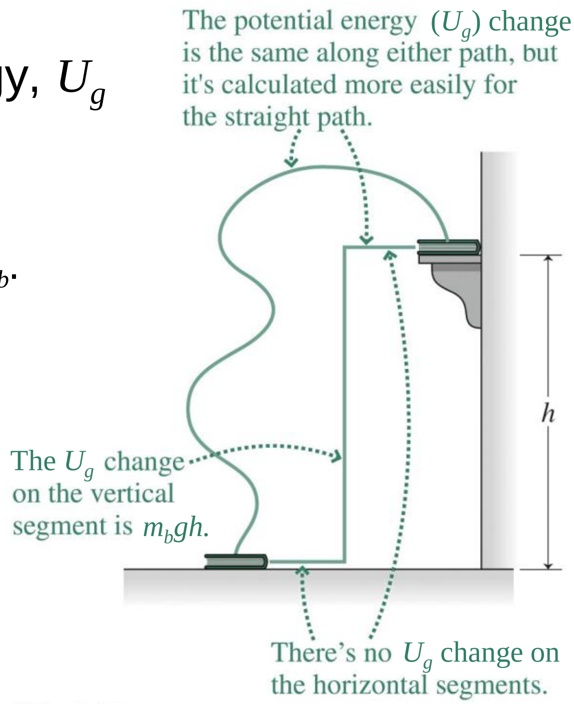
## Gravitational Potential Energy, $U_g$

Consider moving a book of mass $m_b$.

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## Gravitational Potential Energy

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

$$\Delta U_g = mg\,\Delta y$$

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

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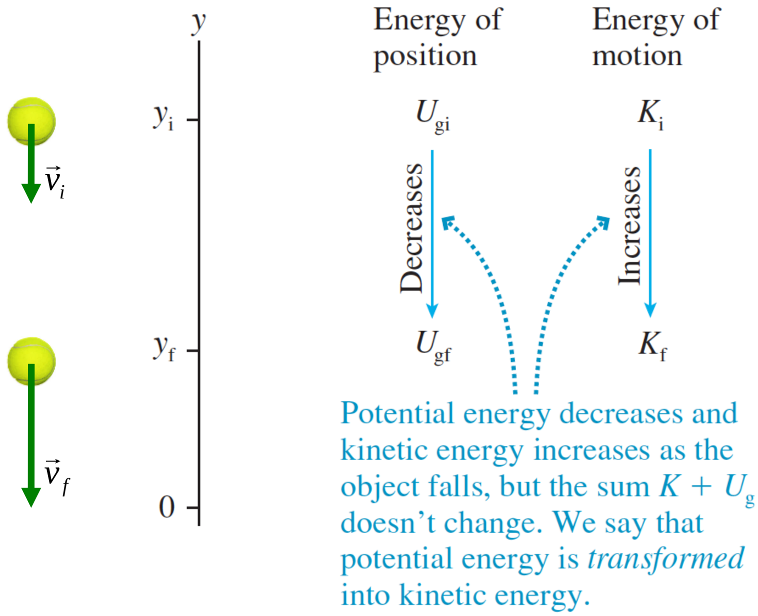
Another way of looking at freefall:

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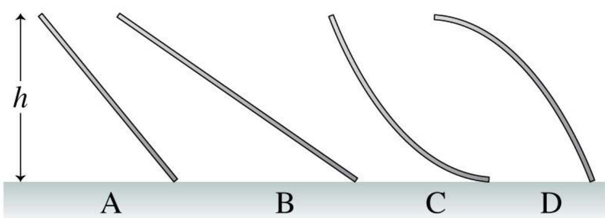
## Poll Question

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.




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. $v_D > v_A = v_B > v_C$

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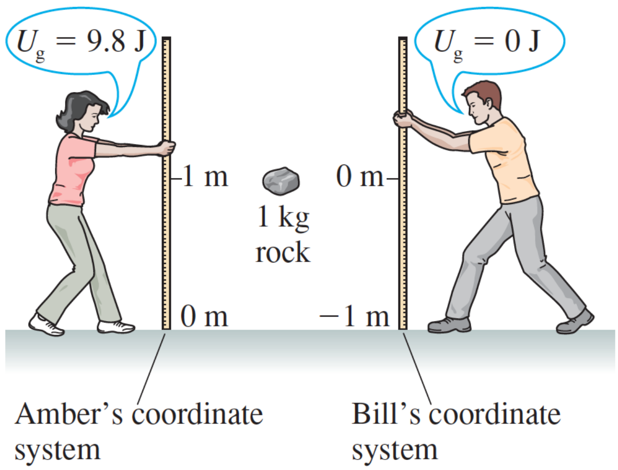
## NOTE: The Zero of Potential Energy

- 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 $\Delta U_g$ has physical significance, not $U_g$ itself.

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**Ch.7 Example.** I hold a ball at a distance of 5.0 m above the ground and release it from rest. How fast is it going just before it hits the ground?

SKETCH & TRANSLATE.

SIMPLIFY & DIAGRAM

REPRESENT MATHEMATICALLY

SOLVE & EVALUATE

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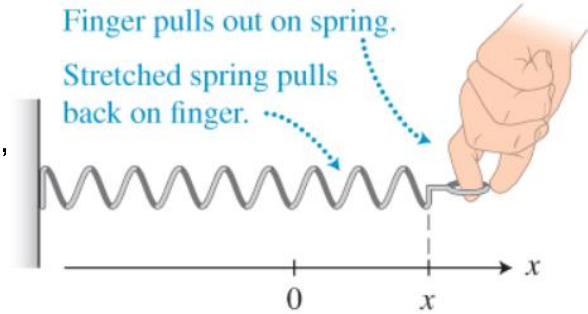
## Elastic Potential Energy

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




- Work = Force × distance
- Hooke's Law for a spring is: $F_{\text{F on S}} = kx$
- 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

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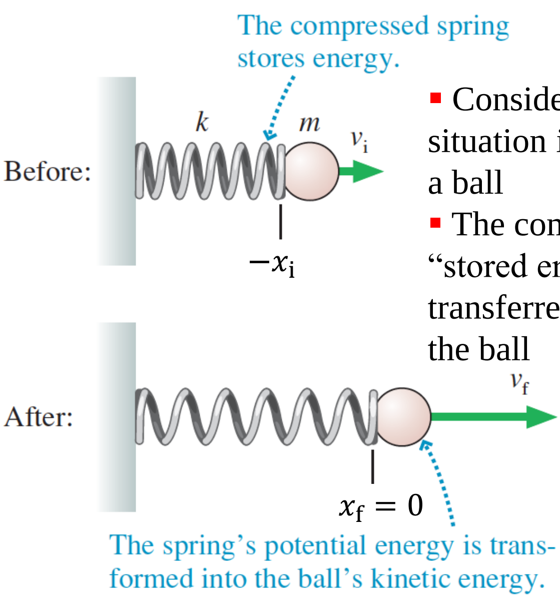


## Elastic Potential Energy

- 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:

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

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## Poll 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.

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**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 & TRANSLATE.

SIMPLIFY & DIAGRAM

REPRESENT MATHEMATICALLY

SOLVE & EVALUATE

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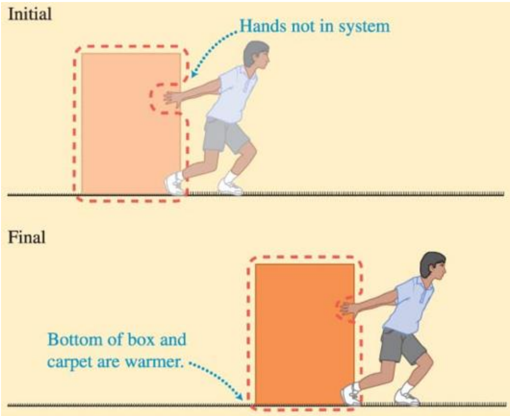
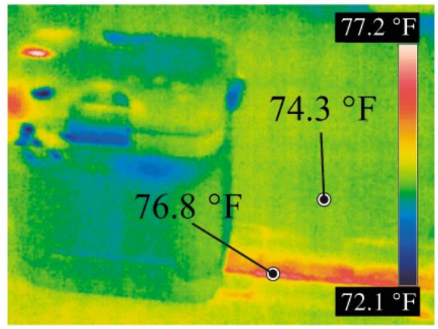
# Internal energy




- 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 $U_{\text{int}}$).




- A "thermal camera" detects infrared waves (just like light waves, but human eyes are not sensitive to these wavelengths)
- Warm things glow in the infrared

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## Poll 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.

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**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 & TRANSLATE.

SIMPLIFY & DIAGRAM

REPRESENT MATHEMATICALLY

SOLVE & EVALUATE

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## Poll Question

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

A. $U_g \rightarrow K$
B. $U_g \rightarrow U_{int}$
C. $K \rightarrow U_g$
D. $K \rightarrow U_{int}$
E. There is no transformation because energy is conserved.

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# Before Class 21 on Friday

- Please read Section 7.6 on the Work Energy Principle, and Section 7.7 on Elastic and Inelastic Collisions
- Plan to meet up with your Practical Pod during Friday's class – you should be able to turn on your microphone in order to participate in the TeamUp Quiz Module 4 Ch.7.
- If you cannot do the TeamUp quiz during class, it can be done either with your pod or on your own at any time over the weekend.

- As usual, I'll be around until 12:30, then a TA will be in the PHY131 Help Centre:
- Zoom Meeting ID: 938 0964 2256
- Passcode: 723874