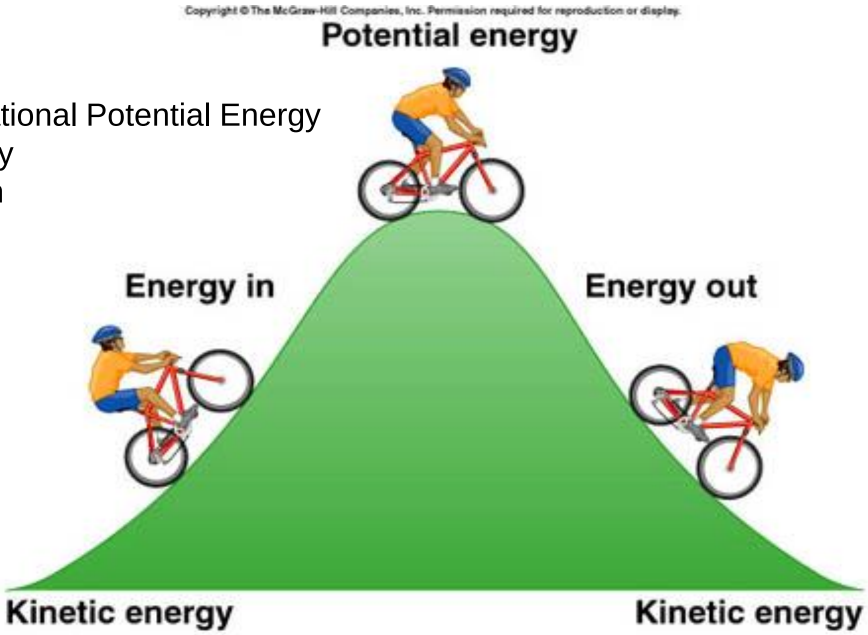
PHY131H1F - Class 20

Today:

7.3 Kinetic Energy, Gravitational Potential Energy
7.4 Elastic Potential Energy
7.5 Work of Sliding Friction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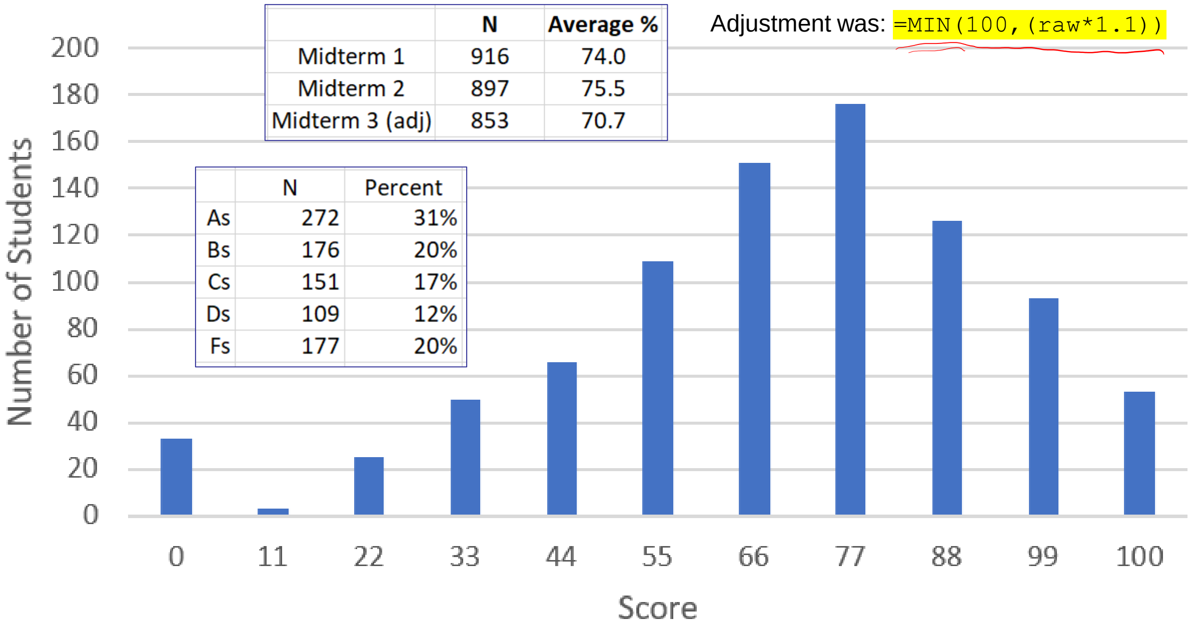
Midterm Assessment 3 Adjusted Scores

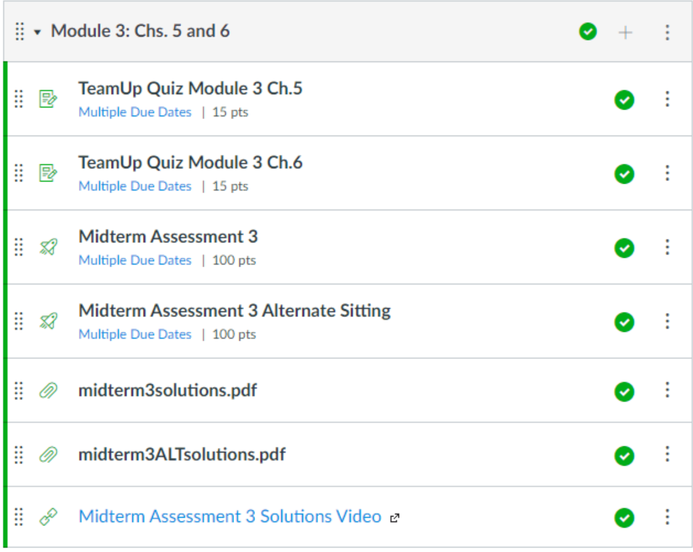


Adjustment was: `=MIN(100,(raw*1.1))`

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

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

Solutions Video Is Posted



Module 3: Chs. 5 and 6

TeamUp Quiz Module 3 Ch.5
Multiple Due Dates | 15 pts

TeamUp Quiz Module 3 Ch.6
Multiple Due Dates | 15 pts

Midterm Assessment 3
Multiple Due Dates | 100 pts

Midterm Assessment 3 Alternate Sitting
Multiple Due Dates | 100 pts

midterm3solutions.pdf

midterm3ALTsolutions.pdf

Midterm Assessment 3 Solutions Video

- 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.

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:

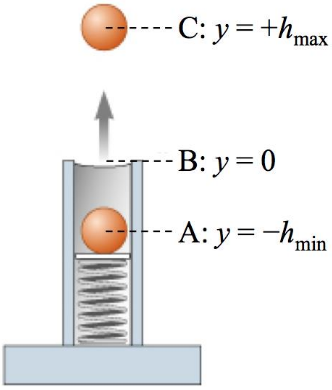
$$E_i + W = E_f$$

- This is similar to $E_i = E_f$, except now you can have **Work, W**: positive or negative energy added by outside nonconservative forces.

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.

- We define the system to be the ball + spring + Earth. The energy conservation equation is:



$$E_i + W = E_f$$

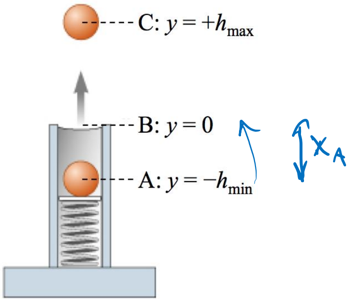
$$U_{si} + U_{gi} + K_i + W = U_{sf} + U_{gf} + K_f$$

- Here W is the work done on the system by things outside the system. In our case nothing is doing work on the ball/spring/Earth System so $W = 0$.

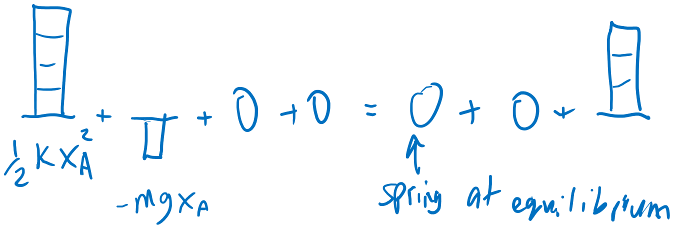
Energy Bar Charts

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.



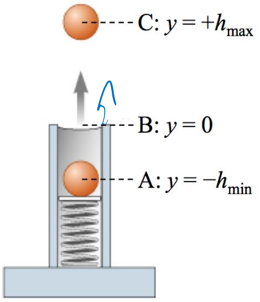
$$U_{sA} + U_{gA} + K_A + W = U_{sB} + U_{gB} + K_B$$



spring at equilibrium (uncompressed)

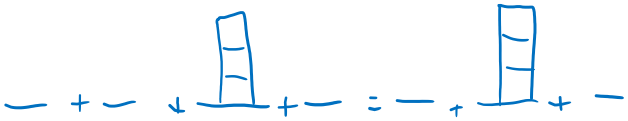
Energy Bar Charts

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.

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

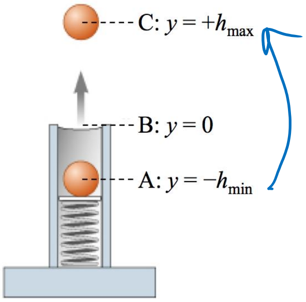


$$0 + 0 + \frac{1}{2}mv_B^2 + 0 = 0 + mgh_{max} + 0$$

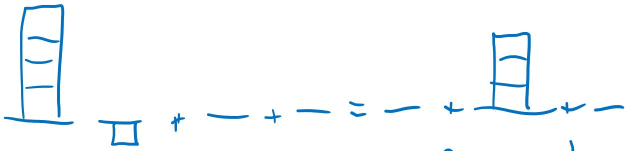
Energy Bar Charts

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!



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



$$\frac{1}{2}k(h_{min})^2 - mgh_{min} + 0 + 0 = 0 + mgh_{max} + 0$$

Gravitational Potential Energy, U_g

Consider moving a book of mass m_b.

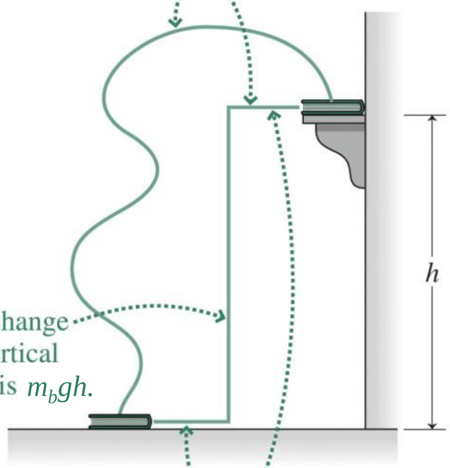
Define system = book + Earth.

U_g of system = $m_b g h$

h = height of book.

K + U_g does not change when book falls.

Define W = 0 since Earth is part of system



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

The U_g change on the vertical segment is $m_b g h$.

There's no U_g change on the horizontal segments.

Gravitational Potential Energy

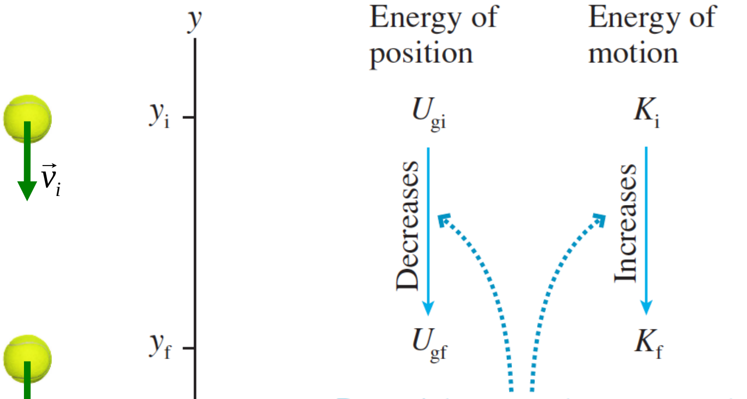
- **Gravitational potential energy** stores the work done against gravity:

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

U_g = Energy stored in Earth + object system.

  - 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.

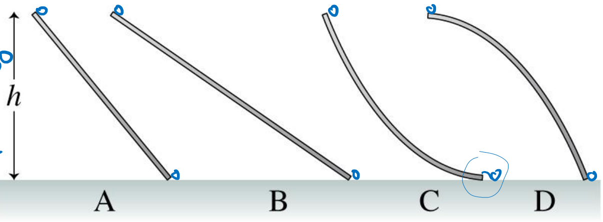
Poll Question

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.

$E_i = E_f$

$\cancel{K_i}^0 + U_{gi} = K_f + \cancel{U_{gf}}^0$

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

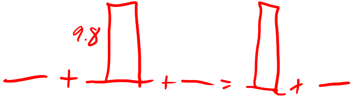


A. $v_C > v_A = v_B > v_D$
B. $v_C > v_B > v_A > v_D$
C. $v_D > v_A > v_B > v_C$
[✓ D.] $v_A = v_B = v_C = v_D$
E. $v_D > v_A = v_B > v_C$

NOTE: The Zero of Potential Energy

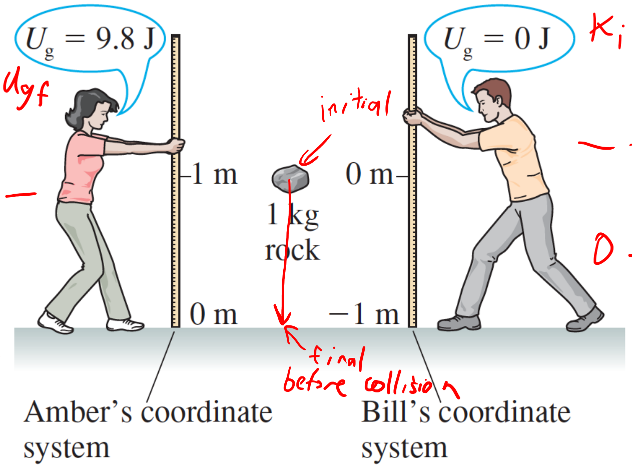
- You can place the origin of your coordinate system, and thus the “zero of potential energy,” wherever you choose and be assured of getting the correct answer to a problem.
- The reason is that only ΔU_g has physical significance, not U_g itself.

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

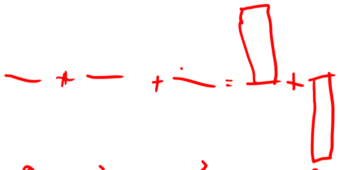


$9.8 = \frac{1}{2} m v_f^2$

$v_f = \sqrt{\frac{2 \times 9.8}{m}}$



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



$0 = \frac{1}{2} m v_f^2 - 9.8$

$v_f = \sqrt{\frac{2 \times 9.8}{m}}$

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.

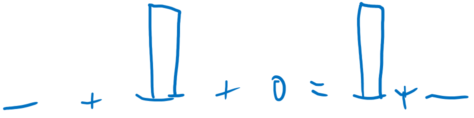
Define system = ball + Earth.

Initial: ○ $v_i = 0$ $h_i = 5.0$ m

Final: $v_f = ?$ $h_f = 0$

SIMPLIFY & DIAGRAM

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



REPRESENT MATHEMATICALLY

$$0 + \cancel{m}gh_i + 0 = \frac{1}{2}\cancel{m}v_f^2 + 0$$

$$gh_i = \frac{v_f^2}{2}$$

$$v_f = \sqrt{2gh_i}$$

SOLVE & EVALUATE

$$= \sqrt{2(9.8)(5)}$$

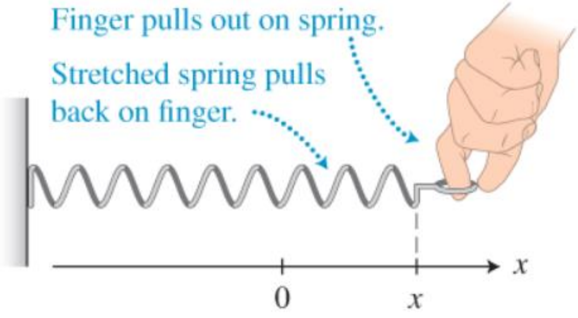
$$\boxed{v_f = 9.9 \text{ m/s}}$$

This does not give direction...

~10 m/s seems about right

~1 second fall.

Elastic Potential Energy


Finger pulls out on spring.

Stretched spring pulls back on finger.

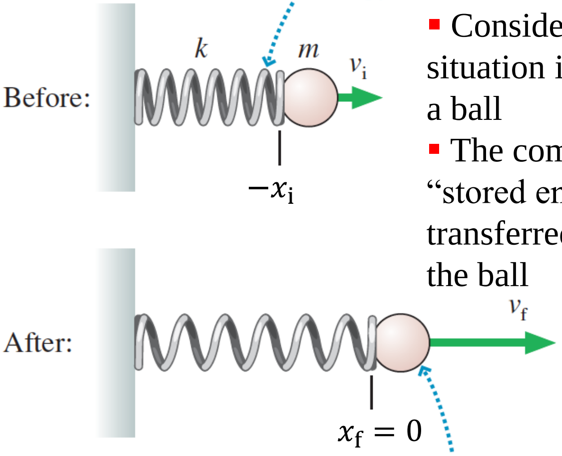
- What is the work done when a Finger stretches a Spring, originally at equilibrium, out to a distance x?

k = Spring constants

units.. $\left[\frac{N}{m}\right]$

- 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

Elastic Potential Energy


The compressed spring stores energy.

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

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

Poll Question

$K_i + U_{si} + \cancel{W}^{0} = K_f + U_{sf}$

$0 + \frac{1}{\cancel{2}} k x_i^2 + 0 = \frac{1}{\cancel{2}} m v_f^2 + 0$

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

solve for v_f:

$\frac{k x_i^2}{m} = v_f^2$

$v_f = \sqrt{\frac{k}{m}} \cdot x_i$

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

$U_s = \frac{1}{2} k x^2$

$K = \frac{1}{2} m v^2$

First shot

$x_i = x_1$

$v_{f1} = \sqrt{\frac{k}{m}} x_1$

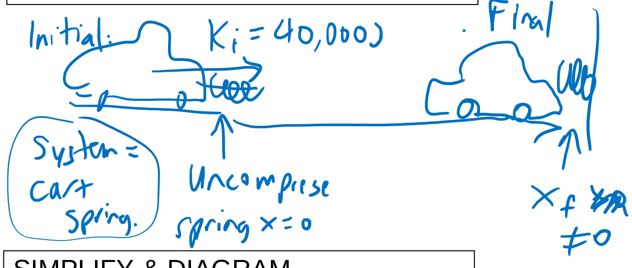
Second Shot

$x_i = 2x_1$

$v_{f2} = \sqrt{\frac{k}{m}} 2x_1 = 2 v_{f1}$

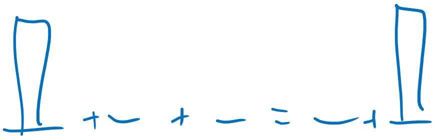
Ch.7 Example. A moving car has 40,000 J of kinetic energy while moving at a speed of 7.0 m/s. A spring-loaded automobile bumper compresses 0.30 m when the car hits a wall and stops. What can you learn about the bumper's spring using this information?

SKETCH & TRANSLATE.



SIMPLIFY & DIAGRAM

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



REPRESENT MATHEMATICALLY

$K_i + 0 + 0 = 0 + \frac{1}{2} k x^2$

$x = 0.30\ m$

Solve for k:

$k = \frac{2 K_i}{x^2}$

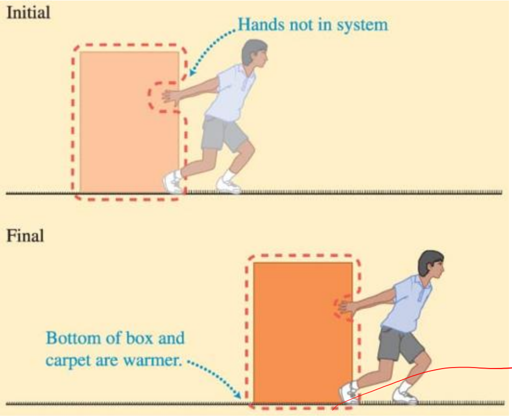
SOLVE & EVALUATE

$k = \frac{2(40000)}{0.3^2}$

$k = 8.9 \times 10^5\ N/m$

That's a stiff spring!

Internal energy



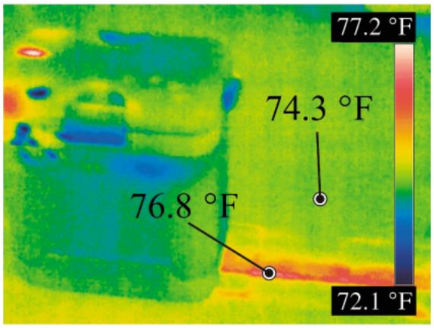
- If a object slides on a surface, the surfaces in contact can become warmer.
- Structural changes in an object can occur when an external force is applied.
- The energy associated with both temperature and structure is called internal energy (symbol U_{int}).

$U_{int} = f_k d$

work done by

kinetic friction

- 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



Poll Question

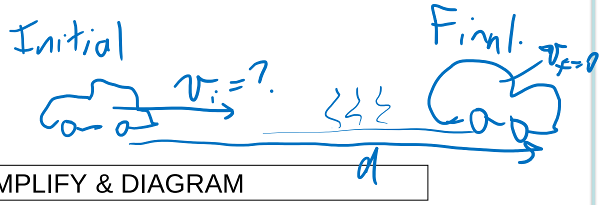
A car starts with speed v_i, but the driver puts on the brakes and the car slows to a stop. As the car is slowing down, its kinetic energy is transformed to

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

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?

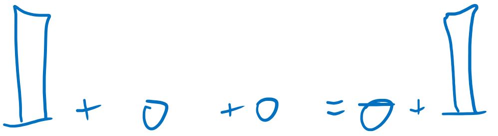
SKETCH & TRANSLATE.

Choose system = car + road surface



SIMPLIFY & DIAGRAM

$K_i + U_{int,i} + W = K_f + U_{int,f}$



REPRESENT MATHEMATICALLY

$U_{int} = f_k d$

$f_k = \mu_k N$

$\Sigma F_y = 0 \Rightarrow N = mg$

$U_{int} = \mu_k m g d$

$\frac{1}{2}\cancel{m}v_i^2 + 0 + 0 = 0 + \mu_k \cancel{m} g d$

Solve for v_i:

$v_i = \sqrt{2\mu_k g d}$

SOLVE & EVALUATE

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

$v_i = 17 \text{ m/s}$

~ 60 km/h . typical city speed.

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