

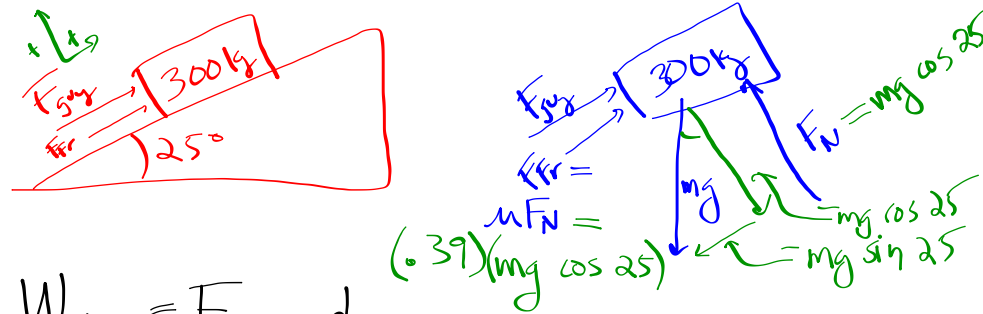
Force \rightarrow vector (\neq follows frame of reference)

Displacement \rightarrow vector (")

Work = $\vec{F} \cdot \vec{d} \rightarrow$ NOT a vector
(\neq don't follow frame of reference ...)

9. A 300-kg piano slides at constant speed 4.5 meters down a 25° incline. It is kept from accelerating by a man who is pushing back on it. The effective coefficient of friction is 0.39. Calculate

- the net work done on the piano.
- the work done by the man on the piano.
- the work done by gravity on the piano.



$$W_{\text{NET}} = F_{\text{NET}} \cdot d$$

$$\sum F_x = F_{\text{guy}} + F_{\text{fr}} - mg \sin 25 = ma_x = 0$$

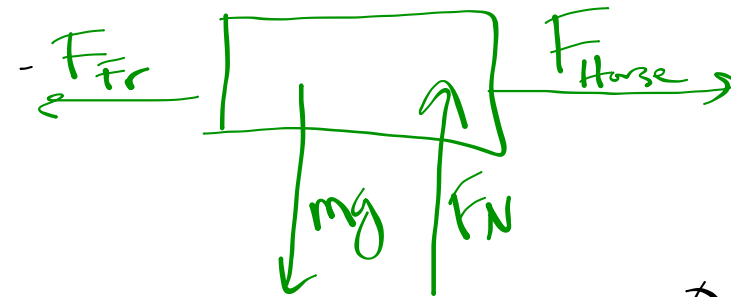
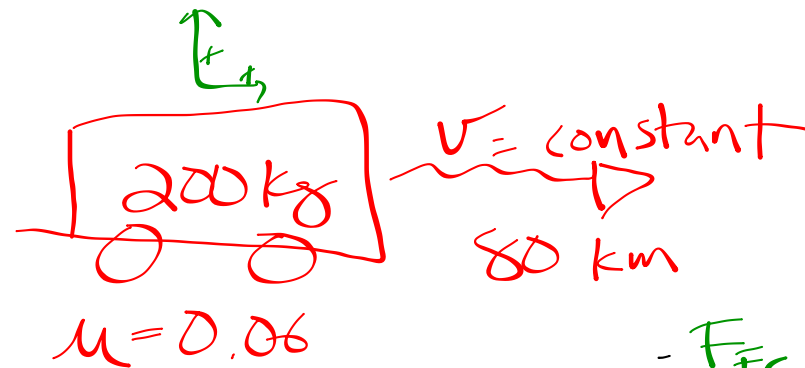
$$W_{\text{NET}} = 0 \cdot (4.5) = 0 \text{ J (on the piano)}$$

$$\begin{aligned} W_{\text{guy}} &= F_{\text{guy}} \cdot d \\ &= (203)(-4.5) \\ &= -915 \text{ J} \end{aligned}$$

$$\begin{aligned} F_{\text{guy}} &= mg \sin 25 - F_{\text{fr}} \\ &= 300(9.8) \sin 25 - \\ &\quad (.39)(300)(9.8) \cos 25 \\ &= 203 \text{ N} \end{aligned}$$

$$\begin{aligned} W_{\text{grav}} &= F_{\text{grav}} \cdot d \\ &= (1242)(-4.5) \\ &= -5589 \text{ J} \end{aligned}$$

3. How much work did a horse do that pulled a 200-kg wagon 80 km without acceleration along a level road if the effective coefficient of friction was 0.060?



$$W_{Horse} = F_{Horse} \cdot d$$

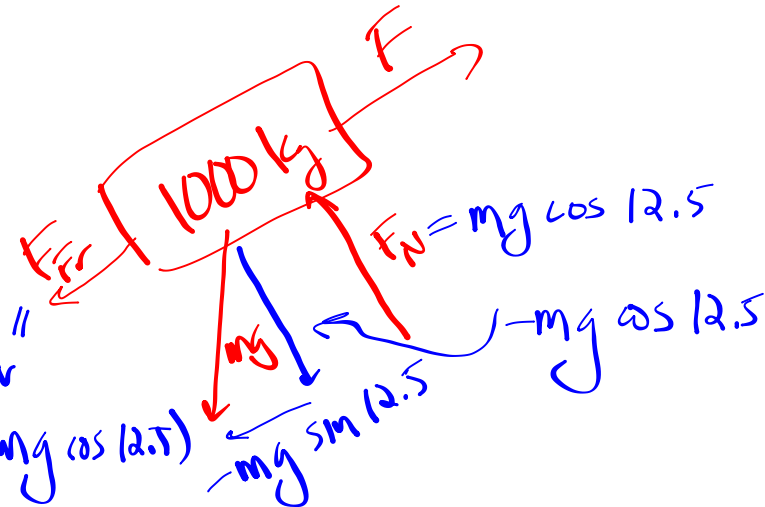
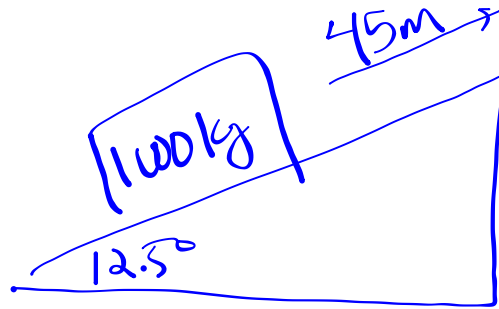
$$= .06(-200)(-9.8) \cdot 80$$

$$= \text{whatever...}$$

$$\sum F_x = F_{Horse} - F_{fr} = m a_x = 0$$

$$F_{Horse} = F_{fr} = \mu F_N = \mu(-mg)$$

5. What is the minimum work needed to push a 1000-kg car 45.0 meters up a 12.5° incline?
- ~~Ignore friction.~~
 - Assume the effective coefficient of friction is 0.30.



$$\sum F_x = F - F_{fr} - mg \sin 12.5 = m \vec{a}_x = 0$$

$$F = (+0.3)(1000)(9.8)(\cos 12.5) + (1000)(9.8)(\sin 12.5)$$

$$= 4991 \quad 2870 + 2121$$

$$W_F = F \cdot d$$


$$= (4991)(45) = 224614 \text{ J}$$

CONSERVATION OF ENERGY (COE)

We wish to develop this idea and make it more useful to use for problem solving

COE: energy can be neither created nor destroyed.

Consider the energy of an object or system to be similar to the money we might have at a bank:

- * Transfers from outside sources 
- * Move money between storage accounts

Possible scenarios at the bank:

- Shift money between bank accounts (from checking to savings, e.g.)
- Make a deposit to increase at least one storage (transfer money into the bank)
- Make a withdrawal to decrease at least one storage (transfer money out of the bank)
- A combination of these . . .

BOTTOM LINE: I'm always accounting for all of my funds

Consider the energy of an object to be similar to the money we have at the bank:

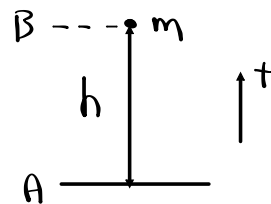
$$\begin{array}{lcl}
 \text{Transfers in or} & = & \text{Changes in the} \\
 \text{out of the bank} & & \text{amounts of} \\
 \text{(WORK)} & & \text{storage accounts} \\
 & & \begin{array}{l} \text{energy because of height} \quad \text{energy stored in spring} \\ \downarrow \qquad \qquad \qquad \downarrow \end{array} \\
 W_{\text{NET}} & = & \boxed{\Delta KE} + \boxed{\Delta GPE} + \boxed{\Delta EPE}
 \end{array}$$

KE = KINETIC ENERGY

GPE = GRAVITATIONAL POT. ENERGY

EPE = ELASTIC POT. ENERGY

What is Potential Energy?



Consider mass m lifted at a constant speed to height h (from A to B)

The work of gravity going up:

$$W_{A \rightarrow B} = F \cdot d$$

$$= (-mg) \cdot (h) = \boxed{-mgh}$$

The work of gravity in going down, returning to the original starting point:

$$W_{B \rightarrow A} = F \cdot d$$

$$= (mg) \cdot (h) = \boxed{mgh}$$

- Whenever the total work by a force on an object moving away from some initial location and then returning back to the same starting point is zero, the force can be considered a CONSERVATIVE FORCE.
- Instead of considering the work done by a conservative force, it is more convenient (and intuitive) to deal with potential energy instead.

$$W_{\text{CONSERVATIVE FORCE}} = -\Delta PE$$

To go from A to B, gravity's work is negative, however the GPE increases.

Two Conservative Forces that we will concern ourselves with in this unit: gravity and a force from a spring.

Gravity:

gravitational potential energy = GPE

$$\Delta GPE = mgh$$

- MUST IDENTIFY WHERE $h = 0$
- h IS A CHANGE IN ELEVATION
- POSITIVE DIRECTION MUST BE UP FOR h

Spring Forces

elastic potential energy = EPE

$$\Delta EPE = \frac{1}{2} kx^2$$

- MUST IDENTIFY WHERE $x = 0$
- x IS A CHANGE IN THE LENGTH OF THE SPRING.

FOR COE:

$$\left(\begin{array}{l} \text{Transfers of energy} \\ \text{into or out of an} \\ \text{object by non-} \\ \text{conservative forces} \end{array} \right) = \left(\begin{array}{l} \text{Changes in the energy} \\ \text{stored in the object} \end{array} \right)$$

$$\sum W_{nc} = \Delta KE + \Delta GPE + \Delta EPE$$

$$\sum W_{nc} = (KE_f - KE_o) + (GPE_f - GPE_o) + (EPE_f - EPE_o)$$

$$\sum W_{nc} = \left(\frac{1}{2}mv^2 - \frac{1}{2}mv_o^2 \right) + (mgh - mgh_o) + \left(\frac{1}{2}kx^2 - \frac{1}{2}kx_o^2 \right)$$

$$\sum W_{nc} = \left(\frac{1}{2}mv^2 + mgh + \frac{1}{2}kx^2 \right) - \left(\frac{1}{2}mv_o^2 + mgh_o + \frac{1}{2}kx_o^2 \right)$$

$$\left(\frac{1}{2}mv_o^2 + mgh_o + \frac{1}{2}kx_o^2 \right) + \sum W_{nc} = \left(\frac{1}{2}mv^2 + mgh + \frac{1}{2}kx^2 \right)$$

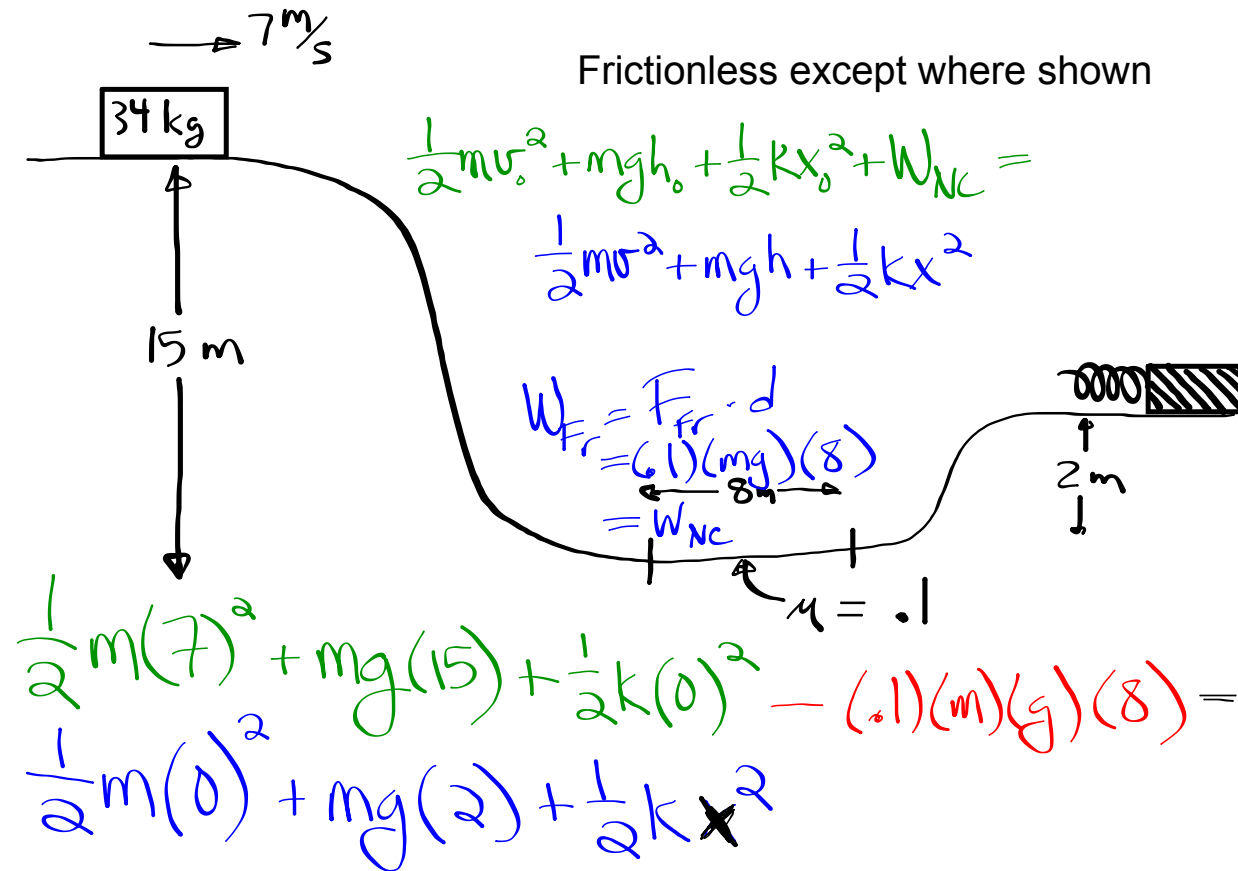
INITIAL ENERGY
OF OBJECT/SYSTEM

FINAL ENERGY OF
OBJECT/SYSTEM

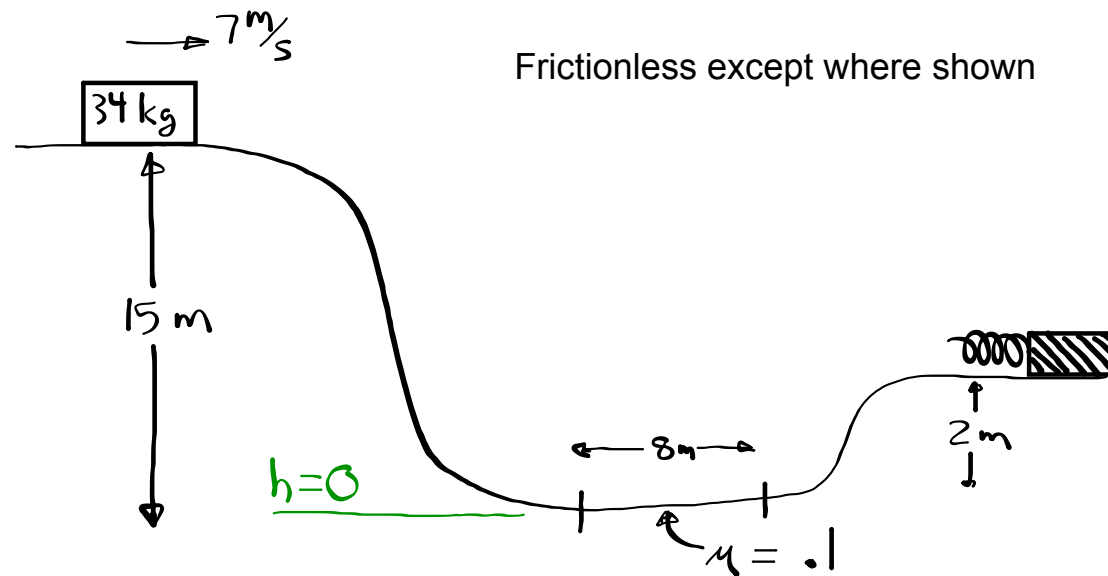
Crazy Long
Energy Equation =
(CLEEF)

+W → ENERGY TRANSFERRED IN
-W → " " " OUT

EXAMPLE: How much is the spring shown below ($k=45 \text{ N/cm}$) deflected when the object, originally moving at 7 m/s , is brought to a stop against the spring?



EXAMPLE: How much is the spring shown below ($k=45 \text{ N/cm}$) deflected when the object, originally moving at 7 m/s , is brought to a stop against the spring?



$$KE_o + GPE_o + EPE_o + \sum W_{nc} = KE + GPE + EPE$$

$$\frac{1}{2}mv_o^2 + mgh_o + \frac{1}{2}kx_o^2 + W_{\text{FRICTION}} = \frac{1}{2}mv^2 + mgh + \frac{1}{2}kx^2$$

$$\frac{1}{2}(34)(7)^2 + (34)(9.8)(15) + \frac{1}{2}(45)(0)^2 - (4mg)(d) = \frac{1}{2}(34)(0)^2 + (34)(9.8)(2) + \frac{1}{2}(45)x^2$$

$$\frac{1}{2}(34)(7)^2 + 34(9.8)(15) + 0 - (.1)(34)(9.8)(8) = 0 + 34(9.8)(2) + \frac{1}{2}(45)x^2$$

$$x = \boxed{14.75 \text{ cm}}$$

