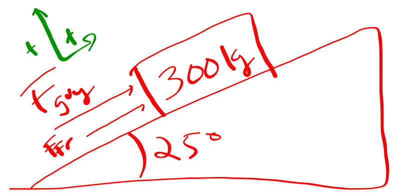
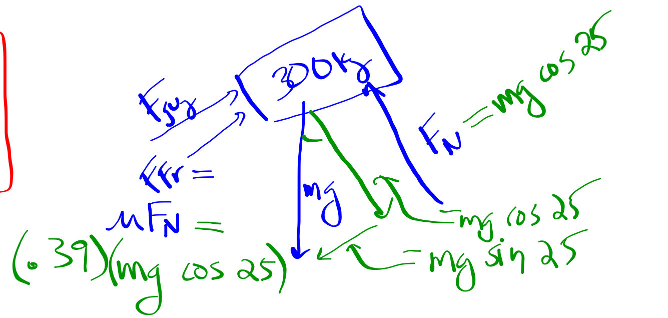
Force → vector (+/− follows frame of refrence)

Displacement → vector (")

Work = F · d → NOT a vector
(+/− <u>don't</u> follow frame of refrence ...)

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
   a) the net work done on the piano.
   b) the work done by the man on the piano.
   c) the work done by gravity on the piano.





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

$$\Sigma F_x = F_{guy} + F_{Fr} - mg \sin 25 = m a_x = 0$$

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

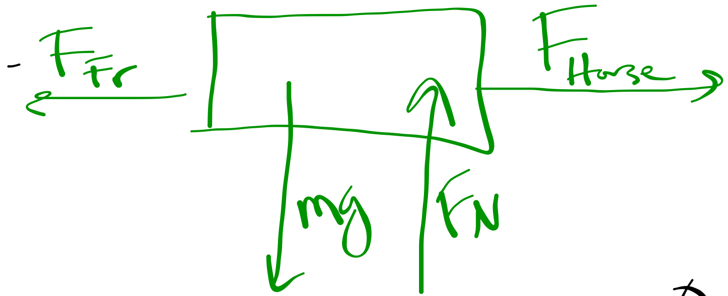
$$W_{GUY} = F_{GUY} \cdot d$$
$$= (203)(-4.5)$$
$$= -915\text{ J}$$

$$F_{guy} = mg \sin 25 - F_{Fr}$$
$$= 300(9.8)\sin 25 - (.39)(300)(9.8)\cos 25$$
$$= 203\text{ N}$$

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

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?

$\mu = 0.06$



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

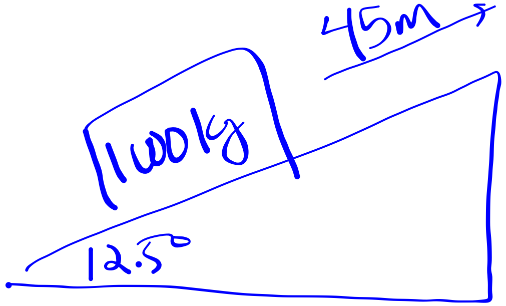
$$= .06(-200)(-9.8) \cdot 80$$

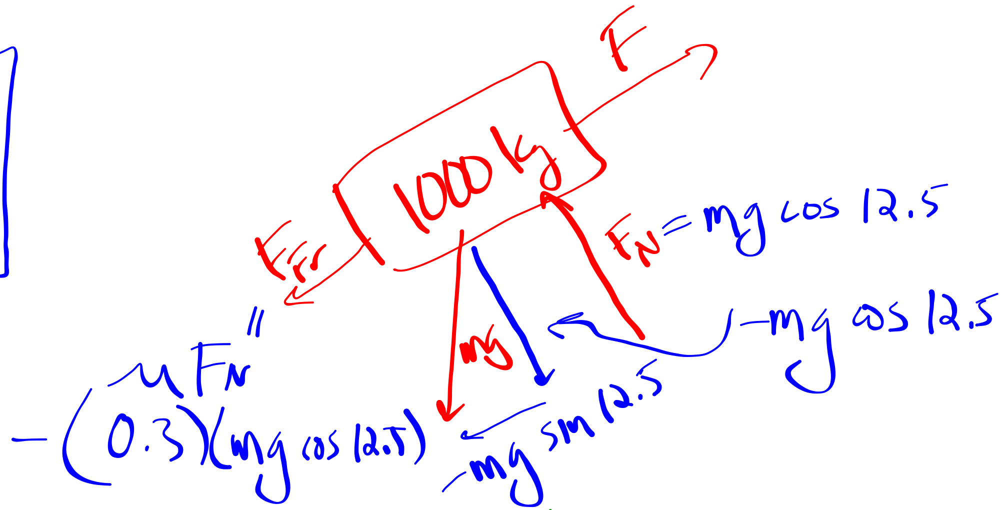
$$= \text{whatever...}$$

$$\Sigma F_x = F_{HORSE} - F_{FR} = m \overset{0}{a_x} = 0$$

$$F_{HORSE} = F_{FR} = \mu F_N = \mu(-mg)$$

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





$$\sum F_x = F - F_{fr} - mg\sin 12.5 = m\cancel{a_x}^{0} = 0$$

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

$$= 4991 \quad 2870 + 2121$$

$$W_F = F \cdot d$$

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

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 Deposit Withdrawal

* 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:

Transfers in or out of the bank = Changes in the amounts of storage accounts

(WORK)

energy because of height

energy stored in spring

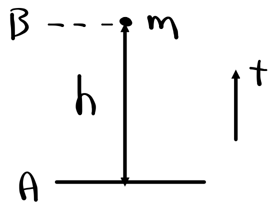
$$W_{NET} = \boxed{\Delta KE} + \boxed{\Delta GPE} + \boxed{\Delta EPE}$$

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:

$$W_{A \to B} = F \cdot d$$
$$= (-mg) \cdot (h) = \boxed{-mgh}$$

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

$$W_{B \to A} = F \cdot d$$
$$= (mg) \cdot (h) = \boxed{mgh}$$

- 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:

(Transfers of energy into or out of an object by non-conservative forces) = (Changes in the energy stored in the object)

$$\Sigma W_{NC} = \Delta KE + \Delta GPE + \Delta EPE$$

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

$$\Sigma W_{NC} = \left(\tfrac{1}{2}mv^2 - \tfrac{1}{2}mv_o^2\right) + (mgh - mgh_o) + \left(\tfrac{1}{2}kx^2 - \tfrac{1}{2}kx_o^2\right)$$

$$\Sigma W_{NC} = \left(\tfrac{1}{2}mv^2 + mgh + \tfrac{1}{2}kx^2\right) - \left(\tfrac{1}{2}mv_o^2 + mgh_o + \tfrac{1}{2}kx_o^2\right)$$

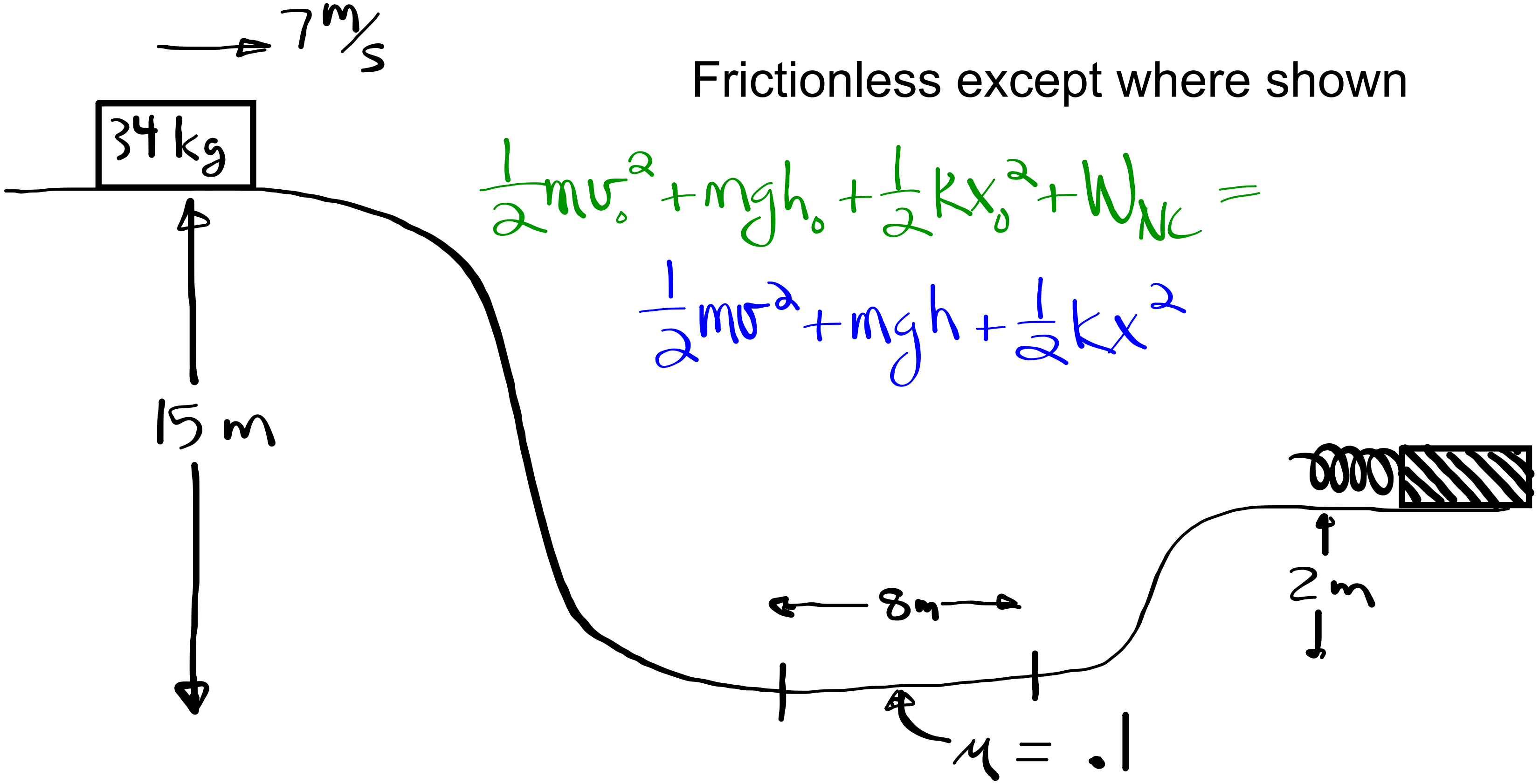
$$\boxed{\underbrace{\left(\tfrac{1}{2}mv_o^2 + mgh_o + \tfrac{1}{2}kx_o^2\right)}_{\text{INITIAL ENERGY OF OBJECT/SYSTEM}} + \underbrace{\Sigma W_{NC}}_{} = \underbrace{\left(\tfrac{1}{2}mv^2 + mgh + \tfrac{1}{2}kx^2\right)}_{\text{FINAL ENERGY OF OBJECT/SYSTEM}}}$$

Crazy Long Energy Equation = CLEE

$+W \rightarrow$ ENERGY TRANSFERRED IN

$-W \rightarrow$ " " OUT

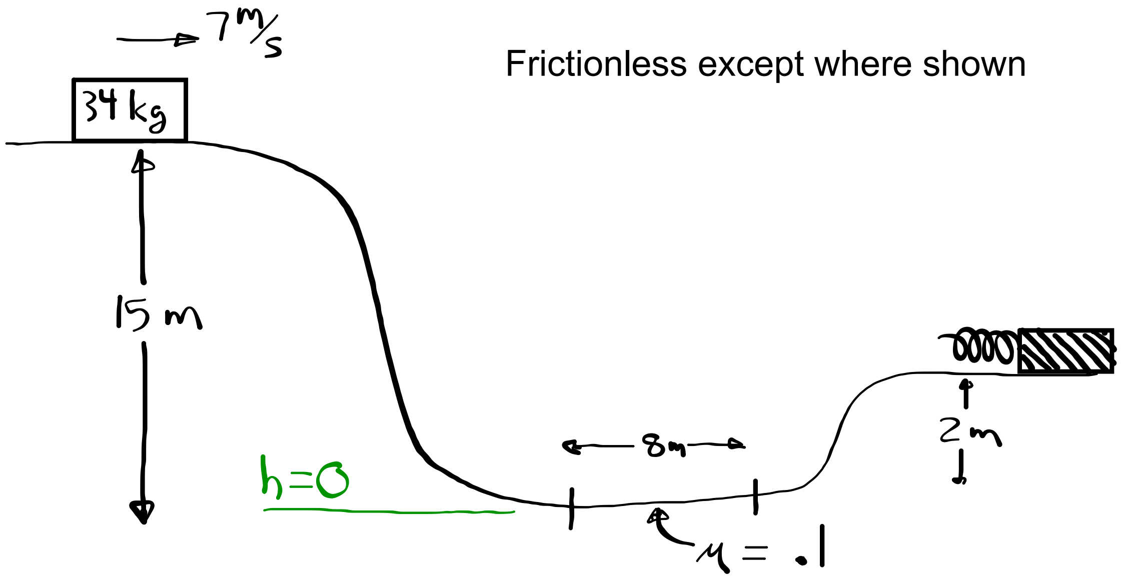
EXAMPLE: How much is the spring shown below (k=45 N/cm) deflected when the object, originally moving at 7 m/s, is brought to a stop against the spring?



$$\frac{1}{2}mv_0^2 + mgh_0 + \frac{1}{2}kx_0^2 + W_{NC} =$$

$$\frac{1}{2}mv^2 + mgh + \frac{1}{2}kx^2$$

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



$$KE_o + GPE_o + EPE_o + \Sigma W_{NC} = KE + GPE + EPE$$

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

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

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

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