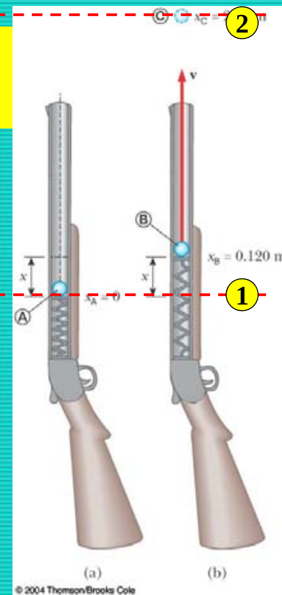
Example 8.5 :

A spring-loaded popgun $x = 0.12$ m, $m = 35$ g, $h = x_c = 20$ m,

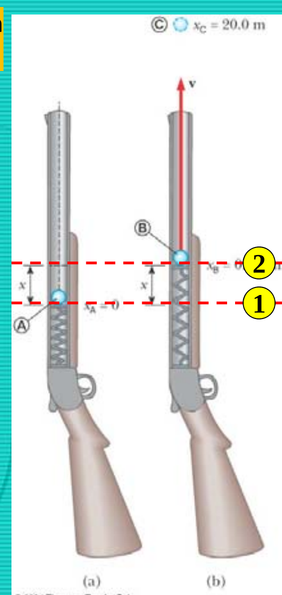
Neglect all resistive forces , $k = ?$

$$\Delta K + \Delta U = 0$$
$$K_2 - K_1 + U_2 - U_1 = 0$$
$$K_2 + U_2 = K_1 + U_1 = constant = E \equiv Total\ mechanical\ energy$$



$$K_2 + U_2 = K_1 + U_1$$
$$0 + U_2 = 0 + U_1$$
$$U_2 = U_{2s} + U_{2g} = 0 + mgh$$
$$U_1 = U_{1s} + U_{1g} = \frac{1}{2}kx^2 + 0$$
$$mgh = \frac{1}{2}kx^2$$
$$k = \frac{2mgh}{x^2} = 953\ N/m$$

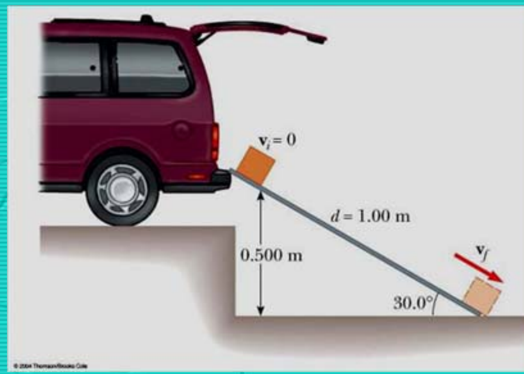
What is the speed of projectile as it moves through equilibrium position of the spring



$$K_2 + U_2 = K_1 + U_1$$
$$K_2 + U_2 = 0 + U_1$$
$$U_2 = U_{2s} + U_{2g} = 0 + mgx$$
$$U_1 = U_{1s} + U_{1g} = \frac{1}{2}kx^2 + 0$$
$$\frac{1}{2}mv_2^2 + mgh = \frac{1}{2}kx^2$$
$$v_2 = \sqrt{\frac{kx^2}{m} - 2gx} = 19.7\ m/s$$

Example 8.6

m =3 kg , d = 1 m , θ = 30° ,
v_i = 0 , f_k = 5 N , h = 0.5 m ,
v_f = ?



$$\Delta K + \Delta U = W_{nc}$$

$$K_f - K_i + U_f - U_i = W_{f_k}$$

$$\frac{1}{2}mv_f^2 - 0 + 0 - mgh = -f_k d$$

$$v_f = \sqrt{\frac{2}{m}\left(mgh - f_k d\right)} = 2.54\ m/s$$

What happen when you don't know h?

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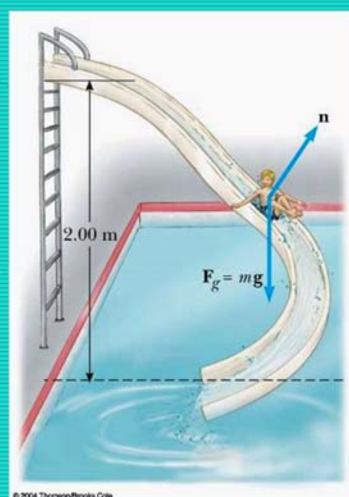
Example 8.6



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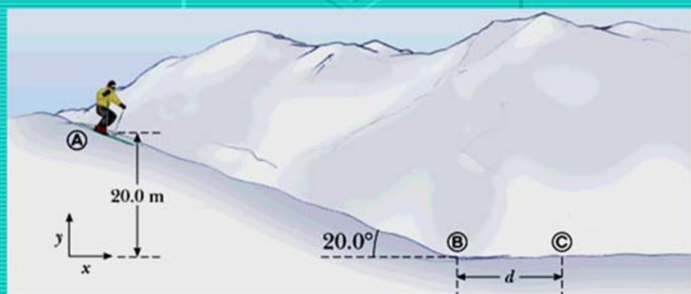
example 8.8

A skier starts from rest at the top of a frictionless incline of height 20.0 m, as shown. At the bottom of the incline, she encounters a horizontal surface where the coefficient of kinetic friction between the skis and the snow is 0.210.

(a)How far does she travel on the horizontal stretch.



$$\Delta E = 0 = \Delta K + \Delta U$$

$$m g h = \frac{1}{2} m v^2$$

$$v = \sqrt{2 g h}$$

$$v = \sqrt{2 \times 9.8 \times 20.0} = 19.8 \ m/s$$

$$\Delta K = K_f - K_i = -f_k d$$

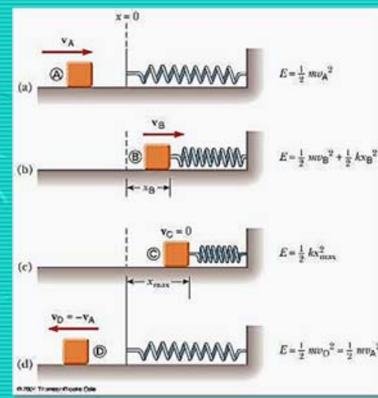
Since $K_f = 0$ $\quad -K_i = -f_k d; \ f_k d = K_i$

$$f_k = \mu_k n = \mu_k m g$$

$$d = \frac{K_i}{\mu_k m g} = \frac{\frac{1}{2} m v^2}{\mu_k m g} = \frac{v^2}{2 \mu_k g} = \frac{(19.8)^2}{2 \times 0.210 \times 9.80} = 95.2 \ m$$

Example 8.9

A block sliding on a smooth, horizontal surface collides with a light spring. (a) Initially the mechanical energy is all kinetic energy. (b) The mechanical energy is the sum of the kinetic energy of the block and the elastic potential energy in the spring. (c) The energy is entirely potential energy. (d) The energy is transformed back to the kinetic energy of the block. The total energy of the system remains constant throughout the motion.



(i) $\mu_k = 0$

$$E_t = \tfrac{1}{2} m v_i^2$$

$$E_t = \tfrac{1}{2} k x_m^2 \quad \Rightarrow x_m = \sqrt{\frac{m}{k}}$$

$$E_t = \tfrac{1}{2} m v_f^2 \quad \Rightarrow \vec{v}_f = -\vec{v}_i$$

(i) $\mu_k \neq 0$

$$E_t - \mu_k mg(x_m + x_0) = \tfrac{1}{2} k x_m^2$$

$$E_t - \mu_k mg 2(x_m + x_0) = \tfrac{1}{2} m v_f^2$$

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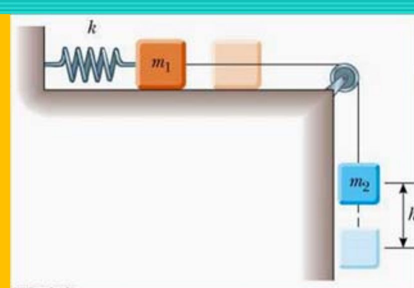
Example 8.10

- As the hanging block moves from its highest elevation to its lowest, the system loses gravitational potential energy but gains elastic potential energy in the spring. Some mechanical energy is lost because of friction between the sliding block and the surface.



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MINI REVIEW: WORK – KE – PE

Work done by constant force: $W = \mathbf{F}\cdot\mathbf{d} = Fd\cos\theta$

e.g. Work done by gravity: $W_g = -mg\,\Delta y$

Change in gravitational PE: $\Delta U_g = -W_g = mg\,\Delta y$

Work done by variable force: $W = \int_{x_1}^{x_2} F_x\, dx$

e.g. Work ***by*** spring: $W_{x_1 \to x_2} = -\frac{1}{2}k\left(x_2^2 - x_1^2\right)$

Change in spring PE: $\Delta U = -W_s = \frac{1}{2}k\left(x_2^2 - x_1^2\right)$

Work – Energy Thm: $\sum W_{non\text{-}con} = \Delta E_{mech} = \Delta K + \Delta U$

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Example : Hotwheel

A toy car slides on the frictionless track shown below. It starts at rest, drops a distance *d*, moves horizontally at speed v_1, rises a distance *h*, and ends up moving horizontally with speed v_2.

Find v_1 and v_2.

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- K+U energy is conserved, so $\Delta E = 0$

$$\Delta K = -\Delta U$$

- Moving down a distance *d*,

$$\Delta U = -mgd, \quad \Delta K = \frac{1}{2} m v_1^2$$

- Solving for the speed:

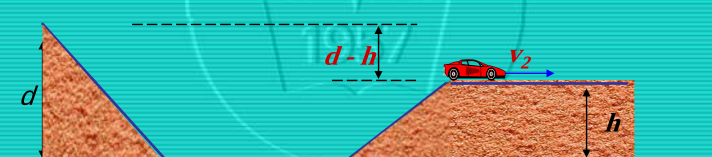
$$v_1 = \sqrt{2gd}$$

- At the end, we are a distance *d - h* below our starting point.

$$\Delta U = -mg(d-h), \quad \Delta K = \frac{1}{2} m v_2^2$$

Solving for the speed:

$$v_2 = \sqrt{2g(d-h)}$$



Example:

With what speed does the weight have just before contact with the nail?

$$\Delta K + \Delta U = 0$$

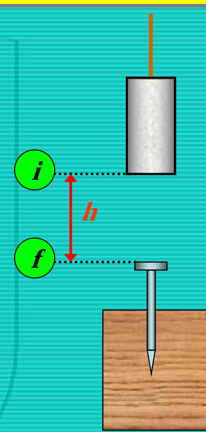
$U_i = mgh$

$U_f = 0$

$K_i = 0$

$K_f = \frac{1}{2}mv^2$

$$v = \sqrt{2gh}$$



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What is the force of resistance between the nail and the block?

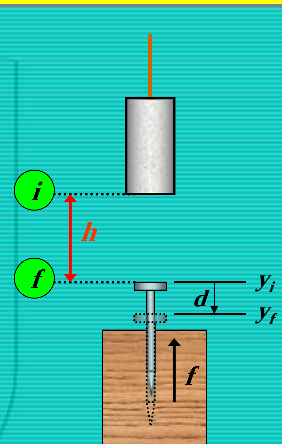
$$\Delta K + \Delta U = W_{nc} = -fd$$

$U_i = 0$

$U_f = -mgd$

$K_i = mgh$

$K_f = 0$



Solve you get

$$f = mg\left(\frac{h+d}{d}\right)$$

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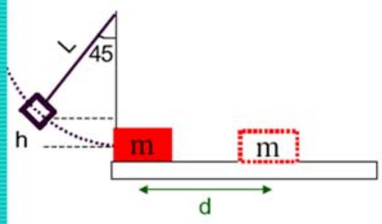
Using Energy to Find Resistive Forces

Pendulum & Sliding Block

What is the work done by friction?



$$KE_i = KE_f = 0$$

$$U_i = mgh$$

$$= mgL(1-\cos\theta)$$

$$U_f = 0$$

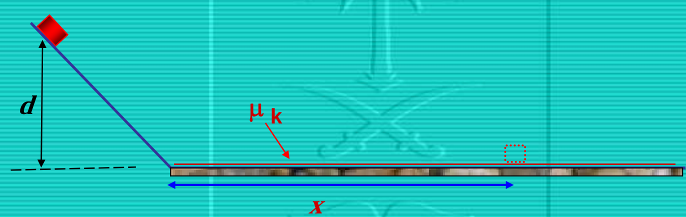
$$\Delta KE + \Delta U = W_{nc}$$

$$W_{nc} = \Delta U = mgL(1-\cos\theta) = -fd$$

Example;

A block slides down a frictionless ramp. Suppose the horizontal (bottom) portion of the track is rough, such that the coefficient of kinetic friction between the block and the track is μ_k.

How far, x, does the block go along the bottom portion of the track before stopping?



Using $W_{nc} = \Delta K + \Delta U$

As before, $\Delta U = -mgd$

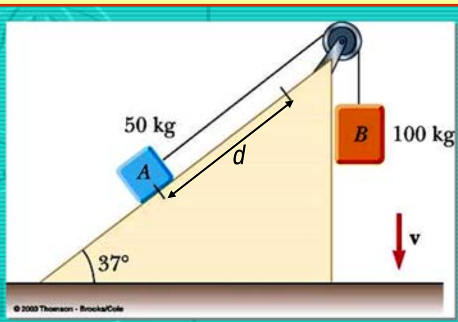
W_{nc} = work done by friction = $-\mu_k mgx$.

$\Delta K = 0$ since the block starts out and ends up at rest.

$W_{nc} = \Delta U$ ⇨ $-\mu_k mgx = -mgd$ ⇨ $x = d / \mu_k$

Example

Two blocks, *A* and *B* (m_A=*50 kg* and m_B=100 kg), are connected by a string as shown. If the blocks begin at rest, what will their speeds be after *A* has slid a distance *d* = 0.25 m? Assume the pulley and incline are frictionless.



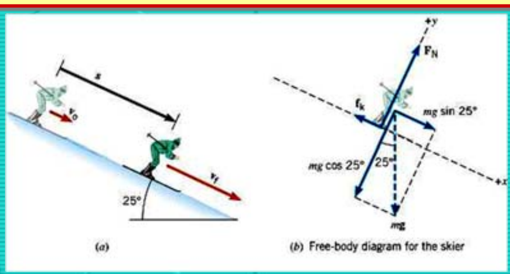
ANS: 1.51 m/s

Example:

A skier (m=58 kg) is traveling down a 25 degree slope. His skies against the snow exert a frictional force of 70 N. He starts out with a velocity of 3.6 m/s. What velocity does he end up with after traveling 57 m downhill?

What is the net force along the direction of the displacement?

$$\sum F_s = mg\sin\theta + (-70N)$$



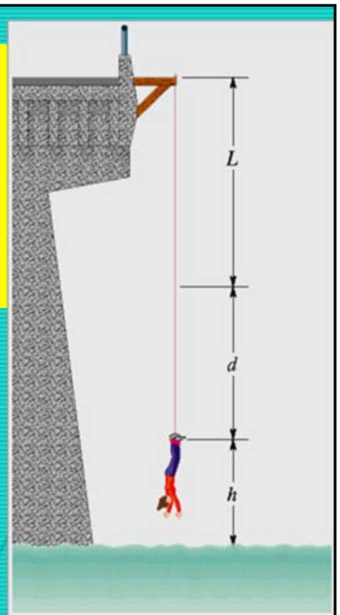
$$W = \sum F_s \times s = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2$$

$$[mg\sin\theta + (-70N)] \times s = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2$$

From this, we can solve for v!

Sample Problem

A 61.0 kg bungee-cord jumper is on a bridge 45.0 m above a river. The elastic bungee cord has a relaxed length of *L* = 25.0 m. Assume that the cord obeys Hooke's law, with a spring constant of 160 N/m. If the jumper stops before reaching the water, what is the height *h* of her feet above the water at her lowest point?



$$\Delta K + \Delta U_e + \Delta U_g = 0$$

$$\Delta U_g = mg\Delta y = -mg(L+d)$$

$$\Delta U_e = \frac{1}{2}kd^2$$

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$$0 + \frac{1}{2}kd^2 - mg\,(L+d) = 0$$

$$\frac{1}{2}kd^2 - mgL - mgd = 0$$

$$\frac{1}{2}(160\ N/m)d^2 - (61.0\ kg)(9.8\ m/s^2)(25.0\ m)$$
$$-(61.0\ kg)(9.8\ m/s^2)d = 0$$

$$d = 17.9\ m$$

$$h = 45.0\ m - 42.9\ m = 2.1\ m$$

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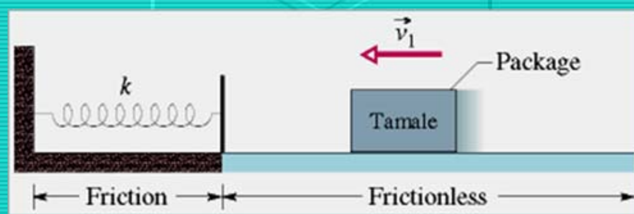
Sample Problem

In Fig., a 2.0 kg package of tamale slides along a floor with speed v_1 = 4.0 m/s. It then runs into and compresses a spring, until the package momentarily stops. Its path to the initially relaxed spring is frictionless, but as it compresses the spring, a kinetic frictional force from the floor, of magnitude 15 N, acts on it. The spring constant is 10,000 N/m. By what distance *d* is the spring compressed when the package stops?



SOLUTION:

$$E_{mec,2} = E_{mec,1} - \Delta E_{th}$$

$$E_{mec,1} = K_1 + U_1 = \frac{1}{2} m v_1^2 + 0$$

$$E_{mec,2} = K_2 + U_2 = 0 + \frac{1}{2} k d^2$$

$$\frac{1}{2} k d^2 = \frac{1}{2} m v_1^2 - f_k d$$

$$5000\, d^2 + 15\, d - 16 = 0$$

$$d = 0.055 \text{ m} = 5.5 \text{ cm}$$

Energy Loss in Automobile

Automobile uses only at 13% of its fuel to propel the vehicle.

Why?

67% in the engine:

1. *Incomplete burning*
2. *Heat*
3. *Sound*

16% in friction in mechanical parts

4% in operating other crucial parts such as oil and fuel pumps, etc

13% used for balancing energy loss related to moving vehicle, like air resistance and road friction to tire, etc

Two frictional forces involved in moving vehicles $m_{car} = 1450kg$ $Weight = mg = 14200N$

Coefficient of Rolling Friction; μ=0.016 $\mu n = \mu mg = 227N$

Air Drag $f_a = \frac{1}{2} D\rho A v^2 = \frac{1}{2} \times 0.5 \times 1.293 \times 2v^2 = 0.647v^2$

Total Resistance $f_t = f_r + f_a$

Total power to keep speed v=26.8m/s=60mi/h $P = f_t v = (691N) \cdot 26.8 = 18.5kW$

Power to overcome each component of resistance $P_r = f_r v = (227) \cdot 26.8 = 6.08kW$

$P_a = f_a v = (464.7) \cdot 26.8 = 12.5kW$

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