Physics 2514

Lecture 32

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Summary

- Introduced concept of work:
  - Energy added due to forces acting on an object, $W_{\text{net}} = \Delta K$ and $W = -\Delta U$;
  - Work given by $W = \int_{s_i}^{s_f} \vec{\mathbf{F}} \cdot d\vec{\mathbf{s}}$
- If the work done is independent of the path, the force is conservative
  - Force can be written as a potential (true for gravity and spring forces);
  - The mechanical energy is conserved.
- Friction is not a conservative force
  - The work done depends on the path;

Clicker

A 2.0 kg book is lying on a 0.75 m high table. You pick it up and place it on a bookshelf 2.25 m above the floor. What is the work done by gravity W_g, and by you W_y from the instant before the book is picked up to the instant after it is placed on the bookshelf.

A) $W_g = 0$ J, $W_y = 0$ J

B) $W_g = 29.4$ J, $W_y = 29.4$ J

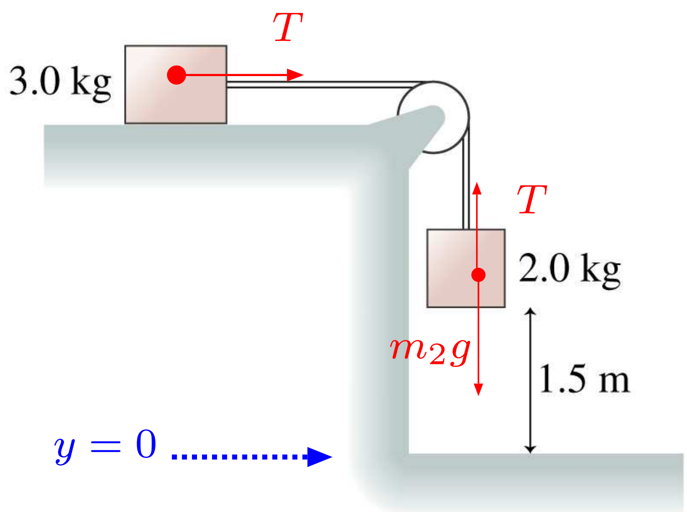
C) $W_g = -29.4$ J, $W_y = 29.4$ J

D) $W_g = -29.4$ J, $W_y = -29.4$ J

E) $W_g = 29.4$ J, $W_y = -29.4$ J

Example Blocks

Determine the speed of the blocks in the figure (assume the blocks start from rest in the configuration shown) just before the hanging block hits the ground if (a) the table is frictionless, (b) the table has $\mu_k = 0.15$



$\mu_k = 0$

Initial energy: $E_i = m_2 g h = 29.4$ J

Final energy: $E_f = \frac{1}{2}(m_2 + m_3)v^2$

Energy conservation: $E_i = E_f$

$$\Rightarrow \quad \frac{1}{2}(m_2 + m_3)v^2 = m_2 g h$$

$$\Rightarrow \quad v = \sqrt{\frac{2 m_2 g h}{m_2 + m_3}} = 3.4 \text{ m/s}$$

(Initial and final energy refer to the mechanical energy)

Example Blocks

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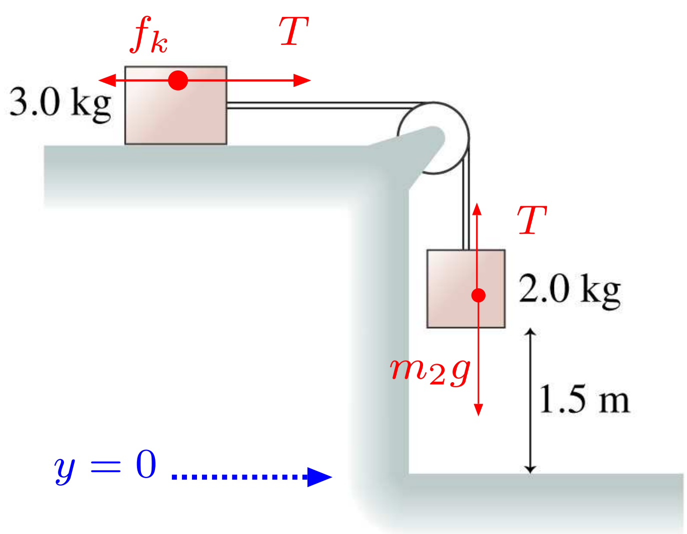


$\mu_k = 0.15$

Initial energy: $E_i = m_2 g h = 29.4$ J

Work fric.: $W_{nc} = -f_k \Delta s = -m_3 g \mu_k h$

$\Delta s = h$ rope doesn't stretch

Final energy: $E_f = \frac{1}{2}(m_2 + m_3)v^2$

Change in mech energy: $E_f - E_i = W_{nc}$

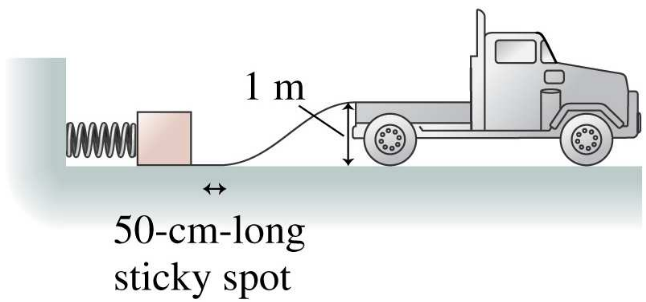
$$\frac{1}{2}(m_2 + m_3)v^2 - m_2 g h = -m g \mu_k h$$

$$\Rightarrow \quad v = \sqrt{\frac{2gh(m_2 - m_3\mu_k)}{m_2 + m_3}} = 3.0 \text{ m/s}$$

Example Work

A freight company uses a compressed spring to shoot 2.00 kg packages up a 1.0-m-high frictionless ramp into a truck, as the figure shows. The spring constant is 500 N/m and the spring is compressed 30.0 cm. A careless worker spills his soda on the ramp. This creates a 50-cm-long sticky spot with a coefficient of kinetic friction 0.30. Will the next package make it into the truck?

A 2.0 kg package is placed against a spring with $k = 500$ N/m that is compressed 0.3 m. The package must pass a 0.5 m region with $\mu_k = 0.3$. Will it be able to increase its height by 1.0 m?



Example Work

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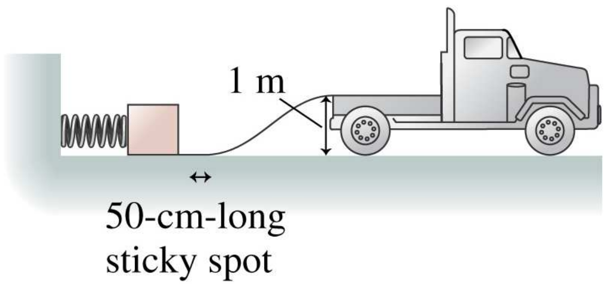


Initial energy: $E_i = \frac{1}{2}k(\Delta s_s)^2 = 22.5$ J

Final energy: $E_f = \frac{1}{2}mv^2 + mgh$

Energy lost to friction:

$$W_f = -mg\mu_k \Delta s_f = -2.94 \text{ J}$$

Use work energy relation $W_f = \Delta E_{mech}$
if $v^2 \geq 0$ package makes it up ramp.

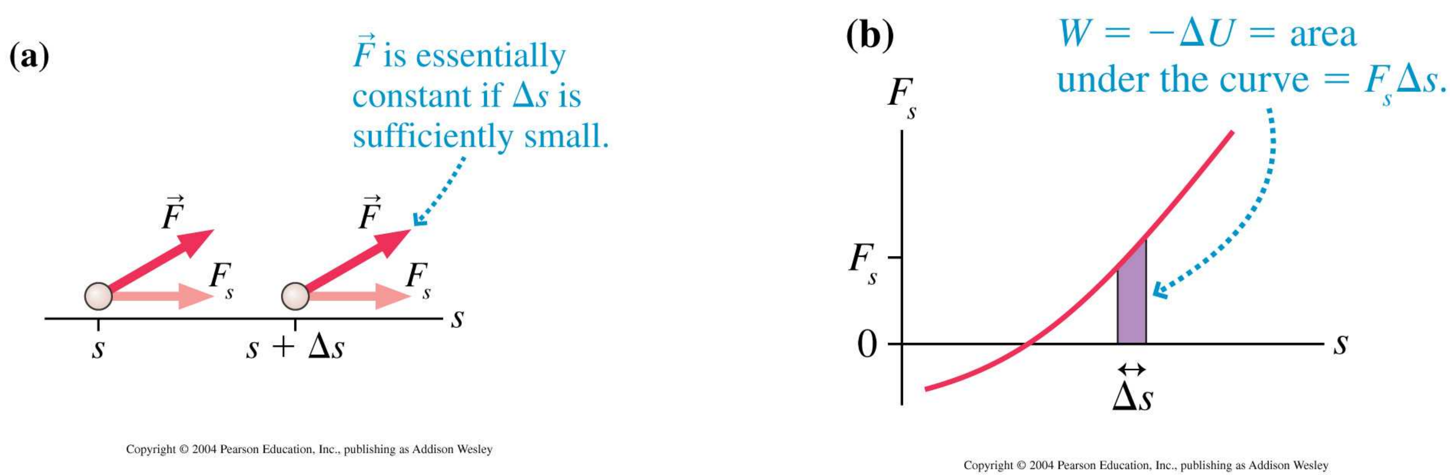
$$W_f = \frac{1}{2}mv^2 + mgh - \frac{1}{2}k(\Delta s_s)^2$$

$$\Rightarrow \quad v^2 = -0.04 \text{ m}^2/s^2$$

No it will not make it up ramp

Potential Energy & Forces

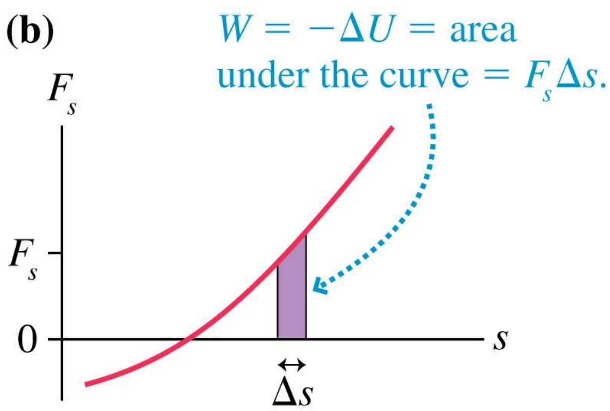
- How to calculate the force from the potential energy

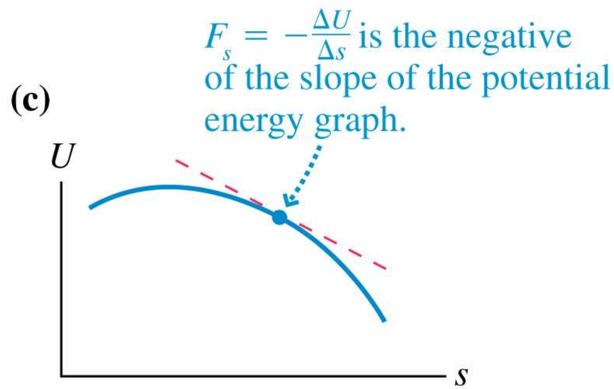


- Work $W(s \to s + \Delta s) = F_s \Delta s$
- Potential energy $\Delta U = -W(s \to s + \Delta s) = -F_s \Delta s$

Potential Energy & Forces

- How to calculate the force from the potential energy





- Potential energy: $\Delta U = -W(s \to s + \Delta s) = -F_s \Delta s$
- Force: $F_s = -\frac{\Delta U}{\Delta s} \quad \Rightarrow \quad F_s = -\lim_{\Delta s \to 0} \frac{\Delta U}{\Delta s} = -\frac{dU}{ds}$

Potential Energy & Forces

- Gravity $U = mgy$ $F = -\frac{dU}{dy} = -mg$
- Spring $U = \frac{1}{2}kx^2$ $F = -\frac{dU}{dx} = -kx$

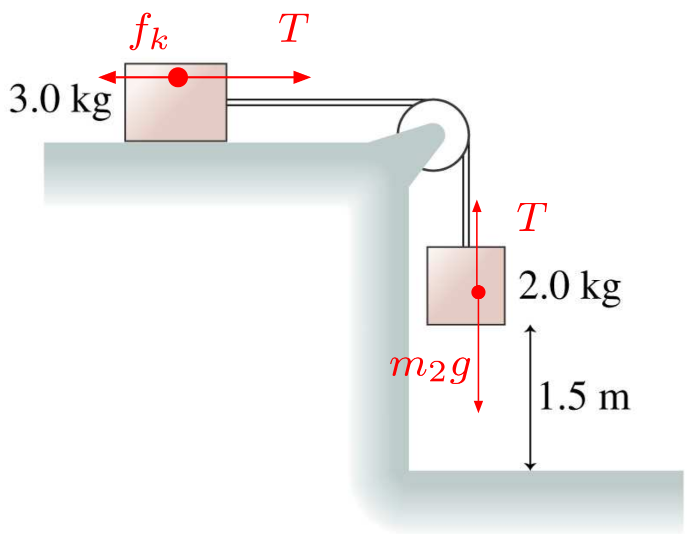
Power

- Define power $P = \frac{dE}{dt}$ the rate at which energy is transfered.
  - The units are J/s which is defined as Watts;
  - Important: This is an instantaneous quantity;
- Consider the rate at which work is done;

$$dW = \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}} \quad \Rightarrow \quad \frac{dW}{dt} = \vec{\mathbf{F}} \cdot \frac{d\vec{\mathbf{r}}}{dt} = \vec{\mathbf{F}} \cdot \vec{\mathbf{v}} = Fv\cos\theta$$

Example Blocks

Determine the rate at which work is done on each block for the case where the table has $\mu_k = 0.15$, by gravity, friction, and the tension in the rope just before the block hits the ground



2 kg block:

Gravity: $\frac{dW_g}{dt} = m_2 g v_f = 58.8$ W

Tension: $\frac{dW_T}{dt} = -T v_f = -40.5$ W

3 kg block:

Friction: $\frac{dW_f}{dt} = -m_3 g \mu_k v_f = -13.2$ W

Tension: $\frac{dW_T}{dt} = T v_f = 40.5$ W

Reminder: $v_f = 3.0$ m/s,

Exercise: $T = 13.5$ N

Assignment

Read chapter 12

Review for exam