PHY 113 A General Physics I
9-9:50 AM MWF Olin 101

Plan for Lecture 13:

Chapter 8 -- Conservation of energy

1. Potential and kinetic energy for conservative forces
2. Energy and non-conservative forces
3. Power

5	09/07/2012	Motion in 2d	4.1-4.3	4.3,4.50	09/10/2012
6	09/10/2012	Circular motion	4.4-4.6	4.29,4.30	09/12/2012
7	09/12/2012	Newton's laws	5.1-5.6	5.1,5.13	09/14/2012
8	09/14/2012	Newton's laws applied	5.7-5.8	5.20,5.30,5.48	09/17/2012
	09/17/2012	Review	1-5		
	09/19/2012	Exam	1-5		
9	09/21/2012	More applications of Newton's laws	6.1-6.4	6.3,6.14	09/24/2012
10	09/24/2012	Work	7.1-7.4	7.1,7.15	09/26/2012
11	09/26/2012	Kinetic energy	7.5-7.9	7.31,7.41,7.49	09/28/2012
12	09/28/2012	Conservation of energy	8.1-8.5	8.6,8.22,8.35	10/01/2012
13	10/01/2012	Momentum and collisions	9.1-9.4	9.15,9.18	10/03/2012
14	10/03/2012	Momentum and collisions	9.5-9.9	9.29,9.37	10/05/2012
	10/05/2012	Review	6-9		
	10/08/2012	Exam	6-9		
15	10/10/2012	Rotational motion	10.1-10.5		10/12/2012

PHY 113 General Physics I -- Section A

MWF 9 AM-9:50 PM	OPL 101	http://www.wfu.edu/~natalie/f12phy113/

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Tutorial sessions in Olin 101

- General information
- Syllabus and homework assignments
- Lecture Notes
- For registered students

- Sundays 5:00-7:00 PM -- Jiajie Xiao
- Mondays 5:00-7:00 PM -- Jiajie Xiao
- Tuesdays 5:00-7:00 PM -- Stephen Baker
- Wednesdays 5:00-7:00 PM -- Stephen Baker
- Thursdays 5:00-7:00 PM -- Loah Stevens
- Fridays 5:00-7:00 PM -- Loah Stevens

Note: Because of PHY 114 exams on Sunday and Monday, the tutorials those nights will be moved from Olin 101 – check for signs – this week only.

General work - kinetic energy theorem:

$$W_{i\to f} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F}_{total} \cdot d\mathbf{r} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

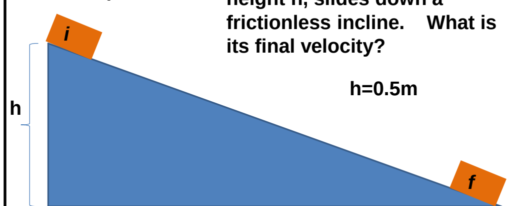
For conservative forces:

$$W_{i\to f} = \int_{\mathbf{r}_i}^{\mathbf{r}_f} \mathbf{F}_{total} \cdot d\mathbf{r} = -\left(U(\mathbf{r}_f) - U(\mathbf{r}_i)\right)$$

$$\Rightarrow \frac{1}{2}mv_i^2 + U(\mathbf{r}_i) = \frac{1}{2}mv_f^2 + U(\mathbf{r}_f) = E$$

Example

A block, initially at rest at a height h, slides down a frictionless incline. What is its final velocity?



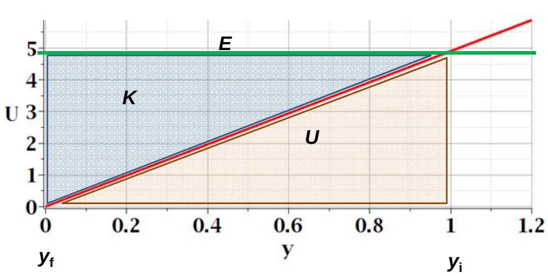
$$i: \quad v_i = 0; \quad U(\mathbf{r}_i) = mgh; \quad E = mgh$$

$$f: \quad v_f > 0; \quad U(\mathbf{r}_f) = 0; \quad E = \frac{1}{2}mv_f^2$$

$$\frac{1}{2}mv_f^2 = mgh$$

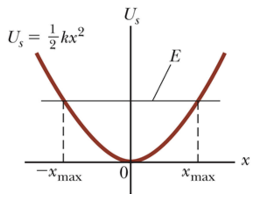
$$v_f = \sqrt{2gh} = \sqrt{2(9.8)(0.5)} = 3.13 \text{ m/s}$$

Energy diagram



Energy diagrams

$$E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$$



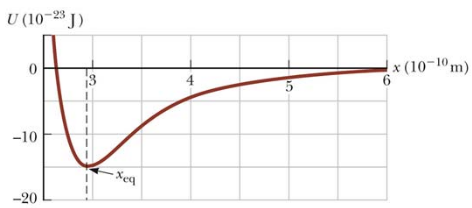
Note: when $x = x_{max}$:

$v = 0, \quad E = \frac{1}{2}\,kx_{max}^2$

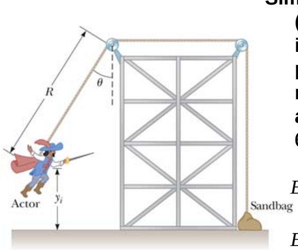
Note: when $x = 0$:

$U(0) = 0, \quad \frac{1}{2}mv^2 = \frac{1}{2}\,kx_{max}^2$

Example: Model potential energy function U(x) representing the attraction of two atoms



Example:



Simplified version:
(Assume that the sandbag is massive enough to provide the tension in the rope and R=3m.) If the actor starts at v_i=0 and θ=60°, what is v_f?

$$E = \frac{1}{2}mv_i^2 + mgy_i = mgR(1-\cos\theta)$$

0

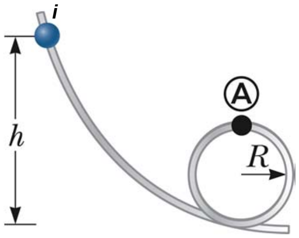
$$E = \frac{1}{2}mv_f^2 + mgy_f = \frac{1}{2}mv_f^2$$

0

$$v_f = \sqrt{2gy_i} = \sqrt{2(9.8)(3)(1-0.5)}$$

$$= 5.4\ \text{m/s}$$

Example: Mass sliding on frictionless looping track

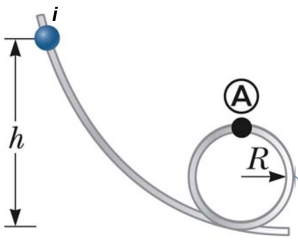


iclicker exercise:

In order for the ball completes the loop at A, what must the value of h?

- A. h=R
- B. h=2R
- C. h>2R
- D. Not enough information.

Example: Mass sliding on frictionless looping track



$$E = \frac{1}{2}mv_i^2 + mgh \quad (v_i^2 \to 0)$$

$$E = \frac{1}{2}mv_A^2 + mg(2R)$$

Condition for staying on track at A :

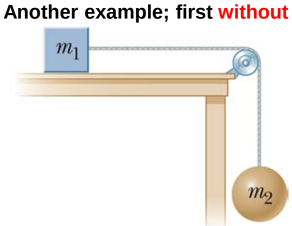
$$-n - mg = -m\frac{v_A^2}{R} \quad (n \to 0)$$

$$\Rightarrow \frac{1}{2}mv_A^2 = \frac{1}{2}mgR$$

$$E = mgh = \frac{1}{2}mv_A^2 + mg(2R) = \frac{1}{2}mgR + 2mgR = \frac{5}{2}mgR$$

$$\Rightarrow h = \frac{5}{2}R$$

Another example; first without friction



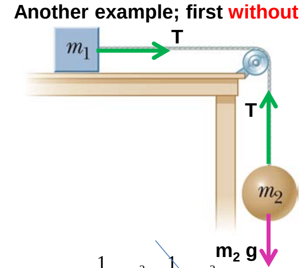
Mass m_1 (=0.2kg) slides horizontally on a frictionless table and is initially at rest. What is its velocity when it moves a distance Δx=0.1m (and m_2 (=0.3kg) falls Δy=0.1m)?

iclicker exercise:

What is the relationship of the final velocity of m_1 and m_2?

- A. They are equal
- B. m_2 is faster than m_1.
- C. m_1 is faster than m_2.

Another example; first without friction



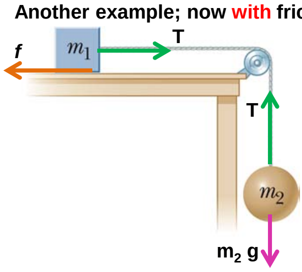
Mass m_1 (=0.2kg) slides horizontally on a frictionless table and is initially at rest. What is its velocity when it moves a distance Δx=0.1m (and m_2 (=0.3kg) falls Δy=0.1m)?

$$W = T\Delta x = \frac{1}{2}m_1 v_f^2 - \frac{1}{2}m_1 v_i^2 \quad (v_i \to 0)$$

$$v_f = \sqrt{\frac{2m_2 g\Delta x}{m_1+m_2}}$$

$$T = m_1 a$$
$$T - m_2 g = -m_2 a$$
$$\Rightarrow T = \frac{m_1 m_2}{m_1+m_2} g$$
$$W = T\Delta x = \frac{m_1 m_2}{m_1+m_2} g\Delta x$$

Another example; now with friction



Mass m_1 (=0.2kg) slides horizontally on a table with kinetic friction and is initially at rest. What is its velocity when it moves a distance Δx=0.1m (and m_2 (=0.3kg) falls Δy=0.1m)?

$$W = (T - f)\Delta x = \frac{1}{2}m_1 v_f^2 - \frac{1}{2}m_1 v_i^2 \quad (v_i \to 0)$$

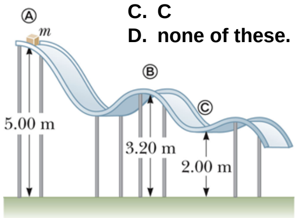
$$T - f = m_1 a$$
$$T - m_2 g = -m_2 a$$
$$\Rightarrow T = \frac{m_1 m_2}{m_1+m_2} g + \frac{m_2}{m_1+m_2} f$$
$$W = (T - f)\Delta x = \frac{m_1 m_2}{m_1+m_2} g\Delta x - \frac{m_1}{m_1+m_2} f\Delta x$$

$$W = (T - f)\Delta x = \frac{1}{2}m_1 v_f^2$$
$$v_f = \sqrt{\frac{2m_2 g\Delta x - 2f\Delta x}{m_1+m_2}}$$
$$f = \mu_k m_1 g$$

iclicker exercise:

Assume a mass m starts at rest at A and moves on the frictionless surface as shown. At what position is the speed the largest?

A. A
B. B
C. C
D. none of these.



Power

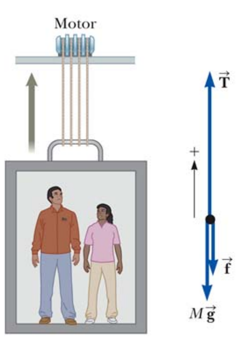
Defined as time rate of change of work:

$$P \equiv \frac{dW}{dt}$$

Note that: $dW = \mathbf{F} \cdot d\mathbf{r}$

$$\frac{dW}{dt} = \mathbf{F} \cdot \frac{d\mathbf{r}}{dt} = \mathbf{F} \cdot \mathbf{v}$$

Units: $P = \frac{\text{(Joules)}}{\text{(s)}} \equiv \text{Watt}$



Power exerted by motor:

$$P \equiv \frac{dW}{dt} = \mathbf{F} \cdot \mathbf{v} = Tv$$

For $T = 2 \times 10^4 N, \quad v = 3m/s$

$$P = (2 \times 10^4 N)(3m/s) = 6 \times 10^4 \text{Watts}$$