PHYS 1441 – Section 001
Lecture #13

Monday, July 6, 2015

Dr. Jaehoon Yu

- Elastic Potential Energy
- Mechanical Energy Conservation
- Power
- Linear Momentum
- Linear Momentum, Impulse and Forces
- Linear Momentum Conservation

Announcements

- Reading assignment: CH7.7
- Quiz #4
  - Beginning of the class Wednesday, July 8
  - Covers CH 6.4 to what we finish tomorrow
  - Bring your calculator but DO NOT input formula into it!
    - Your phones or portable computers are NOT allowed as a replacement!
  - You can prepare a one 8.5x11.5 sheet (front and back) of **handwritten** formulae and values of constants for the exam ➔ no solutions, derivations or definitions!
    - No additional formulae or values of constants will be provided!
- Bring your planetarium extra credit sheet by July 13
- Student survey
- Term 2 results
  - Class average: 60.6/106
    - Equivalent to: 57.2/100
    - Previous results: 64.1/100 and 62.4/100
  - Top score: 98/106

Reminder: Special Project #5

1. A ball of mass $\mathcal{M}$ at rest is dropped from the height h above the ground onto a spring on the ground, whose spring constant is k. Neglecting air resistance and assuming that the spring is in its equilibrium, express, in terms of the quantities given in this problem and the gravitational acceleration g, the distance x of which the spring is pressed down when the ball completely loses its energy. (10 points)
2. Find the x above if the ball's initial speed is v_i. (10 points)
3. Due for the project is this Wednesday, July 8
4. You must show the detail of your OWN work in order to obtain any credit.

Special Project #6

- Make a list of the ***rated power*** of all electric and electronic devices at your home and compiled them in a table. (2 points each for the first 10 items and 1 point for each additional item.)
  - What is an item?
    - Similar electric devices count as one item.
      - All light bulbs make up one item, computers another, refrigerators, TVs, dryers (hair and clothes), electric cooktops, heaters, microwave ovens, electric ovens, dishwashers, etc.
      - All you have to do is to count add all wattages of the light bulbs together as the power of the item
- Estimate the **cost of electricity** for each of the items (taking into account the number of hours you use the device) on the table using the electricity cost per kWh of the power company that serves you and put them in a separate column in the above table for each of the items. (2 points each for the first 10 items and 1 point each additional items). Clearly write down what the unit cost of the power is per kWh above the table.
- Estimate the the total amount of energy in Joules and the total electricity cost ***per month*** and ***per year*** for your home. (5 points)
- Due: Beginning of the class Monday, July 13

Special Project Spread Sheet

PHYS1441-001, Summer 15, Special Project #6

Download this spread sheet from URL: http://www-hep.uta.edu/~yu/teaching/summer15-1441-001/

Just click the file with the name: sp6-spreadsheet.xlsx

Write down at the top your name and the charge per kwh by your electricity company

Item Names	Rated power (W)	Number of devices	Average usage: Number of Hours per day	Daily			Monthly			Yearly		
				Power Consumption (kWh)	Energy Usage (J)	Energy cost ($)	Power Consumption (kWh)	Energy Usage (J)	Energy cost ($)	Power Consumption (kWh)	Energy Usage (J)	Energy cost ($)
Light Bulbs	30, 40, 60, 100, etc	40										
Heaters												
Fans												
Air Conditioner												
Fridgers, Freezers												
Computers												
Game consoles												
Total				0	0	0	0	0	0	0	0	0

Elastic Potential Energy

Potential energy given to an object by a spring or an object with elasticity in the system that consists of an object and the spring.

The force spring exerts on an object when it is distorted from its equilibrium by a distance x is

$$F_s = -kx$$

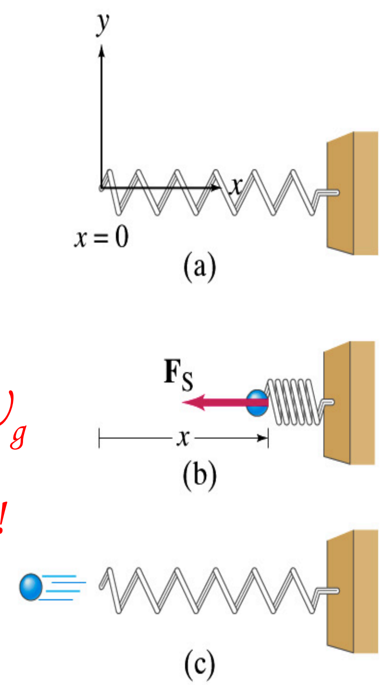
Hooke's Law

The work performed on the object by the spring is

$$W_s = \int_{x_i}^{x_f} (-kx)dx = \left[-\frac{1}{2}kx^2\right]_{x_i}^{x_f} = -\frac{1}{2}kx_f^2 + \frac{1}{2}kx_i^2 = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2$$

The potential energy of this system is

$$U_s \equiv \frac{1}{2}kx^2$$



What do you see from the above equations?

The work done on the object by the spring depends only on the initial and final position of the distorted spring.

Where else did you see this trend?

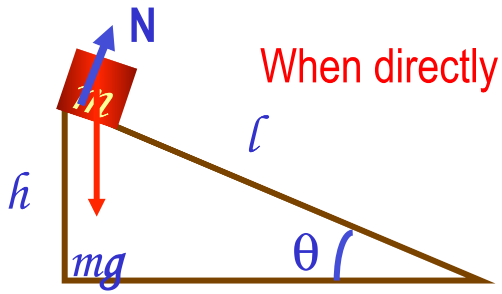
The gravitational potential energy, U_g

So what does this tell you about the elastic force?

A conservative force!!!

Conservative and Non-conservative Forces

The work done on an object by the gravitational force does not depend on the object's path in the absence of a retardation force.



When directly falls, the work done on the object by the gravitation force is $W_g = mgh$

When sliding down the hill of length l, the work is

$$W_g = F_{g-incline} \times l = mg\sin\theta \times l$$
$$= mg(l\sin\theta) = mgh$$

How about if we lengthen the incline by a factor of 2, keeping the height the same??

Still the same amount of work☺

$$\boxed{W_g = mgh}$$

So the work done by the gravitational force on an object is independent of the path of the object's motion. It only depends on the difference of the object's initial and final position in the direction of the force.

Forces like gravitational and elastic forces are called the conservative force

1. If the work performed by the force does not depend on the path.
2. If the work performed on a closed path is 0.

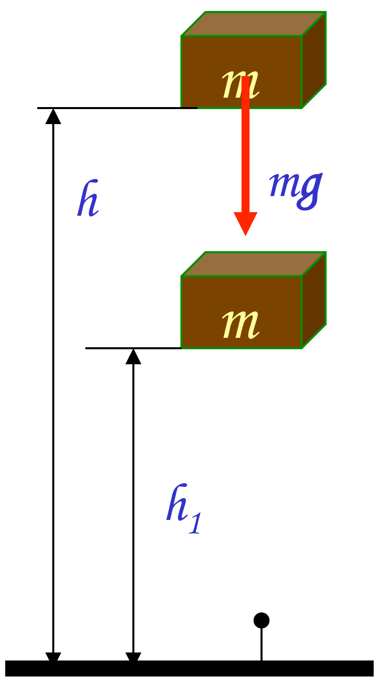
Total mechanical energy is conserved!!

$$\boxed{E_M \equiv KE_i + PE_i = KE_f + PE_f}$$

Conservation of Mechanical Energy

Total mechanical energy is the sum of kinetic and potential energies

$$E \equiv KE + PE$$



Let's consider a brick of mass *m* at the height *h* from the ground

What is the brick's potential energy?

$$PE = mgh$$

What happens to the energy as the brick falls to the ground?

$$\Delta PE = PE_f - PE_i = -Fs$$

The brick gains speed

By how much?

$$v = gt$$

So what?

The brick's kinetic energy increased

$$K = \frac{1}{2}mv^2 = \frac{1}{2}mg^2t^2$$

And?

The lost potential energy is converted to kinetic energy!!

What does this mean?

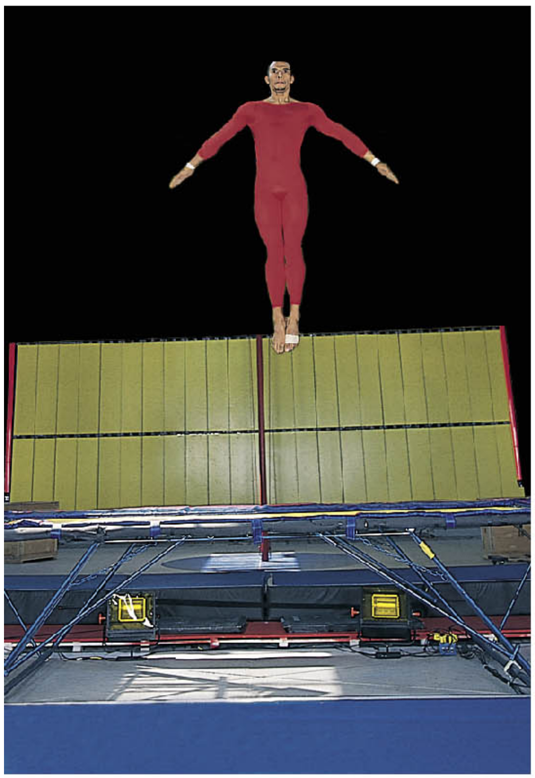
The total mechanical energy of a system remains constant in any isolated systems of objects that interacts only through conservative forces: ***Principle of mechanical energy conservation***

$$E_i = E_f$$

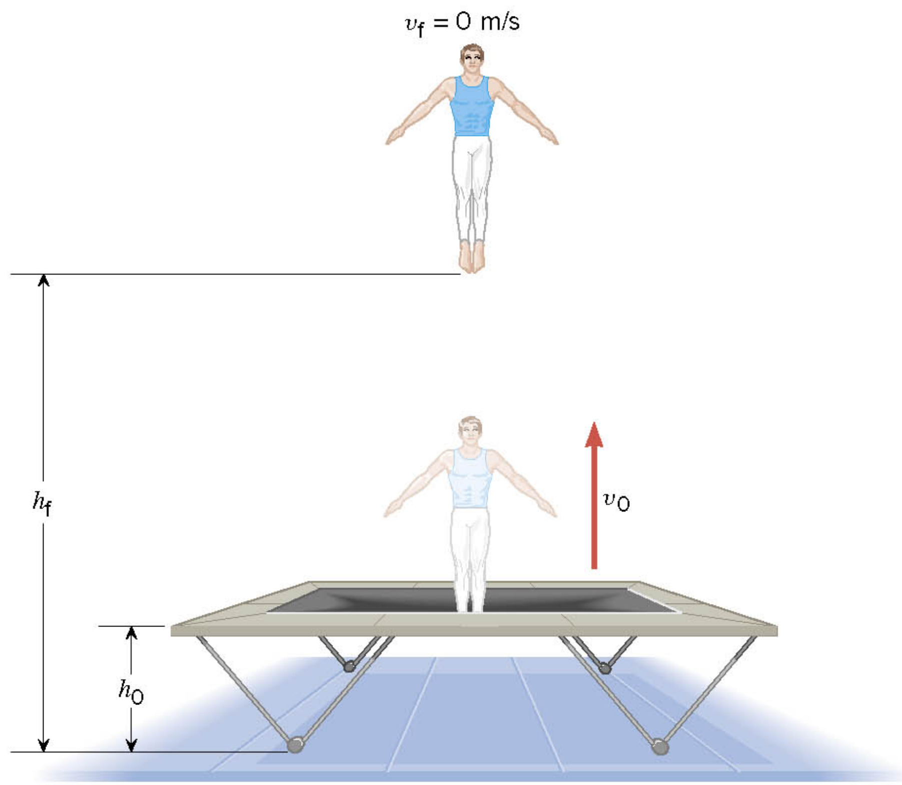
$$KE_i + \sum PE_i = KE_f + \sum PE_f$$

Ex. A Gymnast on a Trampoline

A gymnast leaves the trampoline at an initial height of 1.20 m and reaches a maximum height of 4.80 m before falling back down. What was the initial speed of the gymnast?



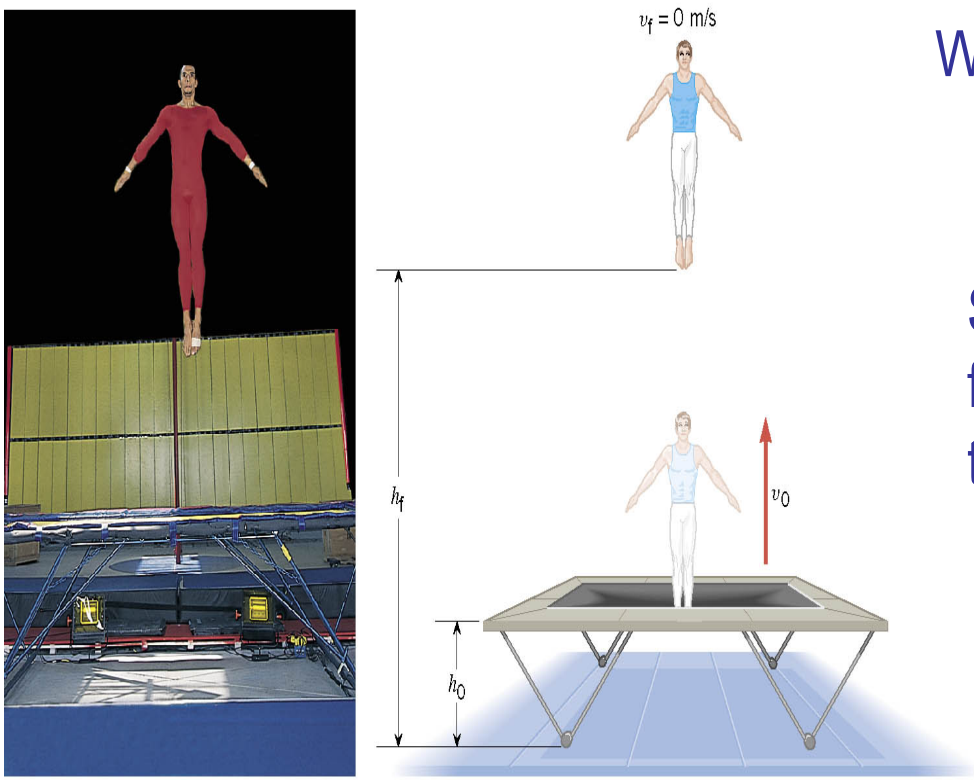
(a)



(b)

Ex. Continued

From the work-kinetic energy theorem $$W = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_o^2$$



(a) (b)

Work done by the gravitational force

$$W_{\text{gravity}} = mg\left(h_o - h_f\right)$$

Since at the maximum height, the final speed is 0. Using work-KE theorem, we obtain

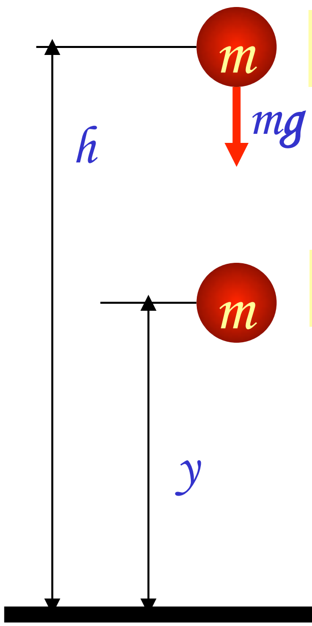
$$\cancel{m}g\left(h_o - h_f\right) = -\tfrac{1}{2}\cancel{m}v_o^2$$

$$v_o = \sqrt{-2g\left(h_o - h_f\right)}$$

$$\therefore v_o = \sqrt{-2\left(9.80\,\mathrm{m/s^2}\right)\left(1.20\ \mathrm{m} - 4.80\ \mathrm{m}\right)} = 8.40\,\mathrm{m/s}$$

Example

A ball of mass m at rest is dropped from the height h above the ground. a) Neglecting the air resistance, determine the speed of the ball when it is at the height y above the ground.



PE	KE	
mgh	0	$mv_i^2/2$
mgy	$mv^2/2$	$mv_f^2/2$
0		

Using the principle of mechanical energy conservation

$$K_i + PE_i = K_f + PE_f$$

$$0 + mgh = \frac{1}{2}mv^2 + mgy$$

$$\frac{1}{2}mv^2 = mg(h-y)$$

$$\therefore v = \sqrt{2g(h-y)}$$

b) Determine the speed of the ball at y if it had initial speed v_i at the time of the release at the original height h.

Again using the principle of mechanical energy conservation but with non-zero initial kinetic energy!!!

$$K_i + PE_i = K_f + PE_f$$

$$\frac{1}{2}mv_i^2 + mgh = \frac{1}{2}mv_f^2 + mgy$$

$$\frac{1}{2}m\left(v_f^2 - v_i^2\right) = mg(h-y)$$

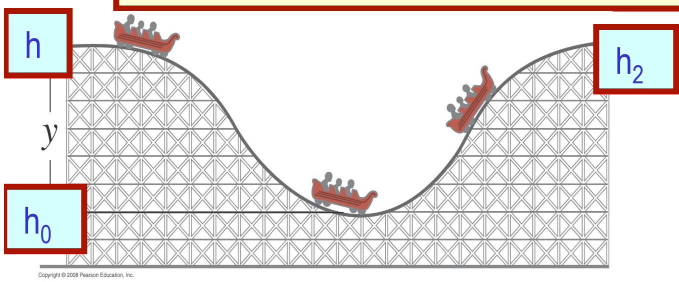
$$\therefore v_f = \sqrt{v_i^2 + 2g(h-y)}$$

This result look very similar to a kinematic expression, doesn't it? Which one is it?

Ex. 6 – 8

Assuming the height of the hill in the figure is 40m, and the roller-coaster car starts from rest at the top, calculate (a) the speed if the roller coaster car at the bottom of the hill.

Using mechanical energy conservation



$$K_i + PE_i = K_f + PE_f = \ 0 + mgh \ = \frac{1}{2}mv^2 + mgh_0$$

$$\frac{1}{2}mv^2 = mg\left(h - h_0\right)$$

$$\therefore v = \sqrt{2g\left(h - h_0\right)} = \sqrt{2 \cdot 9.8 \cdot 40} = 28\left(m/s\right)$$

b) Determine at what height (h2) of the second hill it will have half the speed at the bottom?

Again using the principle of mechanical energy conservation but with non-zero initial kinetic energy!!!

$$K_i + PE_i = K_f + PE_f$$

$$\frac{1}{2}mv_i^2 + mgh_0 \quad = \frac{1}{2}mv_f^2 + mgh_2$$

Reorganize the terms

$$mg\left(h_2 - h_0\right) = \frac{1}{2}mv_i^2 - \frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 - \frac{1}{2}m\left(\frac{1}{2}v_i\right)^2 = \frac{3}{8}mv_i^2 \Rightarrow$$

Solving for h_2-h_0

$$h_2 - h_0 = \ \frac{3}{8}\frac{v_i^2}{g} = \frac{3}{8}\frac{\left(28\right)^2}{9.8} = 30m$$

Power

- Rate at which the work is done or the energy is transferred
  - What is the difference for the same car with two different engines (4 cylinder and 8 cylinder) climbing the same hill?
  - ➔ The time… 8 cylinder car climbs up the hill faster!

Is the total amount of work done by the engines different? NO

Then what is different? The rate at which the same amount of work performed is higher for 8 cylinders than 4.

Average power
$$\boxed{\overline{P} \equiv \frac{\Delta W}{\Delta t} = \frac{Fs}{\Delta t} = F\frac{s}{\Delta t} = F\,\overline{v}}$$
Scalar quantity

Unit? $\boxed{J/s = Watts}$ $\boxed{1HP \equiv 746Watts}$

What do power companies sell? $1kWH = 1000Watts \times 3600s = 3.6\times10^{6}J$

Energy

Energy Loss in Automobile

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

Why?

67% in the engine:
- Incomplete burning
- Heat
- Sound

16% in friction with the road, air

4% in operating other crucial parts such as water pumps, alternator, etc

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

Two frictional forces involved in moving vehicles

$m_{car} = 1450kg \quad Weight = mg = 14200N$

Coefficient of Rolling Friction; μ=0.016

$\mu n = \mu mg = 227N$

Air Drag

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

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

$P_r = f_r v = (227) \cdot 26.8 = 6.08kW$

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

Human Metabolic Rates

Activity	Rate (watts)
Running (15 km/h)	1340 W
Skiing	1050 W
Biking	530 W
Walking (5 km/h)	280 W
Sleeping	77 W

[a]For a young 70-kg male.

Ex. The Power to Accelerate a Car

A 1.10×10^3kg car, starting from rest, accelerates for 5.00s. The magnitude of the acceleration is $a=4.60m/s^2$. Determine the average power generated by the net force that accelerates the vehicle.

What is the force that accelerates the car?

$$F = ma = \left(1.10\times10^3\right)\cdot\left(4.60\,m/s^2\right) = 5060\,N$$

Since the acceleration is constant, we obtain

$$\bar{v} = \frac{v_0 + v_f}{2} = \frac{0 + v_f}{2} = \frac{v_f}{2}$$

From the kinematic formula

$$v_f = v_0 + at = 0 + \left(4.60\,m/s^2\right)\cdot\left(5.00s\right) = 23.0\,m/s$$

Thus, the average speed is

$$\frac{v_f}{2} = \frac{23.0}{2} = 11.5\,m/s$$

And, the average power is

$$\bar{P} = F\bar{v} = \left(5060\,N\right)\cdot\left(11.5\,m/s\right) = 5.82\times10^4\,W$$
$$= 78.0hp$$