PHYSICS 231

INTRODUCTORY PHYSICS I

Lecture 7
Last Lecture

- Work
  
  $$W = \vec{F} \cdot (\vec{x}_f - \vec{x}_i)$$
  
  $= F \Delta x \cos \theta$

- Kinetic Energy
  
  $$KE = \frac{1}{2} mv^2$$

- Work-Energy Theorem
  
  $$KE_f - KE_i = W_{net}$$

- Potential Energy of gravity
  
  $$\Delta PE = mgh$$

- Conservation of Energy
  
  $$PE_f + KE_f = PE_i + KE_i$$
  
  $$\Delta KE = -\Delta PE$$
Work and PE for nonconstant force

\[ \Delta W = F_x \Delta x \]

Work = \[ \sum F_x \Delta x \]

= Area under curve

= \(-\Delta PE\)
Springs (Hooke’s Law)

\[ F = -kx \]

Proportional to displacement from equilibrium
Potential Energy of Spring

\[ F_{\text{app}} = -F_{\text{spring}} = kx \]

\[ \Delta PE = \text{Area under curve} \]

\[ = (1/2)\text{(base)}(\text{height}) \]

\[ = (1/2)(F_{\text{max}})(x_{\text{max}}) \]

\[ = (1/2)(kx)(x) \]

\[ PE = \frac{1}{2} kx^2 \]
Example 5.7a

A 0.50-kg block rests on a horizontal, frictionless surface as in the figure; it is pressed against a light spring by a force of 16 N, with an initial compression of 2.0 cm.

a) What is the spring constant?

800 N/m
Example 5.7b

A 0.50-kg block rests on a horizontal, frictionless surface as in the figure; it is pressed against a light spring by a force of 16 N, with an initial compression of 2.0 cm.

b) The block is released. To what height $h$ does it rise when moving up the incline?

3.3 cm
Example 5.7c

A 0.50-kg block rests on a horizontal, frictionless surface as in the figure; it is pressed against a light spring by a force of 16 N, with an initial compression of 2.0 cm.

c) What was the speed of the block at B, after it left the spring but before going up the incline?

0.8 m/s
Example 5.7d

A 0.50-kg block rests on a horizontal, frictionless surface as in the figure; it is pressed against a light spring by a force of 16 N, with an initial compression of 2.0 cm.

d) If I double the mass, the speed at B will change by a factor of:

A) unchanged  B) 2  C) 1/2
D) 1/sqrt(2)  E) 1/4
Power

- Power is rate of energy transfer
  \[ P = \frac{W}{t} \]

- SI units are Watts (W)
  \[ 1 \text{ W} = 1 \text{ J/s} = 1 \text{ kg} \frac{m^2}{s^3} \]

- US Customary units are hp (horse power)
  \[ 1 \text{ hp} = 550 \text{ ft} \cdot \text{lb/s} = 746 \text{ W} \]
Example 5.10

An elevator of mass 550 kg and a counterweight of 700 kg lifts 23 drunken 80-kg students to the 7th floor of a dormitory 30 meters off the ground in 12 seconds. What is the power required? (in both W and hp)

41 kW = 55 hp
Example 5.11

A 1967 Corvette has a weight of 3020 lbs. The 427 cu-in engine was rated at 435 hp at 5400 rpm.

a) If the engine used all 435 hp at 100% efficiency during acceleration, what speed would the car attain after 6 seconds?

b) What is the average acceleration? (in “g”s)

a) 120 mph  b) 0.91g
Power: Force and velocity

\[ P = \frac{\Delta W}{\Delta t} = \frac{F \Delta x}{\Delta t} \]

\[ P = Fv \]

For the same force, power is higher for higher \( v \)
Example 5.12

Consider the Corvette (w=3020 lbs) having constant acceleration of $a=0.91g$

a) What is the power when $v=10$ mph?

b) What is the power output when $v=100$ mph?

a) 73.1 hp  

b) 732 hp  

(in real world $a$ is larger at low $v$)
Example 5.13

A physics professor bicycles through air at a speed of \( v = 36 \text{ km/hr} \). The density of air is 1.29 kg/m\(^3\). The professor has cross section of 0.5 m\(^2\). Assume all of the air the professor sweeps out is accelerated to \( v \).

a) What is the mass of the air swept out by the professor in one second?

b) What is the power required to accelerate this air?

\[ \text{a) 6.45 kg} \quad \text{b) 323 W = 0.432 hp} \]
Since mass swept out is proportional to $v$, and $KE \sim .5mv^2$, Power scales as $v^3$!

If one goes from 35 km/hr to 50 km/hr, power required would rise by 2.91.

Aerodynamics is important!
Example 5.14

A professional cyclist maintains an average of 420 W over a race lasting 4 hours.

If the cyclist has an efficiency of 20%, how many kilocalories will he burn during the race?
DATA: 1 kcal=4187 J

7222 kcal
Ergometer Demo
Example 5.15

A dam wishes to produce 50 MW of power. If the height of the dam is 75 m, what flow of water is required? (in m$^3$/s)

\[ 68.9 \text{ m}^3/\text{s} = 1.80 \times 10^4 \text{ gallons/s} \]
Example 5.16

How much money does it cost to run a 100-W light bulb for one year if the cost of electricity is 8.0 cents/kW⋅hr?

$70.08
Some energy facts
http://css.snre.umich.edu

• US consumes 24% of Worlds energy (5% of population)
• Each day, each of us consumes:
  • 3 gallons of oil
  • 20 lbs of coal
  • 221 cubic feet of natural gas
• In 2000 the US consumed $9.9 \times 10^{16}$ BTUs

1 BTU is energy required to raise 1 lb of $H_2O$ 1 degree F
1BTU = 1055 J
“Rest” energy

\[ E = mc^2 \]

\( c \) is velocity of light

For small velocities,

\[ E = mc^2 + \frac{1}{2}mv^2 \]

For any \( v \),

\[ E = mc^2 \sqrt{1 - \frac{v^2}{c^2}} \]
Example 5.17

Suppose one had a supply of anti-matter which one could mix with matter to produce energy. What mass of antimatter would be required to satisfy the U.S. energy consumption in 2000? (9.9x10^{16} \text{ BTUs})

574 kg