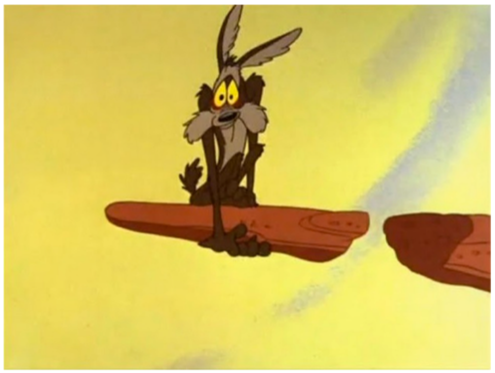
Physics 101: Lecture 10
Potential Energy & Energy Conservation

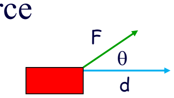


Announcements

- Please get your honors credit learning agreements to me before exam 1!
- Formula sheet has been posted on the class home page.
- I will do an exam review session here (Loomis 151) on **Monday February 19 7pm+.** Bring problems & questions. I will go over the spring 2017 exam.

Review

- Work: Transfer of Energy by Force
  - $W_F = F\ d\cos\theta$



- Kinetic Energy (Energy of Motion)
  - $K = \frac{1}{2} mv^2$
- Work-Kinetic Energy Theorem:
  - $W_{Net} = \Delta K$ (work done ON object by $= K_f - K_i$ all forces = change in kinetic energy)

Today:

- Potential (Stored) Energy: U

Work Done by Gravity 1

- Example 1: Drop ball

$W_g = Fd\cos\theta$

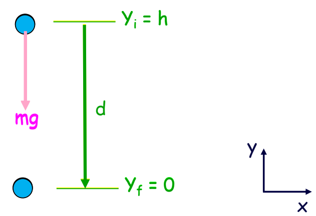
$W_g = (mg)(d)\cos\theta$

$d = h$

$W_g = mgh\cos(0^0) = mgh$

$\Delta y = y_f - y_i = -h$

$\boxed{W_g = -mg\Delta y}$



Note: This work is positive overall

Work Done by Gravity 2

- Example 2: Toss ball up

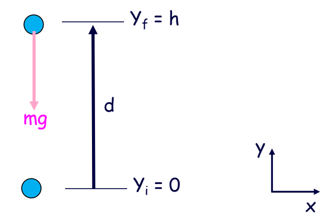
$W_g = (mg)(d)\cos\theta$

$d = h$

$W_g = mgh\cos(180^0) = -mgh$

$\Delta y = y_f - y_i = +h$

$\boxed{W_g = -mg\Delta y}$



Note: This work is negative overall

Work Done by Gravity 3

A) W>0 B) W=0 C) W<0

- Example 3: Slide block down incline

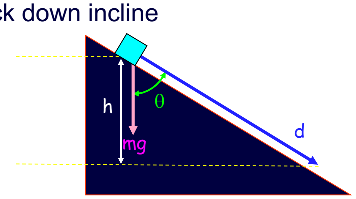
$W_g = (mg)(d)\cos\theta$

$d\cos\theta = h$

$W_g = mgh$

$\Delta y = y_f - y_i = -h$

$\boxed{W_g = -mg\Delta y}$



The same value all three cases!!!
Boxed Eqn has same form

Work and Potential Energy

- Work done by gravity is ***independent of path***
  - $W_g = -m\,g\,(y_f - y_i) = -mg\Delta y$
- True for any CONSERVATIVE force, like gravitation and springs, (all others non-cons.)
- Define potential energy $U_g = m\,g\,y$
  $W_{cons} = -\Delta U = -(U_f - U_i) = -(m\,g\,y_f - m\,g\,y_i)$
- Work-Energy theorem
  $W_{net} = W_{cons} + W_{nc} = \Delta K$
  $W_{nc} = \Delta K - W_{cons} = \Delta K + \Delta U$

Work done by non-conservative forces **(e.g., frictional force)**

How gravitational potential energy and work done by gravity "works"

Example: You raise a brick of mass M from the floor to a height H.

Work done by gravity is: $-MgH$

(F is down and "d=H" is up so angle is 180º, so

$W_g = (Mg)d\cos 180^o = -MgH$)

Change in potential energy is $Mg(h_f - h_i) = MgH$

So… $W = -\Delta U$.

NOTE: Your hand does positive work of MgH

What if we lower the brick from H to the floor?

Energy Conservation

$W_{nc} = \Delta K + \Delta U = \Delta(K + U) = \Delta E$

We define the MECHANICAL energy, E, as the sum of kinetic and potential energies:

$E = K + U$

<u>If there is no work done by non-conservative forces</u>, then $W_{nc} = \Delta E = 0$

which means the TOTAL mechanical energy does not change. That is, E is CONSERVED.

$E_i = E_f$

Skiing Example (no friction)

A skier goes down a 78 meter high hill with a variety of slopes. What is the maximum speed she can obtain if she starts from rest at the top?

No friction => Conserve mechanical Energy!

Total Energy Before:

$E_i = K_i + U_i = \frac{1}{2} mv_i^2 + mgy_i = mgy_i$

Total Energy After:

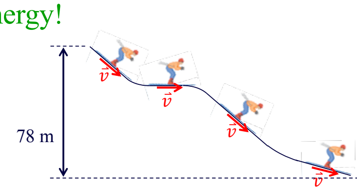
$E_f = K_f + U_f = \frac{1}{2} mv_f^2 + mgy_f = \frac{1}{2} mv_f^2$

Conserve Total Mechanical Energy!

$E_i = E_f$

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

$v_f = \text{sqrt}(2gy) = 39$ m/s



Pendulum Demo

Conservation of Energy ($E_0 = E_f$)

Total Energy Before:

$E_i = K_i + U_i = mgy_0$

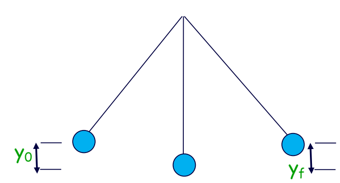
Total Energy After:

$E_f = K_f + U_f = mgy_f$

Conserve Total Mechanical Energy!

$E_i = E_f$ $\quad mgy_0 = mgy_f$

$y_f = y_0$



Potential energy stored in springs

The spring force is conservative, and so work done by springs can be written as the negative change in potential energy:

$$W_{spring} = -\Delta U_{spring}$$

The potential energy stored in a spring that is compressed a distance *d*, or stretched a distance *d*, is given by:

$$U_{spring} = \tfrac{1}{2} kd^2$$

Skiing w/ Friction

A 50 kg skier goes down a 78 meter high hill with a variety of slopes. She finally stops at the bottom of the hill. If friction is the force responsible for her stopping, how much work does it do?

Total Energy changes when friction is present!
(friction is NONCONSERVATIVE)

Total Energy Before:

$E_i = K_i + U_i = mgy_i$

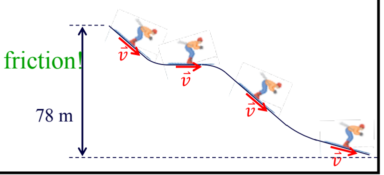
Total Energy After:

$E_f = K_f + U_f = 0$

Change in Energy is work done by friction!

$W_{nc} = \Delta E = 0 - mgy_i$

$= -38200$ Joules



Power (Rate of Work)

- $P = W / \Delta t$
  - Units: Joules/Second = Watt
- How much power does it take for a (70 kg) student to run up the stairs in 141 Loomis (5 meters) in 7 sec?

$P = W / t$

$= m g h / t$

$= (70 \text{ kg}) (9.8 \text{ m/s}^2) (5 \text{ m}) / 7 \text{ s}$

$= 490$ J/s or 490 Watts

Example

A block of mass M slides on a frictionless ramp from a height H, then enters a rough horizontal region, then compresses a spring having spring constant k a distance D. How much work was done by kinetic friction in terms of M, k, D, and H?

Big Idea: Apply the Work-Kinetic Energy Thm

Justification: W-KE Thm relates work to KE and Pot. E, and the last two are related to M, k, D & H

Plan: 1) Apply W-KE Thm: $W_{nc} = \Delta E$

2) Friction is only non-conservative force doing work, $W_{nc}=W_{fric}$

3) For right-hand-side, write down E=K+U in final and initial states and subtract them; in initial state there is only gravitational U. In final state there is only spring U.

$$W_{fric} = E_f - E_i$$
$$= (K_f + U_f) - (K_i + U_i) = U_{spring,f} - U_{grav,i}$$
$$= (1/2)kD^2 - MgH$$

Summary

- Conservative Forces
  - » Work is independent of path
  - » Define Potential Energy U
    - $U_{gravity} = m g y$
    - $U_{spring} = ½ k x^2$
- Work – Energy Theorem

$$W_{nc} = \Delta E = \Delta(K + U)$$
$$= \Delta K + \Delta U$$
$$W_{nc} + W_{cons} = W_{tot} = \Delta K$$

- Power: $P = W / \Delta t$