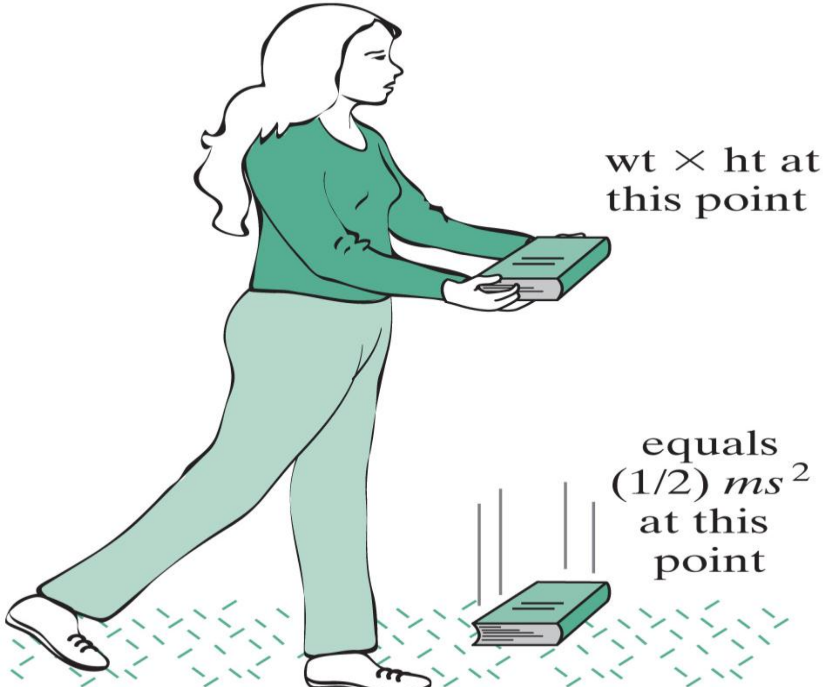
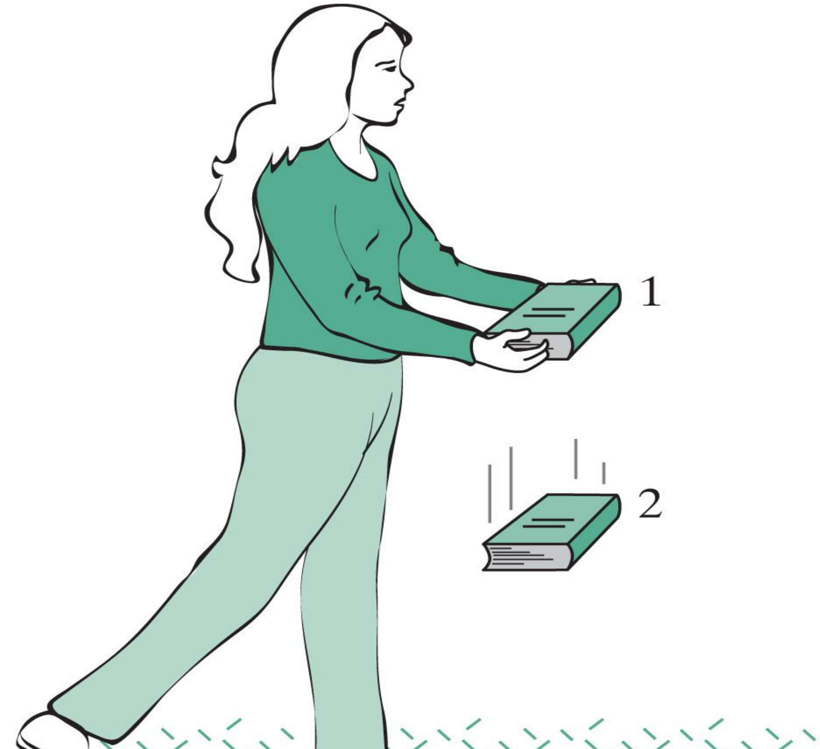
Chapter 6: Work, Energy (incl. conservation), Power

Outline of today's class (apart from quizzes):

Review physics concepts of work and energy
More examples of E conservation & transformations
Different forms of energy
Work – Energy theorem
Power





Remarkable fact (provable from Newton's Laws & experimentally testable, neglecting air resistance, dropped from rest):

$$mgh = (1/2)\, mv^2_{bottom}$$

<u>Note</u>:

This is <u>Energy Conservation</u> in the sense that $E_{total} = E_{grav} + E_{kin} = \text{const.}$!

But also <u>Energy Transformation</u> !

h is just the vertical displacement top to bottom (which is the reference point), regardless of where h is relative to the ground.

m drops out of the above equation! What then what does v depend on, only?

Remember hammer & feather on moon?

CONCEPT CHECK 7 How much kinetic energy does a car have when it moves at 100 km/hr, as compared with when it moves at 50 km/hr? (a) The same amount. (b) One-half as much. (c) One-fourth as much. (d) Twice as much. (e) Four times as much.

CONCEPT CHECK 8 A bag of groceries having a mass of 6 kg and a weight of 60 N falls from a shelf that is 2 m high. Just as it begins to fall, its gravitational energy (relative to the floor) is (a) zero; (b) 12 J; (c) 120 J; (d) none of the above.

CONCEPT CHECK 9 Refer to the preceding question. Neglecting air resistance, just before hitting the floor the bag of groceries' gravitational energy and kinetic energy are (a) both zero; (b) zero and 120 J, respectively; (c) 120 J and zero, respectively; (d) both 120 J; (e) none of the above.

Worth remembering:

Any system having the capacity to do W(ork) has E(nergy).

Both W & E measured in J(oules), but not the same thing!

A system *does* W, but it *has* E.

W refers to a process, whereas E is a property of a system.

Think of E as stored W.

A system's E is the amount of W the system *could* do, whether it does or not.

C.E. 16 A: most direct would be to measure m, a, and distance d.
Then $W = F \times d = m \times a \times d$.
Easier: measure m and v, then $W = E_{kin}$ increase $= .5mv^2$
Example of "work – energy theorem".

Quiz # 38: You slam on your car's brakes, sliding 40 m with locked brakes. How far would you slide if you were moving half as fast?
(a) 20 m (b) 10 m (c) 5 m (d) 40 m
Hint: E_{kin} of the car has to do work against $F_{friction}$ here.

Follow-on question: What is E_{kin} transformed into in this case?

C.E. 18 (a) 1,000 km high (b) increased

(c) At 6,000 km, even though its $E_{gravity}$ is larger at 12,000 km.
(important to fully understand every part of this exercise)

Multitude of various forms of energy:

Kinetic – (*macroscopic*) motion, speed-dependent
Gravitational (potential) – relative to a reference level (important)
Elastic – rubber band, spring, etc.
Thermal – a.k.a. heat, an "*internal*" energy, really *microscopic kinetic energy of atoms & molecules* (chapter 2!), of particular importance in many practical situations (see chapter 7)
Electromagnetic – related to electric & magnetic forces, electric charges (static & in motion), see chapter 8
Radiant – "electromagnetic" radiation, which includes visible light, radio, microwaves, infrared, ultraviolet, X-rays, and gamma-rays
Chemical – atomic or molecular structure & changes therein – important energy source for/in your body!
Nuclear – related to nuclear structure & changes therein

Give some examples of a system that has both E_{kin} & $E_{gravity}$

C.E. 29 & 30

Quiz # 39: A 1000 kg automobile moving at 10 m/s crashes into a brick wall. The amount of energy going into demolishing and warming up the wall and auto is

(a) 50,000 J
(b) 50,000 N
(c) 10,000 J
(d) 10^5 J
(e) 1000 N

The Law of Conservation of Energy

The total energy of all the participants in any process remains unchanged throughout that process. That is, energy cannot be created or destroyed. Energy can be transformed (changed from one form to another), and it can be transferred (moved from one place to another), but the total amount always stays the same.

We’ve never seen violation of energy conservation in any physical process!

Important: E can be transformed or transferred, but *not created, nor destroyed!* E conservation is a very powerful symmetry principle. As it turns out, it is a consequence of the fundamental laws of physics being the same at different times.

→ “Life is a constant struggle to gather and use/transform energy!”

The Work-Energy Principle

Work is an energy transfer. Work reduces the energy of the system doing the work and increases the energy of the system on which work is done, both by an amount equal to the work done.[5]

Re-visit roller coaster – great example of E-transformation and E-conservation

Quiz # 40: Let's ignore rolling friction and air resistance. A ball approaches a 6 m high hill with a speed of 10 m/s. Will the ball clear the hill, i.e. roll over it?

(a) Mass of the ball needs to be known in order to answer.
(b) Sure, why not.
(c) No, it will come to rest at the very top of the hill.
(d) No, not enough energy to make it to the top.

Quiz # 41: Between the starting point and the end point (you're at rest at both points), what (major) E transformation occurs when you climb a rope?

(a) chemical → gravitational
(b) kinetic → gravitational
(c) gravitational → kinetic
(d) chemical → thermal
(e) kinetic → thermal

C.E. 33:
(a) Same since E of the ball is unchanged.
(b) Lower final speed, ball lost some E into warming the surrounding air.

The subatomic particle called "*neutrino*" and the closest the physics community ever came to giving up E conservation (the story of page 126, a bit expanded):

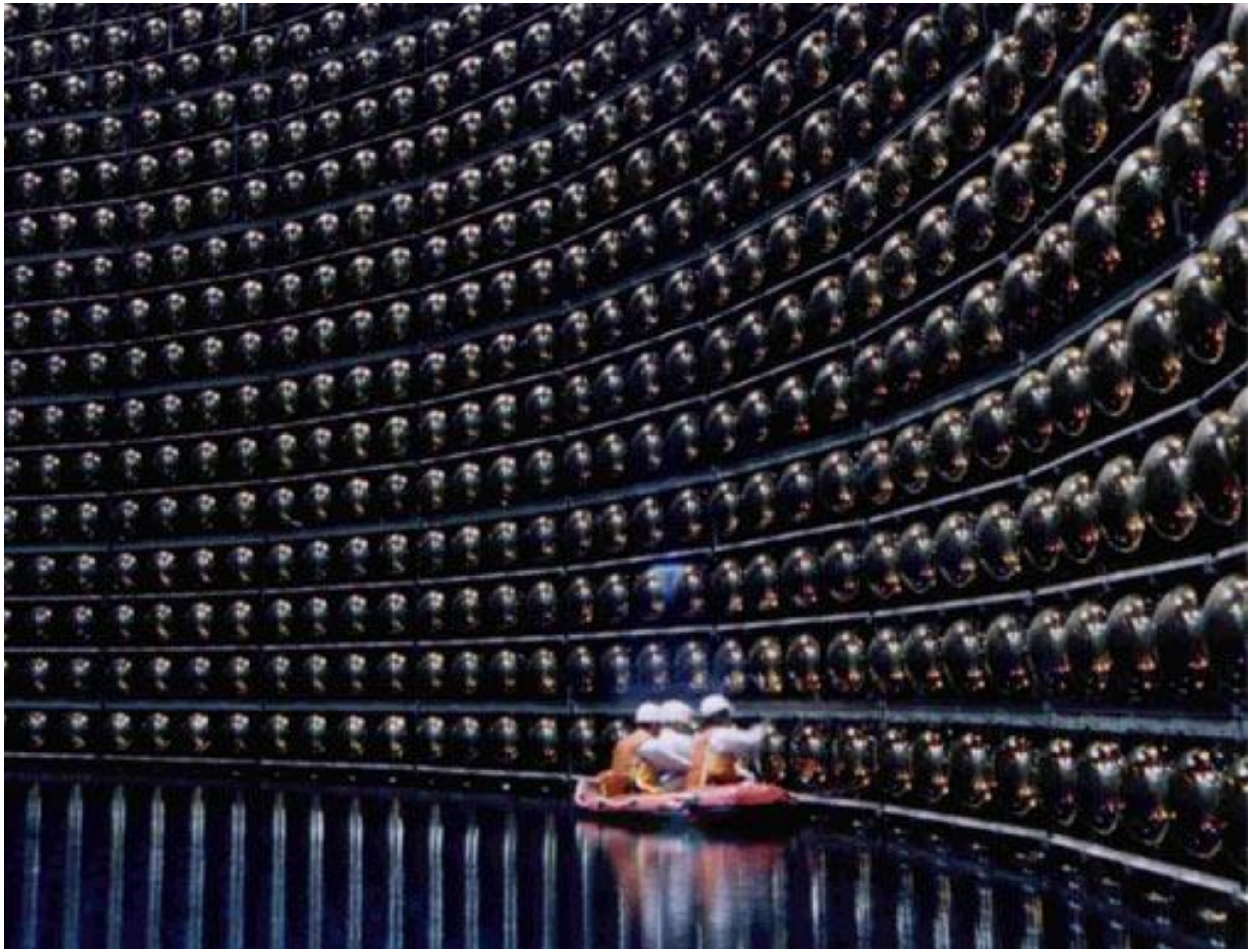
Nuclear beta (β) decay, a kind of "radioactive" decay is effectively the transmutation or decay (inside of an atomic nucleus) of a neutron into a proton and an electron: $n \rightarrow p + e^-$

BUT the energetics didn't work out, the e^- always came away with too little E_{kin}. This went on for over 15 years!

Until Wolfgang Pauli hypothesized a hitherto unknown & undetected particle, also emitted, but not easily detected – dubbed "neutrino". What's really happening: $n \rightarrow p + e^- + \nu_e$, and the ν carries away some of the available energy, thereby restoring E conservation.

Took some 26 years (!) to experimentally detect neutrinos!

To this day detecting neutrinos remains a challenge, witness the so-called Super-Kamiokande detector in Japan:
~40 m diameter by ~40 m high tank with 50,000 tons of water
~13,000 light detectors (PMTs) on the perimeter, 1 km underground



Note the importance of E transformations & E flow: if you look closely, almost every process can be described in such terms.

Good example: automobile….let’s discuss…

Dropping an object, which then comes to rest: