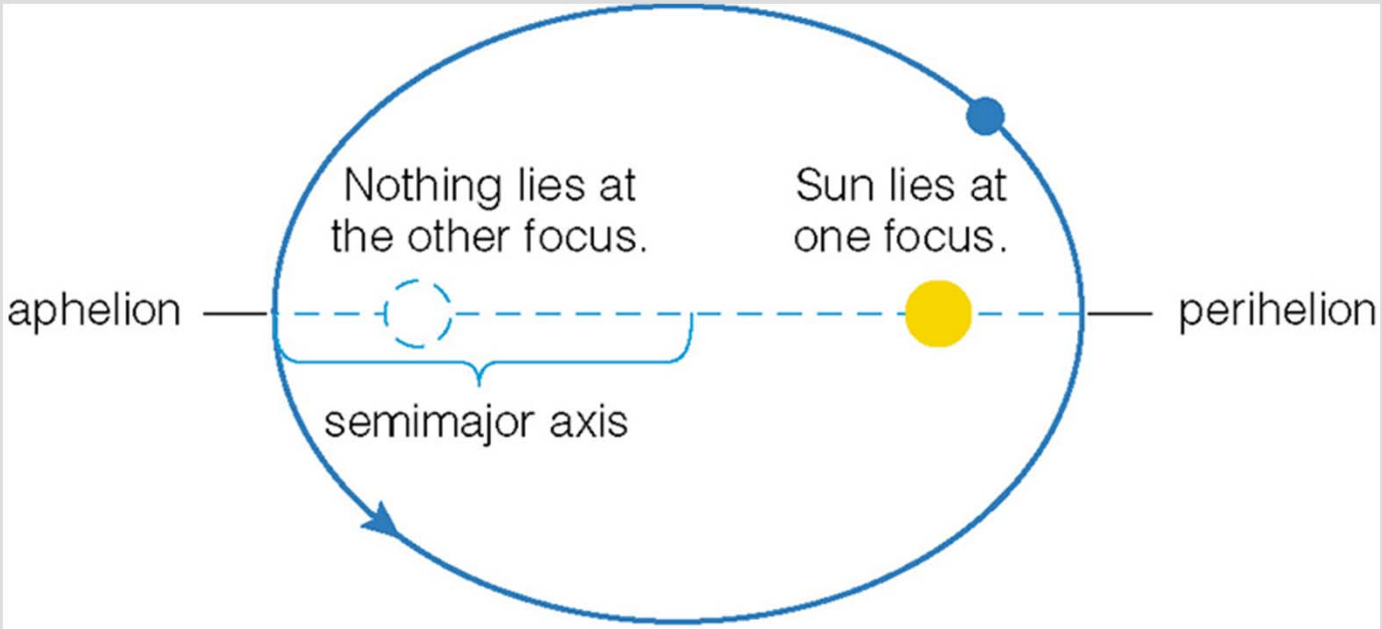
Lecture: September 22, 2010

- How many one dollar bills would it take to make a stack so high it reached the Moon?
- How does this compare to the national debt?

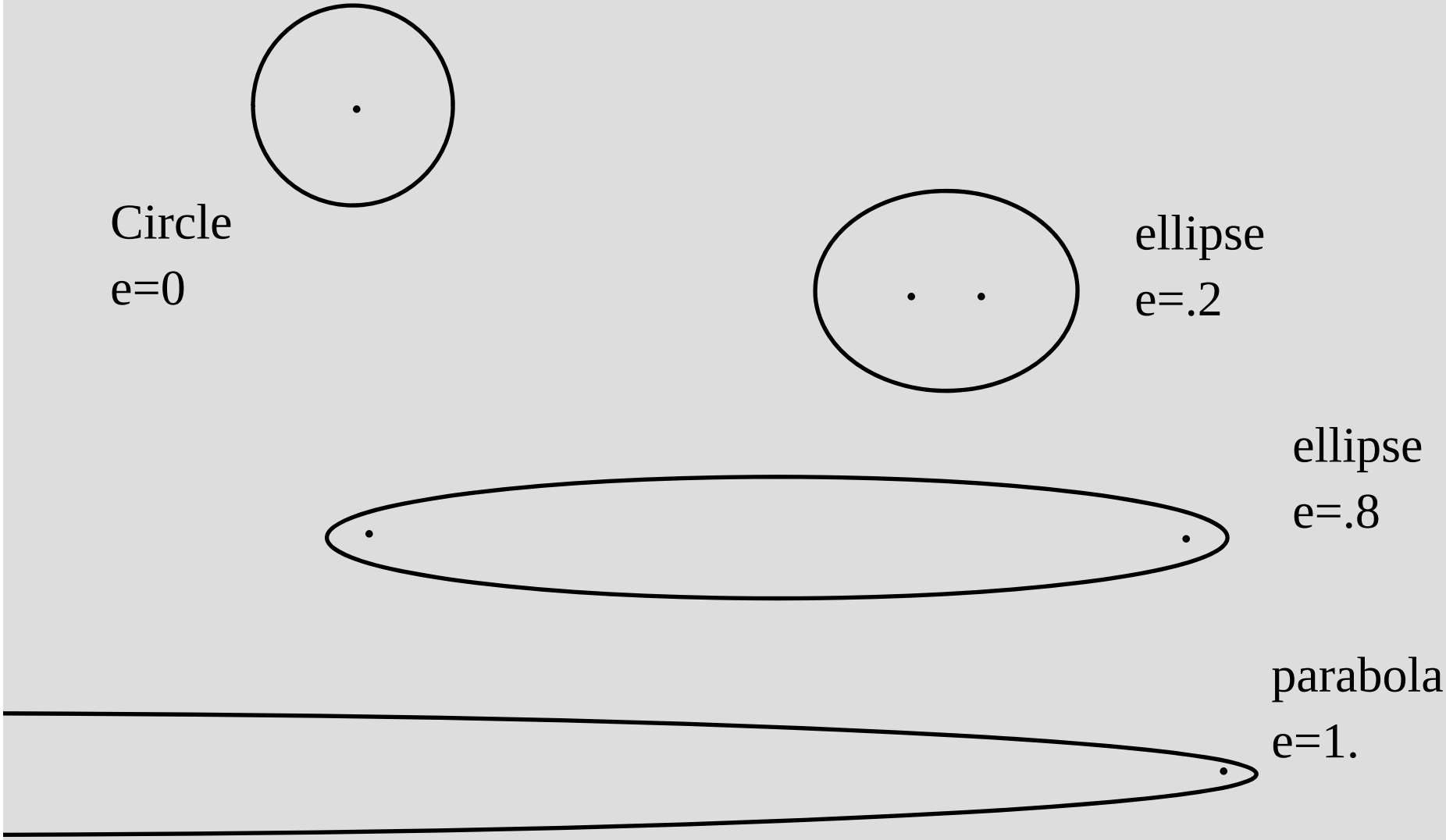
Announcements:

Kepler's Laws

1 Each planet's orbit around the Sun is an ellipse, with the Sun at one focus.

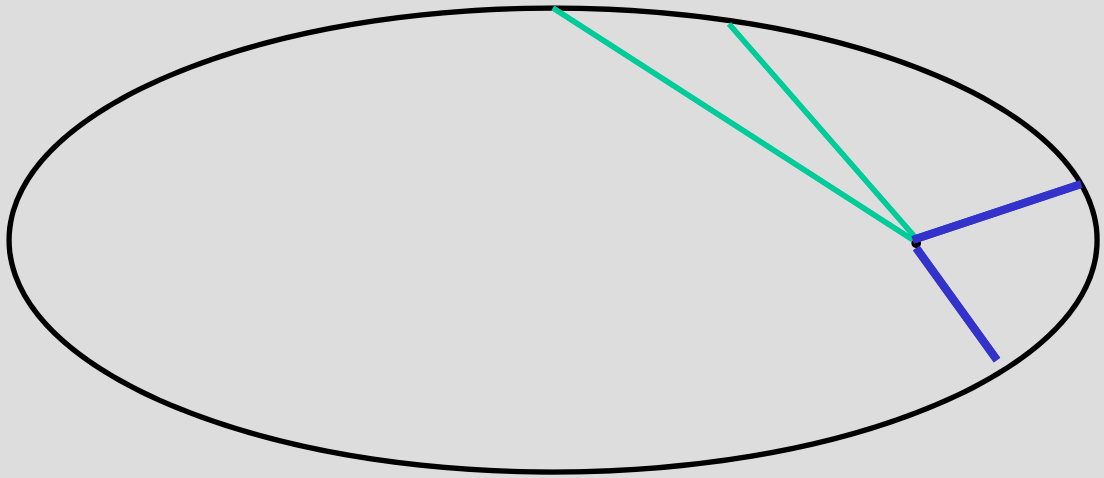


Ellipses



Kepler's Laws

2 A planet moves along its orbit with a speed that changes in such a way that a line from the planet to the Sun sweeps out equal areas in equal intervals of time.



Kepler's Laws

3 The ratio of the cube of a planet's semi-major axis to the square of its orbital period is the same for each planet.

$$a^3 / P^2 = 1$$

If Earth has a=1, then P=1

$$a^3 = P^2$$

Saturn a=10, a^3=1000

P=sqrt(1000) = 30years

Galileo Galilei (1564-1642)

- Improved telescope optics to better than naked eye
- Studied heavens
- wanted to connect physics on earth with the heavens
- *Dialogue Concerning the Two Chief World Systems* [written in Italian]
- Invented modern physical inquiry

  eg dropping balls from tower of Pisa

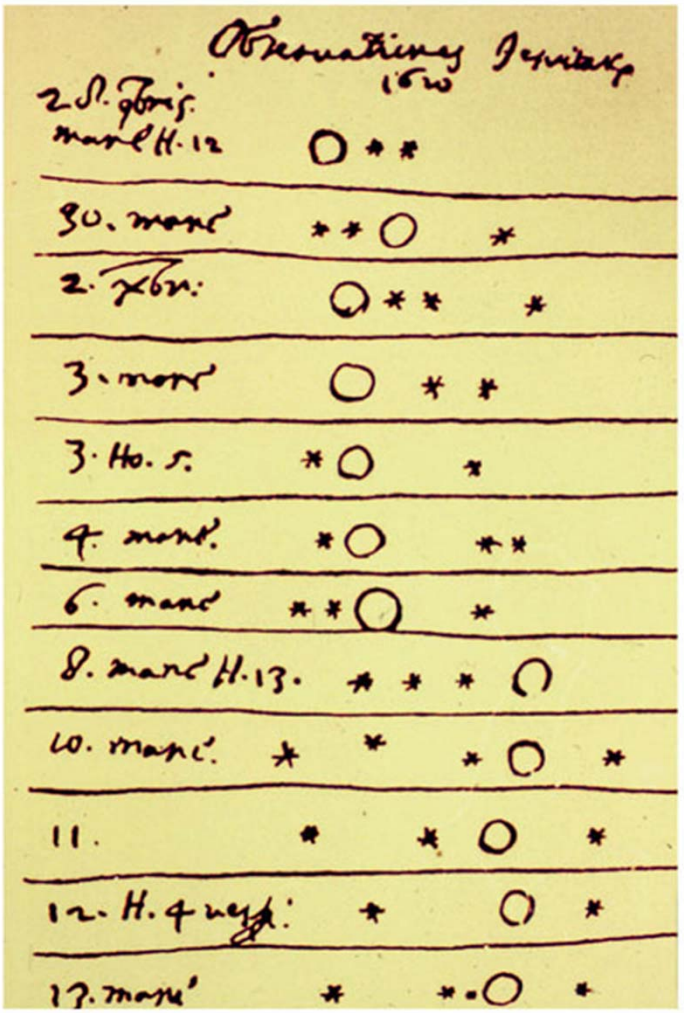
This book got him in trouble with the Church!

Galileo's Observations

- Galileo saw shadows cast by the mountains on the Moon.
- He observed craters.
- The Moon had a landscape; it was a "place", not a perfect heavenly body.

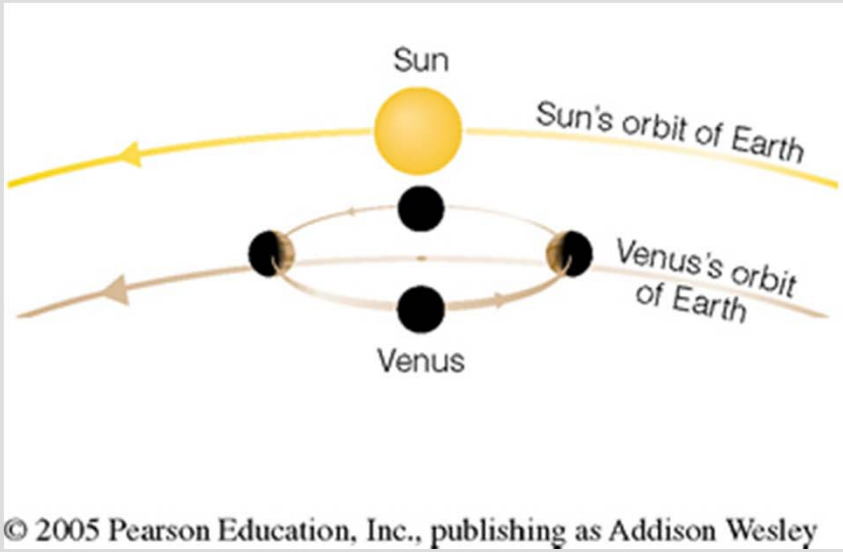
Galileo's Observations

- Galileo discovered that Jupiter had four moons of its own.
- Jupiter was the center of its own system.
- Heavenly bodies existed which did not orbit the earth.



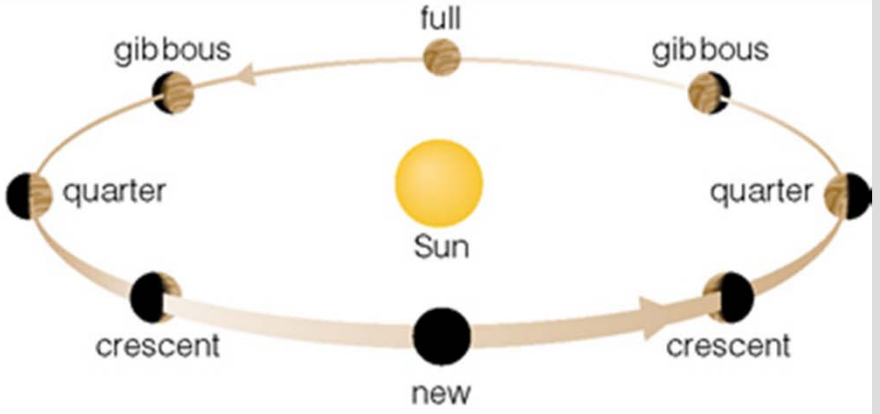
Galileo's observation of the phases of Venus was the final evidence which buried the geocentric model.

Geocentric



No gibbous or full phases!

Heliocentric



All phases are seen!

Galileo observed **all** phases!

Astrology

- claims to study how the positions of the Sun, Moon, & planets among the stars influence human behavior
- was the driving force which advanced ancient astronomy
- Kepler & Galileo were the last astronomers to cast horoscopes… since then astronomy grew apart from astrology into a modern science
- modern scientific tests of astrology fail …it is a *pseudoscience*

4. A Universe of Matter and Energy

"The eternal mystery of the world is its comprehensibility. The fact that it is comprehensible is a miracle."

Albert Einstein (1879 – 1955)
Physicist

What are Matter and Energy?

matter – is material such as rocks, water, air.

energy – is what makes matter move!

Energy is measured in many different units.

The metric unit of energy used by scientists is:

Joule

4,184 joules = 1 calorie

Table 4.1 Energy Comparisons

Item	Energy (joules)
Average daytime solar energy striking Earth, per m^2 per second	1.3×10^3
Energy released by metabolism of one average candy bar	1×10^6
Energy needed for 1 hour of walking (adult)	1×10^6
Kinetic energy of average car traveling at 60 mi/hr	1×10^6
Daily energy needs of average adult	1×10^7
Energy released by burning 1 liter of oil	1.2×10^6
Energy released by fission of 1 kg of uranium-235	5.6×10^{13}
Energy released by fusion of hydrogen in 1 liter of water	7×10^{13}
Energy released by 1-megaton H-bomb	5×10^{15}
Energy released by major earthquake (magnitude 8.0)	2.5×10^{16}
U.S. annual energy consumption	10^{20}
Annual energy generation from the Sun	10^{34}
Energy released by supernova (explosion of a star)	10^{44}–10^{46}

Three Basic Types of Energy

- **kinetic**
  - energy of motion
- **potential**
  - stored energy
- **radiative**
  - energy transported by light

Energy can change from one form to another.

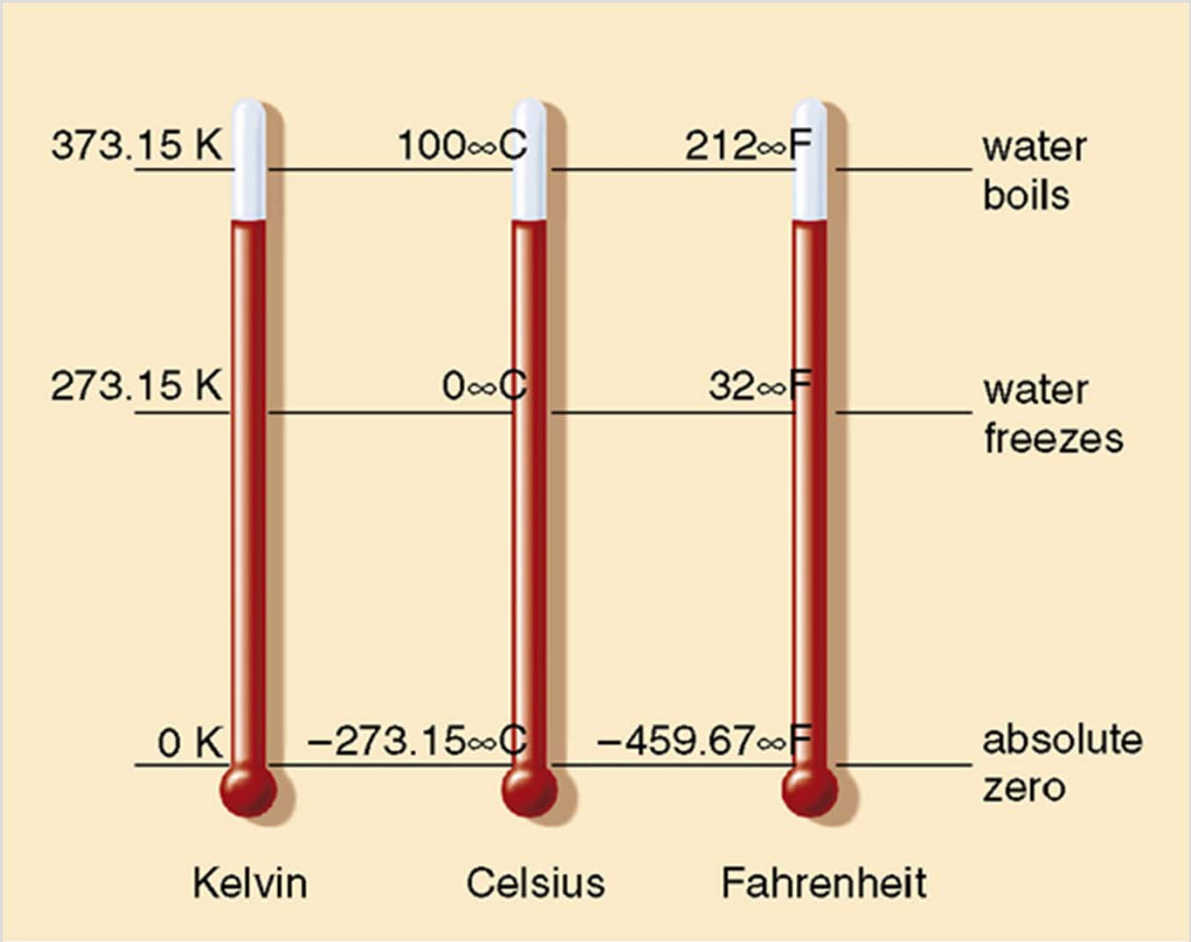
Kinetic Energy

- Amount of kinetic energy of a moving object
  = $1/2\ mv^2$

[if mass (m) is in kg & velocity (v) is in m/s, energy is in joules]

- On the microscopic level
  - the average kinetic energy of the particles within a substance is called the **temperature**.
  - it is dominated by the velocities of the particles.

Temperature Scales



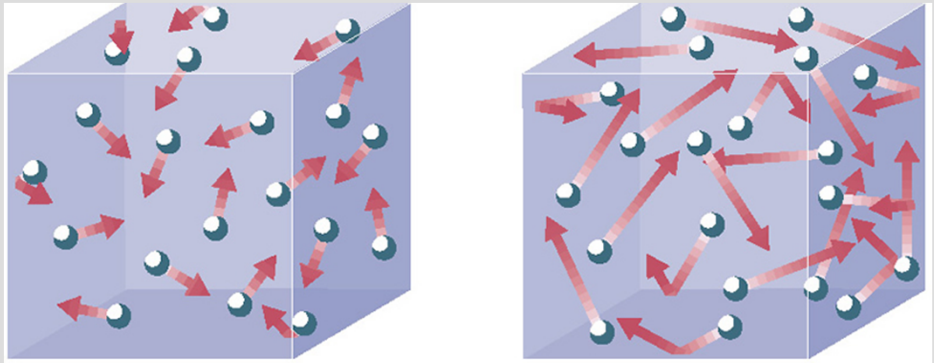
$$T_{Cel} = \frac{T_{Fah} - 32}{1.8}$$

$$T_{Fah} = 32 + (1.8 \times T_{Cel})$$

Temperature vs. Heat

lower T

higher T



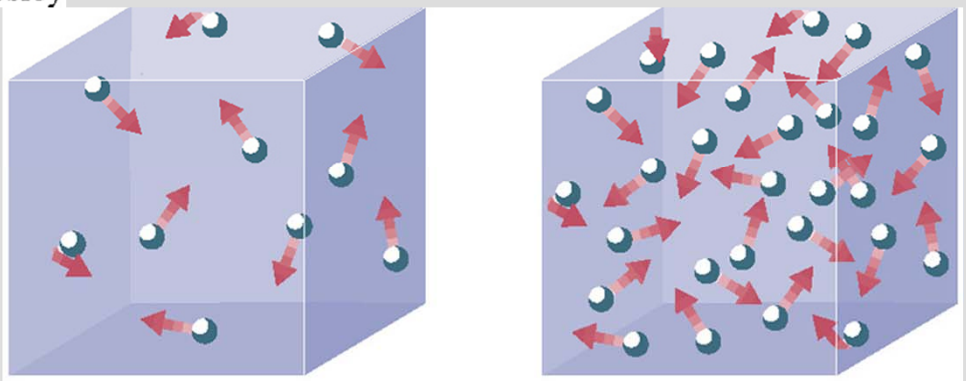
Longer arrows mean higher average speed.

- Temperature is the <u>average</u> kinetic energy.
- Heat (thermal energy) is the <u>total</u> kinetic energy.

less heat

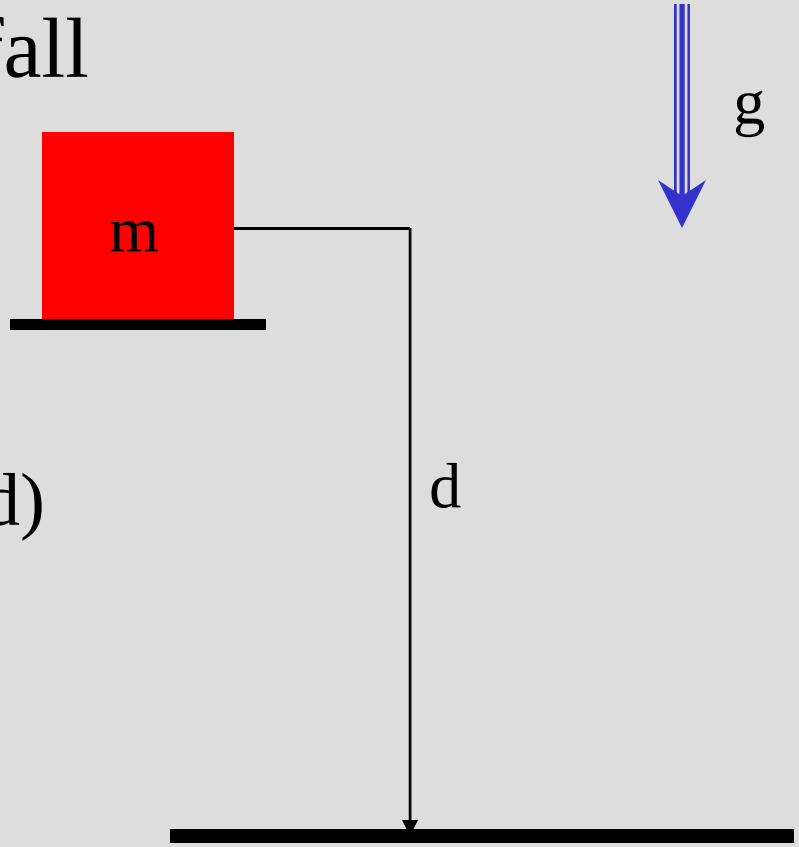
more heat

same T



Potential Energy

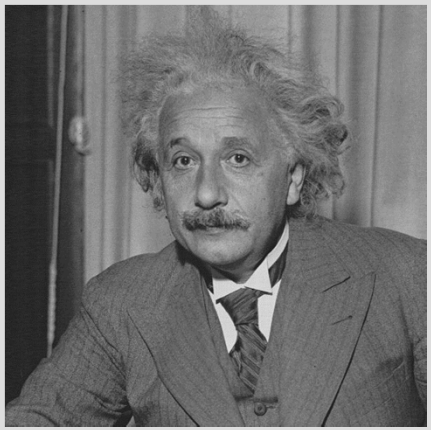
- *gravitational* potential energy is the energy which an object stores due to its ability to fall
- It depends on:
  - the object's mass (m)
  - the strength of gravity (g)
  - the distance which it falls (d)



Potential Energy

- energy is stored in matter itself
- this *mass-energy* is what would be released if an amount of mass, m, were converted into energy

$$E = mc^2$$



[c = 3 x 10^8 m/s is the speed of light; m is in kg, then E is in joules]

Conservation of Energy

- Energy can be neither created nor destroyed.
- It merely changes it form or is exchanged between objects.
- This principle (or *law*) is fundamental to science.
- The total energy content of the Universe was determined in the Big Bang and remains the same today.