Monday, Sep. 22

Syllabus, class notes, and homeworks are at:
www.as.utexas.edu → courses → AST 301, Lacy

Reading for this week: chapter 6

The homework (in back) is due on Friday.

The Wednesday help session has been moved to GRG 424 at 5:00 (for the entire semester).

Note the new time and place.

Newton's version of Kepler's 3rd law

Newton's laws can be used to derive Kepler's 3rd law.

A force is needed to cause a planet to move on a curved path. That force is the force of gravity of the Sun.

By equating the force of the Sun's gravity to the force needed to cause a planet to follow a curved path, we can calculate the speed of the planet.

The result is: $v = (G\, M_{Sun} / a)^{1/2}$,

where v is the average speed of the planet, M_{Sun} is the mass of the Sun, and a is the average distance of the planet from the Sun.

Knowing the speed of the planet, we can calculate the time it takes to orbit the Sun.

The result is: $P^2 \alpha\ a^3 / M_{Sun}$

The Math

$F_{\text{on Earth}} = G\, M_{\text{Earth}}\, M_{\text{Sun}} / r^2$

$a_{\text{of Earth}} = F_{\text{on Earth}} / M_{\text{Earth}} = G\, M_{\text{Sun}} / r^2$

$a_{\text{in orbit}} = v^2 / r$

for $a_{\text{of Earth}} = a_{\text{in orbit}}$ we need:

$G\, M_{\text{Sun}} / r^2 = v^2 / r$, or

$G\, M_{\text{Sun}} = v^2\, r$, or $v^2 = G\, M_{\text{Sun}} / r$

but we also know that v = distance/time = $2\pi r / P$, so

$G\, M_{\text{Sun}} = (2\pi r / P)^2\, r = 4\, \pi^2\, r^3 / P^2$, or

$P^2 = (4\, \pi^2 / G\, M_{\text{Sun}})\, r^3$, or $P^2 \alpha\, r^3/M_{\text{Sun}}$

(for an elliptical orbit, replace r by a – the semimajor axis)

Topics for this week

What is a photon? What is an electromagnetic wave?

How are the photon and wave pictures of light related?

Make a sketch of an atom, showing its parts.

How do the wave properties of electrons result in only certain electron orbits being allowed in an atom?

How does the fact that only certain electron orbits can occur result in photons of only certain wavelengths being emitted?

Describe emission and absorption line spectra and the conditions under which each occurs.

Describe black body radiation and the relations between temperature and the power emitted and the wavelengths of light emitted.

Describe the Doppler shift.

What is light?

We need two ways of looking at light:

It is an electromagnetic wave.

- We often think of radio waves this way.
- In fact they are just very long wavelength light.

It is also a shower of particles called photons.

- x-rays are usually thought of as photons.
- They are very short wavelength light.

For visible light we need both pictures.

What is a wave?

A moving disturbance

like a wave going around the stadium

or a wave in water

or a wave in a spring

For all of these, no object moves with the wave.

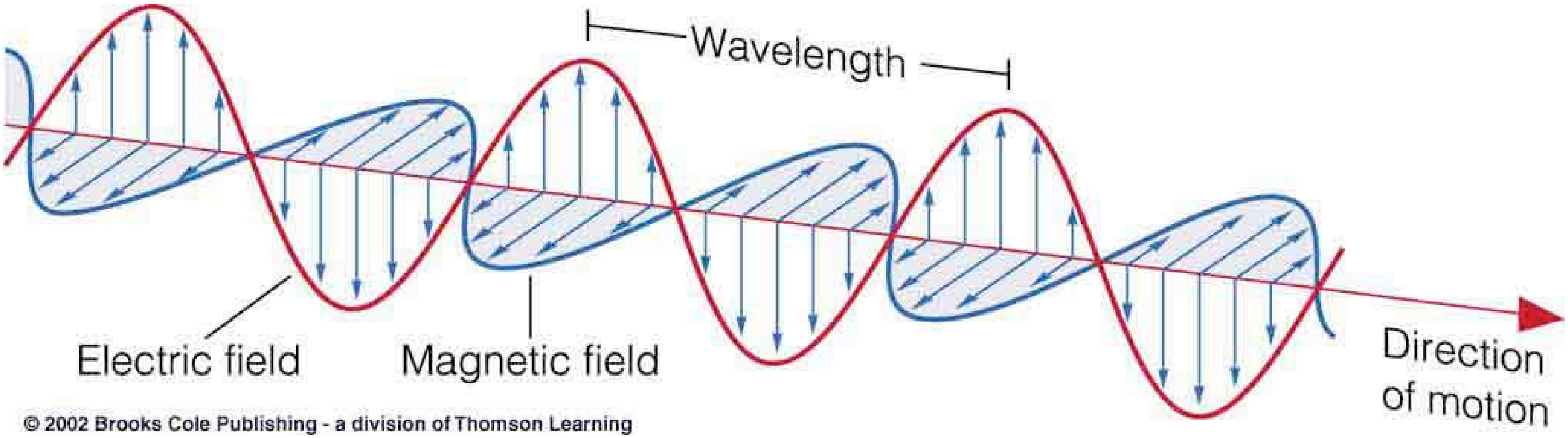
It is only the disturbance that is moving.

Waves can be described by:

wavelength – the distance between peaks

period – the time between peaks passing a point

amplitude – the wave height


Wavelength
Electric field
Magnetic field
Direction
of motion

What is the relation between wavelength and period of a wave?

In one period of a wave, one full cycle (peak through valley and back to peak) passes by.

That means that the wave has moved by one wavelength.

Since speed is distance traveled / time spent, and a wave moves a distance of one wavelength in a time of one period, its speed must be:

speed = distance / time = wavelength / period

$$v = \lambda / p$$

We more often use frequency = 1 / period. Then:

speed = wavelength x frequency

$$v = \lambda \times f$$

What is a photon?

Photons are small bunches of light waves.

Each photon carries a certain amount of energy.

What is energy?

Energy is best defined by examples:

- a hot object has more energy than a cold one.
- a fast-moving object has more energy than a slow one.
- a rock at the top of a hill has more energy than one at the bottom (because when it rolls down it will become a fast-moving object).

What is the energy of a photon?

The concept of energy is useful because we have formulas for each different type of energy.

The energy of a moving object = ½ mass x speed^2.

The amount of heat energy in an object is proportional to its absolute temperature (Centigrade + 273).

If a moving object slides to a stop, its energy of motion is converted to heat energy.

Einstein realized that the energy in a photon of light is proportional to the frequency of the wave in the photon, or inversely proportional to its wavelength:

$E = h\ f = h\ c\ /\ \lambda$

(h is a very small number, called Planck's constant.)