AST 301
Introduction to Astronomy

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AST 301 (Lacy), course website

Unfinished topics from last week

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.

Topics for this week

Describe and compare briefly the compositions and orbits of the terrestrial planets, Jovian planets, asteroids, and comets.

Describe the nebular theory of the formation of the solar system.

How does the nebular theory explain the differences between the terrestrial and the Jovian planets?

How does it explain the asteroids and the comets?

How about moons, especially ours?

How can we measure the age of the solar system?

Spectra of gasses and solids

When solids are heated they emit all wavelengths of light (a continuous spectrum).

How bright the light at different wavelengths is depends on the temperature of the solid. Hotter solids emit more light of all wavelengths, but they especially emit more short wavelength (blue and violet) light.

When gasses are heated they emit only certain wavelengths of light (an emission line spectrum).

Different gasses emit different wavelengths.

A cool object (gas or solid) can absorb some of the light passing through it.

Hot solids – continuous spectra

The temperature of an object is a measure of how much energy its atoms have.

Since atoms in hotter objects have more energy, they can emit photons with more energy than cooler objects can.

(When an atom emits a photon the photon energy comes from the atom, so an atom can't emit a photon with more energy than the atom had.)

So hot objects emit high energy photons, or short wavelength light.

Since $\lambda \propto 1/E_{photon}$ and $E_{photon} \sim E_{atom} \propto T$, $\lambda \propto 1/T$

They also emit more photons that cooler objects do.

The rule is the amount of power emitted (energy emitted each second) is $P_{emitted} \propto T^4$

Emission and absorption line spectra

Hot gas emits light of only certain wavelengths.

If a source emitting a continuous spectrum lies behind cool gas, the gas absorbs some of the light, and it absorbs the same wavelengths of light that it would emit if hot.

To understand why gasses act this way, we need to understand more about how electrons orbit in atoms.

What is an atom?

A hydrogen atom has one proton at its center, with one electron orbiting around the proton.

The proton has a positive electrical charge.

The electron has a negative charge and is about 2000 times less massive than the proton.

Opposite charges attract, with a force law like that for gravity, so we expect the electron orbit to obey laws like Kepler’s laws.

Other atoms have additional protons in their nuclei and additional electrons orbiting around their nuclei.

The also have neutrons (electrically neutral particles with masses similar to proton masses) in their nuclei.

Electron waves

We normally think of electrons as particles.

But like photons, they have both wave and particle properties.

The height of the wave describes the probability of finding the electron in different places.

The wavelength of the probability wave is related to the electron speed, v, by:

$$\lambda = h / mv,$$

where h is Planck's constant and m is the electron mass.

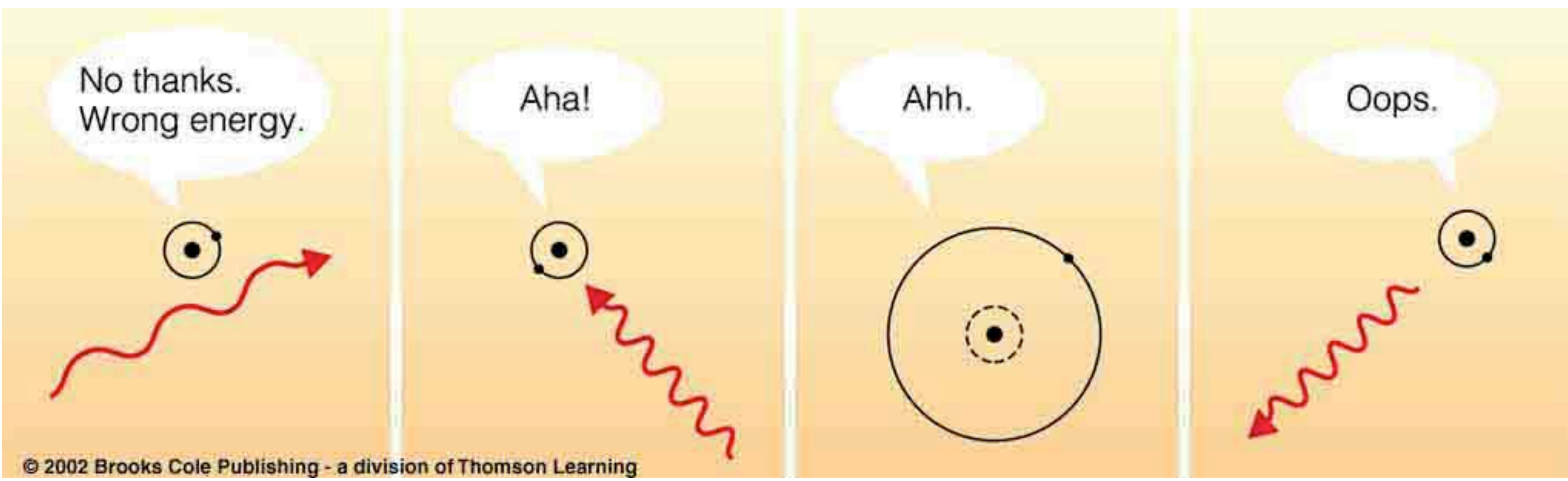
In an atom, an electron must orbit at a distance from the nucleus so that an integral number of probability waves fit around its orbit.

This causes only certain electron speeds or energies to be allowed.

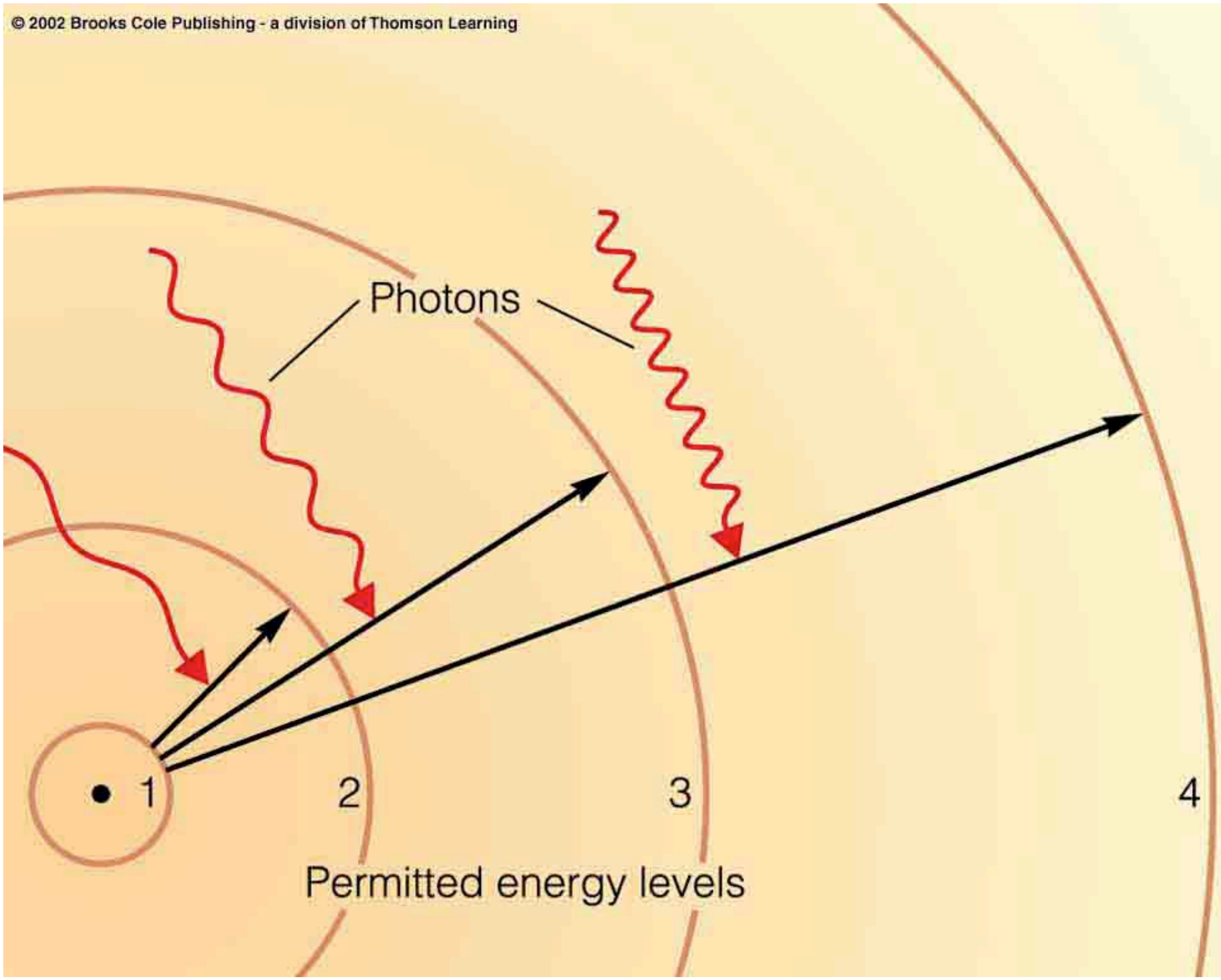
Emission and absorption of light by atoms

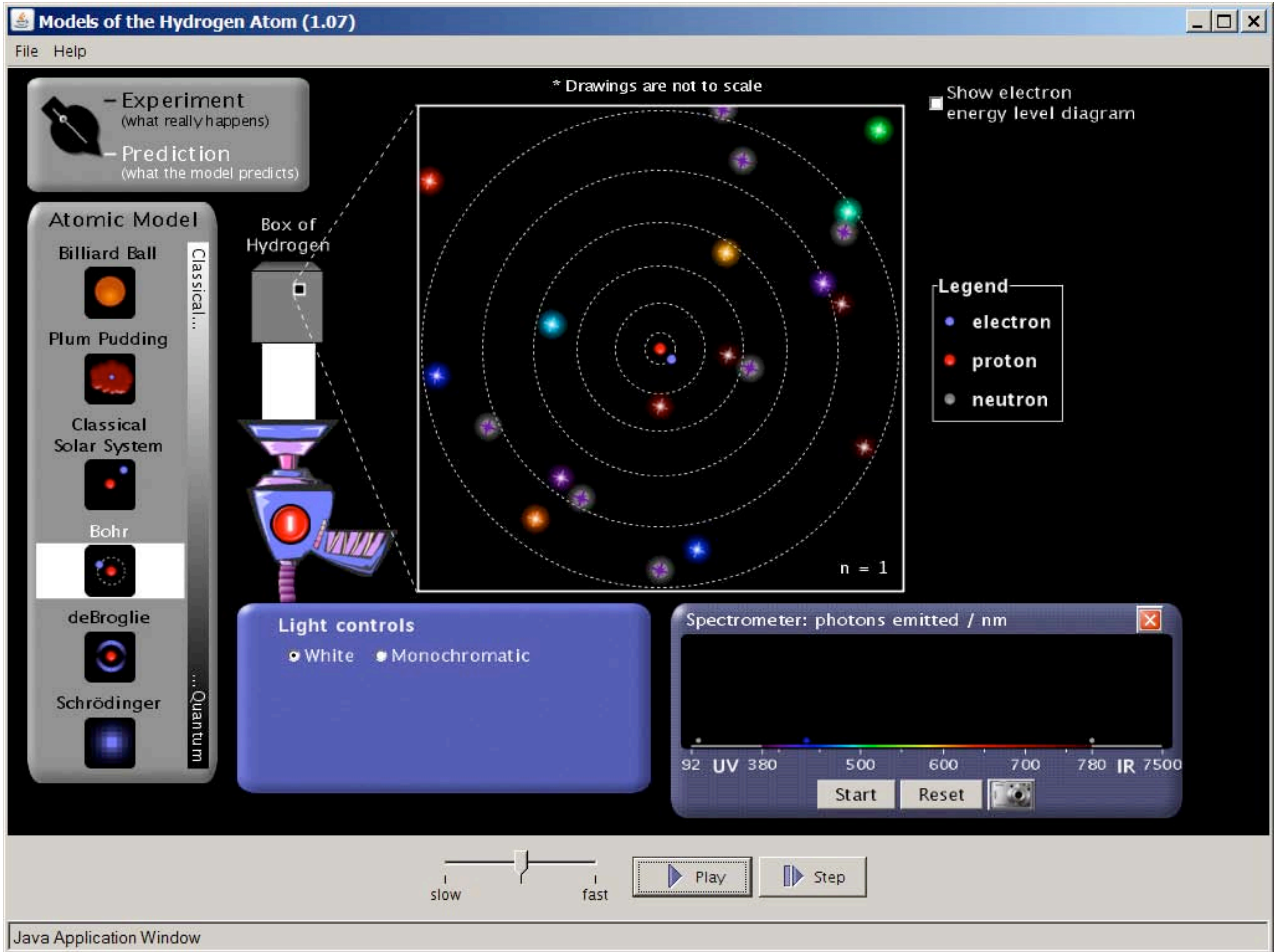
When an atom absorbs light, the photon energy must equal the energy needed to make an electron jump from a small orbit to a bigger one.

When an atom emits light, a photon is created, and the energy of the photon must equal the energy lost by the atom when an electron jumps from one orbit to another.



A big jump for an electron requires a high energy photon, or short wavelength light.




Models of the Hydrogen Atom (1.07)
File Help
Experiment
(what really happens)
Prediction
(what the model predicts)
* Drawings are not to scale
Show electron energy level diagram
Atomic Model
Billiard Ball
Plum Pudding
Classical Solar System
Bohr
deBroglie
Schrödinger
Classical...
...Quantum
Box of Hydrogen
n = 1
Legend
electron
proton
neutron
Light controls
White
Monochromatic
Spectrometer: photons emitted / nm
92 UV 380 500 600 700 780 IR 7500
Start
Reset
slow
fast
Play
Step
Java Application Window

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Photon energies

When an atom emits a photon, the atom loses the amount of energy the photon carries off.

Since atoms can only have certain energies, they can only emit photons of certain energies.

The photon energy must equal the different between two allowed amounts of atom energy.

hf = photon energy = change in atom energy = difference between two allowed amounts of atom energy

Doppler shift

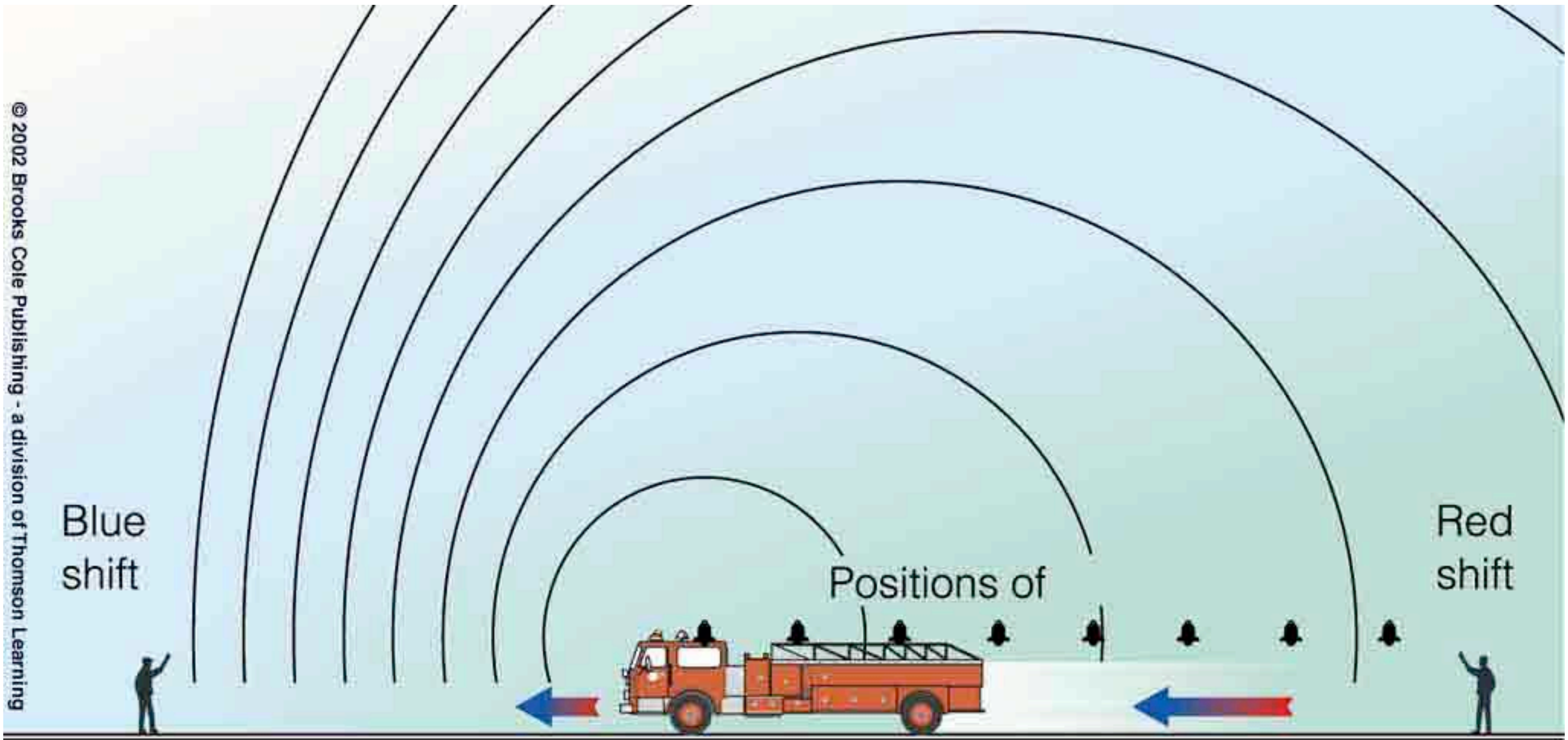
If an object emitting light (or sound) waves is moving relative to an observer, the observed wavelength is different from that emitted.

If the emitter moves toward the observer (or the observer moves toward the emitter) the observed wavelength is shorter than the emitted wavelength.

If the emitter moves away from the observer, the observed wavelength is longer than the emitted wavelength.

If the motion is small compared to the speed of the wave (the speed of light for light waves) the formula for the shift in wavelength is:

$$(\lambda_{observed}-\lambda_{emitted}) / \lambda_{emitted} = v / c$$


Blue shift
Positions of
Red shift