Requests from our TA (and me)

1. You must show your work on numerical problems on homework to receive full credit.
2. You will receive no credit if you copy someone else's homework or allow someone to copy yours.
3. Buy a stapler, and staple multiple homework pages together.

If you don't have the homework handed out last Friday, there are extra copies at the bottom of the homework return boxes.

If you haven't picked up you test #1 yet, it should be in the homework return box.

Three types of spectra

Continuous spectra: hot dense objects (solids or dense gasses) emit light at all wavelengths, with hotter objects emitting more short wavelength light.

Emission line spectrum: if a gas is hotter than whatever is behind it, bright lines will be seen in its spectrum.

Absorption line spectra: if a gas lies between an object emitting a continuous spectrum and the observer, and if that gas is cooler than the object, it will absorb some of the light from the object, causing dark lines in the spectrum.

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.

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

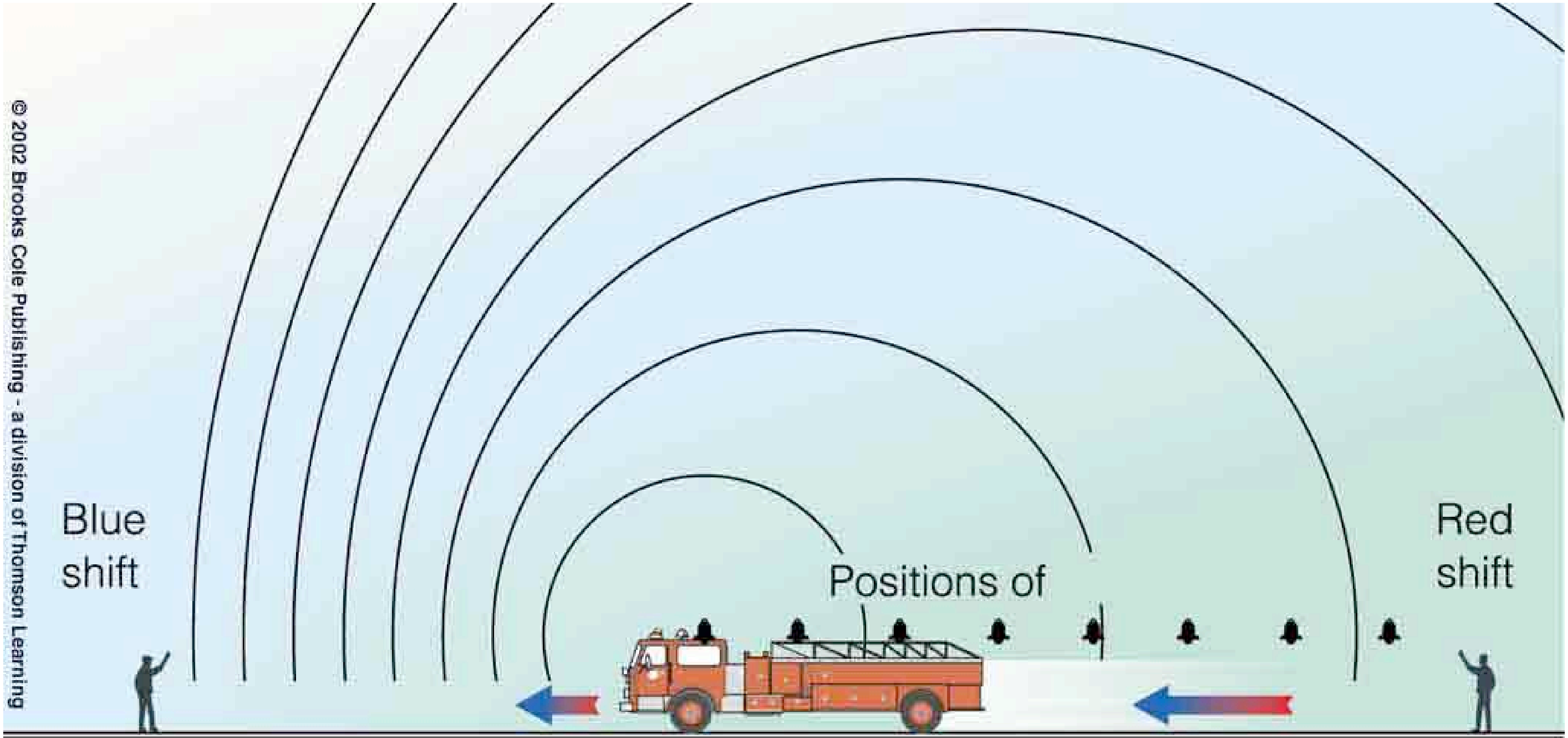
If an object emitting light (or sound) waves is moving relative to an observer, the observed wavelength is different from that emitted.

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

Quiz

The Earth orbits around the Sun with a speed of 30 km/s.

The speed of light is 300,000 km/s.

I observe infrared radiation from sulfur atoms which is emitted at a wavelength of 10 μm.

What is the difference between the emitted wavelength and the wavelength I observe from the moving Earth?

A. .001 μm

The speed of the Earth is 1/10,000 the speed of light.

So the wavelength is shifted by the emitted wavelength divided by 10,000. 10/10,000 = 1/1000 = .001 μm

When the Earth moves toward the source the wavelength decreases to 9.999 μm. When it moves away I observe a wavelength of 10.001 μm.

Information in spectra

What can we learn about stars from their spectra?

composition: different atoms emit and absorb light at different wavelengths.

motion: from the shift in wavelength caused by the Doppler effect we can measure a star's motion toward or away from us.

temperature: hot stars emit their light at shorter wavelengths than cooler stars do. They also have different patterns of absorption and emission lines.

rotation: if a star rotates, one side comes toward us while the other side moves away from us, broadening the absorption and emission lines.

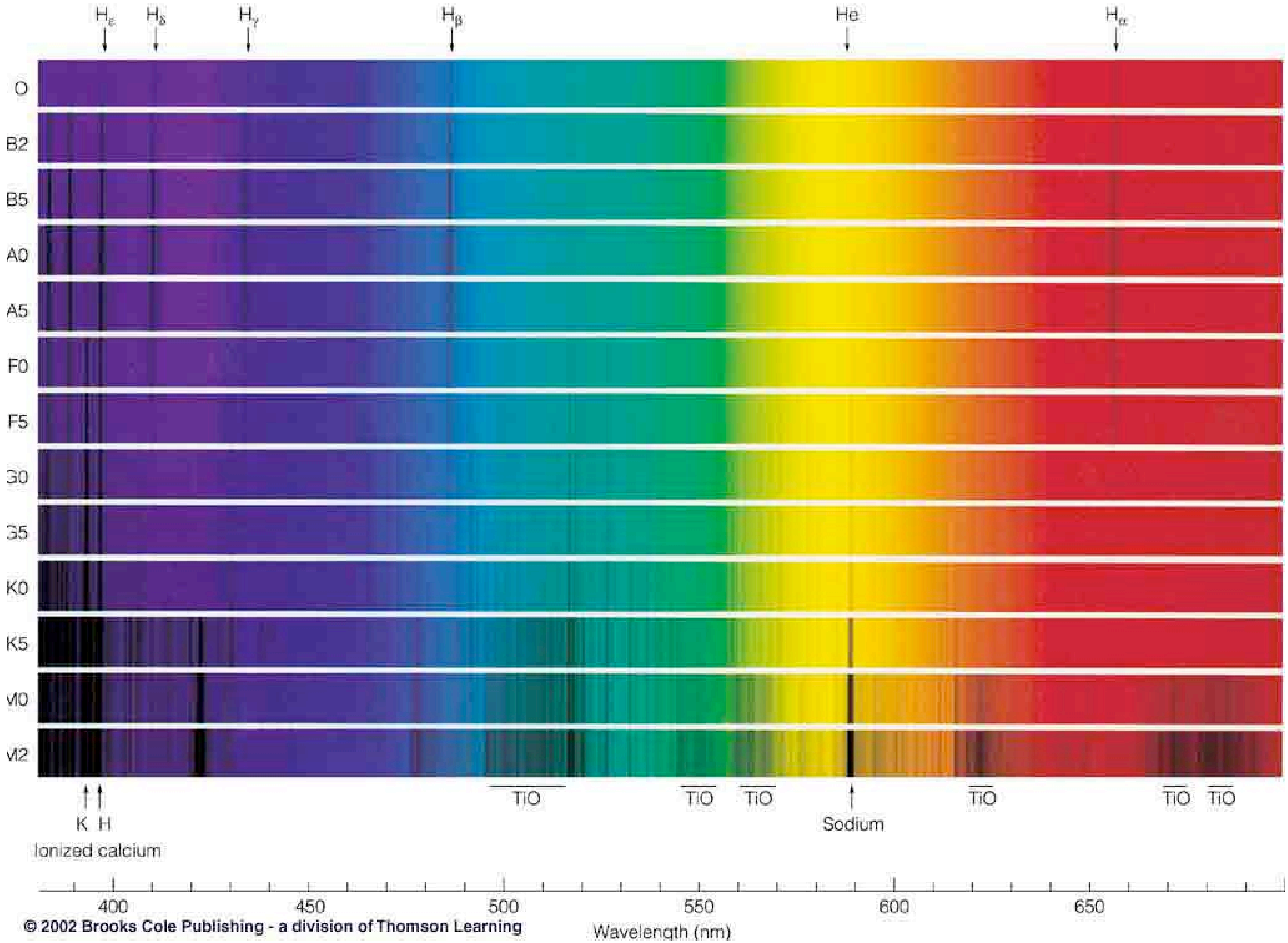
Spectra of stars

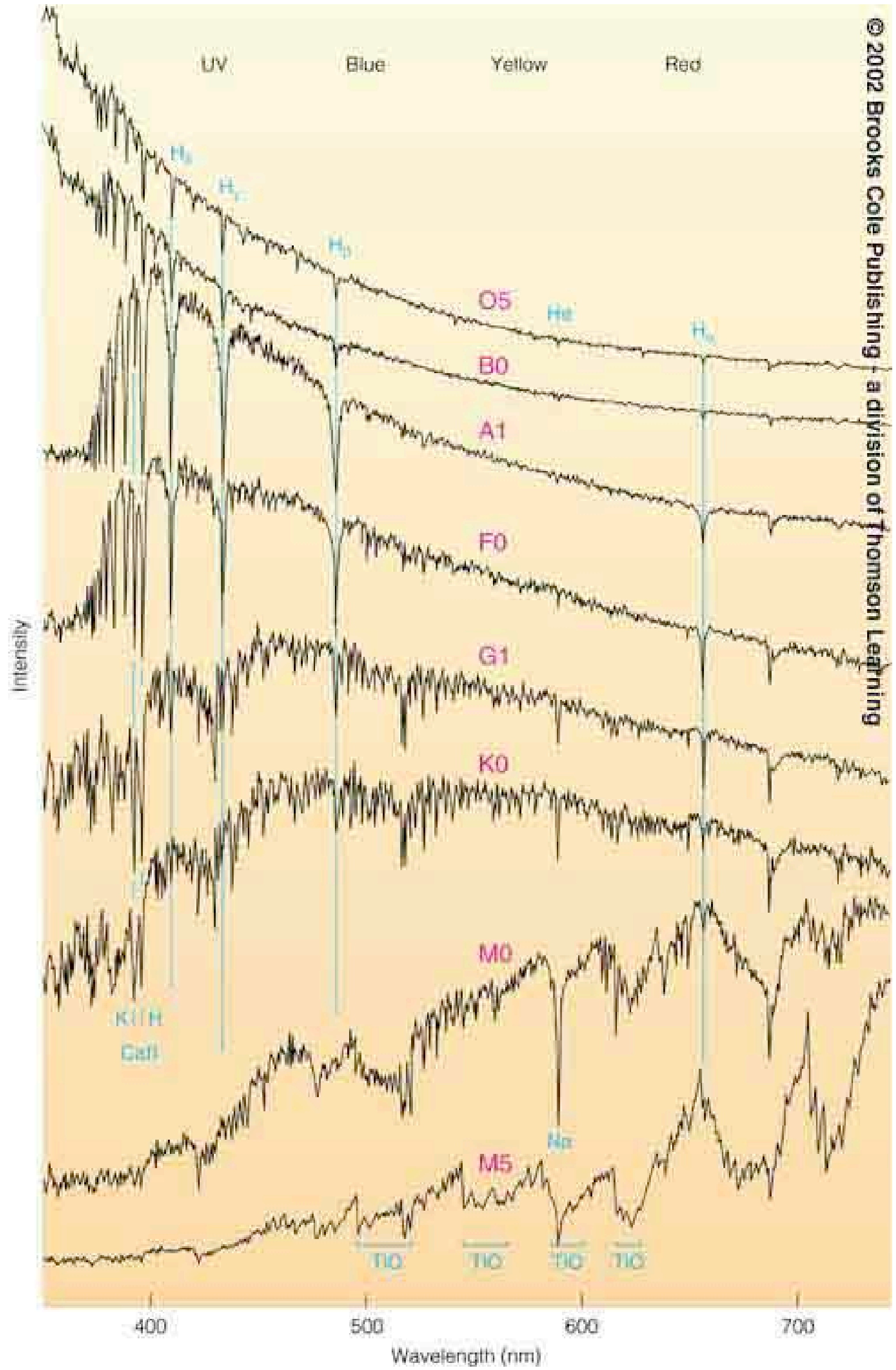
The deep layers of the atmospheres of stars emit light according to the rules for radiation from solids (although they aren't actually solid).

The outer layers of atmospheres of stars produce emission and absorption line spectra.

Studies of the spectra of stars tell us about both the temperatures and the compositions of their atmospheres.

The simplest effect of temperature is that hotter stars appear bluer and cooler stars appear redder, but temperature changes spectra in other ways too.


Hε
Hδ
Hγ
Hβ
He
Hα
O
B2
B5
A0
A5
F0
F5
G0
G5
K0
K5
M0
M2
TiO
TiO
TiO
TiO
TiO
TiO
K H
Ionized calcium
Sodium
400
450
500
550
600
650
Wavelength (nm)


UV
Blue
Yellow
Red
O5
B0
A1
F0
G1
K0
M0
M5
He
Na
K
H
CaII
TiO
TiO
TiO
TiO
Intensity
400
500
600
700
Wavelength (nm)