Announcements

- Scores for first exam on ICON
- The average was 53.4 or 67%.
- The curve is A:80-68, B:64-56, C:52-40, D:36-32, F < 30.
- Material for problem about Kepler satellite was not adequately covered, so everyone was given 4 points for this problem.
- Your answers, the answer key, and the test are all on ICON.

- Office hours this Tuesday will be 1-2 pm.

How is energy transported through the outer regions of the Sun (inside the photosphere)?

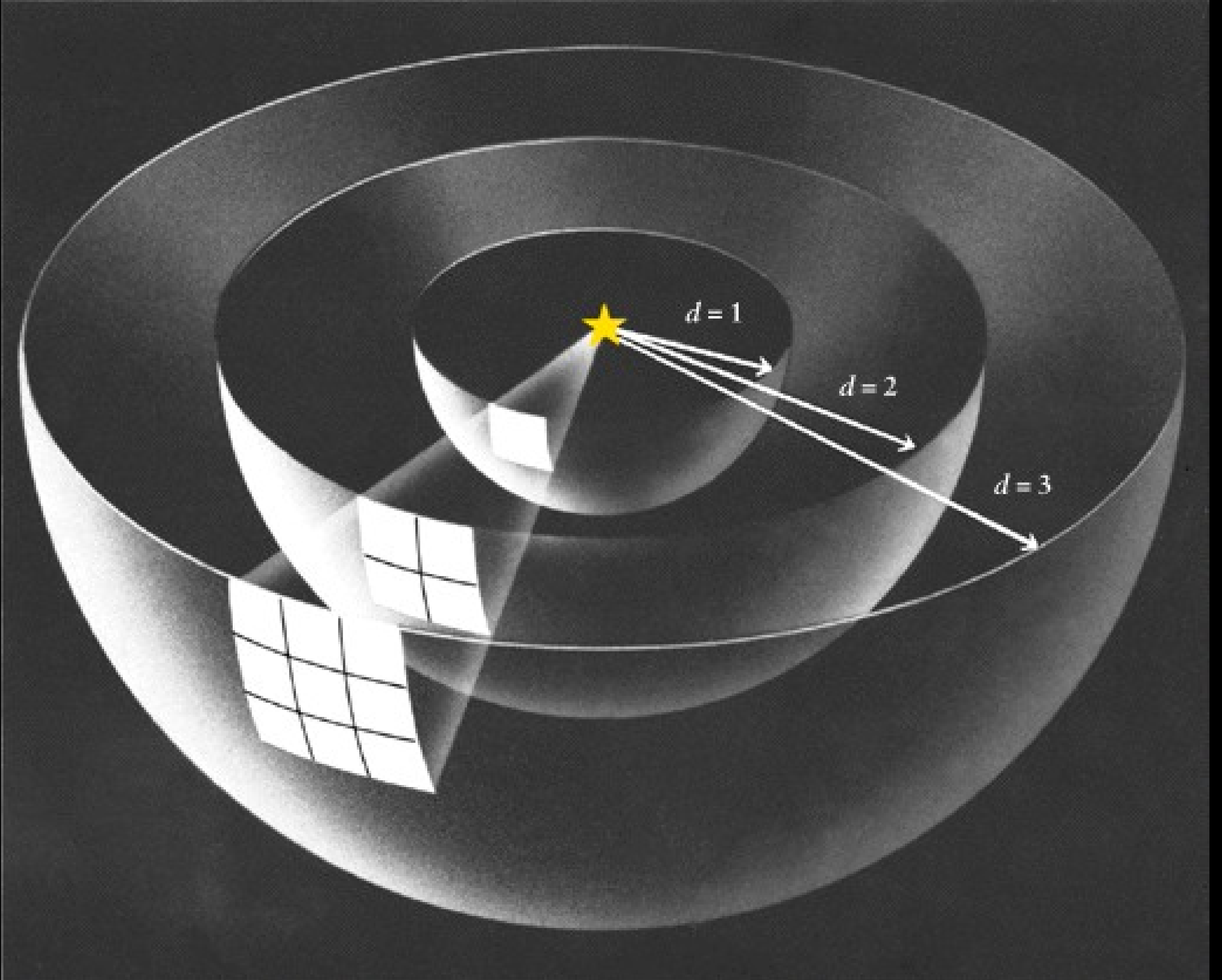
A) Neutrinos
B) Radiation
C) Convection
D) Bus

Stars

- Flux and luminosity
- Brightness of stars
- Spectrum of light
- Temperature and color/spectrum
- How the eye sees color

Flux and luminosity

- **Luminosity** - A star produces light – the total amount of energy that a star puts out as light each second is called its Luminosity.
- **Flux** - If we have a light detector (eye, camera, telescope) we can measure the light produced by the star – the total amount of energy intercepted by the detector divided by the area of the detector is called the Flux.



d = 1
d = 2
d = 3

Flux and luminosity

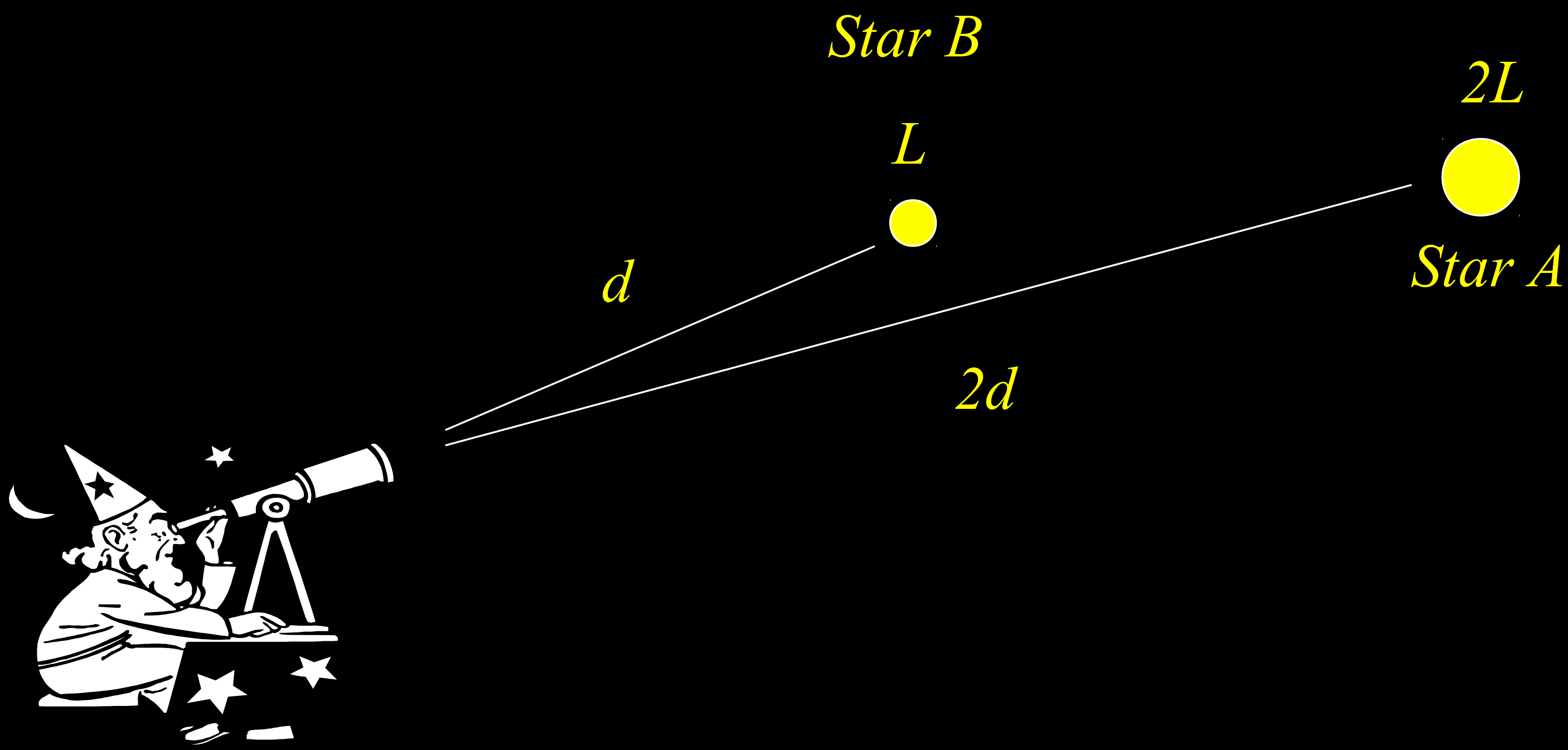
- To find the luminosity, we take a shell which completely encloses the star and measure all the light passing through the shell
- To find the flux, we take our detector at some particular distance from the star and measure the light passing only through the detector. How bright a star looks to us is determined by its flux, not its luminosity. Brightness = Flux.

Flux and luminosity

- Flux decreases as we get farther from the star
  – like $1/\text{distance}^2$
- Mathematically, if we have two stars A and B

$$\frac{\text{Flux}_A}{\text{Flux}_B} = \frac{\text{Luminosity}_A}{\text{Luminosity}_B}\left(\frac{\text{Distance}_B}{\text{Distance}_A}\right)^2$$

Distance-Luminosity relation: Which star appears brighter to the observer?



Flux and luminosity

$$\frac{\text{Luminosity}_A}{\text{Luminosity}_B} = 2 \qquad \frac{\text{Distance}_B}{\text{Distance}_A} = \frac{1}{2}$$

$$\frac{\text{Flux}_A}{\text{Flux}_B} = \frac{\text{Luminosity}_A}{\text{Luminosity}_B}\left(\frac{\text{Distance}_B}{\text{Distance}_A}\right)^2$$

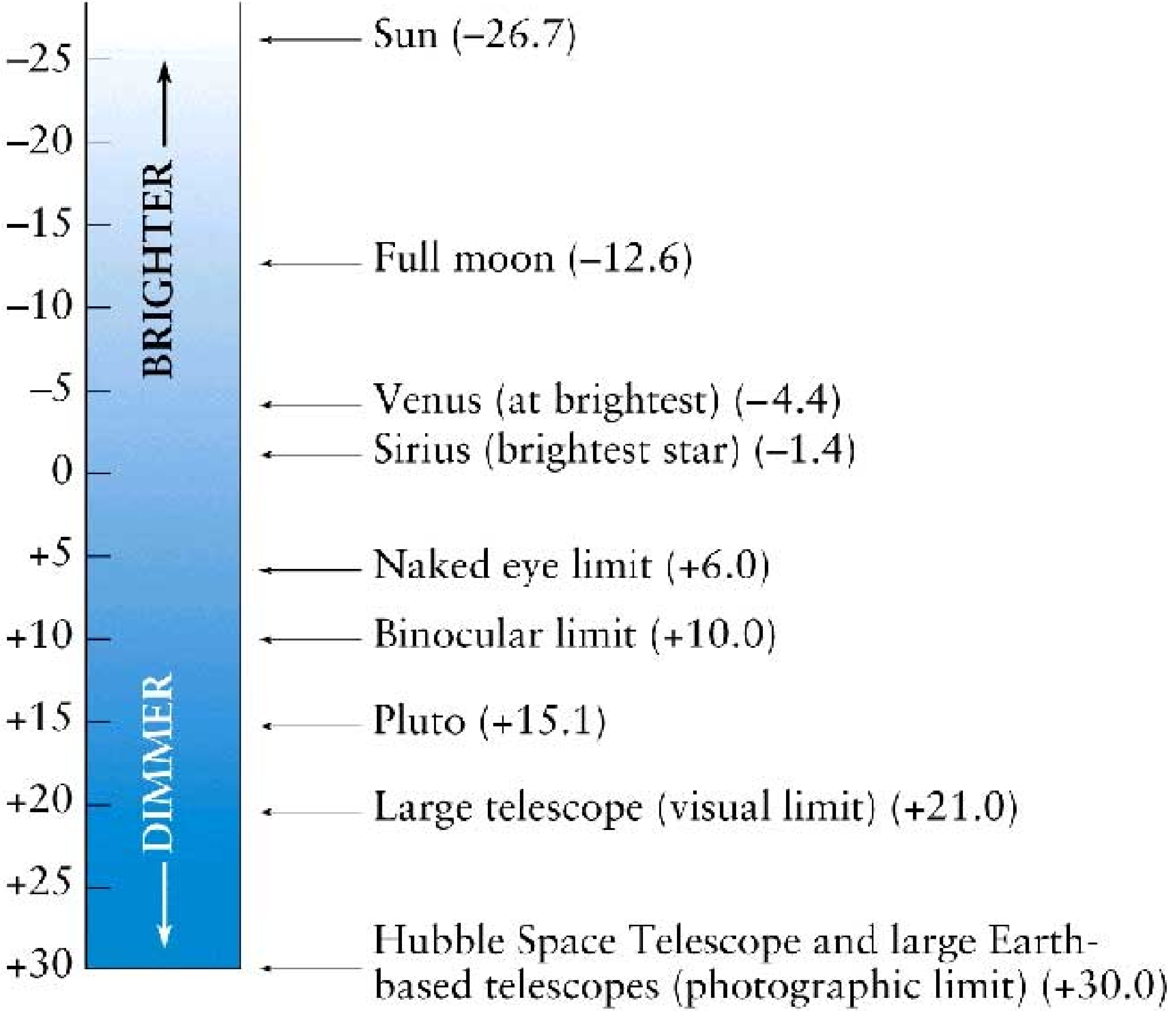
$$= 2\left(\frac{1}{2}\right)^2 = 2\left(\frac{1}{4}\right) = \frac{1}{2} \qquad \text{Flux}_\text{B} = 2 \times \text{Flux}_\text{A}$$

Brightness of stars

- Ptolemy (150 A.D.) grouped stars into 6 `magnitude' groups according to how bright they looked to his eye.
- Herschel (1800s) first measured the brightness of stars quantitatively and matched his measurements onto Ptolemy's magnitude groups and assigned a number for the magnitude of each star.

Brightness of stars

- In Herschel's system, if a star is 1/100 as bright as another then the dimmer star has a magnitude 5 higher than the brighter one.
- Note that dimmer objects have higher magnitudes


–25
–20
–15
–10
–5
0
+5
+10
+15
+20
+25
+30
BRIGHTER
DIMMER
Sun (–26.7)
Full moon (–12.6)
Venus (at brightest) (–4.4)
Sirius (brightest star) (–1.4)
Naked eye limit (+6.0)
Binocular limit (+10.0)
Pluto (+15.1)
Large telescope (visual limit) (+21.0)
Hubble Space Telescope and large Earth-based telescopes (photographic limit) (+30.0)
a

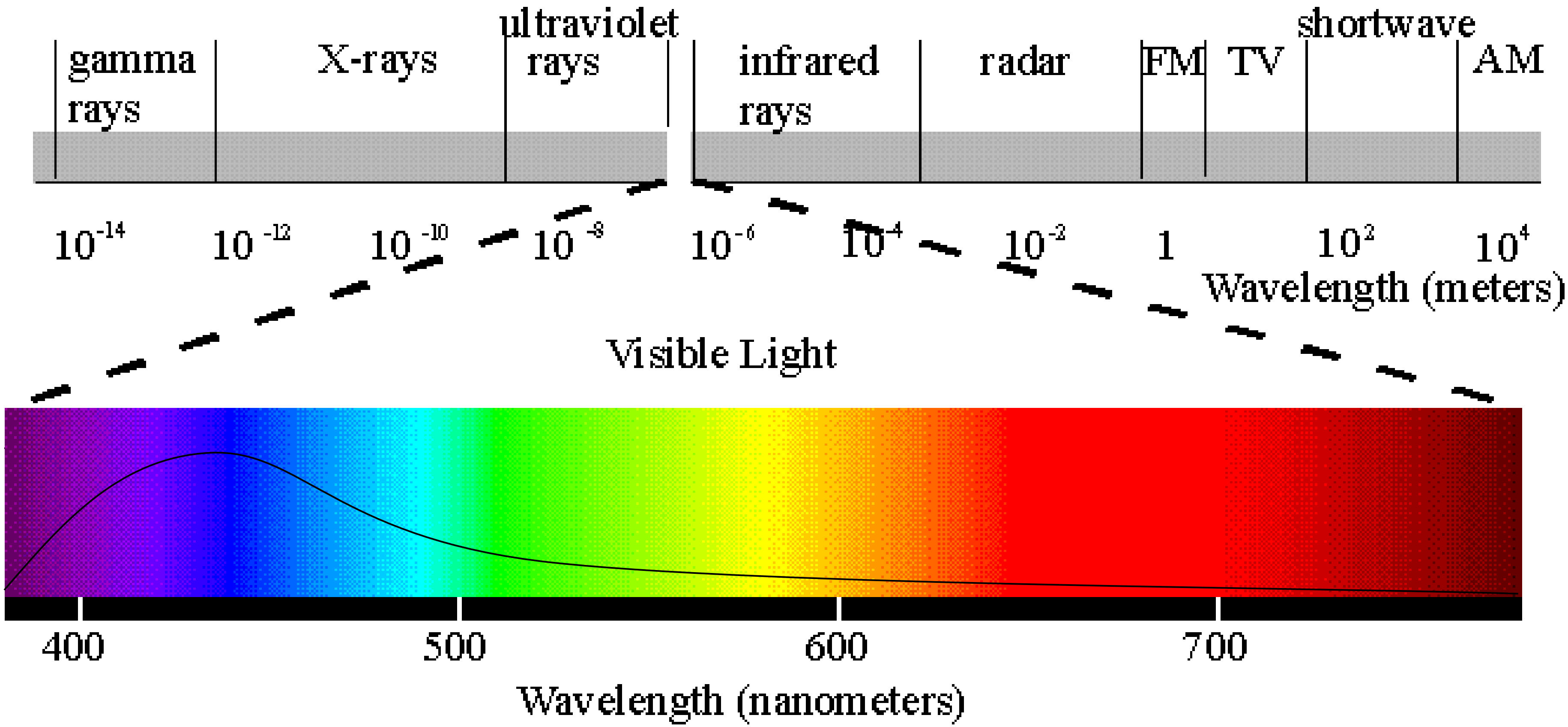
Absolute magnitude

- The magnitude of a star gives it brightness or flux when observed from Earth.
- To talk about the properties of star, independent of how far they happen to be from Earth, we use “absolute magnitude”.
- Absolute magnitude is the magnitude that a star would have viewed from a distance of 10 parsecs.
- Absolute magnitude is directly related to the luminosity of the star.

Which star would appear brightest?

A) Star A - 10 pc away, 1 solar luminosity
B) Star B - 30 pc away, 3 solar luminosities
C) Star C - 5 pc away, 0.5 solar luminosities
D) Charlize Theron

Electromagnetic spectrum



The "spectrum" of a particular star is how much light it produces at each wavelength.

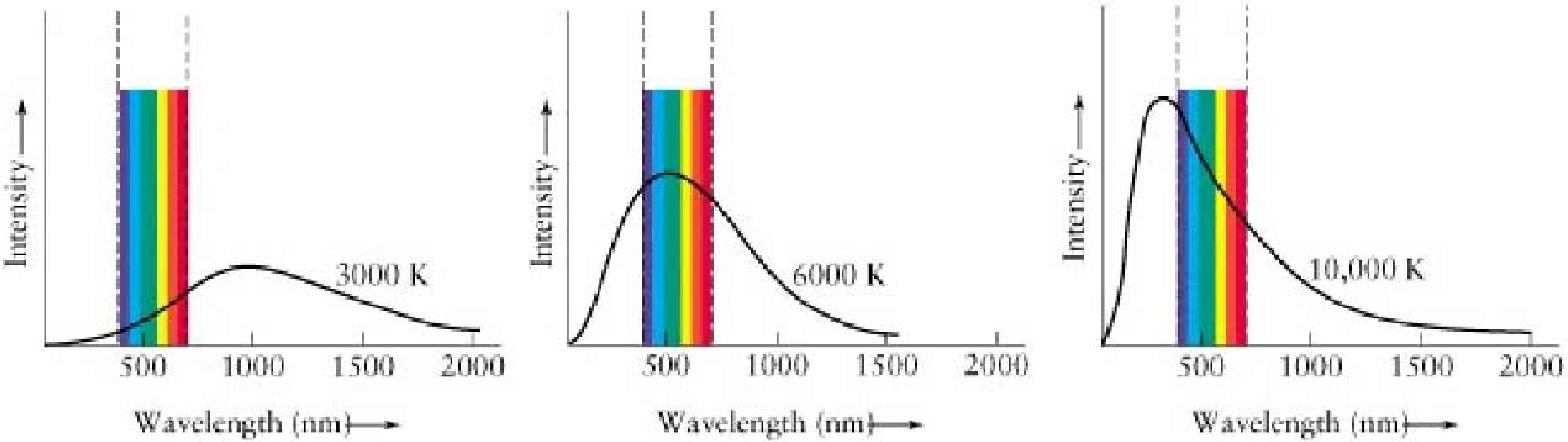
What can we learn from a star’s color?

- The color indicates the temperature of the surface of the star.
- The same is true for the filament in a light bulb or any other hot object. In general, we call radiation from a hot body `black body’ radiation (do demonstration 6B40.10).

Wien’s law

- Cooler objects produce radiation which peaks at longer wavelengths (redder colors), hotter objects produce radiation which peaks at shorter wavelengths (bluer colors).

A star's color depends on its surface temperature



a This star looks red

b This star looks yellow-white

c This star looks blue-white

Spectrum demonstration 6B40.55

Hotter objects produce radiation which is

A) peaked at shorter wavelengths than cooler objects

B) brighter than cooler objects

C) peaked at longer wavelengths than cooler objects

D) dimmer than cooler objects

Spectral classification of stars

- The spectral classification essentially sorts stars according to their surface temperature.Sequence is: O B A F G K M
- O type is hottest (~25,000K), M type is coolest (~2500K)
- Star Colors: **O blue** to M **red**
- Sequence subdivided by attaching one numerical digit, for example: F0, F1, F2, F3 … F9 where F1 is hotter than F3 . Sequence is O … O9, B0, B1, …, B9, A0, A1, … A9, F0, …
- Useful mnemonics to remember OBAFGKM:
  - **O**ur **B**est **A**stronomers **F**eel **G**ood **K**nowing **M**ore
  - (Traditional) Oh, Be A Fine Girl, Kiss Me

Spectral classification of stars

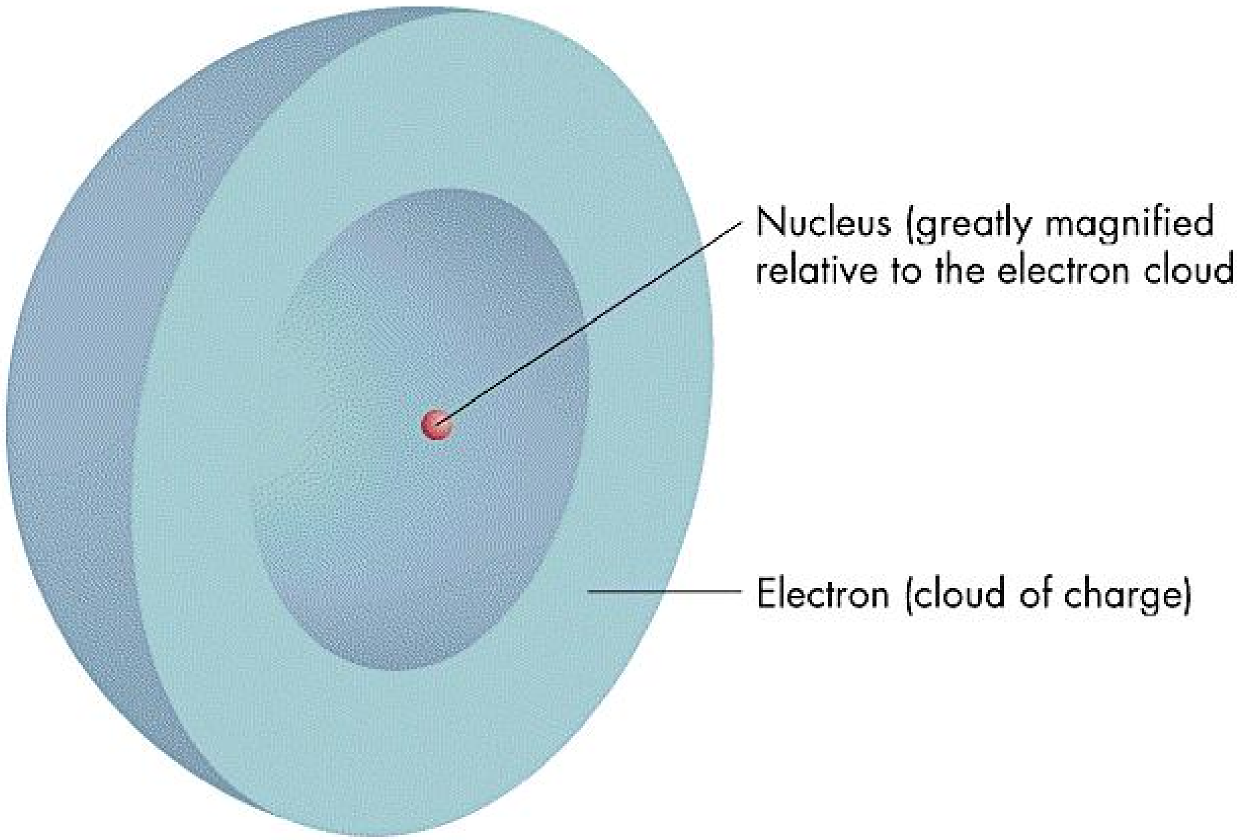
- OBAFGKM spectral classification does not include cooler brown dwarf stars. These stars have such low masses, < 0.08 $M_{\odot}$, that no fusion occurs inside. Spectral class M include the most massive brown dwarfs.

- Need extra spectral types: L, T, Y
- L is hottest, Y is coolest (down to ~300K)
- Note Y brown dwarfs were discovered only this year and are not in the book (written in 2010).
- Invent your own mnemonic for OBAFGKMLTY

Tanning is a result of exposure to ultraviolet radiation. Under which type of star will you tan fastest?

A) B-star
B) M-star
C) Y-star
D) Hollywood star

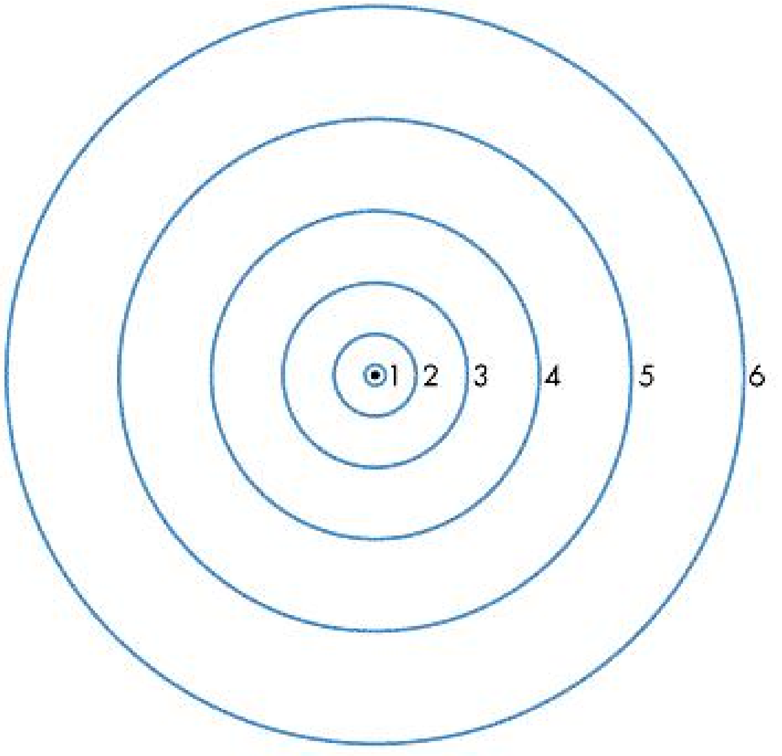
Hydrogen atom



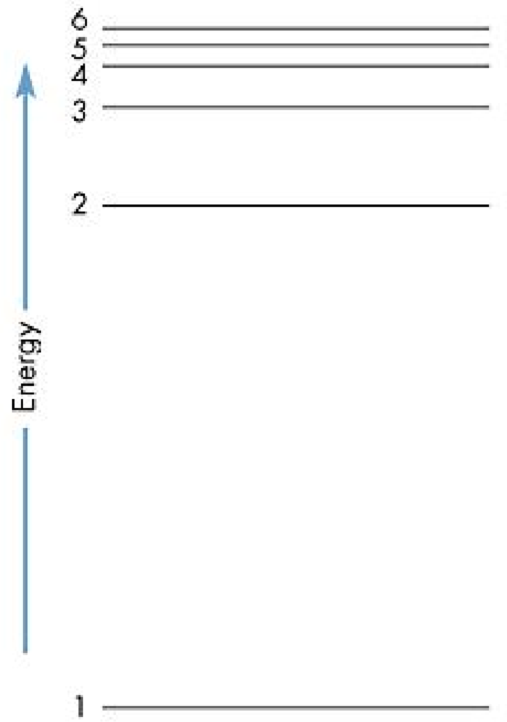
Cross section of a hydrogen atom

Electron orbits around nucleus

Electron orbits

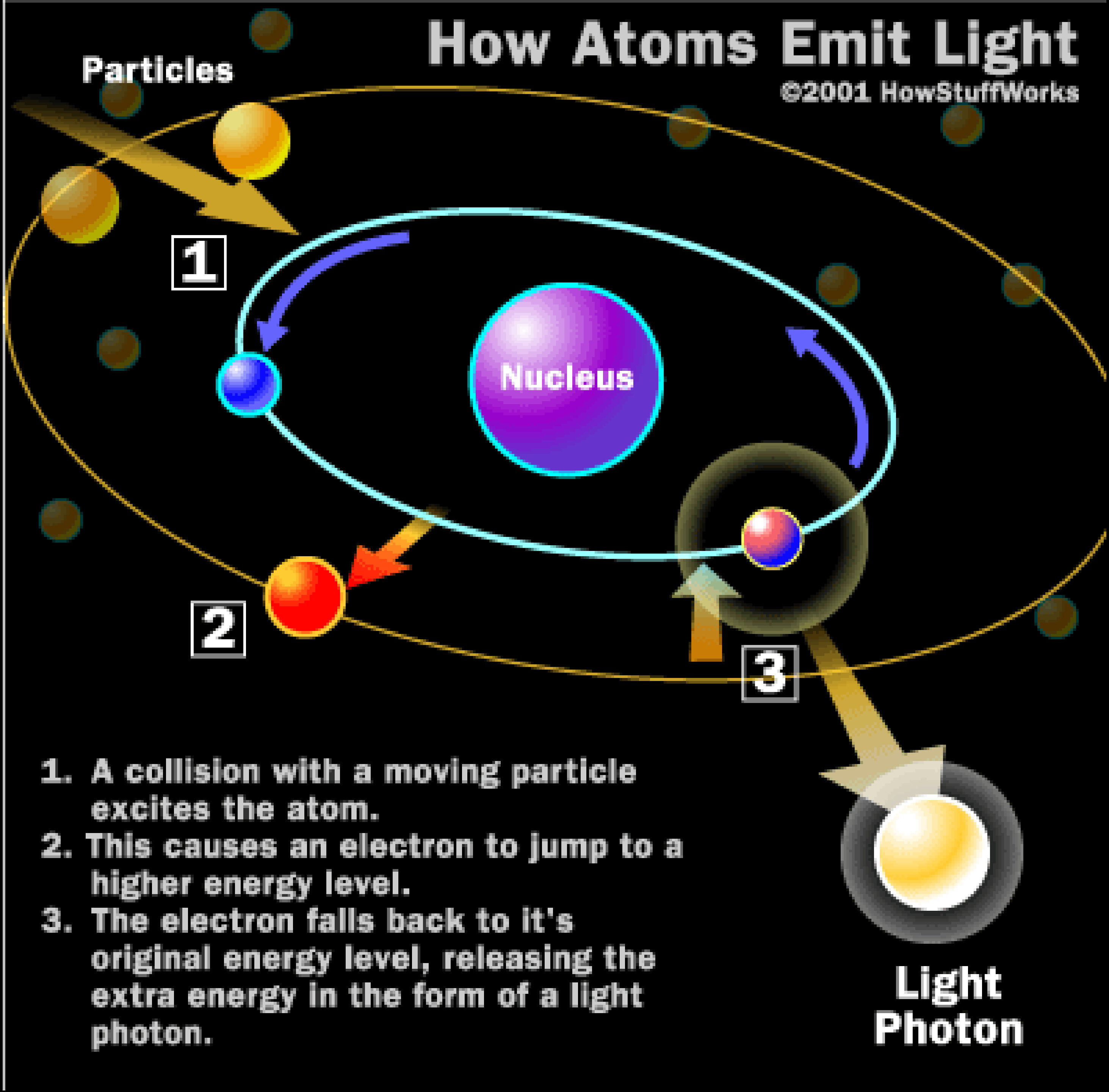


A Possible distances of the electron in a hydrogen atom



B Energy levels for the hydrogen atom

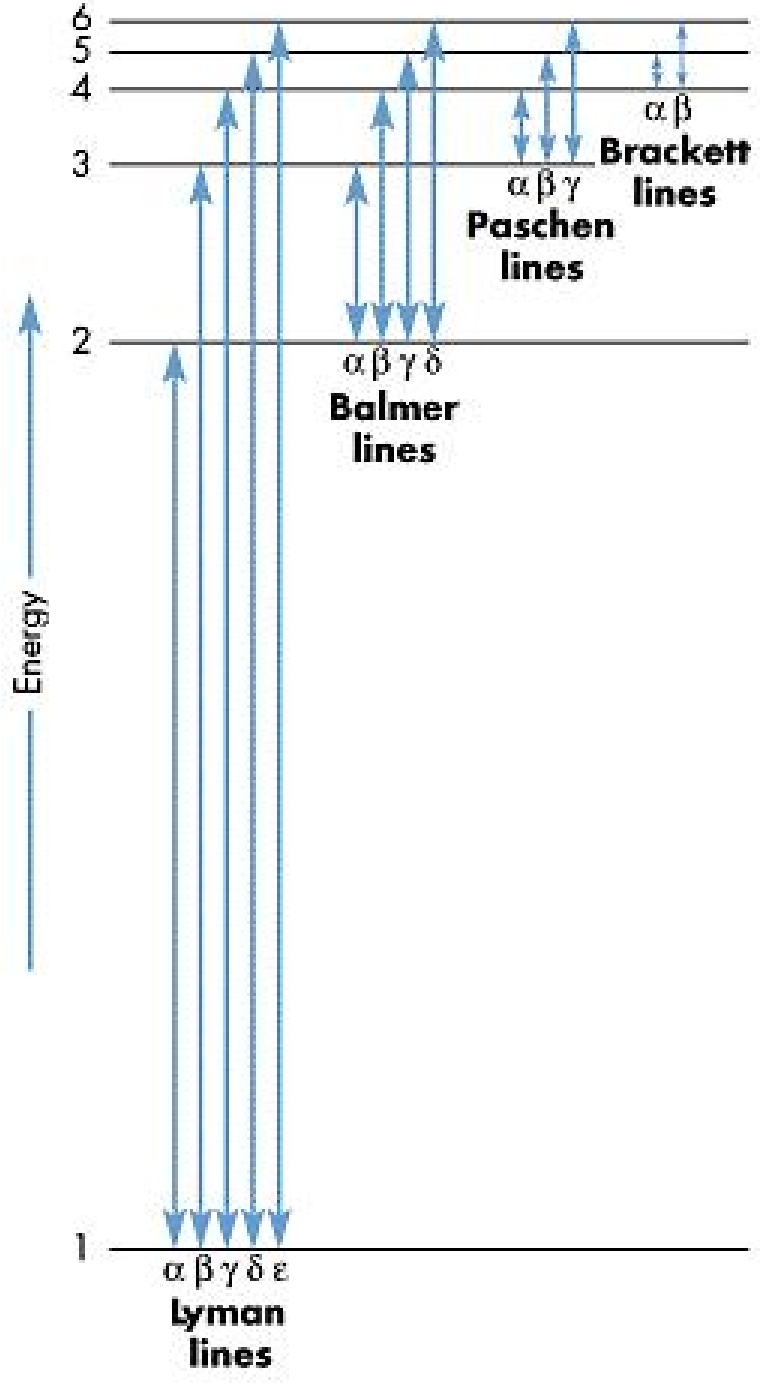
From quantum mechanics, only certain orbits are allowed. Each orbit has a specific energy. Lowest energy level is called 'ground state'.


How Atoms Emit Light
©2001 HowStuffWorks
Particles
1
Nucleus
2
3
1. A collision with a moving particle excites the atom.
2. This causes an electron to jump to a higher energy level.
3. The electron falls back to it's original energy level, releasing the extra energy in the form of a light photon.
Light Photon

How atoms emit light

- The emitted photon has an energy which is exactly the energy difference between the orbits that the electron had before and after.
- Because only certain energies are allowed for the electron orbits, only certain energies of photons can be produced. We call these the spectral lines.

Spectral lines of hydrogen



The length of each arrow determines the energy of the photon emitted.

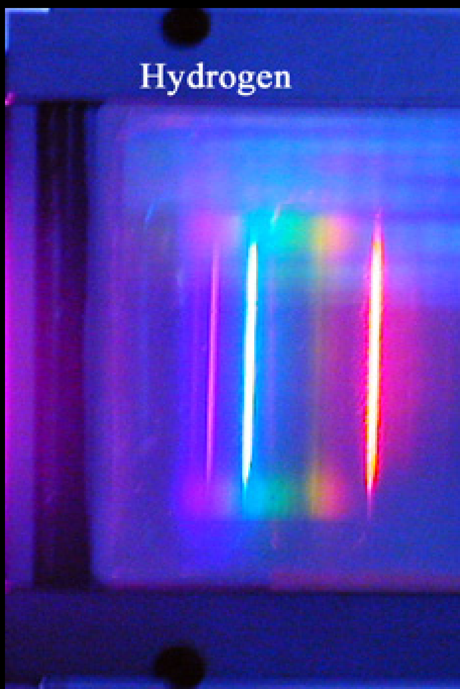
Spectral lines

- Each element (hydrogen, helium, neon, mercury, iron, …) has its own particular set of energy levels and its own set of spectral lines.

- Do demonstration (7B10.10)

Spectra

A



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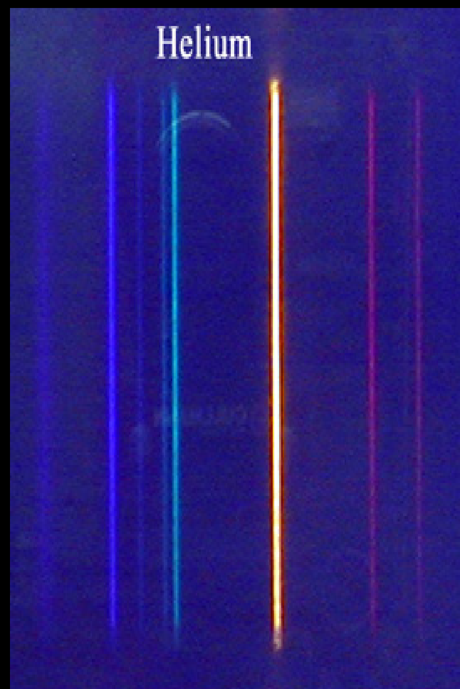
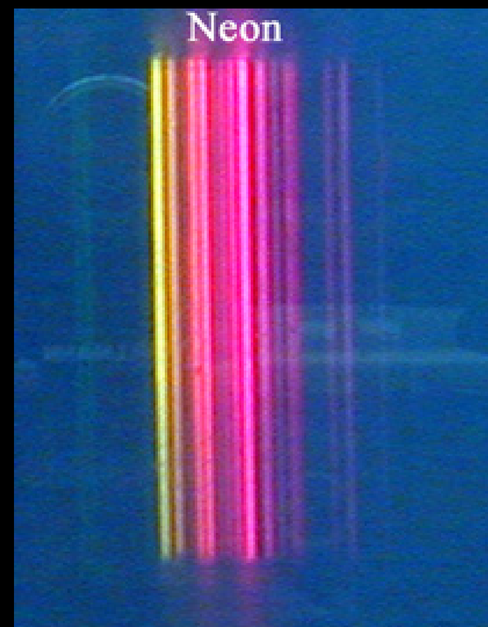
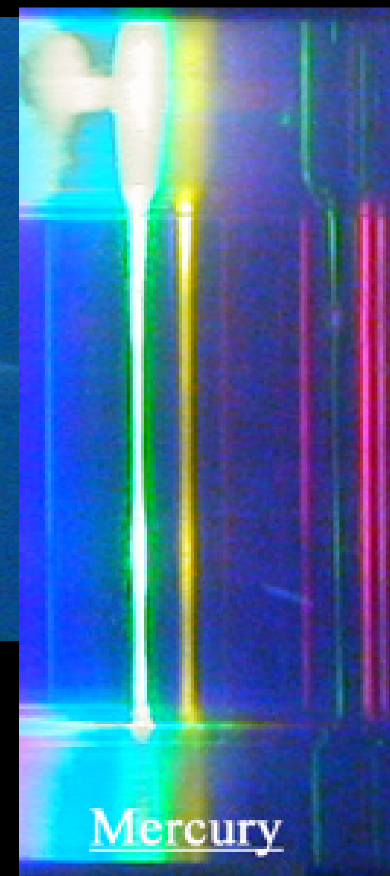


C



D



Uses of spectral lines

- Because each element has it own unique pattern of spectral lines, the spectral lines from stars can be used to determine the composition, or the relative number of atoms of each elements, of the stars

Which of the following statements about electrons is **not** true?

A) Electrons orbit the nucleus rather like planets orbiting the Sun.

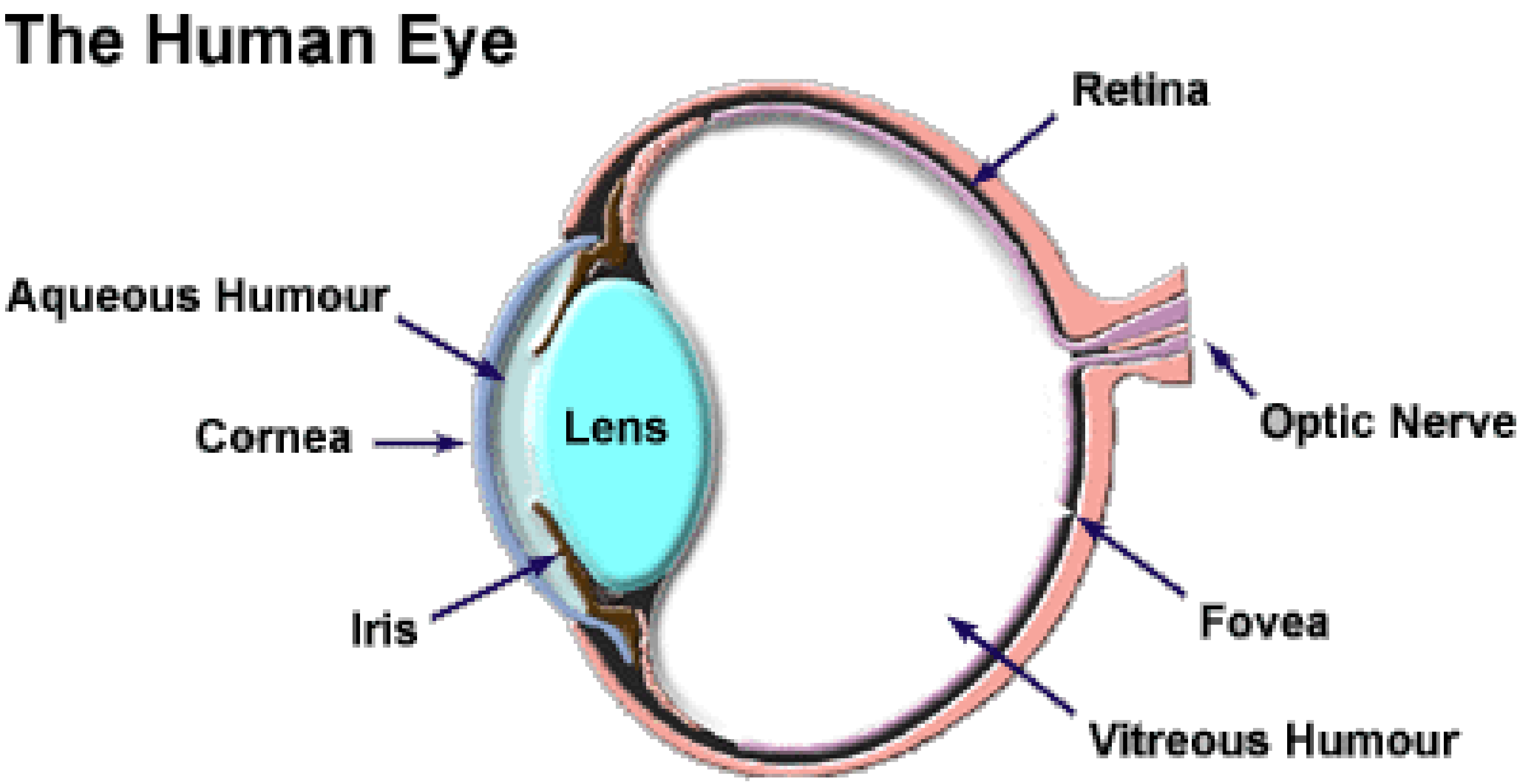
B) Within an atom, an electron can have only particular energies.

C) Electrons can jump between energy levels in an atom only if they receive or give up an amount of energy equal to the difference in energy between the energy levels.

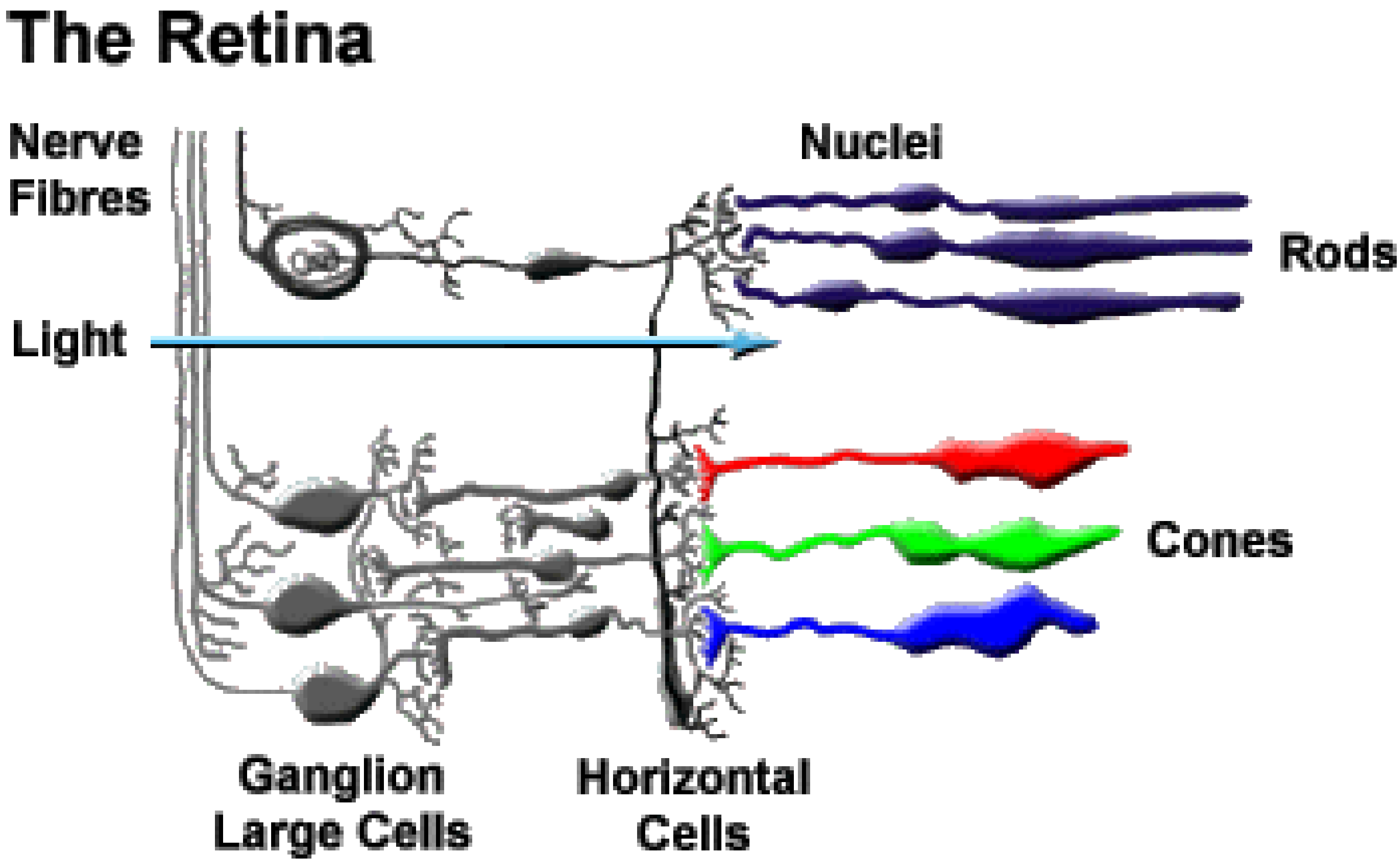
D) An electron has a negative electrical charge.

E) Electrons have very little mass compared to protons or neutrons.

How your eye sees light and color



Rods and cones on the retina sense light

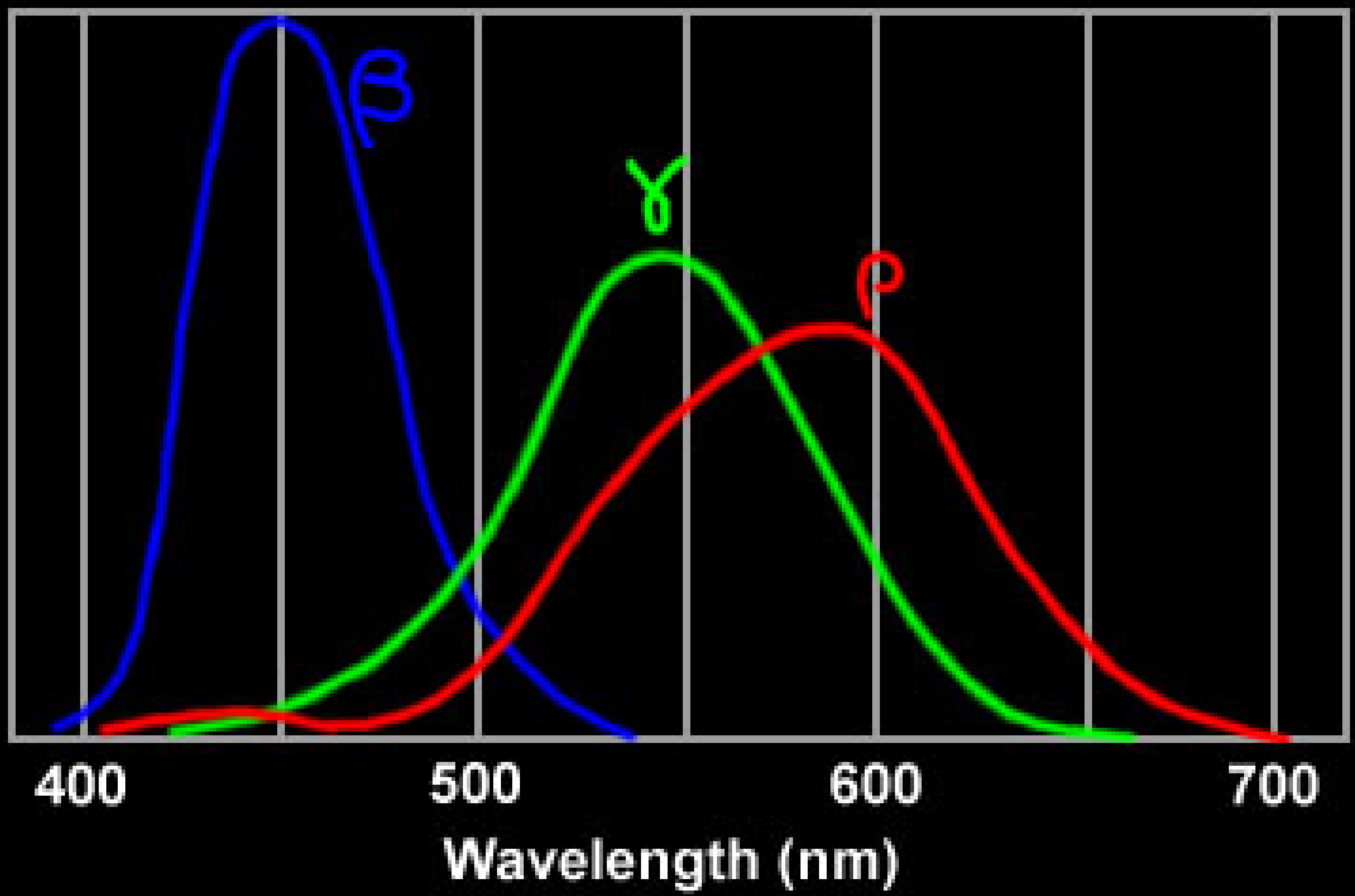


Rods and cones

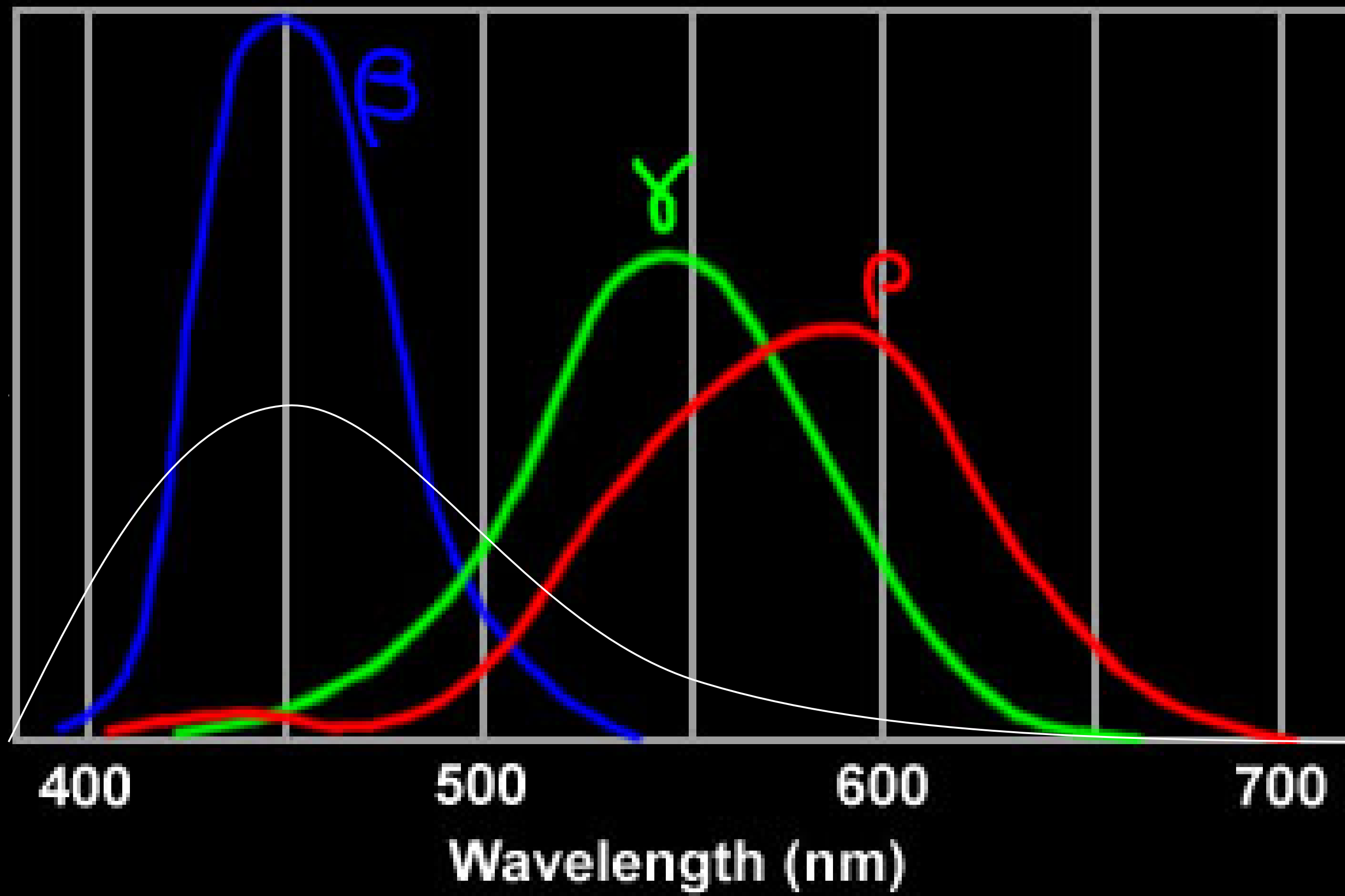
- Cones are color sensors
- There are cones for red, green, and blue
- The color ones perceives depends on the firing rates of the red vs. green vs. blue cones
- Cones need relatively bright light to work

- Rods give finer, more detailed vision
- Rods can work with less light
- At night, color vision is less effective because only the rods function

Sensitivity of cones



A star will produce light overlapping the response of all three cones. The color of the star depends on how strong its spectrum is in the ranges covered by the different cones.



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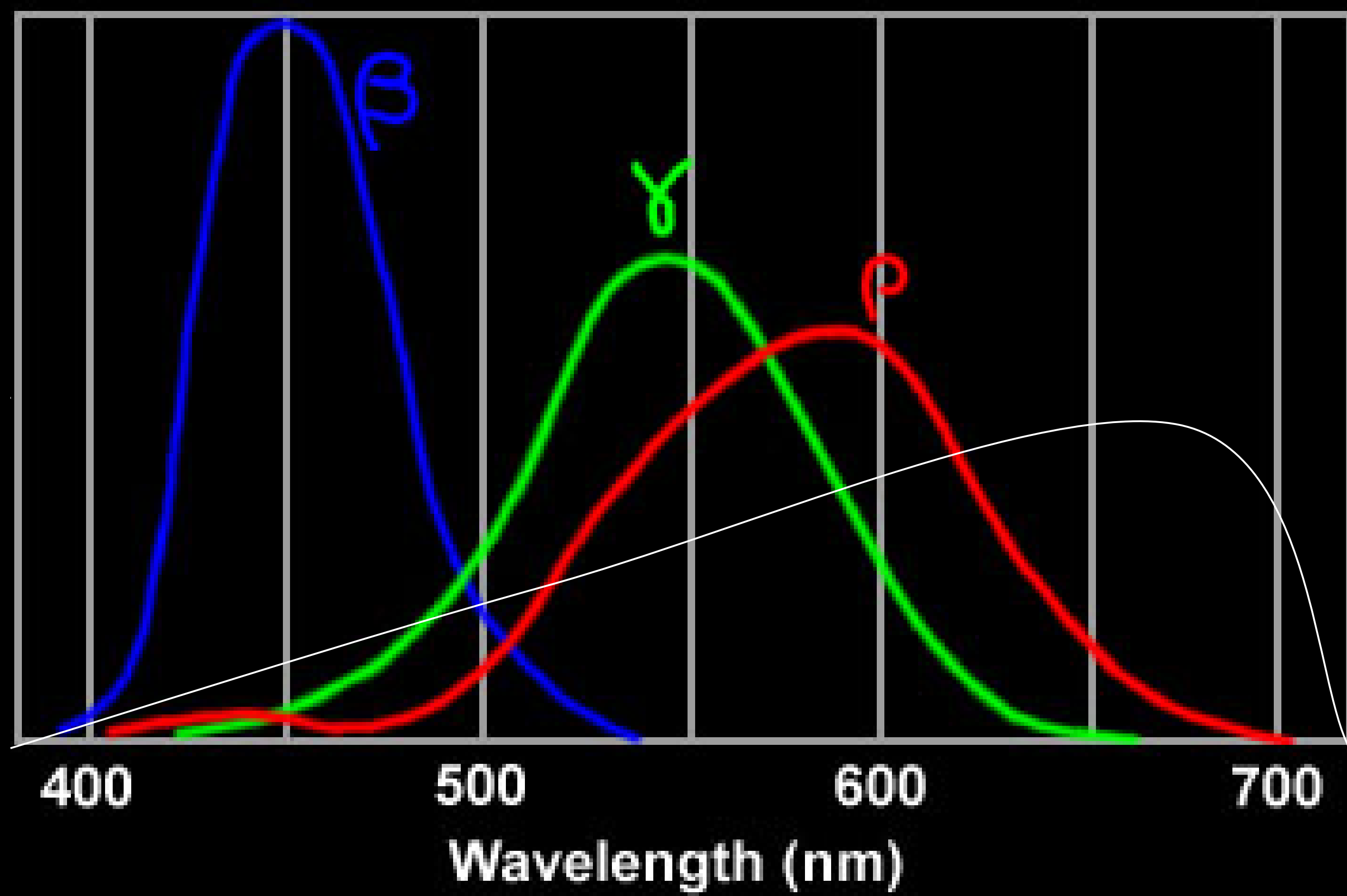

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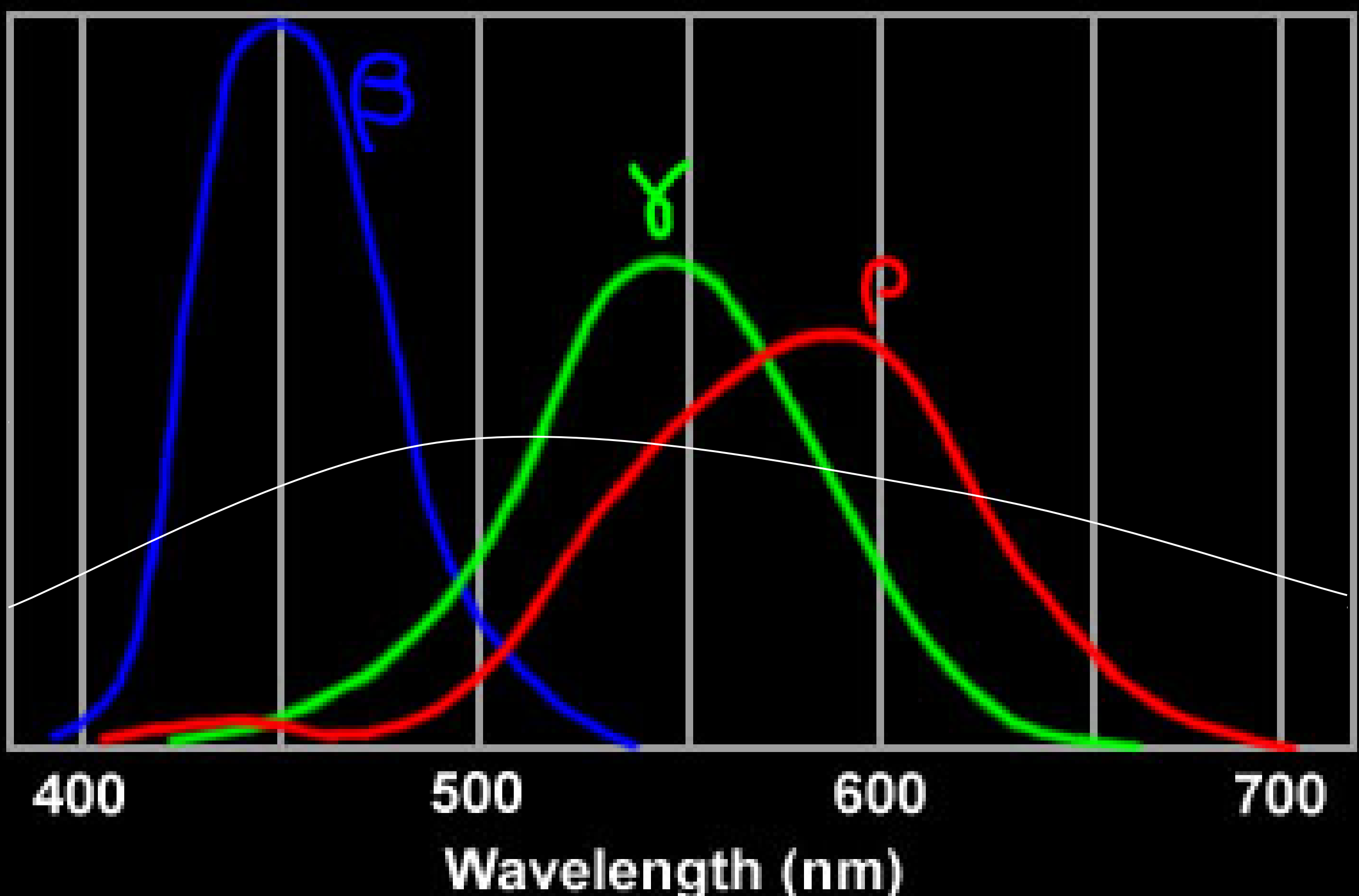

Review Questions

- What are flux, luminosity, and their relation?
- Is the magnitude of a star determined by its flux or luminosity? How about the absolute magnitude?
- How is the color of star related to its temperature?
- What do “spectral types” of stars indicate?
- How does your eye see color?