Quiz 2 Score Distribution

Score	# Papers	% Class
0	12	8%
½	8	5%
1	5	3%
1 ½	20	14%
2	30	21%
2 ½	17	12%
3	34	23%
3 ½	22	15%
4	8	5%

Quiz 2 Feedback

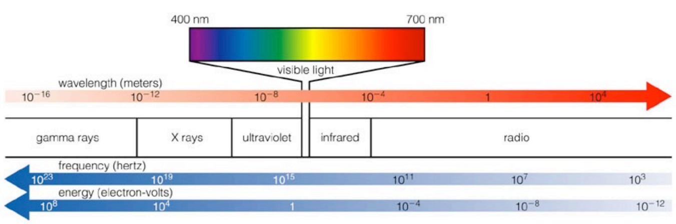
1. λ_A = 100 nm = 10^{-7} m; λ_B = 10 μm = 10^{-5} m. So λ_B is larger than λ_A, by a factor of 100. Which has the smaller frequency and energy? In what spectral regions do they fall?

We have talked a lot about relationships among wavelength λ, frequency ν, and energy e, for different kinds of light. If λ gets bigger, ν gets **smaller**, in order to keep their product constant: $\lambda \times \nu = c$. The other key relation, $e = h \times \nu$, tells us that lower frequency photons have **less energy.**

You should know the basic regions of the electromagnetic spectrum, from shortest λ/highest ν photons (gamma rays) to longest λ/lowest ν photons (radio). The question says that visible light covers 400 – 700 nm. λ_A = 100 nm, so Photon A is in the **ultraviolet**; $\lambda_B = 100 \times \lambda_B$ = 10,000 nm, so Photon B is an **infrared** photon.

The Electromagnetic Spectrum

Remember: as λ increases, ν decreases, & vice versa (They go in ***opposite*** directions, as show by the arrows.)



And: as ν increases, *e* increases; same for decreases. (They go in ***the same*** direction; see arrows.)

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Quiz 2 Feedback

2. Cloud A has all its electrons in the ground state (zero energy), while Cloud B has some electrons in higher energy states. Viewed by themselves, what kind of spectra do they produce?

You can't just use a memorized version of Kirchhoff's Laws, because the question doesn't explicitly tell you the clouds' temperatures. In order to make the correct prediction, you need to understand *how spectral lines are formed*. Cloud B is able to produce **emission lines** because it has electrons in excited levels, that can fall to lower levels and spit out photons. In Cloud A, the electrons are *already* in the lowest possible level; they have nowhere to fall to! Cloud A will produce *no spectral lines at all*. Nor will it produce a continuous, thermal spectrum, if it is a gas cloud of low density (it's not a star).

Electron Orbits or "Energy Levels"

- The lowest energy level for an atom is the **ground state**. All levels above it are **excited states**.
- Electrons must ***gain*** energy in order to jump *from a lower orbit or level to one with higher energy*.
- When electrons fall *from a higher to a lower orbit/energy level*, they **lose** energy by releasing a photon.

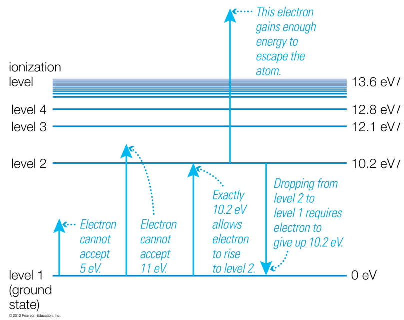

Figure credit: Bennett et al. The Essential Cosmic Perspective, 6e

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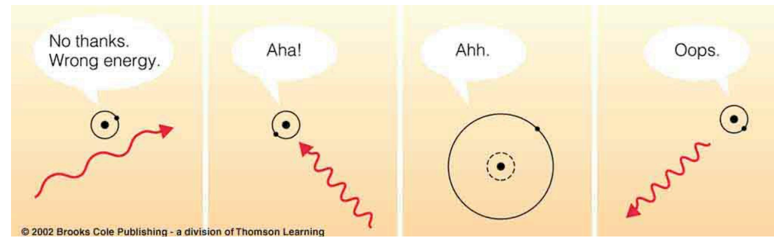
Emission and absorption of light by atoms

When an atom absorbs light, the photon energy must be exactly equal to the energy needed to make an electron jump from a lower-energy orbit to a higher-energy one.

When an atom emits light, a photon is created; the energy of the photon must be exactly equal the energy lost when an electron falls from the higher to the lower-energy state.



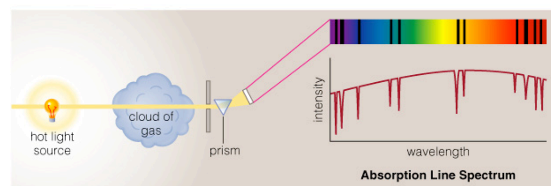
Credit: slide from Prof. J. Lacy

Quiz 2 Feedback

2. (cont'd). How do your predictions change, if there is a star in the background, with its light passing through these clouds?

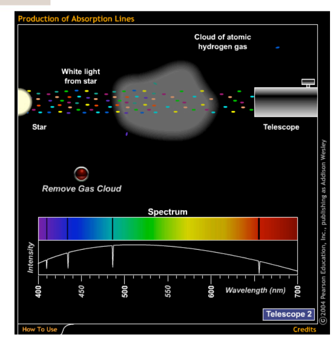
The background star produces a continuous (thermal) spectrum that passes through the cloud, before reaching us. The electrons in Cloud A now have the opportunity to grab energy in the form of photons, and jump up to higher energy levels. When this happens, we see **absorption lines** against the background starlight. You could say that Cloud A is "backlit," and suddenly you can tell that it's there! Although some of those electrons will fall back down again, releasing a photon, that will restore only some, not all, of the light at that wavelength (remember the animation). Cloud B can do the same thing – create absorption lines – but might also show emission lines if there are enough electrons in high energy levels.

How are Absorption Lines Produced?



Phenomenological view: When a continuous spectrum passes through a cloud of cool gas, you see absorption lines.

What is really happening: Light of all colors (wavelengths) is supplied by the background light source. The cloud absorbs only the photon energies which enable its electrons to jump from lower to higher energy levels; they have to match exactly. Then it re-emits in all directions, so fewer photons of that energy flow forward.



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