

Introductory Astronomy

Homework 7: Spectra Not to be handed in. Homework solutions are posted already.

- An ion is a:
 - synonym for an atom.
 - neutral atom.
 - charged atom.
 - molecule.
 - proton.
- Thermal energy or heat energy is:
 - statistically distributed forms of the other kinds of energy: most notably microscopic kinetic energy, microscopic potential energy, and electromagnetic radiation.
 - temperature.
 - the opposite of cold.
 - the microscopic cause of friction.
 - an invisible fluid that causes temperature.
- Any body (including a cloud of dilute gas) at a finite temperature or range of temperatures will radiate (in addition to any reflected light):
 - a pure line spectrum.
 - a perfect blackbody spectrum.
 - only X-rays.
 - electromagnetic radiation.
 - nothing at all.
- A solid, liquid, or dense gas at a uniform temperature (in addition to any reflected light) will:
 - radiate a line spectrum.
 - radiate a greybody spectrum.
 - radiate a blackbody spectrum which is a universal spectrum that depends only on the absolute (i.e., Kelvin scale) temperature of the radiating body.
 - have a uniform color that depends only on the shape of the radiating body.
 - radiate nothing.
- Wien's law for blackbody spectra is

$$\lambda_{\text{micron}}^{\text{max}} = \frac{2898 \text{ micron-K}}{T} .$$

Say one has a stellar spectrum with a maximum wavelength at 0.5 microns. What is the star's approximate photospheric temperature?

- 600 K.
 - 6000 K.
 - 20000 K.
 - 31416 K.
 - 6000 nm.
- The total power per unit area (i.e., flux) radiated by a blackbody radiator is given by the Stefan-Boltzmann law

$$F = \sigma T^4 ,$$
 where $\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$ is the Stefan-Boltzmann constant in MKS units and T is absolute temperature in Kelvins. If temperature is changed by a multiplicative factor of 3, then flux F is changed by a multiplicative factor of:
 - 1/3.
 - 3.
 - 9.
 - 27.
 - 81.

- The layer of a star (e.g., the Sun) from which most of the emitted electromagnetic radiation comes is called the:

- a) photosphere. b) chromosphere. c) hemisphere. d) core. e) corona.
8. The Sun emits a spectrum that is approximately a blackbody spectrum. It isn't exactly a blackbody spectrum because, among other reasons,:
- the photospheric emission forms over a range of temperatures and there is an **EMISSION LINE SPECTRUM** superimposed on the photospheric emission.
 - the photospheric emission forms over a range of temperatures and there is an **ABSORPTION LINE SPECTRUM** superimposed on the photospheric emission.
 - the photospheric emission forms at a single temperature.
 - the coronal emission is almost equal to the photospheric emission.
 - convective layer of the Sun is so huge: about 2/7 solar radii deep.
9. The H α line, usually the strongest **VISIBLE** line of hydrogen, has a wavelength of 656 nm It is a/an _____ line.
- a) X-ray b) ultraviolet c) radio d) red e) red and blue
10. A true blackbody absorbs all the electromagnetic radiation that hits it (i.e., it does not reflect any electromagnetic radiation) and has a uniform temperature. Let us treat the Earth as blackbody and make a correction for the Earth's atmospheric reflection. The light gathering surface area of the Earth is

$$\pi R_{\oplus}^2 ,$$

where $\pi \approx 3.1416$ is pi, a pure number, and R_{\oplus} is the Earth radius. The total light energy gathered per unit time by the Earth is thus

$$f(1 - a)\pi R_{\oplus}^2 , \tag{1}$$

where $f = 1367$ watts per square meter is the mean solar constant (Cox-340) and $(1 - a) = 0.7$ is a factor accounting for the reflection of electromagnetic radiation from the Earth's atmosphere (Rampino, M. R. & Caldiera K. 1994, Ann. Rev. Astron. Astrophys., 32, 83, p. 85).

As a blackbody the Earth radiates a total energy per unit time of

$$A\sigma T^4 , \tag{2}$$

where

$$A = 4\pi R_{\oplus}^2$$

is the surface area of the Earth and σT^4 is the Stefan-Boltzmann law (i.e., the energy radiated per unit area per unit time by a blackbody). The sigma constant is 5.67×10^{-8} in mks units.

Since the Earth is neither a net energy gainer or loser (at least not to an extent important for this problem), expression (1) must equal expression (2) to maintain a constant thermal energy content on Earth. Equating the expressions, we obtain:

$$f(1 - a) = 4\sigma T^4$$

or

$$\begin{aligned} T &= \left[\frac{f(1 - a)}{4\sigma} \right]^{1/4} \\ &= 255 \text{ K} . \end{aligned}$$

This temperature is called the blackbody or effective temperature of the Earth.

- a) At 255 K the Earth would be way hotter than the boiling point of water. The reason the Earth isn't this hot is because the Earth is not actually a blackbody.
 - b) At 255 K the Earth would be colder than the freezing point of water. The reason the Earth isn't this cold is because of the greenhouse **cooling** effect.
 - c) At 255 K the Earth would be colder than the freezing point of water. The reason the Earth isn't this cold is because of the greenhouse **heating** effect.
 - d) At 255 K the Earth is at a comfortable temperature for life. Our simple analysis shows why life is possible on Earth. The same analysis for Venus and Mars would show why life as we know it would be unlikely there. Both Venus and Mars would be too cold. (Venus would be too cold despite being located closer to the Sun because of its high reflectivity.)
 - e) At 255 K Mars is at a comfortable temperature for life. Nevertheless, life there seems unlikely.
11. The Doppler effect causes:
- a) the wavelength of a wave phenomenon to change (or shift) when its **source and receiver** are moving with respect to each other along the source-receiver line.
 - b) the wavelength of a wave phenomenon to change (or shift) when its **source** (but **never** its **receiver**) is moving along the source-receiver line.
 - c) the wavelength of a wave phenomenon to change (or shift) when its receiver (but **never** its source) is moving along the source-receiver line.
 - d) the Sun to appear redder at sunset and sunrise than at midday.
 - e) the Sun to appear redder at midday than at sunset and sunrise.
12. A source of light is moving away from you, and thus the light is:
- a) redshifted. b) blueshifted. c) greenshifted. d) yellowshifted. e) turquoiseshifted.
13. The lines of atomic line spectra are not infinitely narrow in wavelength. There is a natural intrinsic width which is broadened by thermal and collisional effects. But let's ignore those effects for this question. How would an atomic line from a rapidly rotating star appear different from the same atomic line as measured in the laboratory?
- a) The star line would be divided into three lines: a fast line, a slow line, and an intermediate line.
 - b) The star line would **narrower** due to the Doppler effect.
 - c) The star line would be expanded into a blackbody spectrum by the rotation.
 - d) The star line would be **broader** due to the Doppler effect. The part of the star moving toward the observer would broaden the line in the **long wavelength (redward) direction**. The part of the star moving away from the observer would broaden the line in the **short wavelength (blueward) direction**.
 - e) The star line would be **broader** due to the Doppler effect. The part of the star moving toward the observer would broaden the line in the **short wavelength (blueward) direction**. The part of the star moving away from the observer would broaden the line in the **long wavelength (redward) direction**.