Introductory Astronomy **NAME:**

Homework 7: Spectra: Homeworks and solutions are posted on the course web site. Homeworks are **NOT** handed in and **NOT** marked. But many homework problems ($\sim$ 50–70 %) will turn up on exams.

1. Did you complete reading-homework-self-testing for the Introductory Astronomy Lecture (IAL) by the weekly due date?

   a) YYYessss! b) Jawohl! c) Da! d) Sí, sí. e) OMG no!

2. Internal energy or heat energy is:

   a) statistically distributed forms of the other kinds of energy: most notably microscopic kinetic energy, microscopic potential energy, and electromagnetic radiation.
   b) temperature.
   c) the opposite of cold.
   d) the microscopic cause of friction.
   e) an invisible fluid that causes temperature.

3. Any body (including a cloud of dilute gas) at a nonzero temperature or range of temperatures will radiate (in addition to any reflected light):

   a) a pure line spectrum. b) a perfect blackbody spectrum. c) only X-rays.
   d) electromagnetic radiation. e) nothing at all.

4. A solid, liquid, or dense gas at a uniform temperature (in addition to any reflected light) will:

   a) radiate a line spectrum.
   b) radiate a greybody spectrum.
   c) radiate a blackbody spectrum which is a fundamentally important spectrum whose shape depends only on the absolute (i.e., Kelvin scale) temperature of the radiating body.
   d) have a uniform color that depends only on the shape of the radiating body.
   e) radiate nothing.

5. Wien's law for blackbody spectra is

$$\lambda_{\mu\text{m}}^{\text{max}} = \frac{2897.771955\ldots\,\mu\text{m}\,\text{K}}{T} \ .$$

   Say one has a stellar spectrum with a maximum wavelength at $0.5\,\mu$m (i.e., 0.5 microns). What is the star's approximate photospheric temperature?

   a) 600 K. b) 6000 K. c) 20000 K. d) 31416 K. e) 6000 nm.

6. 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, except that it reflects that fraction of light that it actually does reflect. The light gathering surface area of the Earth is

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

   where $\pi = 3.14159265\ldots$ 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

$$f(1-a)\pi R_\oplus^2 \ , \qquad (1)$$

   where $f = 1367.6$ watts per square meter is the mean solar constant and $(1-a) = 0.694$ is a factor accounting for the reflection of electromagnetic radiation from the Earth (Wikipedia: Earth: Bond albedo).

   As a blackbody (except for the reflection correction), the Earth radiates a total energy per unit time of

$$A\sigma T^4 \ , \qquad (2)$$

   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 constant $\sigma = 5.670373 \times 10^{-8}$ 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

$$T = \left[\frac{f(1-a)}{4\sigma}\right]^{1/4} = 254\,\text{K} \ .$$

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

a) At 254 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 254 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 254 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 254 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 254 K, Mars is at a comfortable temperature for life. Nevertheless, life there seems unlikely.

7. An ion is a:

   a) synonym for an atom. b) neutral atom. c) charged atom. d) molecule.
   e) proton.

8. The line spectrum of an atom, ion, or molecule is:

   a) an almost unique identifier of the atom, ion, or molecule.
   b) the radiation emitted when the temperature of the atom, etc., goes over 1000 K.
   c) the radiation emitted when the temperature of the atom, etc., goes over 10,000 K.
   d) the radiation emitted when the temperature of the atom, etc., goes over 25,000 K.
   e) never observed from astronomical bodies outside of Solar System.

9. The Hα line (AKA the H-alpha 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. 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.

11. The Sun emits a spectrum that is approximately a blackbody spectrum. It isn't exactly a blackbody spectrum because, among other reasons:

    a) the photospheric emission forms over a range of temperatures and there is an **EMISSION LINE SPECTRUM** superimposed on the photospheric emission.
    b) the photospheric emission forms over a range of temperatures and there is an **ABSORPTION LINE SPECTRUM** superimposed on the photospheric emission.
    c) the photospheric emission forms at a single temperature.
    d) the coronal emission is almost equal to the photospheric emission.
    e) convective layer of the Sun is so huge: about 2/7 solar radii deep.

12. The Doppler effect for light 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.

13. One light source is moving directly away from you; another light source is moving exactly perpendicular to your line of sight to it for the length of time of the observation: i.e., its moving on a **CIRCLE** centered on you.

a) The first source is Doppler shifted to the **RED** (i.e., to longer wavelength). The second source is **NOT** significantly Doppler shifted unless its velocity is not small compared to the vacuum speed of light.
b) The first source is Doppler shifted to the **BLUE** (i.e., to shorter wavelength). The second source is **NOT** significantly Doppler shifted unless its velocity is not small compared to the vacuum speed of light.
c) **NEITHER** source is Doppler shifted. There can only be a Doppler shift if the velocity is specified in the problem.
d) **BOTH** sources are Doppler shifted to the **RED** by about the same amounts.
e) **NEITHER** source is Doppler shifted. There can only be a Doppler shift when the source is approaching the receiver.

14. 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**.