

Introductory Astronomy

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

007 qmult 00010 1 1 3 easy memory: ion defined

Extra keywords: CK-110-ion

1. An ion is a:

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

SUGGESTED ANSWER: (c)

Wrong answers:

- e) Well a bare proton is the hydrogen ion, but an ion is not a proton.

Redaction: Jeffery, 2001jan01

007 qmult 00100 1 4 1 easy deducto-memory: thermal energy defined

2. Thermal 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.

SUGGESTED ANSWER: (a) However I've given a longer definition than in class in order to be more accurate: but this may only confuse people.

Wrong answers:

- b) The first misconception about heat that is dealt with in any course. In any case, heat is an extensive quantity, temperature an intensive one.
c) Actually coolness would be closer to an opposite. Hot is closer to the opposite of cold.
d) The microscopic cause of friction are electromagnetic forces which often do depend on temperature in some way.
e) Shades of the old phlogiston theory where heat was a substance.

Redaction: Jeffery, 2001jan01

007 qmult 00400 2 4 4 moderate deducto-memory: hot bodies radiate

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

SUGGESTED ANSWER: (d) It's just a wee bit tricky I think to rule out perfect blackbody spectrum.

Wrong answers:

- a) In strictest sense I doubt that anything emits a pure line spectrum, but obviously some things are close enough.

- b) In strictest sense I doubt that anything emits a perfect blackbody spectrum, but obviously some things are close enough. But a dilute gas doesn't: it emits a line spectrum.
- c) Obviously not.
- e) Nah.

Redaction: Jeffery, 2001jan01

007 qmult 00500 1 1 3 easy memory: blackbody spectrum

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 universal spectrum that 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.

SUGGESTED ANSWER: (c)

Wrong answers:

- b) A greybody spectrum?

Redaction: Jeffery, 2001jan01

007 qmult 00650 1 3 2 easy math: using Wien's law for a star

5. 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?

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

SUGGESTED ANSWER: (b) If one remembers the maximum wavelength of the Sun and the Sun's photospheric temperature, then it becomes a memory question.

Wrong answers:

- e) Wrong units.

Redaction: Jeffery, 2001jan01

007 qmult 00670 1 3 5 easy math: using Stefan-Boltzmann law

Extra keywords: CK-98,111-3

6. 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:

- a) 1/3.
- b) 3.
- c) 9.
- d) 27.
- e) 81.

SUGGESTED ANSWER: (e)

Wrong answers:

- b) Wrong guess.

Redaction: Jeffery, 2001jan01

007 qmult 00800 1 4 1 easy deducto-memory: photosphere defined

Extra keywords: CK-249,266

7. 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.

SUGGESTED ANSWER: (a)

Wrong answers:

- d) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

007 qmult 01000 3 1 2 tough memory: Sun's absorption line spectrum

8. 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.

SUGGESTED ANSWER: (b)

Wrong answers:

- a) not an emission line spectrum: this takes memory for most students.
- c) this isn't likely and was denied in book and (one hopes) in the lectures.
- d) No it isn't. This should be memorable from several points of view. We don't ordinarily see the huge corona right.
- e) a red herring.

Redaction: Jeffery, 2001jan01

007 qmult 01100 2 4 4 moderate deducto-memory: H alpha line wavelength

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

SUGGESTED ANSWER: (d)

Wrong answers:

- e) This not logically possible, unless one starts making special qualifications: e.g., consider strongly Doppler shifted versions of the line. But special cases are not best answers.

Redaction: Jeffery, 2001jan01

007 qmult 01200 2 5 3 moderate thinking: Earth's blackbody temperature

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

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

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. & Caldirola K. 1994, Ann. Rev. Astron. Astrophys., 32, 83, p. 85).

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

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

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.

- 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.
- 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.
- 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.
- 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.)
- At 255 K Mars is at a comfortable temperature for life. Nevertheless, life there seems unlikely.

SUGGESTED ANSWER: (c) The trick question. The preamble is hard, but the students don't do the algebra or the math. They just assess the result.

Wrong answers:

- Above boiling temperature: not on the Kelvin scale.

- b) Greenhouse cooling effect?
- d) -18°C is comfortable?
- e) Mars isn't at issue.

Fortran Code

```

      print*
      solcon=1367.  ! Cox-340 average value
*      aa=.367      ! Cox-299 this is only visual light
      aa=.3        ! Rampino & Caldiera - 85 presumably this
*                ! the good average for all wavelengths
      sigma=5.67e-8
      tem=( solcon*(1.-aa)/(4.*sigma) )**25
      print*, 'tem'
      print*, tem
*                254.862

```

Redaction: Jeffery, 2001jan01

007 qmult 01300 1 1 1 easy memory: Doppler effect

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.

SUGGESTED ANSWER: (a) One does have to understand that relative motion is the key thing.

Wrong answers:

- e) Nah.

Redaction: Jeffery, 2001jan01

007 qmult 01310 1 1 1 easy memory: redshift of receding source

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.

SUGGESTED ANSWER: (a)

Wrong answers:

- e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

007 qmult 01500 3 5 5 tough thinking: Doppler effect and line spectra

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**.

SUGGESTED ANSWER: (e) Can students put Doppler effect and line spectra together?

Wrong answers:

- a) red herring for people who are vaguely thinking of the Zeeman effect.
- b) the Doppler effect would do the reverse. If people read the other answers, this would probably become clear.
- c) complete red herring.
- d) the follow up description is wrong. Moving away causes redshift. Moving toward causes blueshift.

Redaction: Jeffery, 2001jan01