Astronomy 161, Winter 2008
Prof. Terndrup

Exam #2 – Friday, February 8, 2008

Enter your name here ______________________________________ (4 points)

Section I. Short calculations, 12 points each. Show your work in the space provided. In the little boxes, write down the number that is your final answer. Your answer(s), in some cases, will require units.

1. This is a question about one of Kepler's laws. You discover a distant object in a nearly circular orbit with a period of 1000 yr. How far does this object orbit from the Sun? Express your answer in astronomical units (au).

100 au

   The law we want relates the period *P* to the size of the semimajor axis *a*. The value of *P* is in years, and the value of *a* is in astronomical units. We have *P* so we want *a*.

   $a^3 = P^2 = 1000^2 = 10^6$

   So *a* = 100 au.

2. An atom absorbs a photon with a wavelength λ = 600 nm. It later emits two photons, one with 1/10 the energy of the original photon, and the other with 3 times the energy of the original photon. What wavelengths of light are emitted?

6000 nm 200 nm

   Wavelength is inversely proportional to energy, so 1/10 the energy means 10 times the original wavelength. 3 times the energy means 1/3 the wavelength.

3. This is a question about the inverse-square law. Outside the Earth's atmosphere, the solar flux is 1400 Watts per square meter. What is the solar flux at Saturn, which is located at a distance of about 10 au?

14 W/sq. m

You need to remember that the Earth is at a distance of 1 au from the Sun. The inverse-square nature of the flux means that at 10 times the distance, the flux is reduced by $1/(10^2) = 0.01$. So the flux is 0.01×1400 Watts per square meter.

4. This is a question about the Wien law. You measure the light coming from the object in the previous problem, and find its spectrum peaks at a wavelength of 100 microns (μm). What is the temperature of this object?

29 K

We solve it this way:

$$T = \frac{2900\mu\text{m} \cdot \text{K}}{\lambda_{\text{max}}} = \frac{2900\mu\text{m} \cdot \text{K}}{100\mu\text{m}} = 29\text{K}$$

Section II – short answers (no math required), 6 points each.

5. Explain why objects fall at the same rate, even if they have different masses.

   The gravitational force is proportional to the mass, so larger masses have larger forces. Larger masses are harder to accelerate, however. The two effects cancel out and the acceleration for all objects is identical.

   Several people answered this by saying that the force on all objects was the same. If that were true, then heavy items would fall more slowly than light ones (remember $F = ma$).

6. Explain why atoms emit or absorb light only at specific wavelengths.

   The electrons in an atom can only have certain energy levels, so therefore transitions from one level to another cannot have any energy but have only specific energies. A photon involved in that transition must therefore have exactly the energy difference between two states of an electron. Since the energy of a photon is (inversely) related to its wavelength, atoms can emit or absorb light only at certain wavelengths.

7. In a few billion years, the Sun will get cooler, but also get about 500 times as luminous as it is now.
   a) Does that mean the Sun will shrink or expand?
   b) What will happen to the temperature of Jupiter when the Sun does this?

   a) The luminosity depends on the surface area and the temperature. If the temperature goes down but the luminosity goes up, then the area has to go up. Therefore the Sun will expand.

   b) If the Sun is emitting 500 times its current energy, then energy will arrive at Jupiter at 500 times the current rate. Thus Jupiter will get hotter.

   Note that it is **not** correct to say that Jupiter will be closer to the (expanded) sun. Jupiter is a long way off, and in any case this would be very small effect compared to the Sun's large increase in luminosity.

8. What is the physical meaning of temperature?

   Temperature is a measure of the average speed of motion of the atoms or molecules in an object.

9. Charon, Pluto's largest moon, has 1/6 the mass of Pluto. Charon and the Pluto have gravitational forces acting on them in their mutual interaction. What is the *direction* of the force on the Charon? on Pluto? How do the *sizes* of the forces

compare?

The force on Pluto is directed towards (i.e., points at) Charon. The force on Charon is directed towards Pluto. The sizes of the forces are identical. All these are parts of Newton's formulation of gravity.

10. Put the following regions of the electromagnetic spectrum in order from lowest energy to highest energy: infrared, radio, gamma ray, ultraviolet, visible, microwave.

    radio, microwave, infrared, visible, ultraviolet, gamma ray.

11. Why do astronomers want to build big telescopes?

    Either to gather light faster or to increase the angular resolution (i.e., to resolve finer details.)

12. Give two advantages to observing from space.

    a) Eliminate the effects of atmospheric turbulence, which reduces the angular resolution.
    b) Capture wavelengths of light which do not pass through the atmosphere.

    I did not like answers that stated that the telescope would be closer to the objects being observed. I never mentioned this in class, and you should remember the distances to objects in space are immensely large. With the exception of planetary probes, all space telescopes orbit very close to the Earth.