Ay 10 - Problem Set #3
Due: September 20, 11am

Please write your full name, section number, and GSI's name at the top of your homework. Also, be sure to put your homework in the correct box in the basement of Campbell Hall. There is a 20% penalty per day for the late submission of assignments, however you do get one "freebie" (see course syllabus for more info).

Remember to always show your work; no credit will be given for just a final answer. However, if you get most of the question right but get the final answer wrong, you will get most of the points. Use a calculator where necessary and dont forget units if the answer requires them.

If you use any resource besides the textbook, lecture, or section (*e.g.* a web site), be sure to include proper attribution for the reference. Feel free to work with other students in the class, but remember that all work turned in must be your own (*i.e.* don't just copy the work of another student).

1. **(10 points)** Consider an atom with **four energy levels**:

$$\begin{aligned} \text{E(Ground State)} &= 0\,eV \\ \text{E(Level 1)} &= 3\,eV \\ \text{E(Level 2)} &= 5\,eV \\ \text{E(Level 3)} &= 6\,eV \end{aligned}$$

Note: eV stands for **electron volt** and is a unit of energy commonly used when dealing with atoms and photons (1 eV $= 1.602 \times 10^{-19}$ Joules)

Imagine, now, a cloud that is composed completely of this kind of atom. The cloud is sufficiently hot that even level 3 is **excited** (meaning there are many atoms in the cloud with electrons in level 3).

(a) Which downward transition (i.e. **emission**) will give the **bluest** (**highest** energy photon)? What is the energy of that photon (in eV)?

(b) Which downward transition (i.e. **emission**) will give the **reddest** (**lowest** energy photon)? What is the energy of the that photon?

(c) Now let's imagine that the cloud is cold enough that all the electrons are in the ground state (meaning that none of the atoms in the cloud have electrons in levels 1 through 3). We place a source of light **behind** the cloud. The light-source emits light with the spectrum depicted in figure 1.

Modify (and hand in) figure 1 so that it matches what you would expect to observe if you were to look **through** the cloud to see the light source.

Hand this page in!

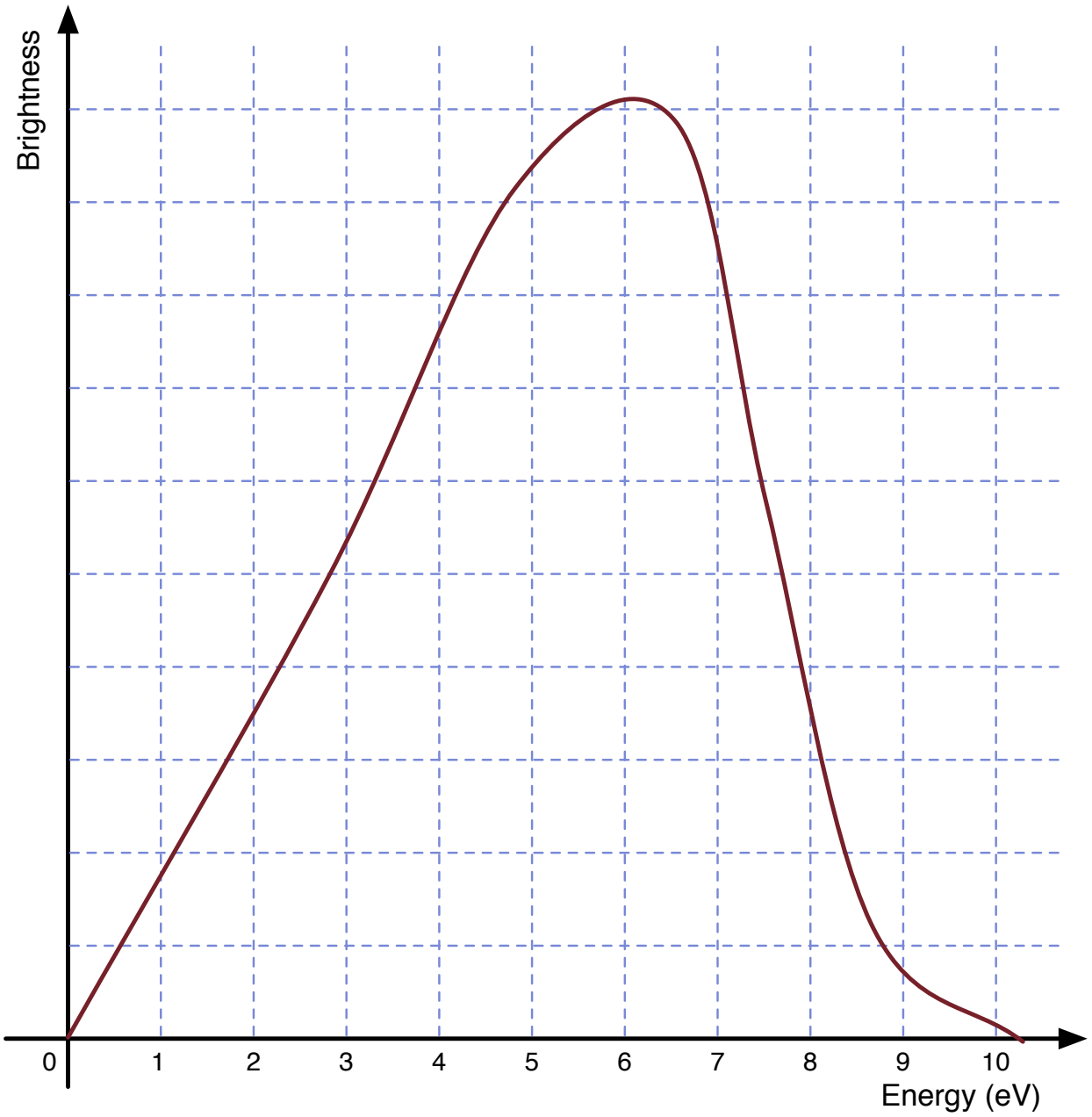

Figure 1: Spectrum emitted by the light-source.

2. **(5 points)** We've seen in lecture that the resolution of a telescope is defined to be the smallest angular separation on the sky that can be resolved. i.e. if two stars on the sky are separated by a larger angle than the resolution angle they will appear as two individual points when imaged by the telescope; but if the two stars are separated by a smaller angle than the resolution angle they will appear as a single fuzzy blob.

   The same argument applies for your eyes. How far away can you be from an oncoming vehicle (at night) to tell if the vehicle is a motorcycle (with one headlight) or a car (with two headlights)? You can assume that your eyes are diffraction-limited, that the diameter of your pupil is D=0.5 cm and that the wavelength of observation is $\lambda = 5000$Å. The typical separation of headlights on a car is 1.2 meters.

3. **(5 points)** The resolution of the Chandra telescope is about 1 arcsec for x-ray photons with wavelength 1Å. The effective collecting diameter of the mirror is 1.2 m. Based on these numbers, is Chandra imaging at its diffraction limit; that is, is it imaging within a factor of 2 of its diffraction limit?

4. **(5 points)** What are some advantages and disadvantages of putting a large telescope on the Moon? In particular:

   (a) How would the moon telescope be better or worse than ground-based observatories?

   (b) How would the moon telescope be better or worse than space-based observatories?

   Think in terms of both scientific merits and *practical* merits.

5. **(5 points)** A 2 m telescope can collect a certain amount of light in one hour.

   (a) Under the same observing conditions, how much time would be required for a **6 m** telescope to collect the same amount of light?

   (b) Again, under the same observing conditions, how much time would be required for a **12 m** telescope to collect the same amount of light?