PTYS/ASTR 206 – Section 3 – Homework 2 – Assigned 2/5/09

NAME:____

(PRINT CLEARLY)

- Homework is due <u>in class</u> on Thursday February 12th.
- Late homeworks can be turned in class on Tuesday February 17th for 50% credit.
- Homeworks turned in later than this receive 0%.
- Students are encouraged to discuss approaches to solving homework problems with each other; however, all work submitted must be the student's own. Do not turn in identical homeworks! See the syllabus for more information.

Hint: Each of these questions should be quick to answer. If you find yourself engaged in a long chain of complicated reasoning or more than a few lines of math then something is probably wrong! Make sure to start this early and talk to the TA or myself with any questions.

Another hint: Some questions require you to calculate the volume of a sphere. A simplified version of the formula to calculate the volume of a sphere, with a radius r, is:

$$\mathbf{4.19 * r^3}$$

Question 1: Craters on Asteroids

The mass of the asteroid Ceres (the largest asteroid) was just measured at $9.04*10^{20}$ Kg and its radius is 476 km. Assume that Ceres is a sphere and calculate its volume. What is the average density of this object? Is it closer to ice (1000 kg m^{-3}) or rock (3000 kg m^{-3})?

volume $= 4.19 * (476\,000\ m)^3$

volume $= 4.52 \times 10^{17}\ m^3$

Density $= \frac{\text{mass}}{\text{volume}} = \frac{9.04 \times 10^{20}\ kg}{4.52 \times 10^{17}\ m^3} = 2000\ kg\ m^{-3}$

It's halfway between ice and rock so Ceres is a mixture of both.

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Given its mass and radius, the gravitational acceleration at the surface is 0.27 ms^{-2}. Rock and *cold* water ice are both quite strong (assume a strength of $2*10^8$ Pascal). Use the formula in the lecture on cratering to figure out at what diameter craters on Ceres will transition from simple to complex.

$$\text{Transition Diameter} = \frac{\text{Strength}}{\text{Density} * \text{gravity}}$$

$$= \frac{2 \times 10^8 \ Pa}{2000 \ kg\, m^{-3} * 0.27 m s^{-2}}$$

$$= 370{,}370 m$$

Craters need to be 370 km in size to be complex.

Compare this crater size to the size of Ceres. The Dawn mission will visit Ceres in a few years; do you expect us to find many complex craters there? Why?

Ceres isn't much bigger than this (476 km in radius). Craters this big could destroy the asteroid So not many of them could have happened.

Question 2: Wavelengths of light emission?

The Earth's surface and lower atmosphere have a temperature of about 300K and radiate like a blackbody. What wavelength of the spectrum do they radiate most at? Use Wien's law from the lecture notes.

$$\lambda_{\text{peak emission}} = \left(\frac{0.0029}{T}\right) m$$

$$= 9.67 \times 10^{-6} m = 9.67 \ \mu m \text{ (microns)}$$

At this wavelength, is the Earth or the Sun radiating more energy from each square meter? Why? The sun is radiating more at all wavelengths (including this one) because it has the higher temperature.

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Why can't we observe astronomical objects at a wavelength of 10-11 microns? What do we 'see' if we try that?

We need to be careful when we do this. Earth's atmosphere is radiating at about 10 microns (see part a). If we try to look through it then ~~we can~~ the stars signal can get swamped by atmospheric emission.

Question 3: Energy in vs. energy out

The solar power at 1AU is 1370 W m^{-2}. The Moon absorbs 90% of the radiation that hits it. When the sun is directly over a patch of the lunar surface how much energy is each square meter absorbing?

$$0.9 \times 1370 \ Wm^{-2} = 1233 \ Wm^{-2}$$

absorbed

The temperature of this patch is 350K, how much energy is each square meter emitting? (Use the formula in the lecture notes). Is this patch of surface warming up or cooling down?

$$F = \sigma T^4$$

$$= 5.67 \times 10^{-8} * (350)^4 \ Wm^{-2}$$

$$= 851 \ Wm^{-2}$$

851 Watts leave each square meter, but 1233 Watts are absorbed. More energy absorbed than emitted means that the surface is heating up.

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When the emitted and absorbed radiations are the same then the temperature of the surface isn't changing. What is this 'equilibrium temperature' in this situation?

Absorbed = Emitted

$$1233 \text{ Wm}^{-2} = \sigma T^4$$

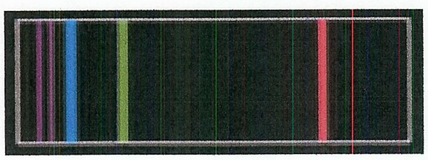
$$\left(\frac{1233}{5.67\times10^{-8}}\right) K^4 = T^4$$

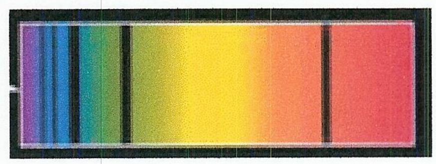
$$2.17\times10^{10} K^4 = T^4$$

$$\boxed{384 K = T}$$ ← The equilibrium temperature

Question 4: Spectra

We observe two patches of gas, their spectra are shown below. One of these patches is in front of the sun and the other is off to one side. Which is which? Why?


A


B

A is off to the side.

B shows absorption lines in the solar spectrum so B must be in front of the sun.

A shows only emission lines so it cannot be in front of the sun.

When we measure absorption lines in the light reflected from a planet's surface, what are the three locations where that absorption could be taking place?

① The atmosphere of the Sun adds absorption lines

② The planets surface adds absorption lines

③ The Earth's atmosphere adds absorption lines

④ Not all planets have atmospheres, but if this one did then it would also add lines

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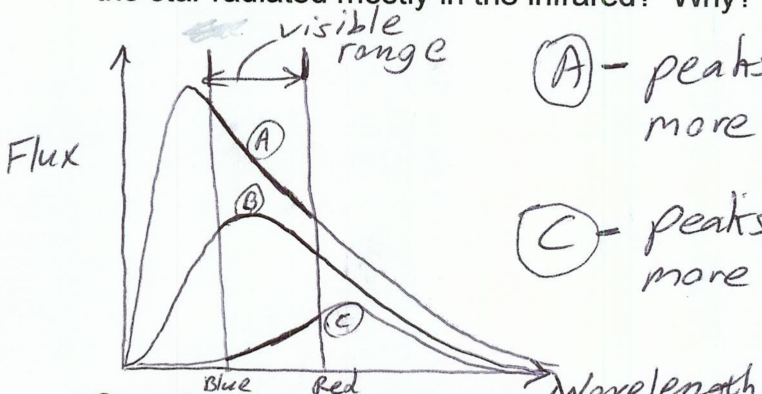
A grey body reflects all wavelengths equally. What visible color would a body like that have if it were orbiting a star that radiated mostly in the ultraviolet? Would it change if the star radiated mostly in the infrared? Why?



(A) - peaks in the UV
more blue light emitted than Red

(C) - peaks in the IR
more red light emitted than Blue

A grey body reflects light without changing its color so it appears red for (C) and blue for (A)

Question 5: Asteroid Energies

Meteor crater was created by an iron meteorite 50m in diameter, traveling at about 12 km s^{-1} (lower than once thought!). Calculate the energy of such an impact? Assume the asteroid is spherical and that its density is 6000 kg m^{-3}.

kinetic energy = ½ * mass * velocity²

mass = volume * density

mass = $4.19 * (25)^3 \, m^3 * 6000 \, kg \, m^{-3} = 3.93 \times 10^8$ kg

energy = $\frac{1}{2} * 3.93 \times 10^8 \, kg * (12000 \, m \, s^{-1})^2 = 2.82 \times 10^{16}$ Joules

The asteroid that finished off the dinosaurs and created the crater Chicxulub was 10km across and traveling at 20 km s^{-1} with a rocky composition (density of 3000 kg m^{-3}). How much energy does this correspond to? How many meteor-crater events add up to one Chicxulub event?

Use the same formula's as above.

mass = $4.19 \, (5000 m)^3 * 3000 = 1.57 \times 10^{15}$ kg

Energy = $\frac{1}{2} * 1.57 \times 10^{15} \, kg * (20000 \, m s^{-1})^2 = 3.14 \times 10^{23}$ Joules

$$\frac{1 \text{ chicxulub event}}{1 \text{ meteor crater event}} = \frac{3.14 \times 10^{23}}{2.82 \times 10^{16}} = 1.1 \times 10^7$$

i.e. There was ~11 million times more energy in the chicxulub event

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Under what conditions will an asteroid break up in the atmosphere? If we double the speed of the impact does that increase or decrease the likelihood of an atmospheric breakup? Why?

An asteroid will break up if the ram pressure from the atmosphere exceeds the material strength of the body.

Doubling the speed doubles the ram pressure and makes it more likely that the strength of the impactor will be exceeded (i.e it will be more likely to break up)