Name: _____

Astronomy 141
Winter Quarter 2012

Homework #3

Due Tuesday, February 14 in class

Instructions

This handout is your worksheet. Please write your answers in the spaces provided. In cases where a calculation is called for, please show your work including any sketches, so we can evaluate your answer and assign partial credit as appropriate. Answers given without showing at least some of the calculation will receive no credit. We will only accept homework turned in on this worksheet.

This homework assignment consists of the 3 problems below.

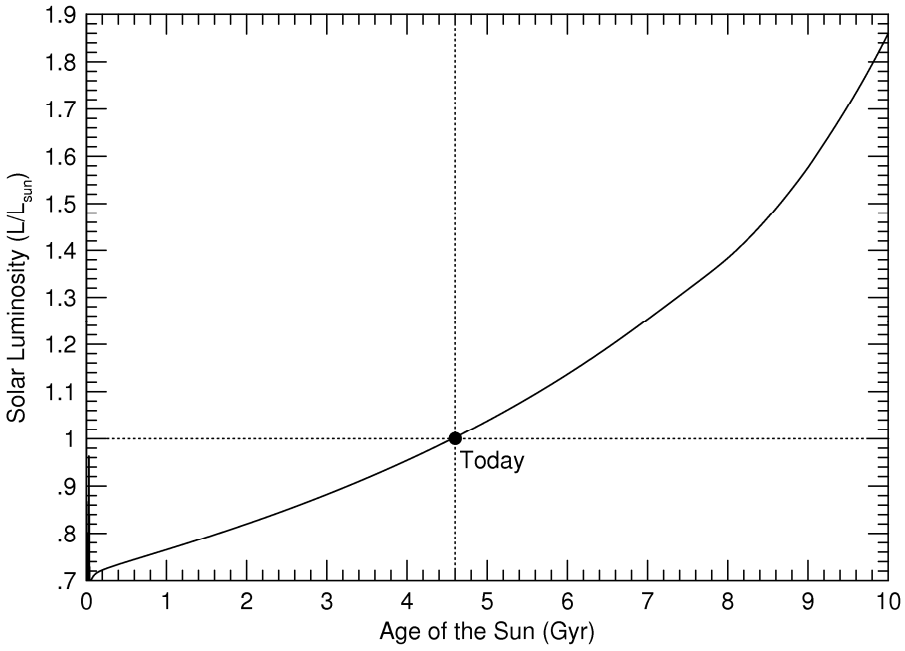
1. The equilibrium temperature of an object made of methane ice depends on how far away it is from the Sun in AU by the following formula:

$$T_{eq} \approx 150K\sqrt{\frac{1}{D}}$$

Pure methane ice sublimates into methane gas at a temperature of 40K. Consider the following solar system objects, and fill in the table with (a) T_{eq} at their distance and (b) say whether methane is expected to be an ice or a gas on the surface of that object.

Object	D	(a) T_{eq} in Kelvin	(b) Methane is ...
Ceres	2.8 AU		
Enceladus	10 AU		
Triton	30 AU		
Pluto	40 AU		

2. As the Sun ages, its luminosity (absolute brightness) steadily increases as shown in the plot below:



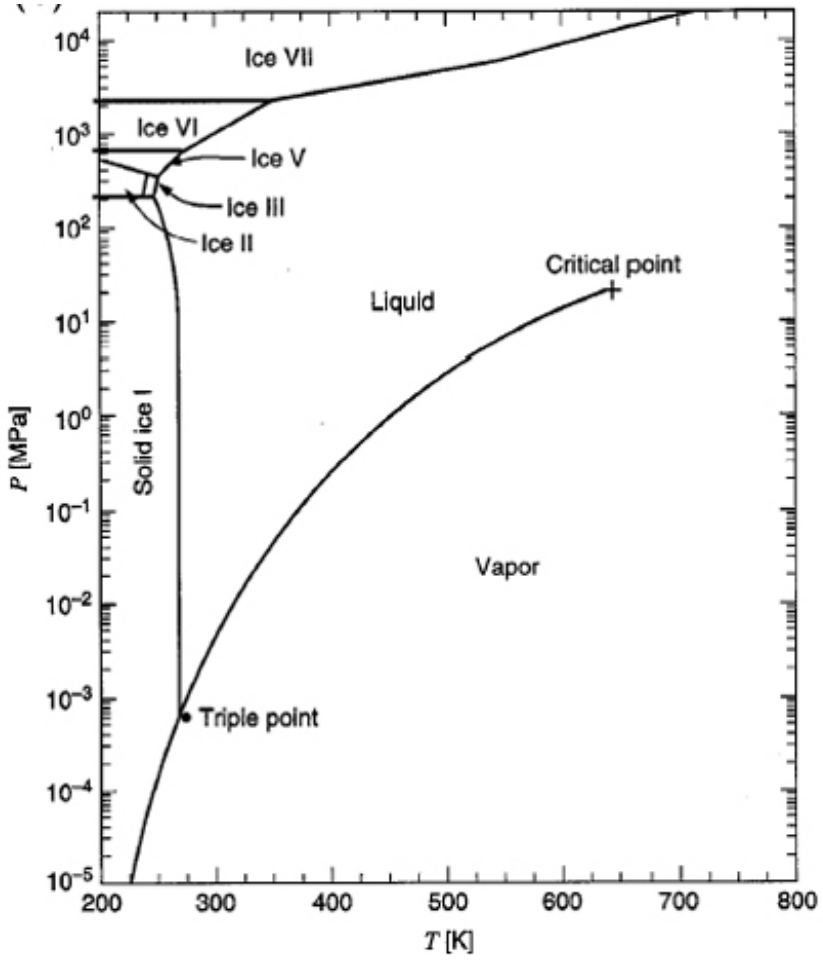
The average temperature of the Earth depends on the luminosity of the Sun: for every 1% increase in the Sun's luminosity, the Earth's average temperature gets hotter by 0.25%. Today, the Sun is 4.6 Gyr old, and the average temperature of the Earth is 290K. Use the plot above to answer the following questions:

a. How many years in the future will the Sun be 10% brighter than it is today? Express your answer in Gyr from today to the nearest 0.1 Gyr.

b. What will the average temperature of the Earth be when the Sun is 10% brighter?

c. A "Runaway Greenhouse Effect" will be triggered when the Earth's average temperature rises above 310K. How bright must the Sun be to have this temperature on Earth? How many years in the future will this occur (in Gyr to the nearest 0.1 Gyr)?

3. The diagram below is the "phase diagram" for water. For a given pressure (in units of MPa) and temperature (in units of K), it tells you whether or not water will be liquid, solid, or vapor (gas).



Using this diagram, answer the following questions:

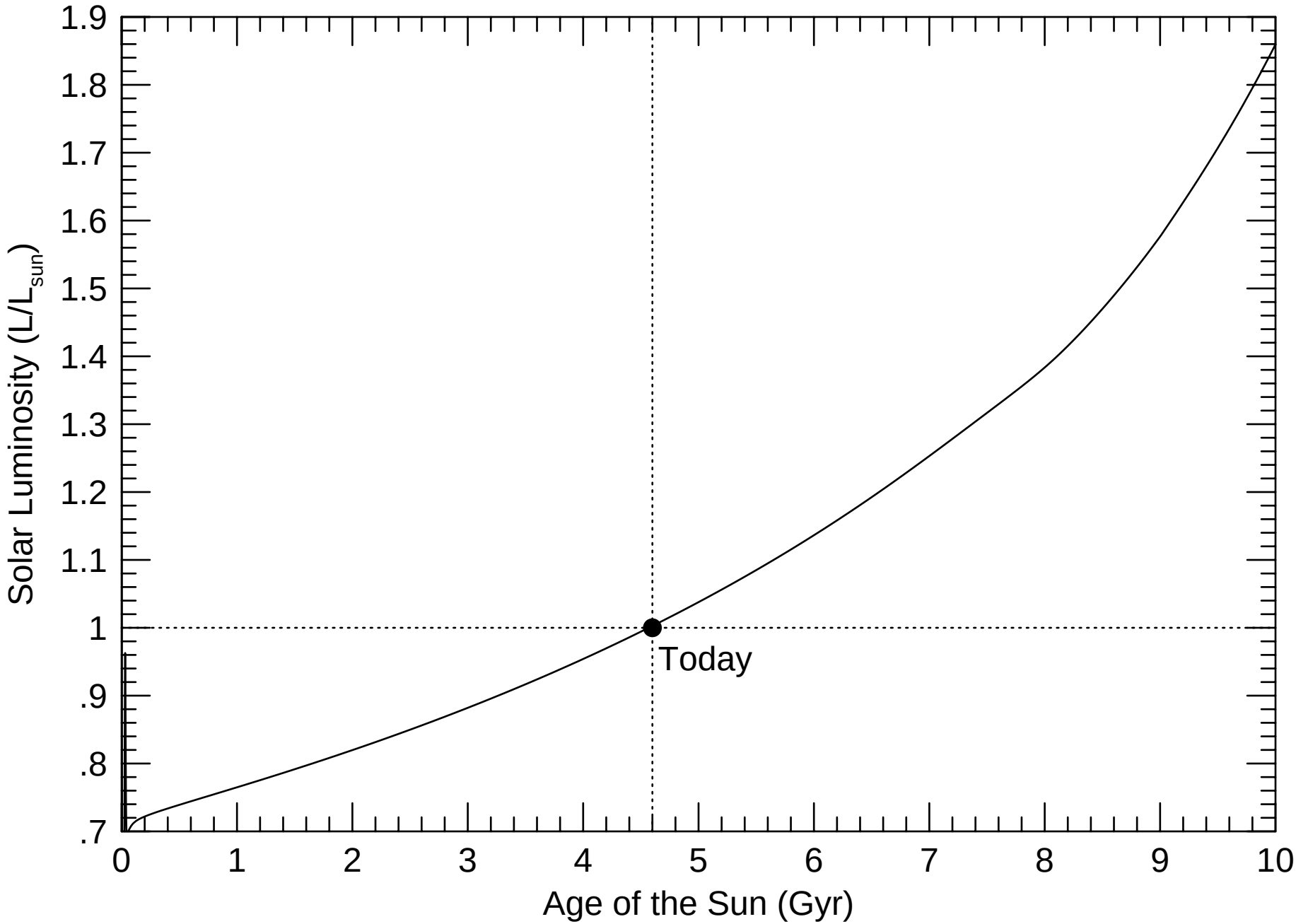
a. The mean temperature on Earth is 290K and the typical pressure is about 0.1 MPa. Put a dot on the diagram above for Earth's typical conditions and label it "Earth". What is the expected phase (solid, liquid, or vapor) of water on the surface of the Earth?

b. The mean temperature on Mars is 225K and the typical pressure is 10^{-3} MPa. Put a dot on the diagram above for typical Mars conditions and label it "Mars". What is the expected phase of water on the surface of Mars?

c. The mean temperature of Venus is 725K and the typical pressure is 10 MPa. Put a dot on the diagram above for typical Venus conditions and label it "Venus". What is the expected phase of water on the surface of Venus?

d. The Sun shines on a block of exposed water ice on the surface of Mars, heating it up to 300K at the same air pressure. What phase will the heated water ice turn into?

e. Based on your answers for b and d above, what are the prospects for finding liquid water on the surface of Mars?


1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
.9
.8
.7
Solar Luminosity (L/L$_{sun}$)
Today
0
1
2
3
4
5
6
7
8
9
10
Age of the Sun (Gyr)