

Instructions: You may put your answers right on the quiz sheets. If you need extra space feel free to attach additional pages, but indicate by the question that you've gone to extra pages. There is a stapler at the front of the room. The last page of the quiz lists equations, constants, and conversions that you may need.

Remember: READ EACH QUESTION COMPLETELY!!!! SHOW YOUR WORK!!!! BE CAREFUL OF UNITS!!!!

True or False (circle T or F to indicate True or False, each is worth 3 points):

1. T or F In the Earth's northern hemisphere the rotation around a large low pressure system is in the clockwise direction.
2. T or F In cool places in the universe we find that the most common molecules are compounds containing helium because helium is the most abundant element around to form molecules with.
3. T or F A low pressure gas at low temperatures will absorb light at discrete wavelengths.
4. T or F The thermosphere is so hot because of radiative heating by extreme ultraviolet light from the Sun interacting with N_2 , O_2 , and O in the processes of absorption, ionization, and dissociation.
5. T or F The surface of Venus is so much hotter than expected by a simple radiative equilibrium calculation because there is so much ozone in Venus' atmosphere producing a significant greenhouse effect.
6. T or F The terrestrial planets have more volatiles relative to the outer planets because the terrestrial planets formed close to the Sun where volatiles could readily condense out.
7. T or F If the optical depth of a gas is greater than one that means that it is nearly transparent to light.
8. T or F The spectrum of sunlight peaks in the visible wavelengths, but the spectra radiated by the planets tend to peak in the infrared wavelengths.
9. T or F If the temperature profile of an atmosphere drops off more rapidly with increasing altitude than the adiabatic lapse rate then it is an unstable situation and convection will most likely occur.
10. T or F The ideal gas law says that if you have a parcel of gas and you hold the number density in the parcel constant but increase the temperature, then the pressure will decrease.

Short Answers (Write a few sentences to answer each question):

11. Explain why the Earth has a stratosphere and mesosphere, but the atmospheres of most of the other planets in the solar system do not. (10 pts) 5 pts

The Earth has ozone (O_3), which is formed by UV sunlight interacting with O_2 .
 Ozone absorbs UV sunlight, heating the middle part of the atmosphere.

12. Explain why winds near large scale pressure systems tend to move parallel to isobars even though the pressure forces are perpendicular to the isobars. (10 pts)

Pressure forces want to make wind blow from high to low pressure, but in large scale systems the coriolis effect turns the wind to the side (to right in N. hemisphere & left in S. hemisphere).

13. The atmospheres of both Mars and Venus are composed of mostly CO₂, yet while Venus has a huge greenhouse effect, Mars has only a small greenhouse effect. Why is this the case? (10 pts)

Venus has a thick atmosphere (90 atm) whereas Mars has a thin atmosphere (7 millibars). There just isn't a lot of atmosphere on Mars to make much greenhouse effect.

Don't need to know numbers

Calculations (Perform the necessary calculations showing your all your work):

14. What is the pressure at 2 km above the surface of Mars if the surface pressure is 7.0 millibars, the temperature is constant with altitude and is 219 K, the mean molecular mass of the predominantly CO₂ atmosphere is 7.3x10⁻²⁶ kg, the specific heat of CO₂ is 851 $\frac{\text{Joules}}{\text{kg}\cdot\text{K}}$, the acceleration due to gravity is 3.7 m/sec², and the mean distance from Mars to the Sun is 1.52 AU. (10 pts)

Use the barometric equation: $p = p_{ref} e^{-\frac{(z - z_{ref})}{H}}$

But first you need the scale height

5 pts → $H = \frac{kT}{mg} = \frac{(1.38 \times 10^{-23} \text{ J/K})(219 \text{ K})}{(7.3 \times 10^{-26} \text{ kg})(3.7 \text{ m/sec}^2)} = 11200 \text{ m} = 11.2 \text{ km}$

so plugging back into the barometric equation for 2 km:

5 pts → $p_{2km} = (7.0 \text{ mbar}) e^{-\frac{(2 \text{ km} - 0 \text{ km})}{11.2 \text{ km}}} = (7 \text{ mbar}) e^{-0.178}$

$p_{2km} = 5.86 \text{ millibars}$

15. Titan is a satellite of Saturn and has an atmosphere composed mostly of N_2 but with some CH_4 and other gases. The pressure at the surface of Titan is 1.5 atm and the temperature at the surface is 94 K. Titan, like Saturn is 9.52 AU from the Sun. Titan's albedo is 0.2 and the acceleration due to gravity at the surface is 1.35 m/sec^2 .

- a. First, calculate the effective (equilibrium) temperature of Titan (10 pts)

$$T_e = \left[\frac{S_0 (1-\alpha)}{D^2 4\sigma} \right]^{1/4} = \left[\frac{1368 \frac{\text{W}}{\text{m}^2} (1-0.2)}{(9.52)^2 4(5.67 \times 10^{-8} \frac{\text{W}}{\text{m}^2 \text{K}^4})} \right]^{1/4}$$

$$T_e = 85 \text{ K}$$

- b. Next, calculate the optical depth of the atmosphere of Titan assuming the "slab" or "two-stream" approximation (10 pts)

The "slab" model gave us

$$\tau = \left(\frac{T_g}{T_e} \right)^4 - 1 = \left(\frac{94 \text{ K}}{85 \text{ K}} \right)^4 - 1 = 0.5$$

$$\tau = 0.5$$

16. Suppose we send a probe to a planet around another star. Before it enters the planet's atmosphere it measures the flux coming from the star at a wavelength of 300 nm to be $1 \times 10^{15} \frac{\text{Photons}}{\text{cm}^2 \cdot \text{sec}}$. After the probe lands on the surface of the planet it points its sensor toward the star again, which just happens to be directly overhead. This time it measures the flux of 300 nm light reaching the surface as $8 \times 10^{14} \frac{\text{Photons}}{\text{cm}^2 \cdot \text{sec}}$. Calculate the optical depth of the planet's atmosphere at 300 nm. (10 pts)

Use $I = I_0 e^{-\tau}$, but solve for τ

$$\frac{I}{I_0} = e^{-\tau}$$

$$\ln\left(\frac{I}{I_0}\right) = -\tau$$

$$\tau = -\ln\left(\frac{I}{I_0}\right) = -\ln\left(\frac{8 \times 10^{14} \frac{\text{photons}}{\text{cm}^2 \cdot \text{sec}}}{1 \times 10^{15} \frac{\text{photons}}{\text{cm}^2 \cdot \text{sec}}}\right) = -\ln(0.8)$$

$$\tau = 0.22$$

Some potentially useful equations:

$$\text{Power} = \text{Area} \cdot \sigma \cdot T^4$$

$$T_e = \left[\frac{S_0 \cdot (1 - \alpha)}{D^2 \cdot 4 \cdot \sigma} \right]^{1/4}$$

$$p = n \cdot k \cdot T$$

$$dp = -g \cdot n \cdot \bar{m} \cdot dz$$

$$\rho = n \cdot \bar{m}$$

$$\bar{m} = \frac{\sum_i f_i \cdot m_i}{\sum_i f_i}$$

$$f_i = \frac{n_i}{n_{\text{total}}}$$

$$F = m \cdot a$$

$$F_g = \frac{G \cdot m_1 \cdot m_2}{R^2}$$

$$p \approx p_{\text{ref}} \cdot e^{-\left(\frac{z - z_{\text{ref}}}{H}\right)}$$

$$n \approx n_{\text{ref}} \cdot e^{-\left(\frac{z - z_{\text{ref}}}{H}\right)}$$

$$H = \frac{k \cdot T}{m \cdot g}$$

$$\frac{dT}{dz} = -\frac{g}{c_p}$$

$$I = I_0 \cdot e^{-\tau}$$

$$\tau_i = \int_s \sigma_i \cdot n_i \cdot ds$$

$$N = \int_s n \cdot ds$$

$$\tau_{\text{total}} = \sum_i \tau_i$$

$$\lambda_{\text{max}} = \frac{2.9 \times 10^6 \text{ nm} \cdot \text{K}}{T}$$

$$T_g^4 = (1 + \tau) \cdot T_e^4$$

$$E = h\nu$$

$$\nu = \frac{c}{\lambda}$$

Some potentially useful constants and conversions:

$$\sigma = 5.67 \times 10^{-8} \frac{\text{Watts}}{\text{m}^2 \cdot \text{K}^4}$$

$$k = 1.38 \times 10^{-23} \frac{\text{Joules}}{\text{K}}$$

$$G = 6.67 \times 10^{-11} \frac{\text{Newtons} \cdot \text{m}^2}{\text{kg}^2}$$

$$N_A = 6.022 \times 10^{23} \frac{\text{particles}}{\text{mole}}$$

$$h = 6.626 \times 10^{-34} \text{ Joules} \cdot \text{sec}$$

$$S_0 = 1368 \frac{\text{Watts}}{\text{m}^2} \text{ at } 1 \text{ AU}$$

$$c_p = \frac{5}{2} \cdot \frac{k}{m}, \text{ or } \frac{7}{2} \cdot \frac{k}{m}, \text{ or } \frac{9}{2} \cdot \frac{k}{m}$$

$$1 \text{ m} = 100 \text{ cm} = 10^9 \text{ nm} = 10^{-3} \text{ km}$$

$$1 \text{ Newton} = 1 \frac{\text{kg} \cdot \text{m}}{\text{sec}^2}$$

$$1 \text{ Joule} = 1 \text{ Newton} \cdot \text{m}$$

$$1 \text{ Watt} = 1 \frac{\text{Joule}}{\text{sec}}$$

$$1 \text{ Pascal} = 1 \frac{\text{Newton}}{\text{m}^2} = 10^{-2} \text{ millibar}$$

$$1 \text{ atm} = 1013 \text{ millibar} = 1.013 \times 10^5 \text{ Pascal}$$

$$1 \text{ AU} = 1.5 \times 10^8 \text{ km}$$

$$c = 3 \times 10^8 \frac{\text{m}}{\text{sec}}$$