29:61 General Astronomy

3rd Hour Exam — Solution

1.

$$4\pi R^2 \sigma T_{eq}^4 = \left(\frac{L_\odot}{4\pi r^2}\right) \pi R^2 (1-A)$$

$$4\sigma T_{eq}^4 = \left(\frac{L_\odot}{4\pi r^2}\right)(1-A)$$

$$T_{eq} = \left[\left(\frac{L_\odot}{4\pi r^2}\right)\frac{(1-A)}{4\sigma}\right]^{1/4}$$

Choose numbers

$$r = 9.5\,AU = 9.5(1.496\times 10^{11})\,m$$

$$=$$

$$L_\odot = 3.839\times 10^{26}\,W$$

$$\sigma = 5.670\times 10^{-8}$$

$$A = 0.95$$

$$T_{eq} = \left[\left(\frac{3.839 \times 10^{26}}{4\pi (9.5[1.496 \times 10^{11}])^2} \right) \frac{(1 - 0.95)}{(4) 5.67 \times 10^{-8}} \right]^{1/4}$$

$T_{eq} = 43K$

2\. $V_{esc} = 8.0$ km/sec

Calculate rms thermal speed

$$v_{rms} = \sqrt{\frac{3 k_B T}{m}}$$

m = mass of molecule

CO_2 has atomic weight of $12 + 2(16) = 44$

so $m = 44(1.673 \times 10^{-27} \text{ kg})$

other data,

$k_B = 1.381 \times 10^{-23}$

$T = 290 K$

so $$v_{rms} = \sqrt{\frac{3(1.381\times10^{-23})(290)}{44\,(1.673\times10^{-27})}}$$

$$= 404 \text{ m/sec} = 0.40 \text{ km/sec}$$

The "rule of thumb" used for planetary retention is that

$$V_{esc}/6 > v_{rms}$$

In this case, $V_{esc}/6 = 1.5 \text{ km/sec} > 0.40 \text{ km/sec}$

so we would conclude yes, this planet will retain a CO_2 atmosphere.

3. (a) With this information, you can calculate the <u>mean</u> <u>density</u> of the planet, $\bar{\rho}$

(b) $$\bar{\rho} = M/V = \frac{M}{\frac{4}{3}\pi R^3}$$

We have $R = 6380 \text{ km} = 6.38\times10^{6} \text{ m}$

so $$\bar{\rho} = \frac{3\,(3.0\times10^{24})}{4\pi\,(6.38\times10^{6})^3}$$

$$= 2757 \text{ kg/m}^3$$

3(c) $\bar{\rho} = 2757 \text{ kg/m}^3$ is considerably less than the mean density of the Earth (5500 kg/m^3). This density is comparable to that of many normal minerals. It would indicate that the planet is not differentiated, that is, does not have an iron-nickel core.

4. Hydrostatic equilibrium is a balance between the pressure in a fluid (liquid or gas) and the weight of overlying fluid (the weight of all the fluid above a point.

If z is a coordinate pointing upwards, then the equation is

$$\frac{dp}{dz} = -\rho g$$

where g is the acceleration due to gravity, and ρ is the density of the fluid.

5. A plasma is gas which is ionized (at least partially ionized) in that some or all of the atoms have had an electron knocked out, so there are positively charged ions and electrons (negatively charged) in the gas.

6. Lorentz force,

(a) $\vec{F} = q\vec{v} \times \vec{B}$

The magnitude of the vector force is

$$|\vec{F}| = F = qvB\sin\theta$$

where θ is the angle between $\vec{v}$ and $\vec{B}$. We could calculate that out but it would be tough. The simplest thing to do is set $\sin\theta = 1$, so

$$F \simeq qvB$$

Variables: $q = 1.602 \times 10^{-19}$ C
$v = 400$ m/sec
$B = 3.1 \times 10^{-5}$ T

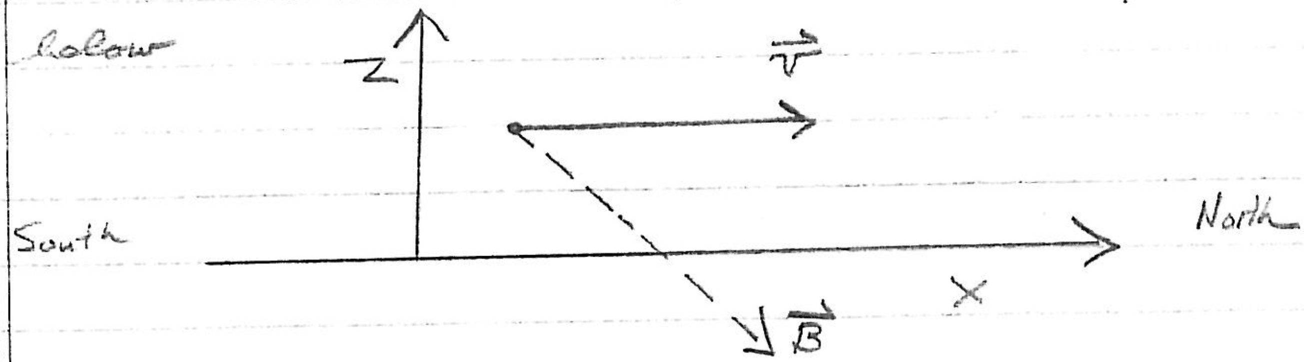
so $F \simeq (1.602 \times 10^{-19})(400)(3.1 \times 10^{-5})$

$= 1.99 \times 10^{-21}$ N

(b) Direction of force will be direction of $\vec{v} \times \vec{B}$

Choose a Cartesian coordinate system such that x points north, y points west, and Z points up.

In this coordinate system $\vec{v} = v\hat{i}$, and $\vec{B}$ lies in the X–Z plane. See diagram below



From this, you can see that (right hand rule) $\vec{v} \times \vec{B}$ is into the paper, i.e. to the west.

(7) There are craters on Venus, but they are relatively rare. The craters from early in the history of the solar system have been covered up.

The number of craters corresponds to an "exposure time" of only about 500 million years.

This implies that the surface of Venus was covered by flows of lava from the interior of Venus 500 Myr ago. Since Venus and Earth are similar in physical properties, this produces speculation ~~the~~ that Earth might have had floods of magma, too.

In fact, large lava flows on to the surface of the Earth occured at the time the dinosaurs became extinct (66 Myr ago) and at the time of the End-Permian extinction (250 Myr ago).

(8) Earlier spacecraft missions have shown that water flowed on the surface of Mars early in the history of the solar system (3.0 - 4.5 Gyr ago).

The goal of the spacecraft exploration is to determine if there was liquid water on the surface for substantial periods of time, long enough for life to have potentially developed.

Spacecraft will answer this by studying the types of minerals in old rock formations, and looking for those that formed in water. The spacecraft also look for other rock properties indicating presence of water, such as collections of small rocks in stream beds.

9 The solar system formed 4.5 – 4.6 billion years ago. We know this from <u>radioisotope</u> <u>dating</u> of the age of formation of Moon rocks, meteorites, Mars rocks, and the oldest rocks on Earth.

The ages extend <u>up</u> <u>to</u> 4.5–4.6 Gyr ago, but none are older.

10 There are many attributes in which the two sets of planets differ. Here are some of the ways. There are others, too.

(1) <u>Location in solar system</u>. Terrestrial planets are in the inner solar system ($a \leq 1.5$ AU), Jovian planets are in outer solar system ($a \geq 5.0$ AU)

(2) <u>Masses</u>. The Jovian planets are much more massive than the terrestrial planets (e.g., Uranus, Neptune $> 10 M_\oplus$), Jupiter and Saturn even more.

(3) <u>Chemical</u> <u>composition</u>. The terrestrial planets are made of elements that form rocks, such as iron, silicon, oxygen.

Terrestrial planets are formed of the same elements that make up the Sun and stars, hydrogen and helium.