1. How did the size of the Neanderthal brain compare to that of modern man? When did Neanderthal man become extinct?

The Neanderthal brain was similar in size to that of modern man. While it differed somewhat in structure, its total size may have been a bit larger. Neanderthals became extinct about 30,000 years ago.

When did man develop agriculture and establish permanent villages?

About 10,000 years ago (~ 8000 BC).

2. In the century after Galileo’s discoveries, what did most intellectuals think about the possibilities of life on other planets? Why?

Once telescopes became widely available, it was realized that the other planets were worlds like the Earth. Many intellectuals argued that all the planets were inhabited. (They had no idea of the physical conditions, even lack of atmosphere, etc. on some of them.) One argument was that just as God had created the Earth for man, He would not have created these other worlds without purpose.

3. How does the pressure of the atmosphere of Mars compare to that of the Earth? (Give an approximate numerical value.) What is the main gas in the atmosphere of Mars? Besides indications of abundant liquid water, what evidence suggests Mars once had much more atmosphere?

The pressure is about 0.007 (1/150) that of the Earth’s atmosphere.

The main gas is carbon dioxide (CO₂).

The most important line of evidence (apart from indications of liquid water) comes from analysis of isotopic abundances in the present atmosphere. The enhancement of deuterium and the heavy isotope of nitrogen shows that indeed most of the original atmosphere has escaped and Mars once had a much higher atmospheric pressure.

4. Where are the Galilean satellites? They are about the same size as the planet Mercury, but have a very different density. How does the bulk composition of the Galilean satellites differ from that of Mercury? Which of the Galilean satellites is most strongly heated, and what heats it?

The Galilean satellites are the four largest satellites of Jupiter, discovered by Galileo.

While Mercury is composed of rock and iron and has a high density, the Galilean satellites, like other satellites of the outer solar system, have large amounts of ices and more volatile materials, and thus a lower bulk density.

Io, the innermost Galilean satellite is most strongly heated – it has active (sulfur) volcanos. It is heated by the tidal stresses it experiences as it orbits Jupiter in a slightly elliptical orbit.
5. Venus is 0.72 AU from the Sun, but this is close enough for it to be unlivable. Suppose you could lower the Sun’s luminosity so that Venus would get the same flux of solar radiation that the Earth receives now. What would the value of this lower luminosity be? (Please calculate a numerical answer in solar units.)

The easiest way to do this is to recall that the flux from a star of luminosity $L$ is just $F = L/4\pi a^2$ where $a$ is the distance from the star. If we want $F$ to stay the same, then $L/a^2$ has to stay the same. For the Earth $L = 1$, $a = 1$ and $L/a^2 = 1$. Thus we need $L = a^2$, so $L = 0.72^2 = 0.52$

You could also just use our formula for the temperature of a planet,

$$T = \frac{280}{\sqrt{a}} (L_*)^{1/4},$$

For Venus, $a = 0.72$. If Venus were to get the same flux the Earth gets now, its temperature would be that of the Earth, $T = 280$. Putting these values into the equation, we have

$$280 = \frac{280}{\sqrt{0.72}} (L_*)^{1/4},$$

The factors of 280 cancel out and we find $(L_*)^{1/4} = \sqrt{0.72}$. Square both sides twice to get $L_* = 0.72^2 = 0.52$.

6. The Earth has lots of water, but little carbon dioxide in its atmosphere. Venus has lots of carbon dioxide but little water. Assuming these planets started out rather similar, where did the Earth’s carbon dioxide go, and what happened to the Venusian water?

(a) The Earth’s CO$_2$ is locked up in the crust in carbonate rocks like limestone. This happened due to chemical reactions or even more effectively due to organisms using the CO$_2$ dissolved in the oceans.

(b) Water on Venus remained as vapor in the atmosphere, where it reached the upper layers and the solar UV could break it down: $H_2O \rightarrow H + H + O$. The light H atoms escaped into space and the O reacted with minerals in the crust, leaving the Venus atmosphere without water.

7. The Earth is characterized by volcanic activity, plate tectonics and a strong magnetic field. What can we say about these characteristics with regard to the other terrestrial planets, Mars and Venus?

There is no good evidence that Mars or Venus have the sort of plate tectonics that characterize the Earth. Mars has had a lot of volcanic activity (including the solar system’s largest volcano) but most of that was in the distant past. The surface of Venus does not have many craters, indicating that volcanic activity has re-paved the surface; that activity may continue today. Neither Venus nor Mars have significant magnetic fields compared to Earth’s. This is probably because the core of Mars has solidified, and because Venus rotates too slowly to generate a magnetic field.
8. Why is it hard to obtain images of planets orbiting other stars? Have any such images been obtained yet?

In visible light, the star is typically $10^9$ times brighter than the planets. This makes it extremely hard to see the planets. Nevertheless, in one or two cases, images have been obtained of very large planets far from very dim stars. These images were obtained at infrared wavelengths where the star does not outshine the planet by such a large factor.

Extrasolar planets may be detected by gravitational lensing. What is the basis of this method and how does it work (draw a diagram)? What is a major drawback of this method?

If a nearer star passes directly along the line of sight to a bright distant star, the gravitational field of the nearer star will bend the light and cause a brightening of the distant star. If that nearer star should have a planet, the planet’s gravitational field will cause a ‘blip’ on the light curve, revealing its presence. The major drawback is that this is a random, one-time event that will never repeat, so we can’t learn any more about the planet by further observation.

9. Many extra-solar planets (exoplanets) have been discovered. About how many are known at present? Name two features of these planets and/or their orbits were not at all expected by astronomers. What method has been used to discover most of these planets?

We have now found over 200 exoplanets.

Unexpected features include (a) the existence of planets larger than Jupiter in orbits closer to the star than Mercury is to the Sun (they could not have formed that close to the star), and (b) the large number of planets that have very eccentric orbits about their stars, unlike the planets in our solar system.

Most of these planets were found by measuring the changes in the Doppler shift of the star as they orbit the center of mass of the system.

10. In some cases we have been able to measure the radius of an extrasolar planet. Under what circumstances can this be done? What sort of observations must be made? To what level of accuracy?

This can be done in cases where we are viewing the system in the plane of the planet’s orbit, and can observe the transit of the planet across the disk of the star. This will cause a small decrease in the brightness of the star, and the length of time for this decrease to occur can tell us the planet’s radius. The amount of the decrease also depends on the area of the planet and hence its radius.

What we measure is the change in the star’s brightness. Since a planet like Jupiter would only cause a drop of about 1% in the brightness of a star like the Sun, we must make these measurements to an accuracy of much better than 1%.