Reach for the Stars

Science Olympiad Division B
Saturday, February 24, 2007
Case Western Reserve University

Names	**School/Team**
Total Score	

You have 50 minutes to complete this test.

1) What are some of the major observed differences between the craters on the Moon and on the Earth? What accounts for these differences? When were the craters on each formed?

2) Why does the same side of the Moon always face the Earth? (Explain.) Why are there more maria on the near side than the far side?

3) Categorise/identify the following objects based on the given observations, and explain why you identify each as such:

a) Object moves at a slow, constant rate relative to the background stars, and is an unresolved point source.

b) Object moves at a slow, constant rate relative to the background stars, and is a small fuzzy blob.

c) Object moves very slowly, and over lots of observations, you see it reverse directions in its orbit, then reverse again.

4) Saturn's ring system lies within its Roche limit. Is it therefore possible for any large bodies to coalesce within the ring system? Are any such bodies observed? If so, how do they avoid destruction? (Think about what the Roche limit is based on)

5) Aliens have communicated with you in your dreams. They claim to live on a planet which orbits Merak (in Ursa Major). You made a website about it, the Homeland Security Task Force found it, and now are on your way to federal prison. As your final defense (instead of a phone call), you are given unlimited access to any observing facility on or around the Earth, to try to prove that this planet exists. Where will you want to observe from, and what kind of observations should you take? How much time will you need, and how are you going to prove that there is a planet orbiting Merak? If there is indeed a planet, are you guaranteed to detect it?

6) Mercury is currently orbiting the Sun in a 3:2 spin-orbit resonance. (This means that for every 3 times it rotates, it revolves around the Sun twice.) This sort of resonance is common throughout the solar system - examples of other resonances are 4:1, 1:2, 2:5, 1:8, or in decimals, 4, 0.5, 0.4, 0.125. What sorts of other resonances are possible? Could a planet orbit the Sun with a $\frac{\pi}{2}$ spin-orbit resonance? What about a $\frac{\sqrt{2}}{2}$ resonance? A $\frac{7}{9}$ resonance? What determines possible resonances?

7) TIME WARP! It's suddenly 1683, and you're an astronomer (actually you're probably an astrologer - sorry!). You use your state-of-the-art 3 inch refractor to observe Jupiter's moons in their orbits over a 6 month period. (These observations start with Jupiter at opposition, and end with it at conjunction.) Over the course of your observations, you notice that the observed eclipses of the moons slightly are getting later than the times you had predicted them to be. Can you account for this deviation? (Your measurements are perfect – there is no error there.) Does it matter if the Sun or the Earth is at the center of the solar system? Draw a diagram for both cases.

8) The Sun is evolving and changing with time. As it is a fairly average star, chugging away on its fairly average life time, we understand its evolution pretty well (from observing many other stars like it). How much longer will the Sun continue to be able to support life as we know it on Earth? How will the Sun eventually destroy all life on Earth? (HINT: the answer is NOT total incineration when the Sun goes into its red giant stage.)

9) a) Planets are spheres. Why?

b) Asteroids are not spheres. Why not?

c) Planets are not *actually* spheres. Explain why not and what causes it.

10) You are in Northern Brazil exploring the uncharted depths of the rainforest, and in between fending off ravenous swarms of mosquitoes, you notice bright streaks of light in the sky, similar to photos you've seen of the Northern Lights over Alaska. These are indeed aurorae. Is this a common occurrence in Brazil? Where would you expect to see them more frequently, and why? How could they occur over Brazil?

11) *NEWS FLASH!* The Moon has just become a black hole! How is this possible - if you had unlimited powers of force/energy, how could you accomplish this? Now that we have a black hole orbiting us, what sort of changes would we experience? (Think about tides, solar eclipses, the space station, and more!)
(Side note: the Moon-black-hole would have a spherical event horizon of radius 0.1 millimeters!)

12) TIME WARP – AGAIN!)!!! Now it's 3000 BC, and you've got a lot of time on your hands. You've got this crazy notion that the Earth is round, and want to prove it. Explain as many ways as you can to do this, given the tools of the times (and your own unlimited time/energy).

13) There was a recent comet of extraordinary brightness. Where is it currently located and visible from (generally)? What was its name (and when could we see it – time of day)? Even after its nucleus passed below the horizon in the Northern Hemisphere, we could still see part of it – which part was this, how were we able to see it, and what did it look like? (Feel free to draw a picture.)

14) Yvette is "in some kind of trouble" with the law, and needs to get to Mars, and fast! She hijacks a small spacecraft, but forgets to fill the gas tank before she leaves Earth. She's not sure how far she can get with the fuel she has, and can't afford to get caught by "The Man". What is the most efficient orbit she can take to get from Earth to Mars? Hint: She should fire her engines once to get out of Earth's orbit and into some kind of transfer orbit, and then fire them again once she reaches Mars' orbit and stops. Given that Earth orbits at 1 AU with an eccentricity of 0.02, and Mars orbits at 1.5 AU with an eccentricity of 0.09, what is the radius and eccentricity of her ideal transfer orbit?

15) The gravitational attraction between two objects is:

$$F_{grav} = \frac{GM_1M_2}{R^2}$$

Where G is the gravitational constant, M_1 and M_2 are the masses of the two objects, and R is the distance between them. To have a stable orbit, this gravitational attraction must be balanced by the centripetal acceleration (due to the planet's velocity around the star, for example). This centripetal acceleration is:

$$A_{centrip} = \frac{v^2}{R}$$

Where v is the velocity of the object orbiting, and R is the distance at which it orbits (assuming a circular orbit). Using Newton's second law ($F_{centrip} = M_2a$), these forces (gravitational and centripetal) must be equal. Thus, we find the condition for stable orbits, that:

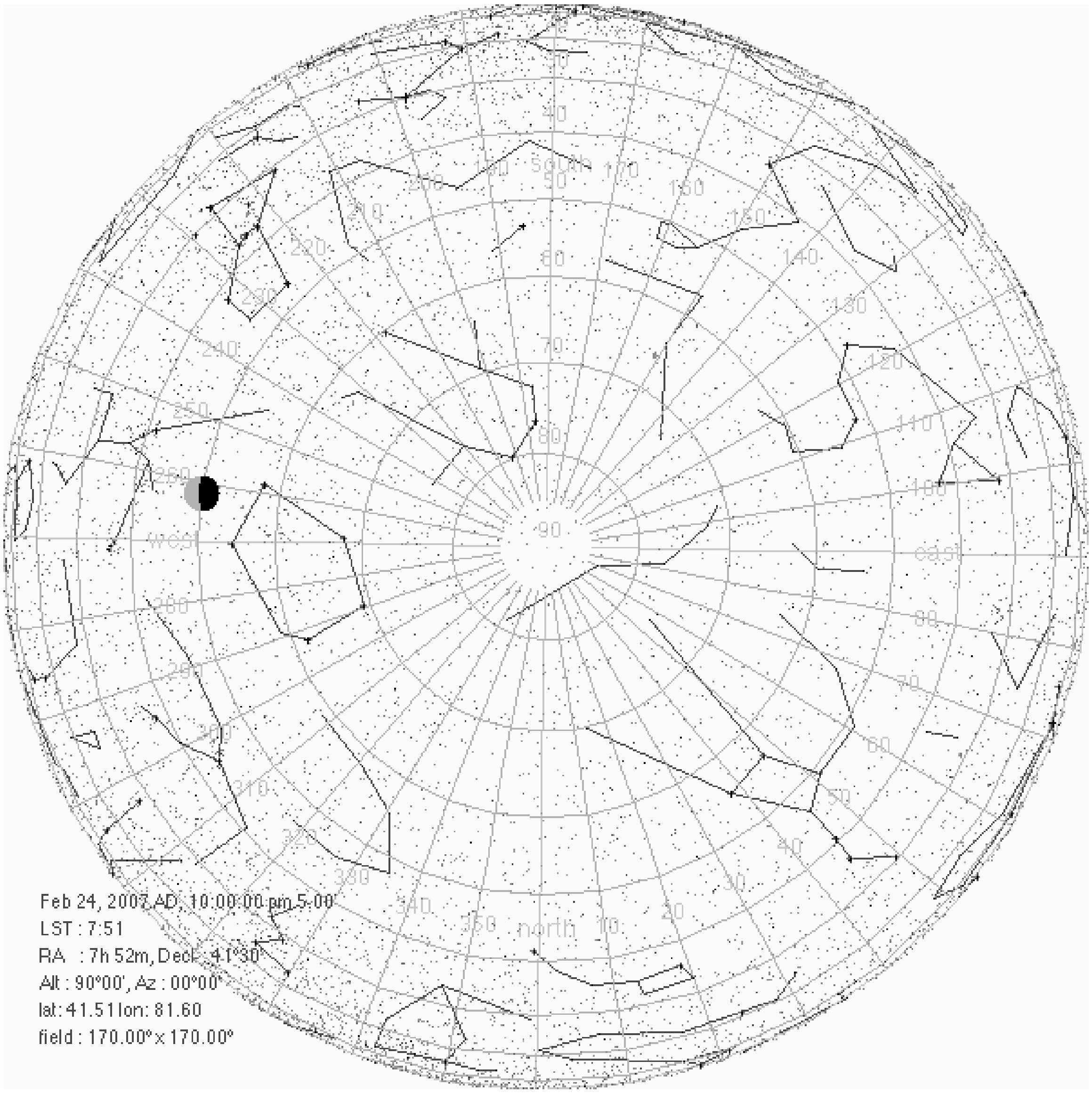
$$v^2 = \frac{GM_1}{R}$$

Where M_1 is the mass of the larger object, being orbited (like the Sun).
Now, what would happen if the gravitational force was given by a different equation, such as this one:

$$F_{grav2} = \frac{GM_1M_2}{R}$$

What would this require for stable orbits? Follow the same procedure as above, but with this new equation. When you get a result for v^2, see what it depends on, and explain what that means for stable orbits. (How would this change our solar system if it was true? Since the Earth and Venus are of similar mass, how fast would we each be orbiting the Sun?)

16) Indicate on this constellation chart where all visible planets are. Also label the constellations each planet is in. (The chart is given for 10pm tonight.)



17) Label as many features/geologic events as you can on this image of Mars' surface: