Workshop Tutorials for Physics

MR12: **Gravity and Kepler's laws**

A. Qualitative Questions:

1. The radius of the Earth is approximately 6,400 km. The International Space Station orbits at an altitude approximately 400 km above the Earth's surface, or at a radius of around 6,800 km from the Earth's centre. Hence the force of gravity experienced by the space station and its occupants is almost as great as that experienced by people on the surface of the Earth.
So why do astronauts and cosmonauts feel weightless when orbiting the Earth in a space station?

2. If you throw a ball up in the air, it falls back to the ground.
a. Briefly explain in terms of the relevant physics principles how a communications satellite can stay apparently suspended high above the earth's surface, and not fall as a ball does.
The Mir space station was in orbit from1986 until April 2001. Mir had a mass of more than 100 tons and consisted of seven modules launched separately and brought together in space over a period of 10 years.
b. What effect does increasing the mass of a space station, such as Mir, have on its orbit? Does the orbital speed need to be changed to maintain a fixed orbit?

B. Activity Questions:

1. Drawing orbits

Place one pin at the sun position and another at the other focus for one of the planets.
How do you know where the other focus should be?
Now cut a piece of string to a (scaled down) length equal to twice the sum of the aphelion and perihelion distances ($l = 2(a+p)$). Tie the string in a loop and put it around the pins. Hold the pen in the loop so that it pulls the loop taut and use the string to guide the pen to draw the orbit.
Repeat for one or two other planets.
Which planets have the most eccentric orbits? Which have the least eccentric?

2. Models of the solar system

Compare the different models of the solar system.
In what ways are they different? How are they similar?

3. Kepler's Second Law

Move the "planet" around the sun.
Note the line joining the planet to the sun and observe the area that it sweeps out.
What happens to the velocity of the planet as it moves
further away from the sun (towards aphelion)?
What happens as it moves closer to the sun (towards perihelion)?

C. Quantitative Questions:

1. Many science fiction stories feature men going to mars and meeting Martians. In some stories the space travelers are able to walk around quite comfortably and even breathe the Martian atmosphere.
a. Given the table of information below, what is the acceleration due to gravity on Mars?
b. What is the escape velocity at the surface of mars?
c. What effect is this lower escape velocity likely to have on the Martian atmosphere compared to the Earth's atmosphere?
d. Would it be feasible to try to give Mars an (unenclosed) Earth-like atmosphere so that it could be colonised by humans? What would need to be done, and how habitable could Mars be made?

2. In the year 2010 astronomers at the Parkes radio-astronomy facility discover what appears to be radio signals coming from Jupiter. As a senior physicist in the Australian space program your job is to get a satellite in orbit above the source of the signal to monitor it. The plan is for the space shuttle Kookaburra to head off to Jupiter and put a communications satellite at the right orbit to keep it directly above the signal.
a. What height above the surface of Jupiter must the satellite be put?
b. What velocity must it have to maintain this orbit?

Useful data.

	Earth	Mars	Jupiter
Mass ($\times 10^{24}$ kg)	5.97	0.642	1899
Diameter (km)	12,756	6794	142,984
Acceleration due to Gravity (m.s^{-2})	9.8		23.1
Escape velocity (km.s^{-1})	11.2		59.5
Period of rotation (h)	23.9	24.6	9.9

$G = 6.67 \times 10^{-11}$ N.m^2.kg^{-2}.