Artificial Gravity

Data handling question

In most science fiction films involving space ships the actors walk normally around their craft whether the motors are switched on or off. An accurate depiction of 'weightlessness' would add too much to the cost of the film. If the problem is ever mentioned at all it is due to some device which manages to produce the same gravitational force as 6×10^{24} kilograms of planet Earth without being so inconveniently heavy!

A notable exception was the classic '*2001: A Space Odyssey'* where a space station orbiting the Earth rotated to provide simulated gravity.

We do not feel the force of gravity. What we feel, and inaccurately call our weight, is the ground pushing up on us. If we take away the ground by stepping off something we feel nothing – try it. If we can get the ground to push up on us then we will feel 'weight'.

If a space station is rotating then any person in it will move in a circular path which requires a centripetal force. This is provided by the outermost surface of the space station. Using the formulae

$$a = -\frac{v^2}{r}$$

$$v = r\omega$$

$$\omega = \frac{2\pi}{T}$$

we get $a = -r\omega^2$ and then

$$a = -r\frac{4\pi^2}{T^2}$$

so for a given space station we can calculate how long it must take to rotate once in order to simulate Earth's gravity.

1. The International Space Station will, when completed, be 108.5 meters along its largest axis. Assuming that it rotates about the centre of this axis, show that its period of rotation will have to be about 15 seconds to simulate Earth gravity.
   g on Earth = 9.8 m/s^2

2. In order to avoid high rotation speeds that might cause disorientation to those on the station and danger to those spaceships trying to dock on it designers might state a minimum rotation period and then calculate what size space station is needed. If the minimum time is to be 2 minutes, calculate the size of station needed to simulate Earth's gravity.

In his novel *'Islands in the sky'* the author Arthur C. Clarke imagined that the Solar System had been colonised from end to end. Travelling between the planets would prove problematic to humans due to differences in local gravity. His solution was space stations made up of several linked circles of increasing radius. All the circles would have the same orbital period but different radii so the simulated gravity in each one would be different. Passengers arriving from a small planet, say Pluto, would enter the circle with the lowest simulated gravity and move from ring to ring as their muscles strengthened. The final ring would contain the docking station for the shuttle to and from Earth. People going from Earth to Pluto would get used to the problems of reduced gravity by going through the process in the other direction.

3. As people would spend a long time on the station all the amenities were to be provided including swimming pools. Describe what it would look like to be at one end of a very long swimming pool on such a space station.

4. The space station Clarke envisaged would be huge, easily visible from the Earth's surface. Make a few sensible estimates and calculate how large a structure would have to be to have four rings varying from Earth's gravity to Pluto's. Make clear which ring provides which simulated gravity.

   mass of Pluto = 1.50×10^{22} kg
   radius of Pluto = 1.15×10^{6} m

5. Once the rocket motors on a spaceship are switched off all its contents, including passengers will seem 'weightless'. Rotating those parts of the ship which contained people would provide a simulated gravity. The size of ship needed for a self-sufficient voyage from Earth to Pluto and back again would be very large so the rotation rate would not have to be very high. The rate of rotation could be varied over the course of the long journey to provide the same acclimatisation process as on the space station. Estimate (very roughly) the size of spaceship and hence the initial and final periods of rotation.

Social and Human context

Effective colonisation of other planets will require long journeys by astronauts who will have to perform difficult functions on arrival. Long periods to allow adaptation to the local conditions will not be possible.