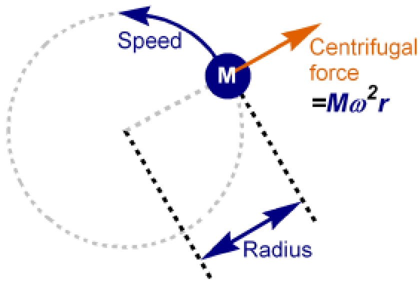

Gravitron ride at an amusement park

Most science fiction stories require some form of artificial gravity to keep spaceship passengers operating in a normal earth-like environment. As it turns out, weightlessness is a very bad condition for astronauts to work in on long-term flights. It causes bones to lose about 1% of their mass every month. A 30 year old traveler to Mars will come back with the bones of a 60 year old!

The only known way to create artificial gravity it to supply a force on an astronaut that produces the same acceleration as on the surface of earth: 9.8 meters/sec^2 or 32 feet/sec^2. This can be done with bungee chords, body restraints or by spinning the spacecraft fast enough to create enough centrifugal acceleration.

Centrifugal acceleration is what you feel when your car 'takes a curve' and you are shoved sideways into the car door, or what you feel on a roller coaster as it travels a sharp curve in the tracks. Mathematically we can calculate centrifugal acceleration using the formula:

$$A = \frac{V^2}{R}$$

where V is in meters/sec, R is the radius of the turn in meters, and A is the acceleration in meters/sec^2.

Let's see how this works for some common situations!

Problem 1 - The Gravitron is a popular amusement park ride. The radius of the wall from the center is 7 meters, and at its maximum speed, it rotates at 24 rotations per minute. What is the speed of rotation in meters/sec, and what is the acceleration that you feel?

Problem 2 - On a journey to Mars, one design is to have a section of the spacecraft rotate to simulate gravity. If the radius of this section is 30 meters, how many RPMs must it rotate to simulate one Earth gravity (1 g = 9.8 meters/sec^2)?

Problem 3 – Another way to create a 1-G force is for the rocket to continuously fire during its journey so that its speed increases by 9.8 meters/sec every second. Suppose that NASA could design such a rocket system for a 60 million km trip to Mars. The idea is that it will accelerate during the first half of its trip, then make a 180-degree flip and decelerate for the remainder of the trip. If

$$\text{distance} = 1/2aT^2$$
$$\text{speed} = aT,$$

where **T** is in seconds, **a** is in meters/sec^2, and distance is in meters, how long will the trip take in hours, and what will be the maximum speed of the spacecraft at the turn-around point?

Problem 1 - The Gravitron is a popular amusement park ride. The radius of the wall from the center is 7 meters, and at its maximum speed, it rotates at 24 rotations per minute. What is the speed of rotation in meters/sec, and what is the acceleration that you feel?

Answer: For circular motion, the distance traveled is the circumference of the circle C = 2 π (7 meters) = 44 meters. At 24 rpm, it makes one revolution every 60 seconds/24 = 2.5 seconds, so the rotation speed is 44 meters/2.5 sec = 17.6 meters/sec.

The acceleration is then A = $(17.6)^2/7$ = **44.3 meters/sec^2**. Since 1 earth gravity = 9.8 meters/sec^2, the 'G-Force' you feel is 44.3/9.8 = 4.5 Gs. That means that you feel 4.5 times heavier than you would be just standing in line outside!

Problem 2 - On a journey to Mars, one design is to have a section of the spacecraft rotate to simulate gravity. If the radius of this section is 30 meters, how many RPMs must it rotate to simulate one Earth gravity (1 g = 9.8 meters/sec^2)?

Answer: The circumference is C = 2 π (30) = 188 meters. 1 RPM is equal to rotating one full circumference every minute, for a speed of 188/60 sec = 3.1 meters/second. So V = 3.1 meters/sec x RPM. Then A = $(3.1RPM)^2$ / 188 = 0.05 x RPM^2. We need 9.8 = 0.05RPM^2 so **RPM = 14**.

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Answer: The turn-around point happens at the midway point 30 million km from Earth, so d = 3.0×10^{10} meters, a = 9.8 meters/sec^2, and so solving for T,

$3.0\times10^{10} = ½ (9.8) T^2$ so
T = 78,246 seconds or
for a full trip = 2x78246 seconds = **43 hours**!

Speed = 9.8 x 78246 = 767,000 meters/sec = **767 kilometers/sec**.