Problem

An orbiting space station may be made to rotate to provide an artificial gravity. Given that the radius is $25\,m$, find the rotation period required to produce an apparent gravity equal to $0.7\,g$. A man whose normal weight is $75\,kg\,weight$ runs around the station in one direction and then the other (i.e. on a circle on the inside of the cylindrical wall) at $5\,ms^{-1}$. Find his apparent weight in each case. What effects will he experience if he climbs a ladder to a higher level, climbing at $1\,ms^{-1}$?

Solution

Angular velocity ω required for gravity of $0.7\,g$

$$\begin{aligned}\omega^2 r &= 0.7\,g \\ \omega^2 &= \frac{0.7 \times 9.81}{25} = 0.275 \\ \omega &= 0.524 \\ \tau &= \frac{2\pi}{\omega} = 11.99\,s\end{aligned}$$

A rotation period of $12.0\,s$ will produce the required artificial gravity on the inside of the outer wall or 'floor' of the space station.

In this rotating frame the man will experience additional centrifugal and Coriolis 'forces' if he starts to move, hence

Running around in the same rotational direction as the station, his total acceleration a and weight m

$$\begin{aligned}a &= 0.7\,g + \frac{v^2}{r} - 2\omega v \\ &= 0.7\,g + \frac{5^2}{25} - 2(0.524)(5) \\ &= 6.867 + 1 - 5.24 \\ &= 2.627 \\ m &= (2.627 \times 75)/g \\ &= 20.08\,kg\,weight\end{aligned}$$

Running in the opposite direction the Coriolis is reversed

$$\begin{aligned}a &= 6.867 + 1 + 5.24 = 13.107 \\ m &= (13.107 \times 75)/g \\ &= 100.2\,kg\,weight\end{aligned}$$

His apparent weight is $20.1\,kg$ if he runs with the rotation, but $100.2\,kg$ if he runs against it.

As he climbs a ladder the apparent gravity ($\omega^2 r$) would become lower i.e. his weight would be decreasing. However the Coriolis force would now be at right angles to his motion (sideways). He would experience a force of $2m\omega v = 2 \times 75 \times 0.524 \times 1$ or $78.6\,N$.