Question (1350001)

Gravitational field and the weight of an astronaut in the International Space Station.

The International Space Station orbits Earth at an altitude of about 350 km (from Earth’s surface).

(a) What is the magnitude of Earth’s gravitational field \( g \) at the altitude of the space station?
(b) What is the weight of a 90-kg astronaut who is in the space station? (Note weight in this case is defined as the gravitational force by Earth on the astronaut.)

Solution

(a) Begin by drawing a picture, showing Earth and the space station (not to scale, of course).

![Figure 1: Earth and the space station.](image)

The magnitude of Earth’s gravitational field \( g \) at a distance \( r \) from the center of Earth is

\[
g = \frac{GM_{\text{Earth}}}{|\vec{r}|^2}
\]

In this case, the space station is at a distance \( r \) that is equal to the radius of Earth plus the altitude of the space station \( h \).

\[
r = R_E + h = 6400 \text{ km} + 200 \text{ km} = 6800 \text{ km} = (6800 \text{ km})(\frac{1000 \text{ m}}{1 \text{ km}}) = 6.8 \times 10^6 \text{ m}
\]

The Earth’s gravitational field at this height has a magnitude

\[
g = \frac{GM_{\text{Earth}}}{|\vec{r}|^2} = \frac{(6.7 \times 10^{-11} \text{ N m}^2/\text{kg}^2) 6.0 \times 10^{24} \text{ kg}}{(6.8 \times 10^6 \text{ m})^2} = 8.7 \text{ N/kg}
\]
Note that this is less than $g$ at the surface of Earth which is 9.8 N/kg, which is consistent with the fact that $g$ decreases as distance from Earth increases.

(b) The weight of a 90-kg astronaut in the space station is the gravitational force by Earth on the astronaut. It is most easily found by

$$w = mg$$

where $w$ is the magnitude of the weight of the astronaut, $m$ is the mass of the astronaut, and $g$ is the magnitude of the gravitational field of Earth at the location of the astronaut. Thus, the astronaut’s weight is

$$w = mg$$
$$= (90 \text{ kg})(8.7 \text{ N/kg})$$
$$= 783 \text{ N}$$

On the surface of Earth, the astronaut weighs $90 \times 9.8 = 882 \text{ N}$. Thus, the astronaut’s weight in the space station is $783/882 = 89\%$ of her weight on Earth. Note that the astronaut is NOT WEIGHTLESS! In fact, it’s her weight that actually keeps her in orbit. Without any gravitational force, she would not orbit Earth.