PHYS1511: College Physics 1
Mechanics, Heat and Sound

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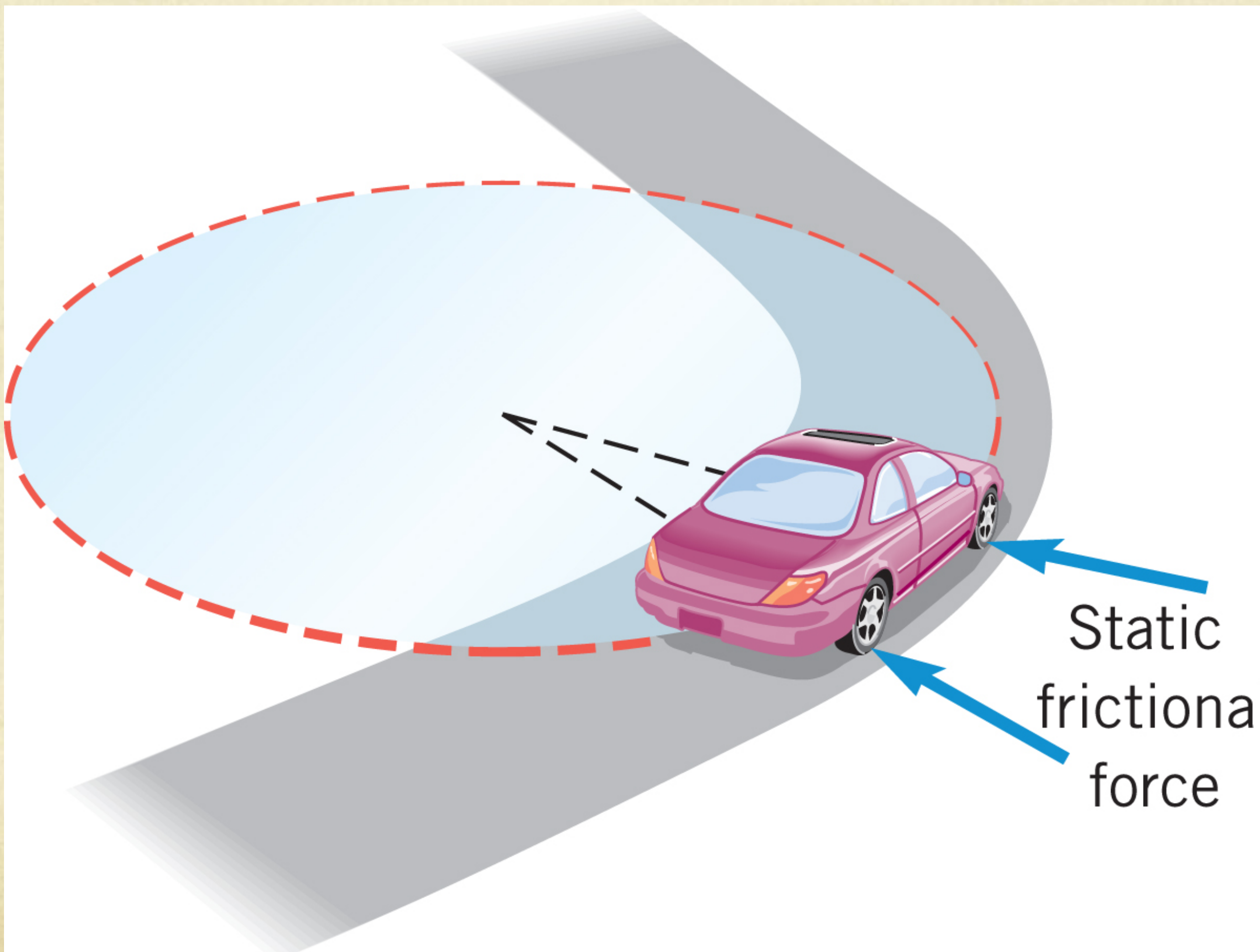
Agenda for today

- Banked curves
- Satellites in Circular Orbit
- Apparent Weightlessness
- Vertical Circular Motion

On an unbanked curve, the static frictional force provides the centripetal force.



What is the max speed you can go before slipping?

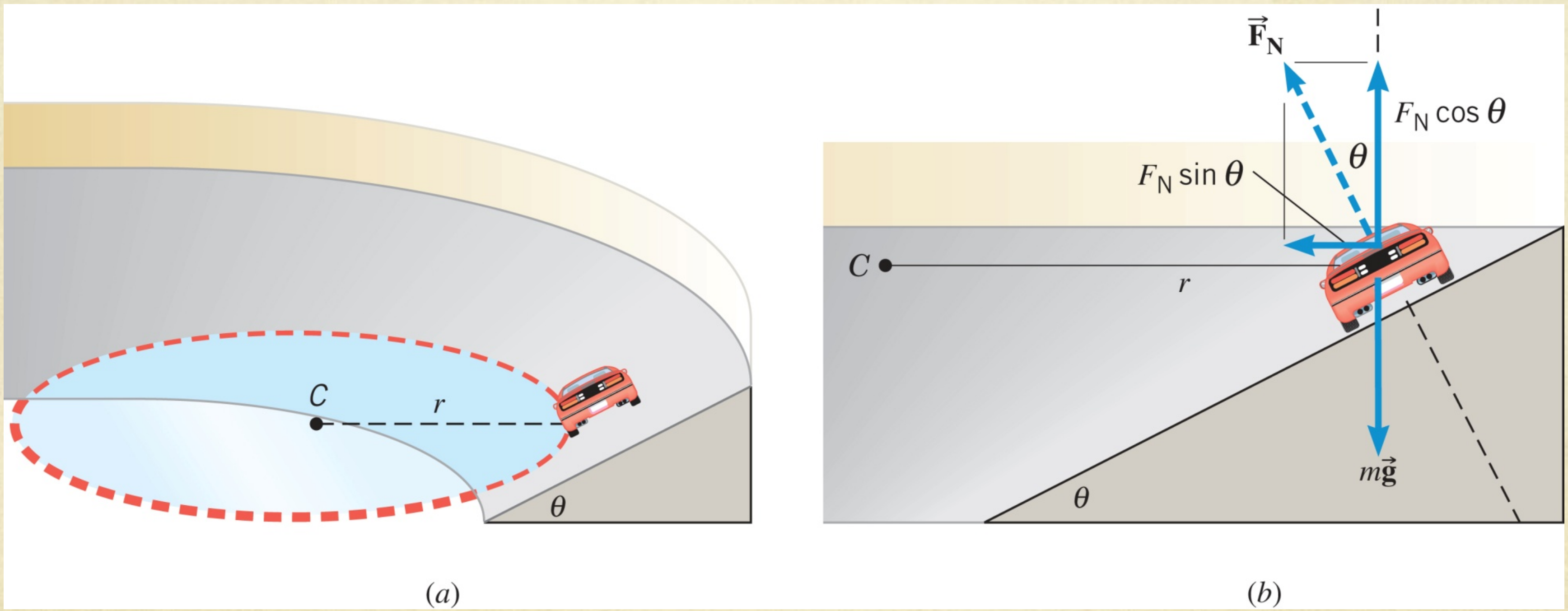
$$F_c = m\frac{v^2}{r} = f_s^{\max} = \mu_s F_N$$

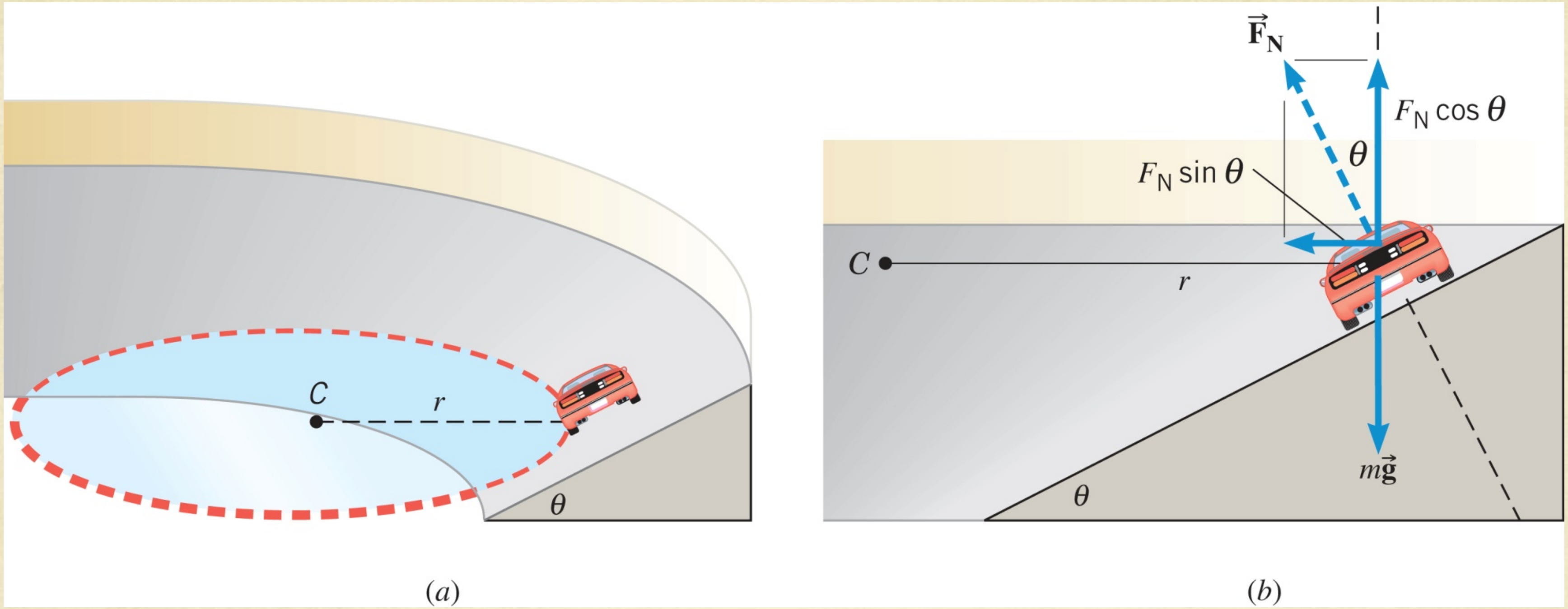
$$F_N = mg$$

so

$$v = \sqrt{rg\mu_s}$$

On a frictionless banked curve, the centripetal force is the horizontal component of the normal force. The vertical component of the normal force balances the car's weight.





$$F_c = F_N \sin\theta = m\frac{v^2}{r}$$

$$F_N \cos\theta = mg$$

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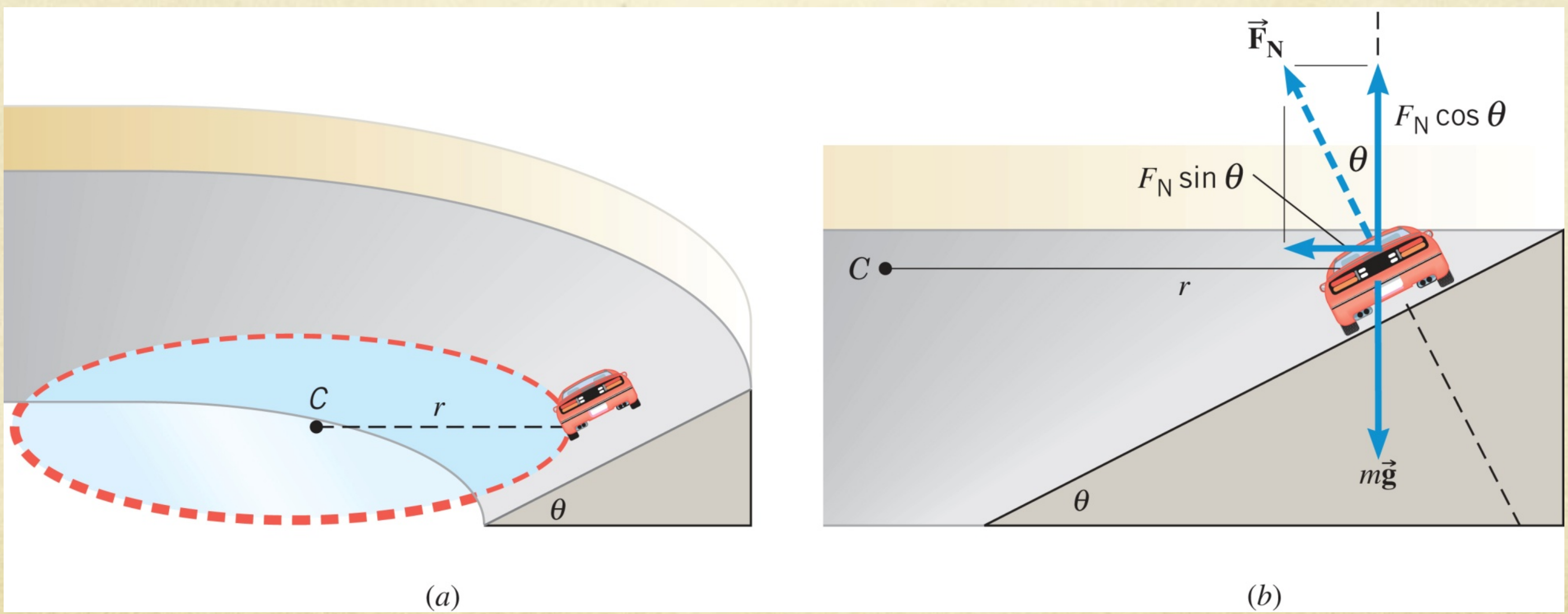
$$F_N \cos\theta = mg$$

$$\tan\theta = \frac{v^2}{rg}$$



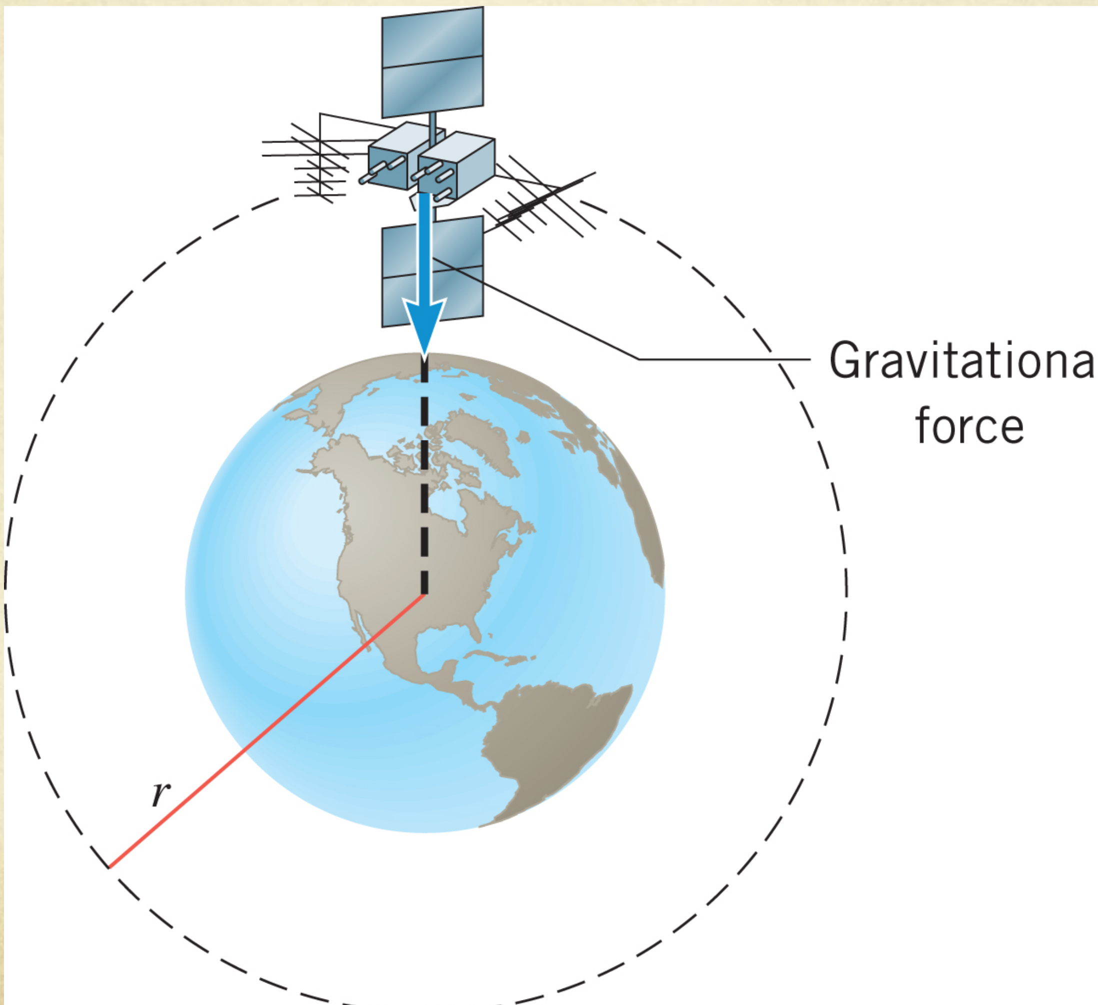
Example: The Daytona 500

The turns at the Daytona International Speedway have a maximum radius of 316 m and are steeply banked at 31 degrees. Suppose these turns were frictionless. At what speed would the cars have to travel around them in order to remain on the track?

$$\tan\theta = \frac{v^2}{rg} \quad \longrightarrow \quad v = \sqrt{rg\tan\theta}$$

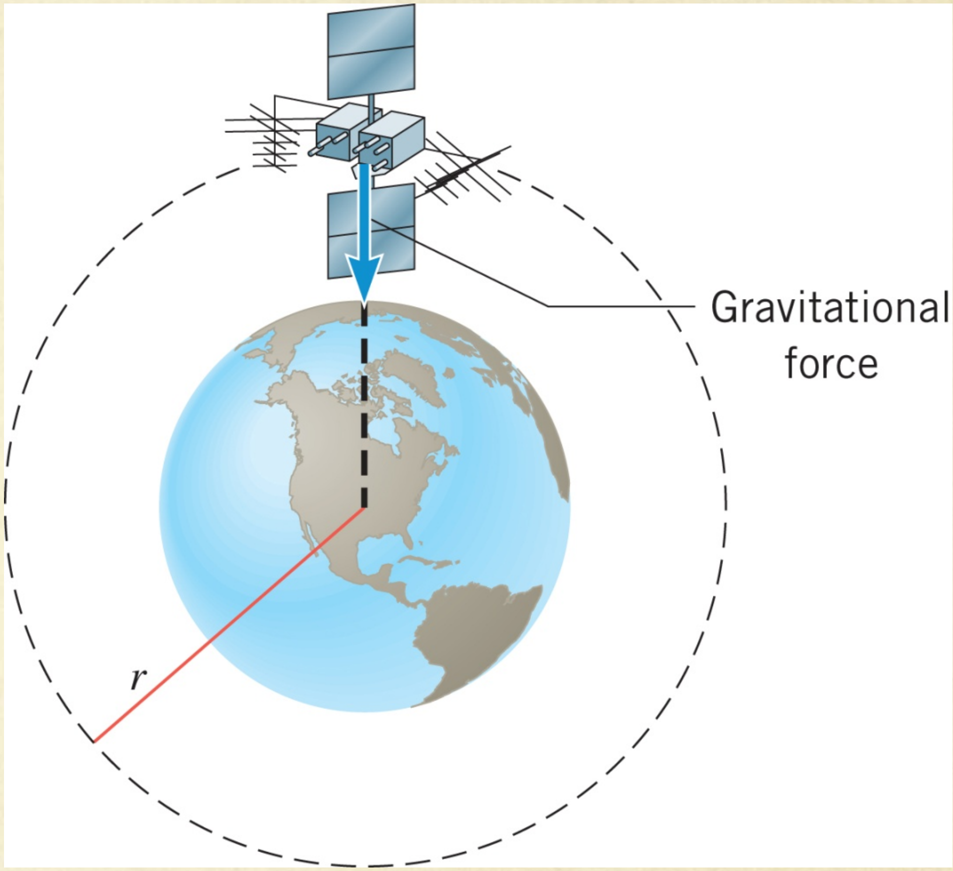
$$v = \sqrt{(316\,\mathrm{m})(9.8\,\mathrm{m/s^2})\tan 31^\circ} = 43\,\mathrm{m/s} \;\; (96\,\mathrm{mph})$$

There is only one speed that a satellite can have if the satellite is to remain in an orbit with a fixed radius



$$F_c = G\frac{mM_E}{r^2} = m\frac{v^2}{r}$$

$$v = \sqrt{\frac{GM_E}{r}}$$



Example 9: Orbital Speed of the Hubble Space Telescope

Determine the speed of the Hubble Space Telescope orbiting at a height of 598 km above the earth's surface.

$$v = \sqrt{\frac{\left(6.67\times10^{-11}\,\text{N}\cdot\text{m}^2/\text{kg}^2\right)\left(5.98\times10^{24}\,\text{kg}\right)}{6.38\times10^{6}\,\text{m} + 598\times10^{3}\,\text{m}}}$$

$$= 7.56\times10^{3}\,\text{m/s} \quad \left(16900\,\text{mi/h}\right)$$

Two satellites *A* and *B* of the same mass are going around Earth in concentric circular orbits. The distance of satellite *B* from the Earth's center is twice that of satellite *A*. What is the ratio of the centripetal force acting on *B* to that acting on *A*?

A. 1/8
B. 1/4
C. 1/2
D. 1
E. 2

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$$F_c = G\frac{mM_E}{r^2} = m\frac{v^2}{r}$$

$$\frac{F_B}{F_A} = \left(\frac{r_A}{r_B}\right)^2 = \frac{1}{4}$$

Period of a circular orbit

$$v = \sqrt{\frac{GM_E}{r}} = \frac{2\pi r}{T}$$

$$T = \frac{2\pi r^{3/2}}{\sqrt{GM_E}}$$

Global Positioning System

$$T = 24 \text{ hours}$$

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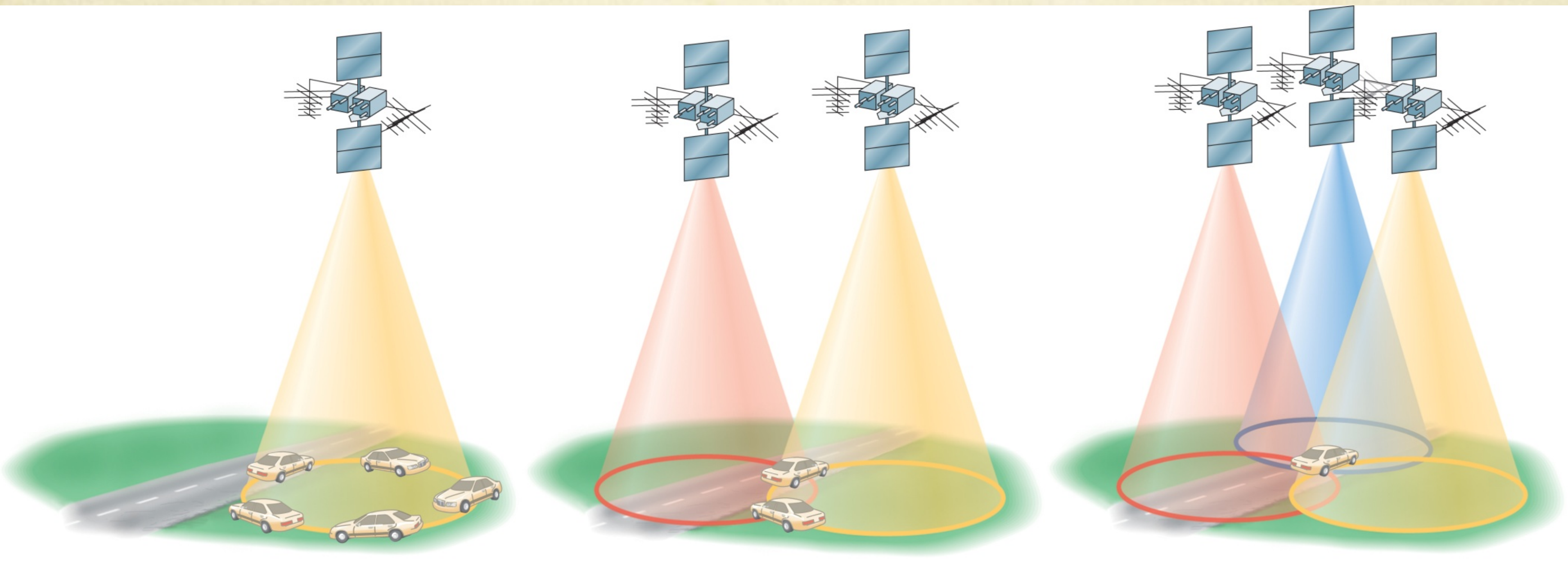
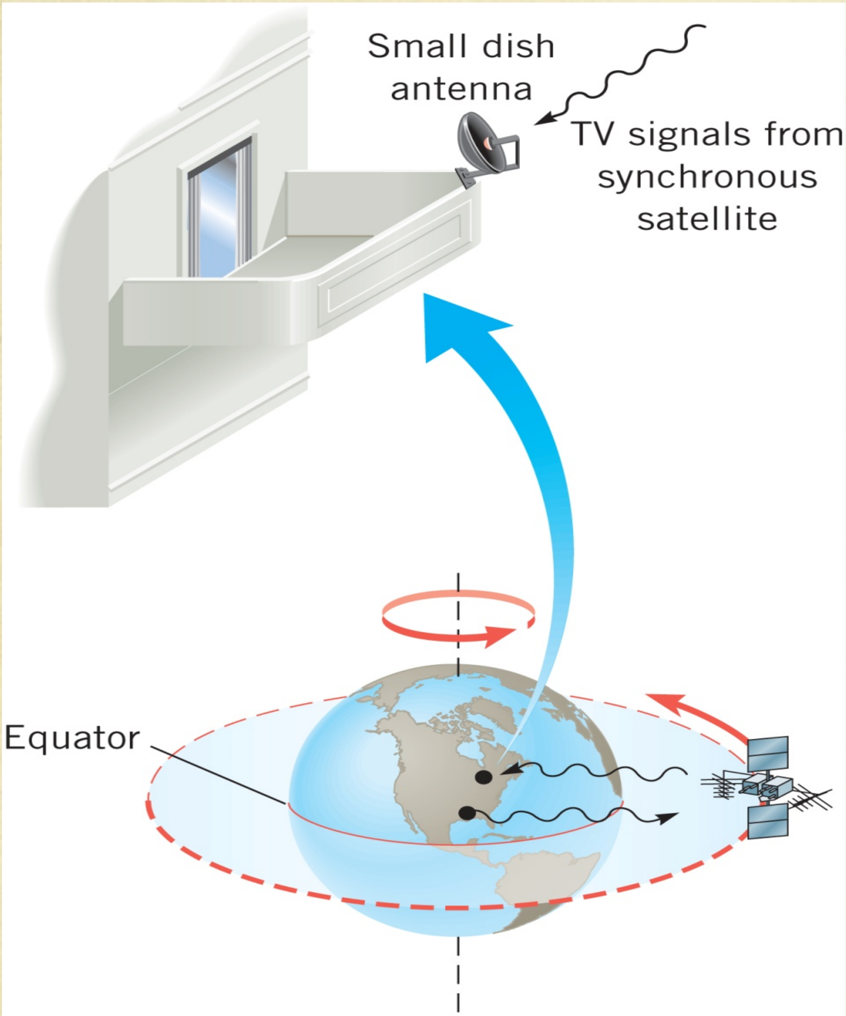


(a) (b) (c)

Synchronous Satellites



$$T = \frac{2\pi r^{3/2}}{\sqrt{GM_E}} \qquad r = \frac{T\sqrt{GM_E}}{2\pi}$$

$$T = 1 \text{ day}$$

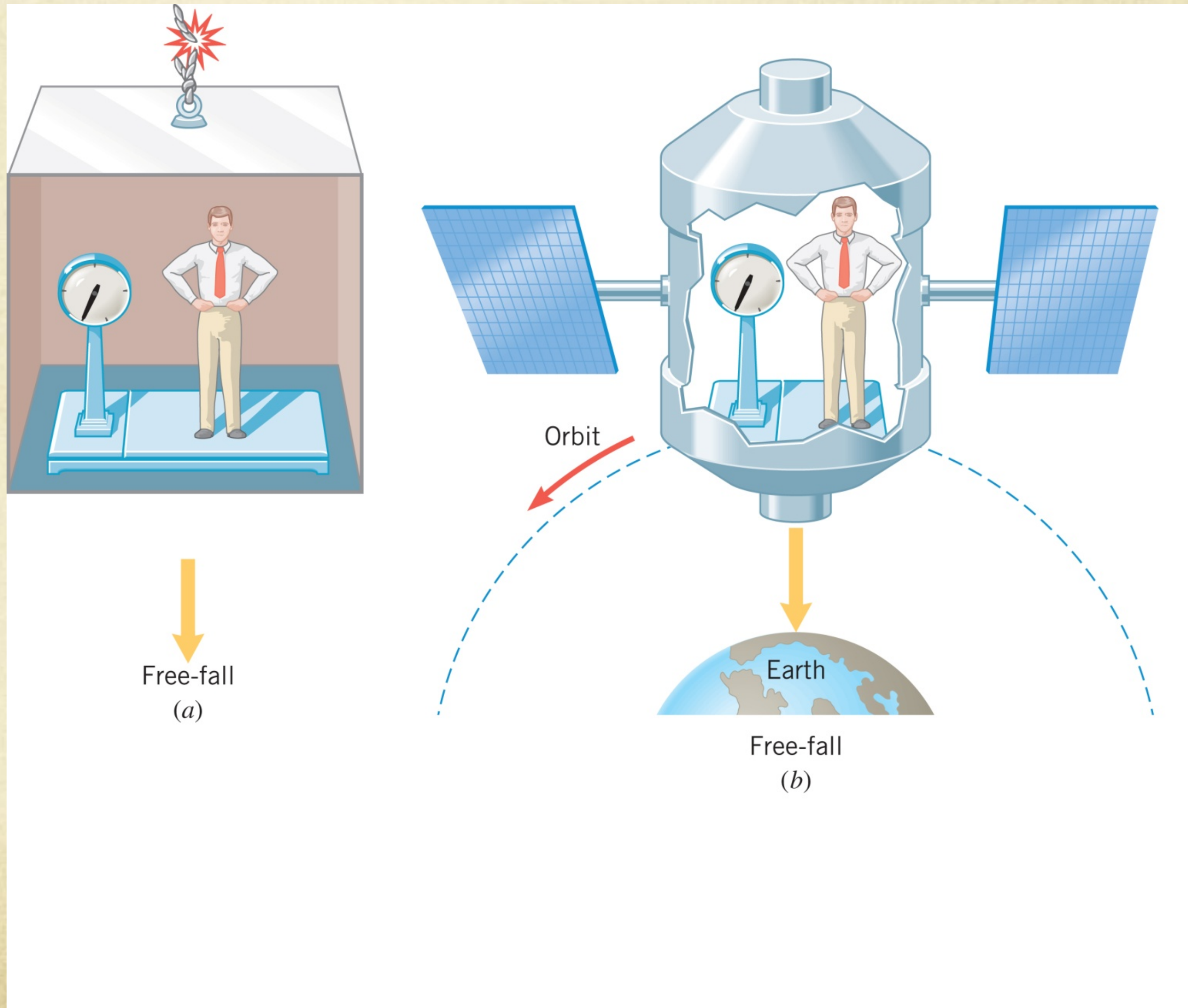
$$r = 4.23 \times 10^7 \text{ m}$$

$$R_E = 6.38 \times 10^6 \text{ m}$$

$$h = r - R_E = 3.59 \times 10^7 \text{ m (22 300mi)}$$

Example: Apparent Weightlessness and Free Fall

In each case, what is the weight recorded by the scale?



Example: Artificial Gravity

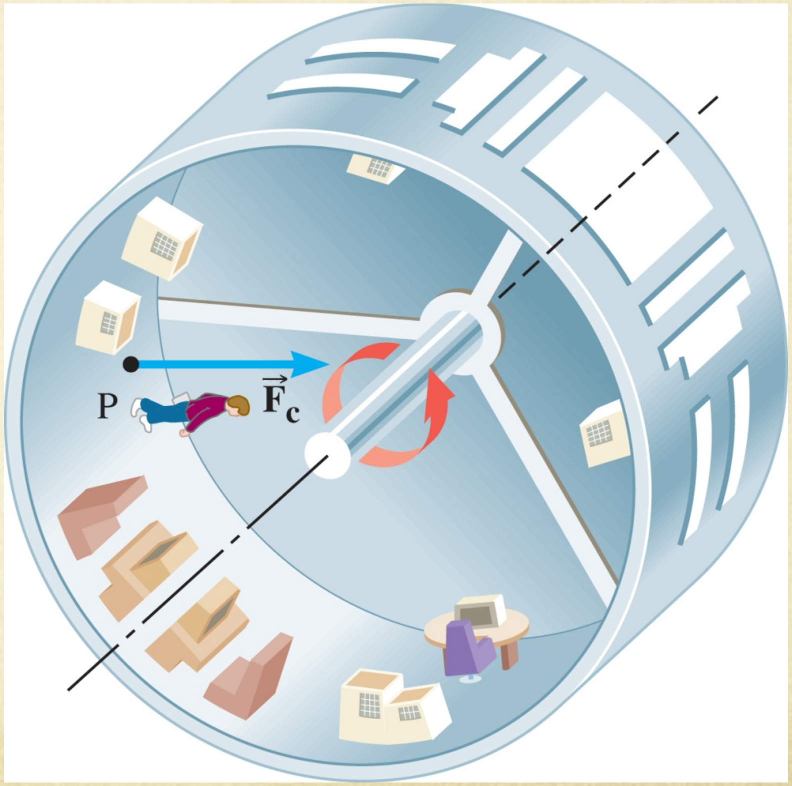
At what speed must the surface of the space station move so that the astronaut experiences a push on his feet equal to his weight on earth? The radius is 1700 m.

$$F_c = m\frac{v^2}{r} = mg$$

$$v = \sqrt{rg}$$

$$= \sqrt{(1700\,\mathrm{m})(9.80\,\mathrm{m/s^2})}$$

$$= 130\,\mathrm{m/s}$$



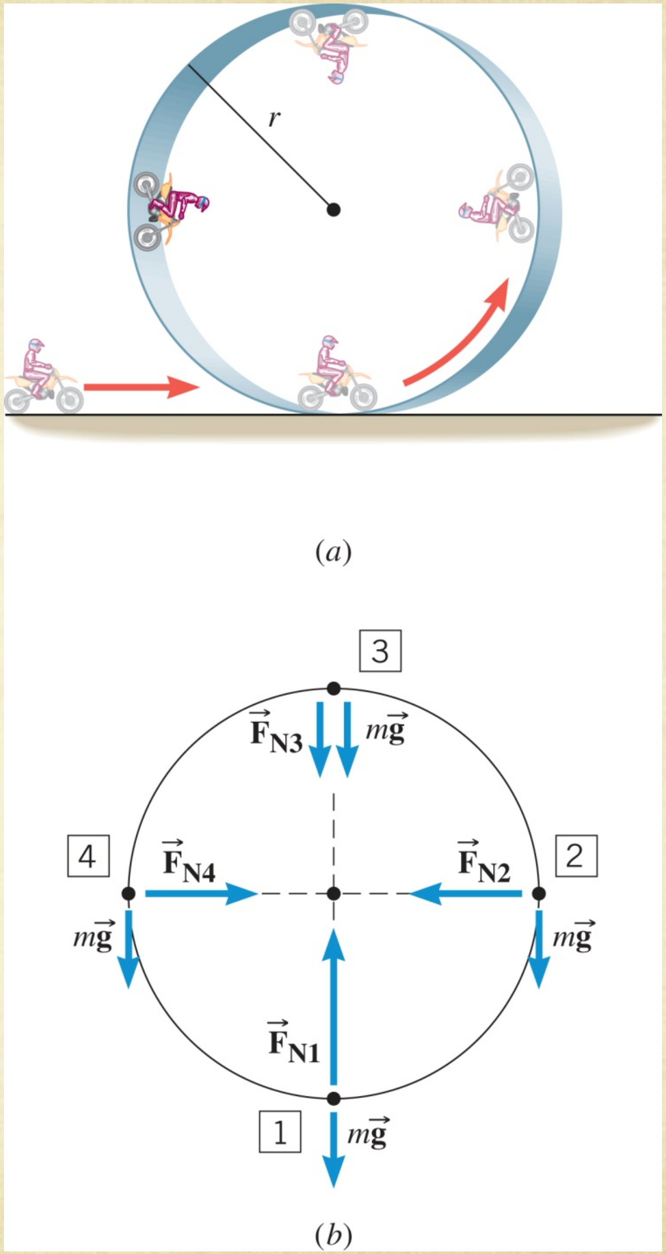
Vertical circular motion

$$F_{N1} - mg = m\frac{v_1^2}{r}$$

$$F_{N2} = m\frac{v_2^2}{r}$$

$$F_{N4} = m\frac{v_4^2}{r}$$

$$F_{N3} + mg = m\frac{v_3^2}{r}$$



A stone is tied to a string and whirled around at a constant speed. Assuming the constant speed is the same in both cases, is the string more likely to break when the circle is

A. horizontal
B. vertical

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