Chapter 6: Force and Motion—II

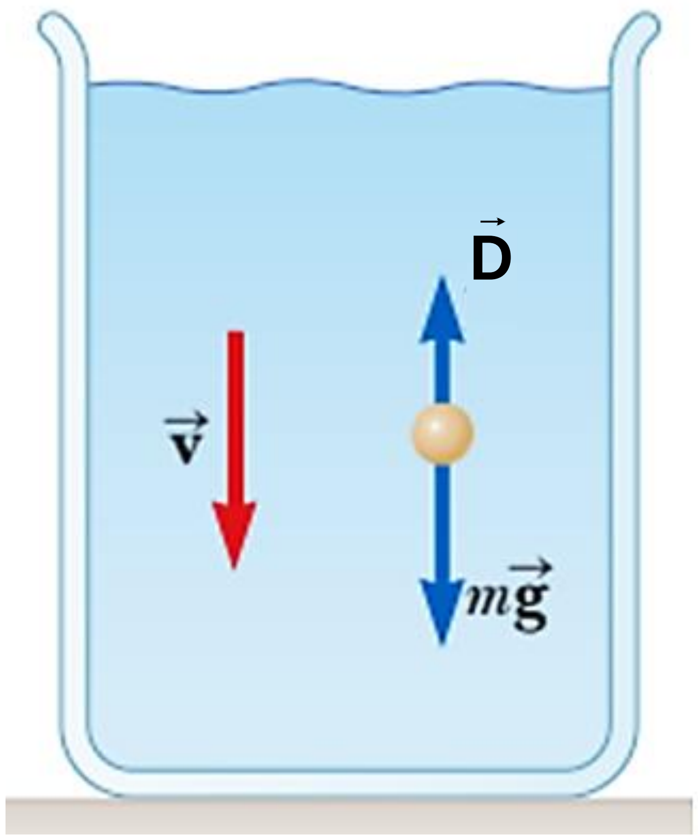
- ✓ **Forces of Friction**
- ✓ **Drag Force**
- ✓ **Centripetal Force**
- ✓ **Motion in Accelerated Frames**

Session 12:

- ✓ **Drag Force**
- ✓ **Centripetal Force**
- ✓ **Motion in Accelerated Frames**

Drag Force

- A fluid is anything that can flow, generally either a gas or a liquid (air, water).
- When there is a relative velocity between a fluid and a body, the body experiences a drag force that opposes the relative motion.



$$\vec{D} = -b\vec{\mathbf{v}}$$

$$\vec{D} = -b\,v^2\,(\hat{\mathbf{v}})$$

Drag Force

$$D = \frac{1}{2} c \rho A v^2$$

- **C** is a dimensionless empirical quantity (**drag coefficient**).
- **ρ** is the **density of air**.
- **A** is the **cross-sectional area** of the object.
- ***v*** is the **speed** of the object.

$$F_{y,net} = mg - \frac{1}{2} c \rho A v_T^{\;2} = ma \approx 0$$

$$v_T = \sqrt{\frac{2mg}{c \rho A}}$$

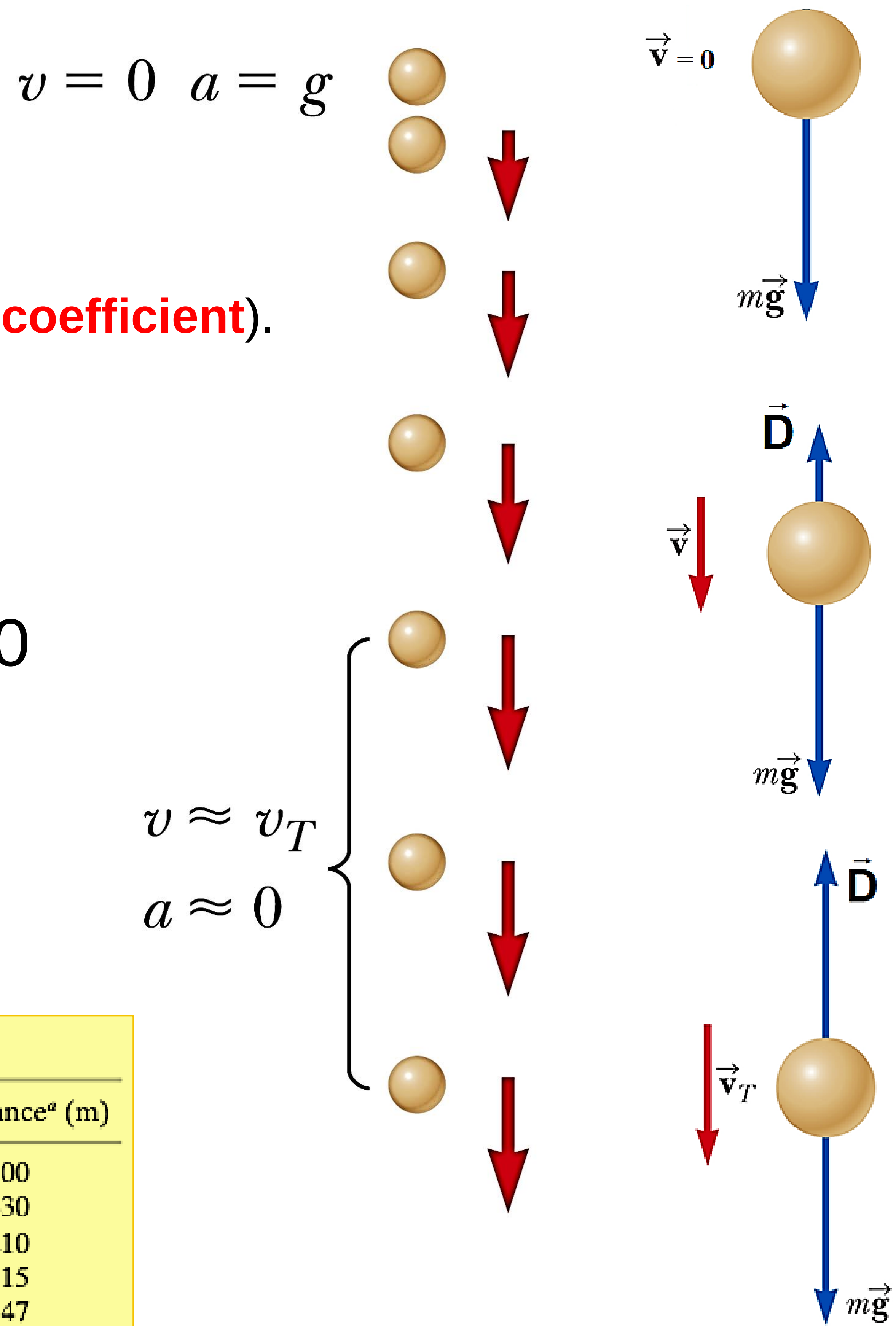
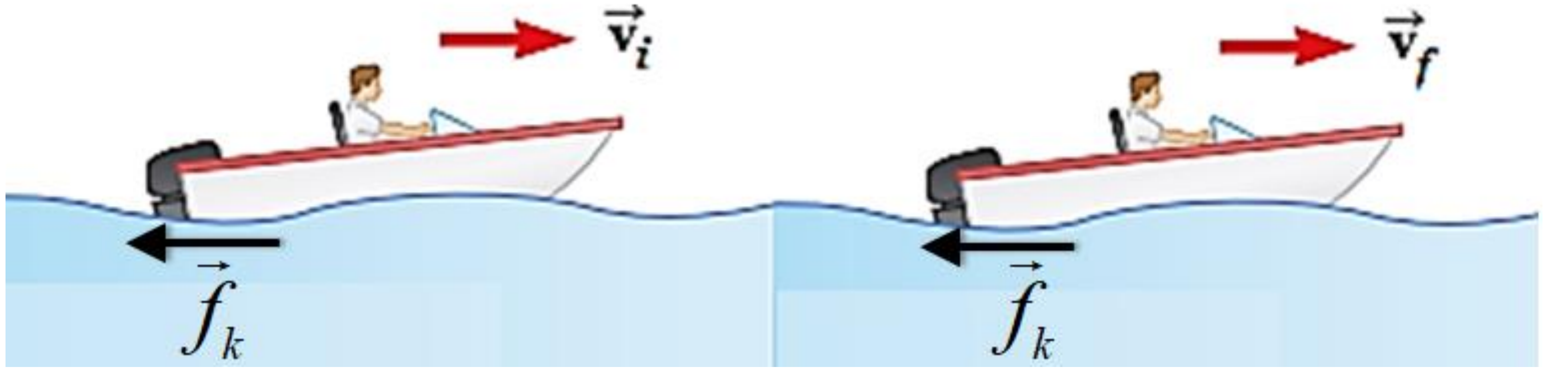


Table 6-1 **Some Terminal Speeds in Air**

Object	Terminal Speed (m/s)	95% Distance[a] (m)
Shot (from shot put)	145	2500
Sky diver (typical)	60	430
Baseball	42	210
Tennis ball	31	115
Basketball	20	47
Ping-Pong ball	9	10
Raindrop (radius = 1.5 mm)	7	6
Parachutist (typical)	5	3

Ex 6: (Problem 6.33 Halliday)

A **1000 kg boat** is traveling at **90 km/h** when its engine is shut off. The magnitude of the **frictional force between boat and water** is proportional to the speed ***v*** of the boat: **f_k=70*v***, where ***v*** is in meters per second and **f_k** is in newtons. Find the **time required** for the boat to slow to **45 km/h**.



$$F_{net} = ma \Rightarrow -f_k = ma \Rightarrow -70v = m\frac{dv}{dt} = 1000\frac{dv}{dt}$$

$$\frac{dv}{dt} = -\frac{70}{1000}v \Rightarrow \frac{dv}{v} = -\frac{7}{100}dt \Rightarrow \int_{v_i}^{v_f}\frac{dv}{v} = \int_{t_i}^{t_f}(-\frac{7}{100})dt$$

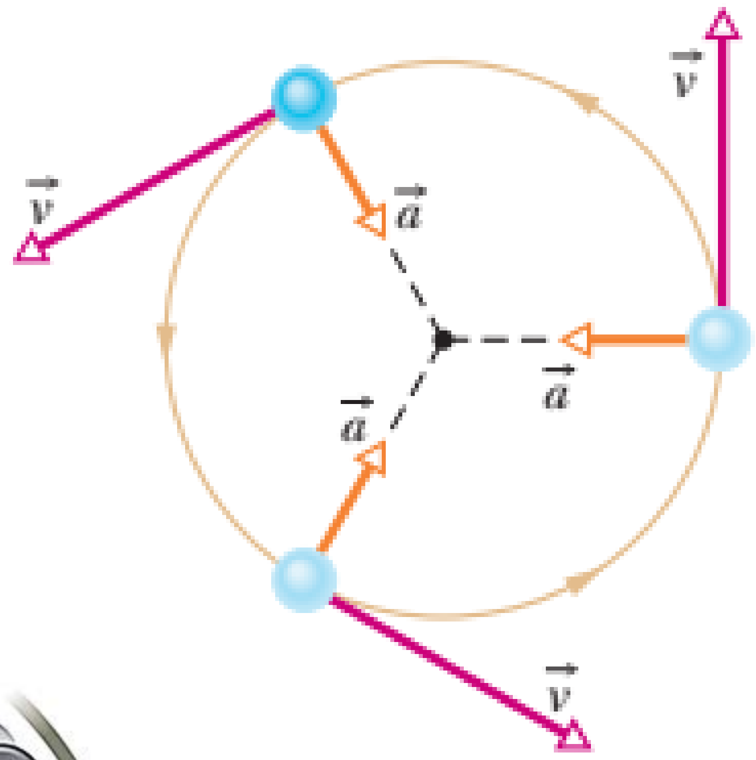
$$\ln\frac{v_f}{v_i} = -\frac{7}{100}(t_f - t_i) = -\frac{7}{100}\Delta t \Rightarrow \boxed{\Delta t = -\frac{100}{7}\ln\frac{v_f}{v_i} = -\frac{100}{7}\ln\frac{45}{90} = 9.9\ s}$$

Centripetal Force

- A particle is in **uniform circular motion** if it travels around a circle or a circular arc at **constant (uniform) speed.**
- The particle is **accelerating** because the **velocity changes in direction**.

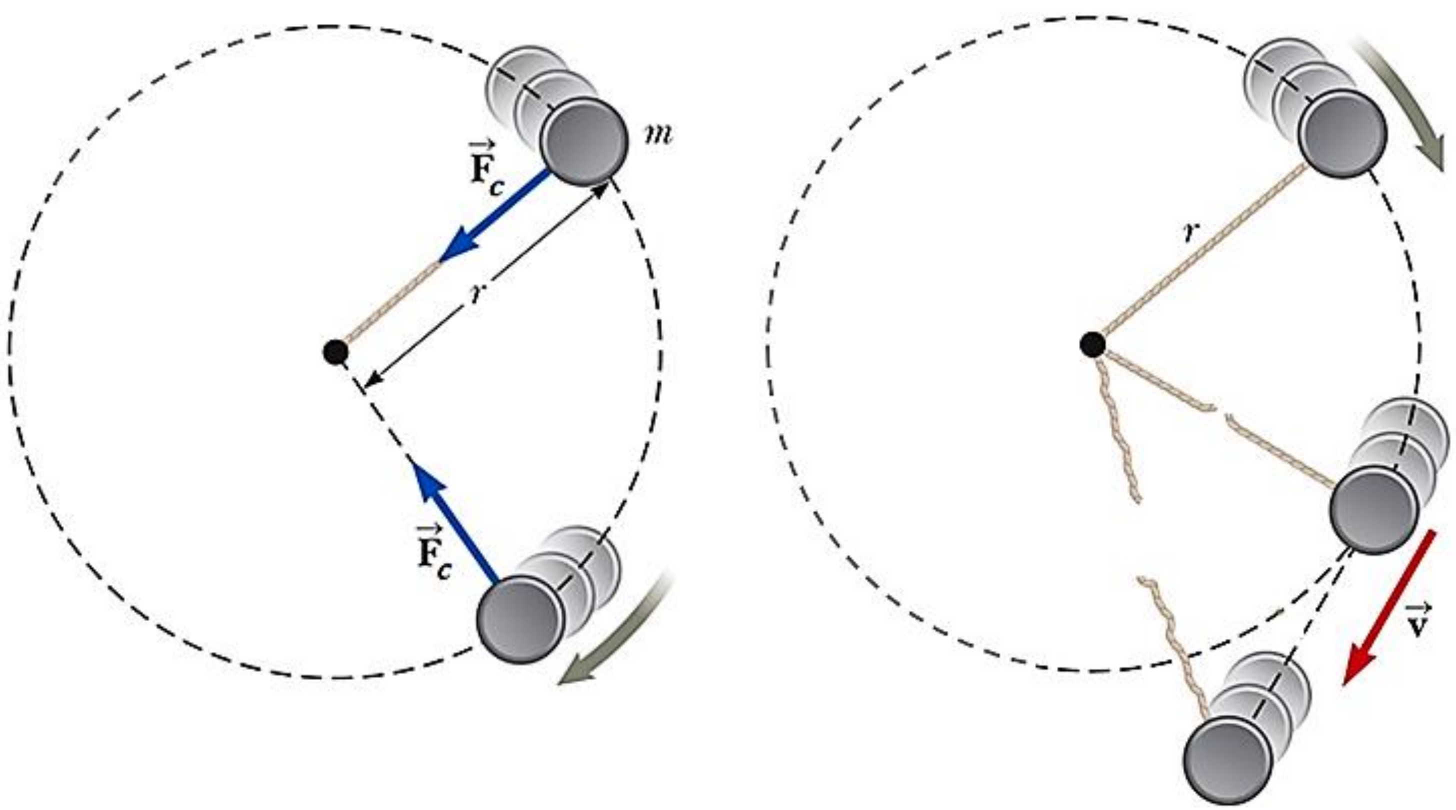
Centripetal Acceleration

$$a_C = \frac{v^2}{r}$$



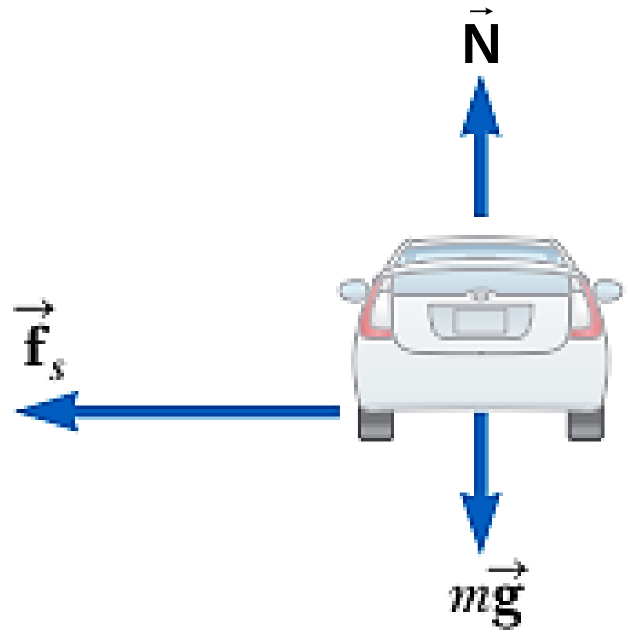
Centripetal Force

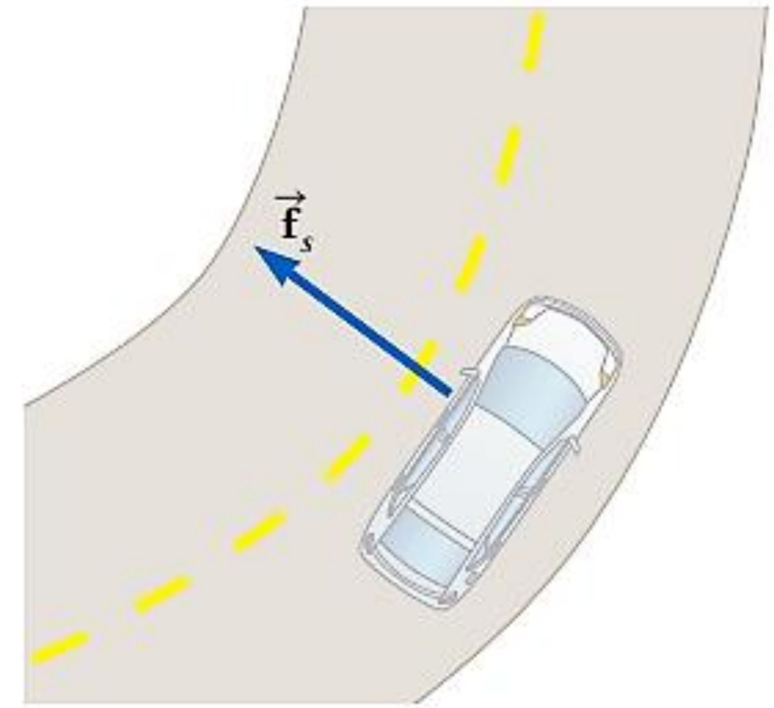
$$F_C = ma_C = m\frac{v^2}{r}$$



Ex 7: A **1500-kg car** moving on a flat, horizontal road negotiates a curve as shown in Figure. If the **radius of the curve** is **35.0 m** and the **coefficient of static friction** between the tires and dry pavement is **0.523**, find the **maximum speed the car** can have and still make the turn successfully.

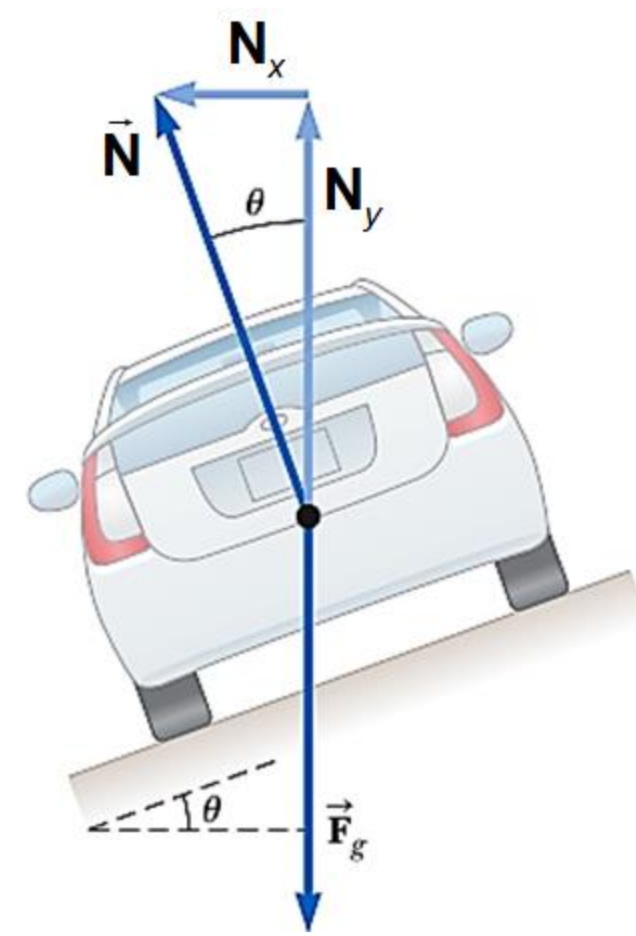
$$\begin{cases} f_s = m\dfrac{v^2}{r} \\ N = mg \end{cases} \Rightarrow f_{s,max} = m\frac{v_{max}^{\ 2}}{r}$$





$$\mu_s N = \mu_s mg = m\frac{v_{max}^{\ 2}}{r} \Rightarrow \boxed{v_{max} = \sqrt{\mu_s rg} = 13.4\ m/s}$$

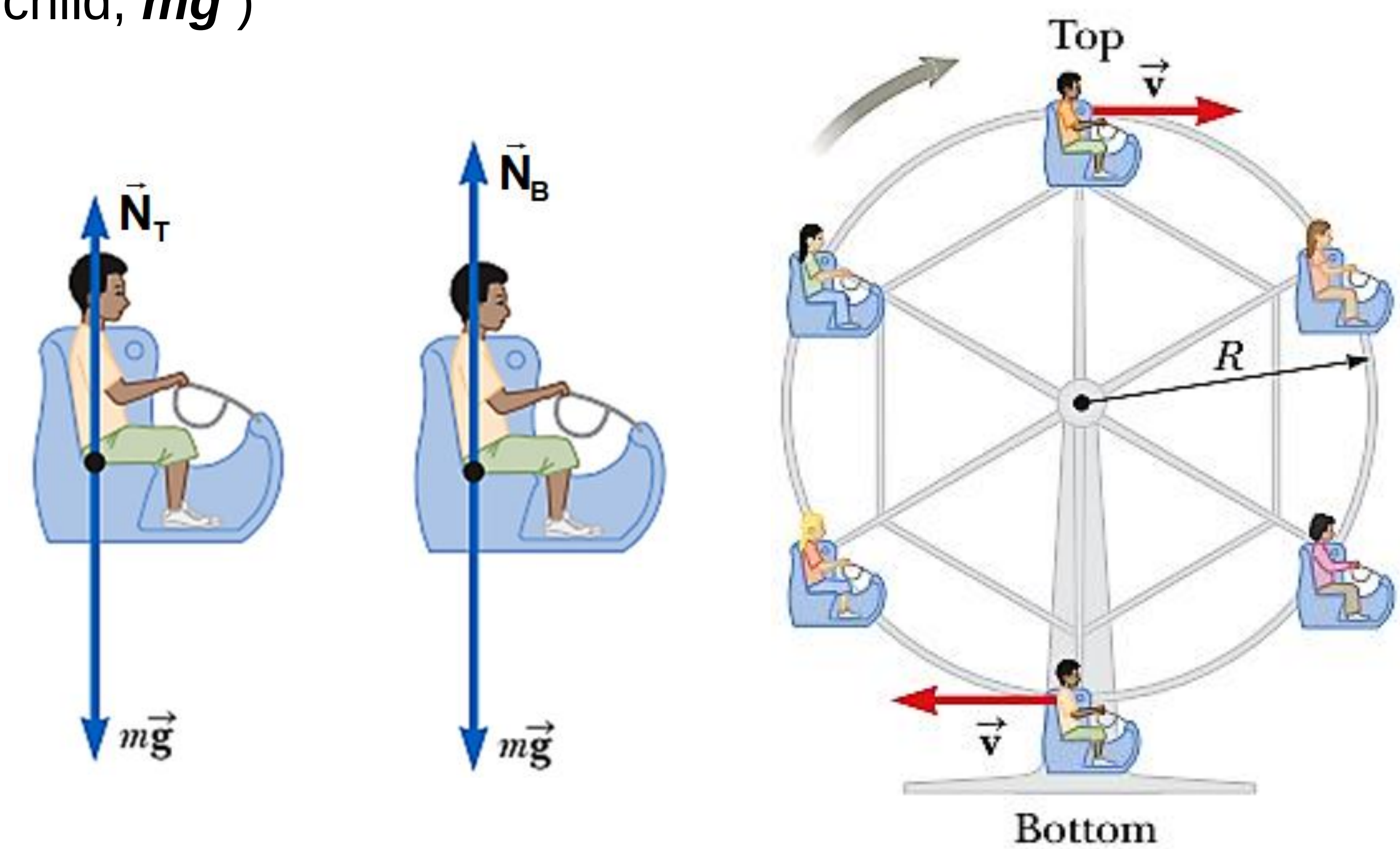
$$\begin{cases} N_x = N\sin\theta = m\dfrac{v^2}{r} \\ N_y = N\cos\theta = mg \end{cases} \Rightarrow \tan\theta = \frac{v^2}{rg}$$



$$\boxed{\theta = \tan^{-1}\left(\frac{v^2}{rg}\right) = \tan^{-1}\left(\frac{13.4^2}{35\times 9.8}\right) = 27.6^\circ}$$

Ex 8: A child of mass **m** rides on a Ferris wheel as shown in Figure. The child moves in a vertical circle of radius **10.0 m** at a constant speed of **3.00 m/s**. Determine the force exerted by the seat on the child (a) at the bottom of the ride, (b) at the top of the ride. (Express your answer in terms of the weight of the child, ***mg***)

$$F_c = m\frac{v^2}{R}$$



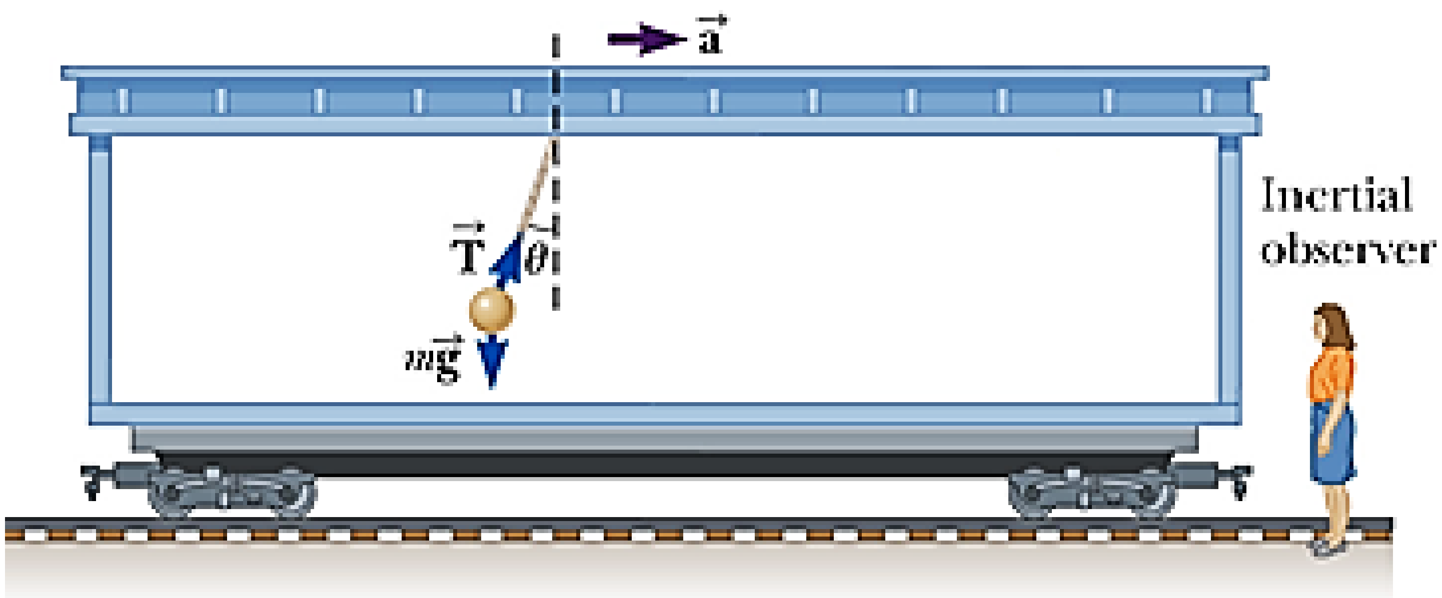
$$N_B - mg = m\frac{v^2}{R} \Rightarrow N_B = mg + m\frac{v^2}{R} = mg(1 + \frac{v^2}{Rg}) \Rightarrow \boxed{N_B = (1.09)mg}$$

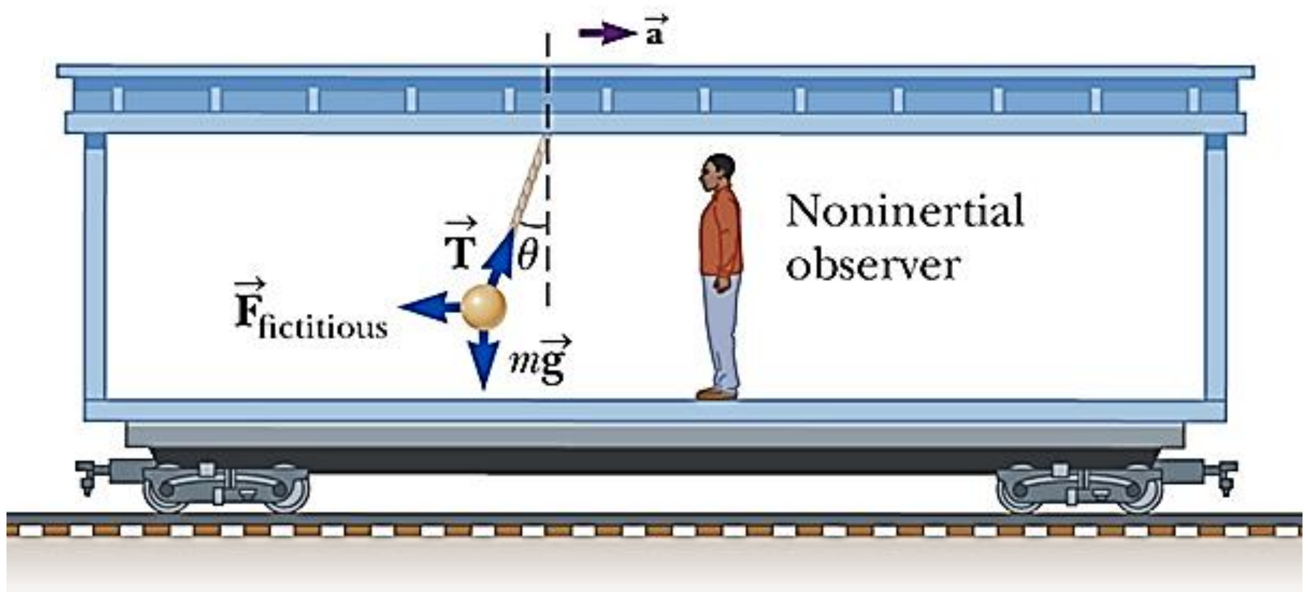
$$mg - N_T = m\frac{v^2}{R} \Rightarrow N_T = mg - m\frac{v^2}{R} = mg(1 - \frac{v^2}{Rg}) \Rightarrow \boxed{N_T = (0.91)mg}$$

Motion in Accelerated Frames

❖ The **real force** are always interactions between two objects.

❖ The **fictitious force** is due to observations made in an accelerated frame.



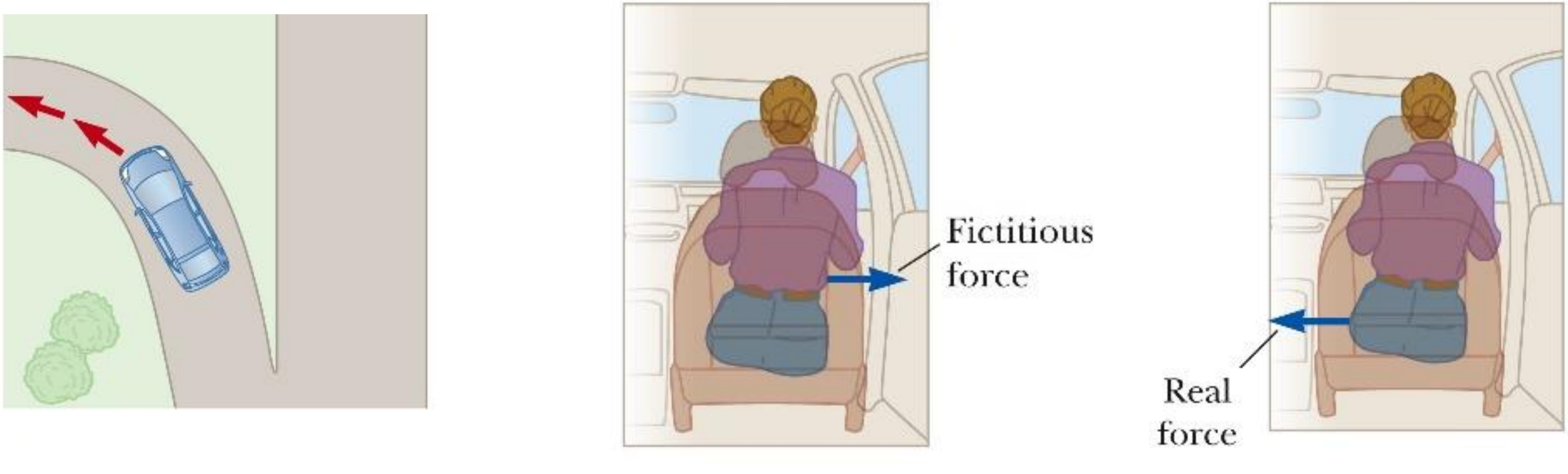


$$\begin{cases} F_{x,net} = T\sin\theta = ma \\ F_{y,net} = T\cos\theta - mg = 0 \end{cases}$$

$$\begin{cases} F'_{x,net} = T\sin\theta - F_{fictitious} = 0 \\ F'_{y,net} = T\cos\theta - mg = 0 \end{cases}$$

$$\boxed{F_{fictitious} = ma}$$

Motion in Accelerated Frames



- From the **frame of the passenger**, a force appears to push her toward the door (**Centrifugal Force**).
- From the **frame of the Earth**, the car applies a leftward force on the passenger (**Frictional Force**)