D03 INERTIAL AND NONINERTIAL REFERENCE FRAMES

SPH4U

FRAMES OF REFERENCE

- **Inertial Frame of Reference:** a frame in which the law of inertia is valid
  - Other laws of physics also apply
  - Any frame moving an a constant velocity relative to the inertial frame is also an inertial frame

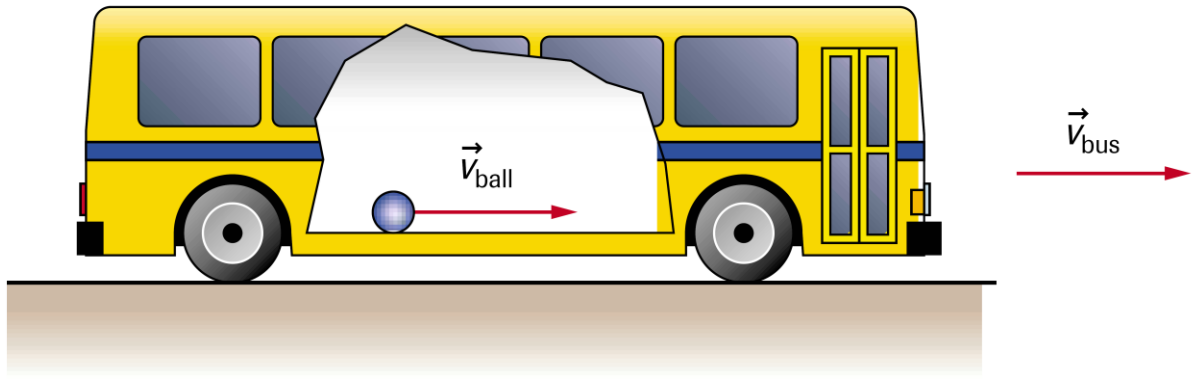

Figure 1
The bus and the ball move at a constant velocity. Relative to the bus, the ball is at rest.

FRAMES OF REFERENCE – CONT.

- **Noninertial Frame of Reference:** a frame in which the law of inertia is not valid
  - Frame of reference is undergoing acceleration

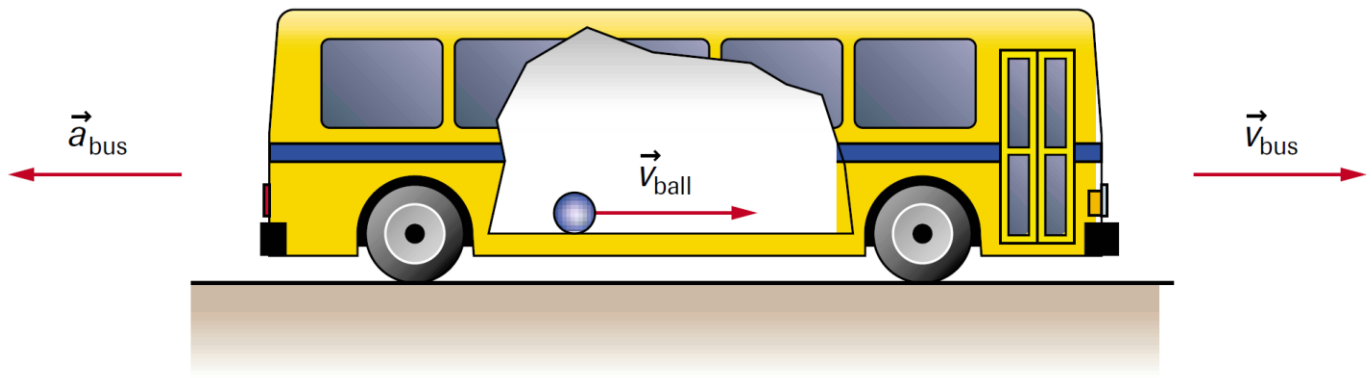

Figure 2
When the brakes are applied, the bus slows down, but the ball tends to continue moving forward at a constant velocity relative to the ground. Thus, relative to the bus, the ball accelerates forward.

FRAMES OF REFERENCE – CONT.

- **Fictitious Force:** an invented force used to explain motion in an accelerating frame of reference

EXAMPLE 1

Draw an FBD for the ball shown in (a) **Figure 1** and (b) **Figure 2**. Indicate the fictitious force in (b) relative to the frame of reference of the bus.

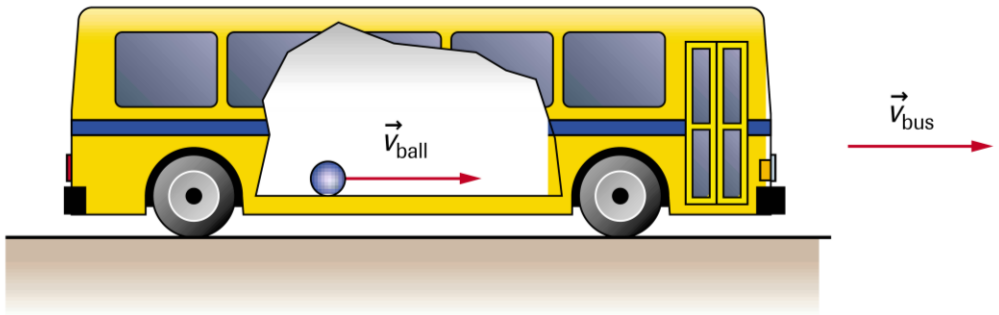

Figure 1
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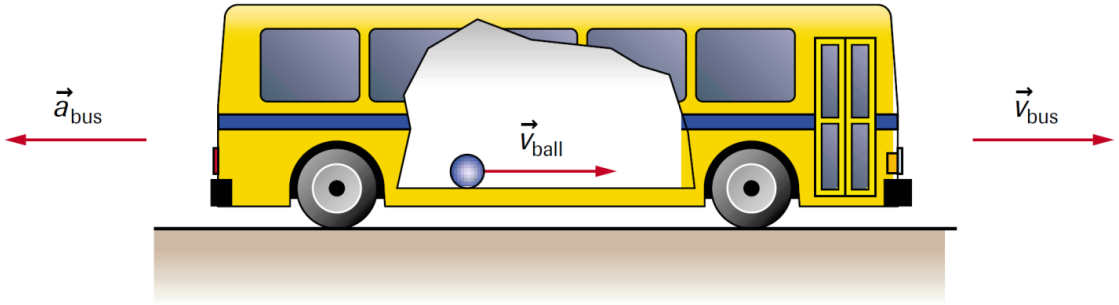

Figure 2
When the brakes are applied, the bus slows down, but the ball tends to continue moving forward at a constant velocity relative to the ground. Thus, relative to the bus, the ball accelerates forward.

EXAMPLE 1 – SOLUTIONS

Figure 3 shows the required diagrams. We use the symbol $\vec{F}_{fict}$ to represent the fictitious force.

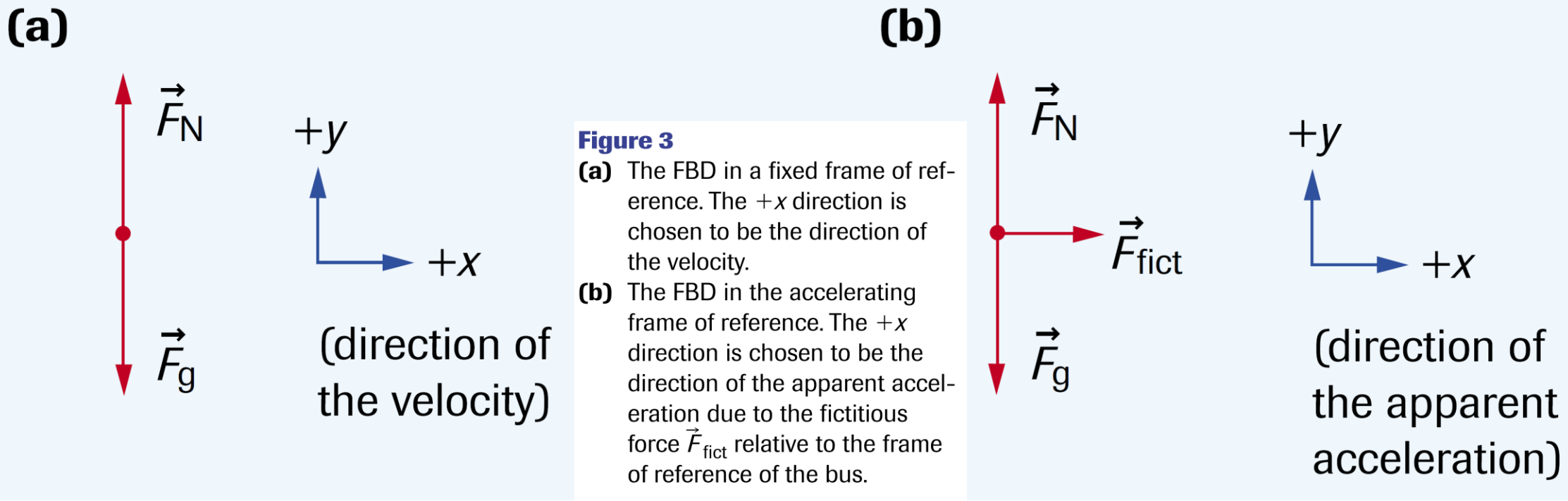

Figure 3
(a) The FBD in a fixed frame of reference. The $+x$ direction is chosen to be the direction of the velocity.
(b) The FBD in the accelerating frame of reference. The $+x$ direction is chosen to be the direction of the apparent acceleration due to the fictitious force $\vec{F}_{fict}$ relative to the frame of reference of the bus.

EXAMPLE 2

A teacher suspends a small rubber stopper from the roof of a bus, as in **Figure 3(a)** from the chapter opener. The suspending cord makes an angle of 8.5° from the vertical as the bus is accelerating forward. Determine the magnitude of the acceleration of the bus.

(a)

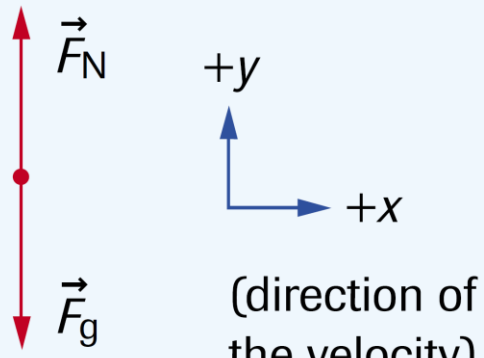

Figure 3

(a) The FBD in a fixed frame of reference. The $+x$ direction is chosen to be the direction of the velocity.

EXAMPLE 2 – SOLUTIONS

To solve this problem, we will look at the situation from Earth's frame of reference because it is an inertial frame. We begin by drawing the system diagram and the FBD in that frame, as shown in **Figure 4**.

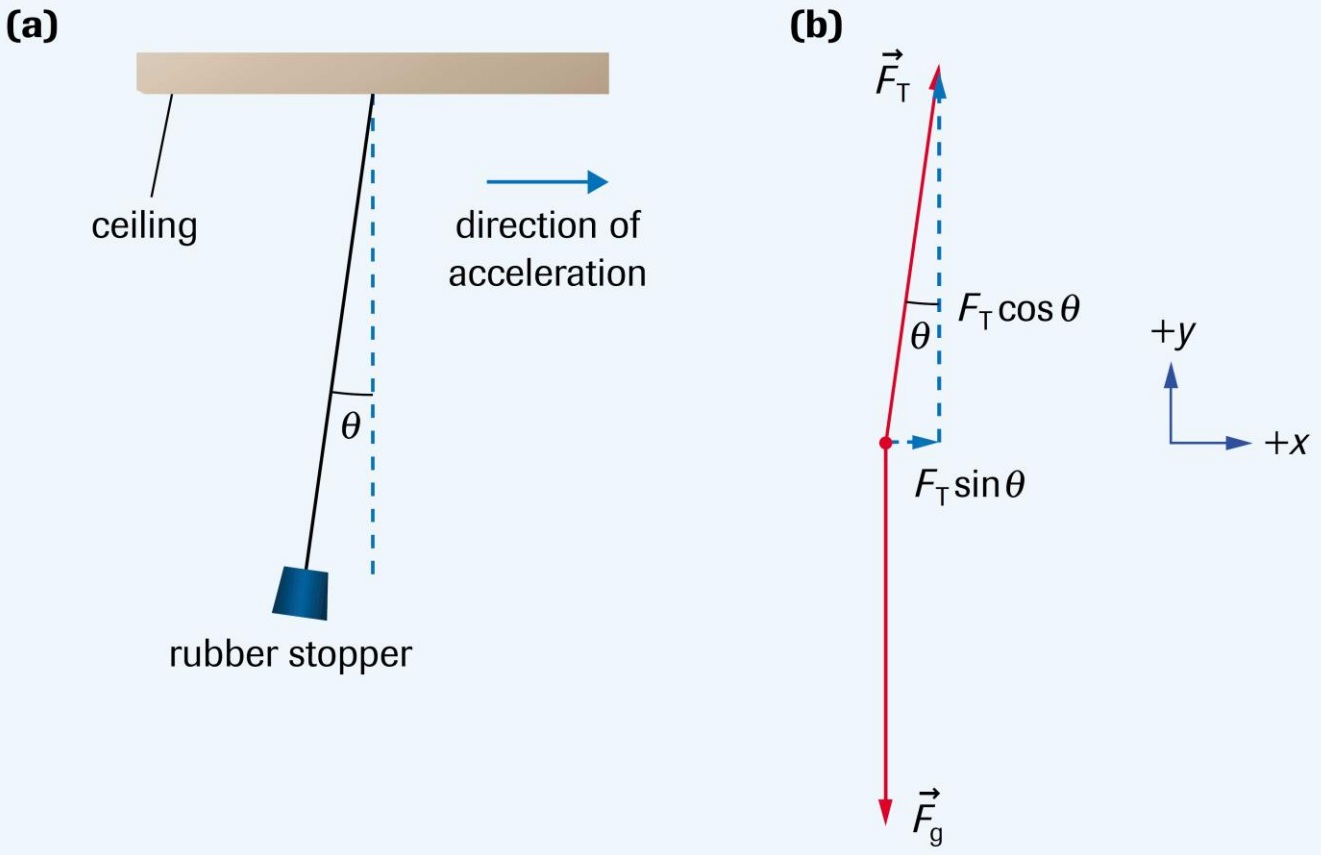

Figure 4
(a) System diagram of improvised rubber-stopper accelerometer
(b) FBD of accelerometer bob

EXAMPLE 2 – SOLUTIONS CONT.

It is the horizontal component of the tension that causes the acceleration. Since both it and the horizontal acceleration are unknowns, we must use two equations. We start with the vertical components:

$$\sum F_y = ma_y = 0$$

$$F_T \cos\theta - F_g = 0$$

$$F_T \cos\theta = F_g \text{ where } F_g = mg$$

$$F_T = \frac{mg}{\cos\theta}$$

EXAMPLE 2 – SOLUTIONS CONT.

This expression for F_T can now be substituted into the equation for the horizontal components:

$$\begin{aligned}
\sum F_x &= ma_x \\
F_T \sin\theta &= ma_x \\
a_x &= (F_T)\left(\frac{\sin\theta}{m}\right) \\
&= \left(\frac{mg}{\cos\theta}\right)\left(\frac{\sin\theta}{m}\right) \\
&= g\left(\frac{\sin\theta}{\cos\theta}\right) \\
&= g\tan\theta \\
&= (9.8\ \text{m/s}^2)(\tan 8.5°) \\
a_x &= 1.5\ \text{m/s}^2
\end{aligned}$$

The magnitude of the acceleration is 1.5 m/s^2.

SUMMARY

- An inertial frame of reference is one in which the law of inertia (Newton's first law of motion) holds.
- An accelerating frame of reference is a noninertial frame where the law of inertia does not hold.
- In a noninertial frame of reference, fictitious forces are often invented to account for observations.

PRACTICE

Readings

- Section 2.5 (pg 108)

Questions

- pg 111 #1,2