بسم الله الرحمن الرحيم

وزارة التعليم العالي
Ministry of Higher Education

King Saud University
College of Science
Physics & Astronomy Dept.

PHYS 103 (GENERAL PHYSICS)

CHAPTER 6: CIRCULAR MOTION

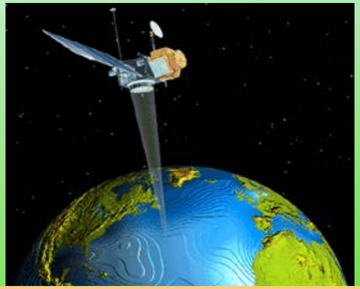
LECTURE NO. 9

THIS PRESENTATION HAS BEEN PREPARED BY: *DR. NASSR S. ALZAYED*

Lecture Outline

- Here is a quick list of the subjects that we will cover in this presentation. It is based on Serway, Ed. 6

- *Applications on Newton's Laws*
- *Newton's Second Law Applied to Uniform Circular Motion*
- *Example 6.2 The Conical Pendulum*
- *Example 6.4 What Is the Maximum Speed of the Car?*
- *Example 6.5 The Banked Exit Ramp*
- *Lecture Summary*
- *Interactive Quiz*
- *Interactive Flash*
- *End of Presentation*

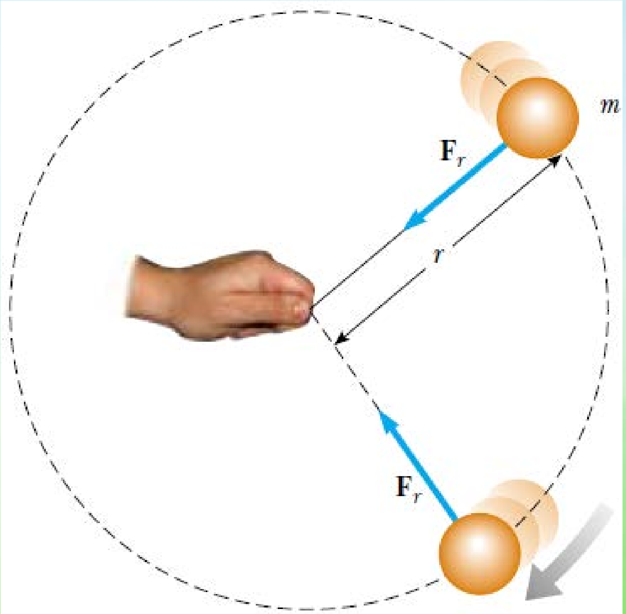


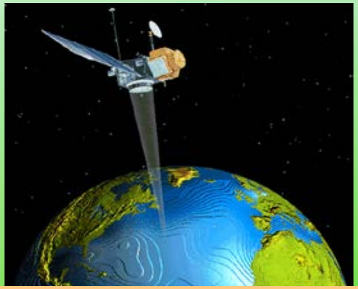
Newton's Second Law

- Applying Newton's Second Law to Uniform Circular Motion we get:

$$a_c = \frac{v^2}{r} \qquad \text{(centripetal acceleration)}$$

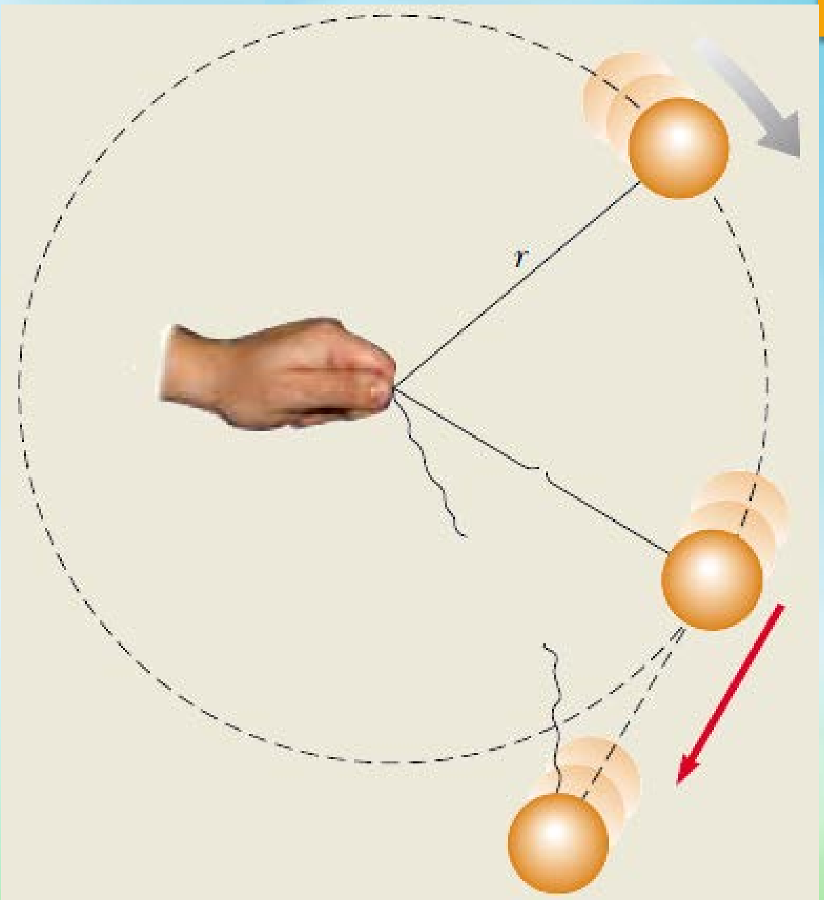
- The acceleration is called centripetal acceleration because ac is directed toward the center of the circle
- $\mathbf{a}_c$ is always perpendicular to $\mathbf{v}$
- If we apply Newton's second law along the radial direction, we find that the net force causing the centripetal acceleration can be evaluated:
- $$\sum \boldsymbol{F} = ma_c = m\frac{v^2}{r} \qquad (6.1)$$

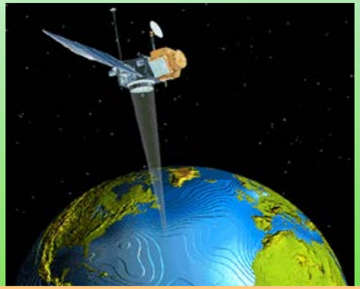




Circular Motion

- A force causing a *centripetal acceleration* acts toward the *center of the circular path* and causes a change in the direction of the velocity vector.
- If that force should vanish, the object would no longer move in its circular path; instead, it would move along a straight-line path tangent to the circle.
- This idea is illustrated in the figure for the ball whirling at the end of a string in a horizontal plane. If the string breaks at some instant, the ball moves along the straight-line path tangent to the circle at the point where the string breaks.





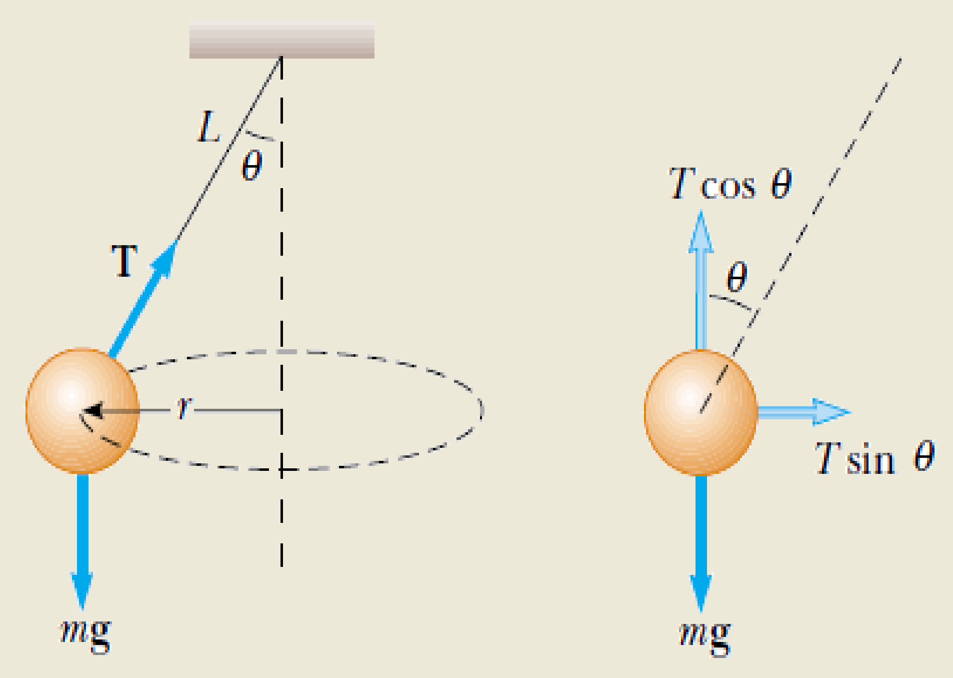
Example 6.2 The Conical Pendulum

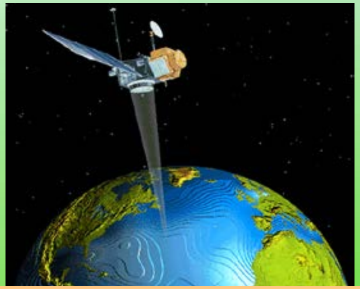
- A small object of mass m is suspended from a string of length L. The object revolves with constant speed v in a horizontal circle of radius r, as shown in Figure. (Because the string sweeps out the surface of a cone, the system is known as a conical pendulum.) *Find an expression for v*.
- ***Solution***:

- We shall apply Newton's 2nd law as we did before.
- We need first to analyze forces and apply the law in x, then y directions.

$$\sum F_x = ma_x \qquad (1)$$

$$\sum F_y = ma_y \qquad (2)$$





Example 6.2 (continued)

- Solving we get:

$$(1) \Rightarrow T\cos\theta = mg \qquad (3)$$

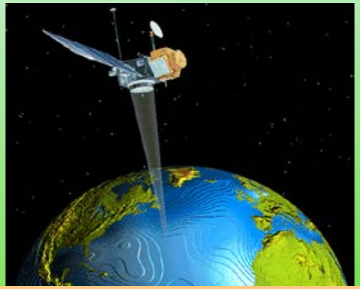
$$(2) \Rightarrow T\sin\theta = \mathrm{ma_c} = m\frac{v^2}{r} \qquad (4)$$

$$(4) \div (3): \Rightarrow \frac{T\sin\theta}{T\cos\theta} = \frac{m\frac{v^2}{r}}{mg} \Rightarrow \tan\theta = \frac{v^2}{gr}$$

$$\therefore \mathrm{v} = \sqrt{gr\tan\theta} \qquad (5)$$

$$\because r = L\sin\theta$$

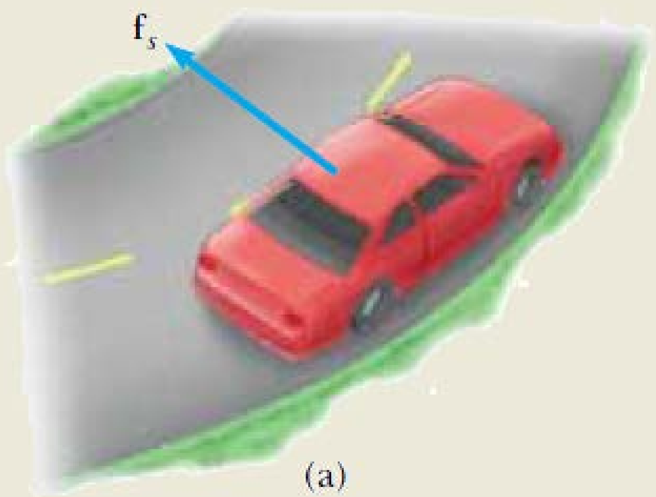
$$\therefore (5) \Rightarrow \mathrm{v} = \sqrt{Lg\sin\theta\tan\theta}$$



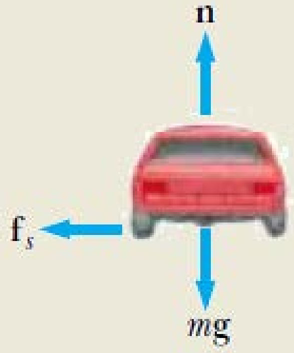
Example 6.4 A car on a Curve

- A 1 500-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 0.500, *find the maximum speed the car can have and still make the turn successfully.*

- ***Solution***: In this case, the force that enables the car to remain in its circular path is the force of *static friction*. (Static because no slipping occurs at the point of contact between road and tires.
- We shall apply Newton's 2nd law.



(a)



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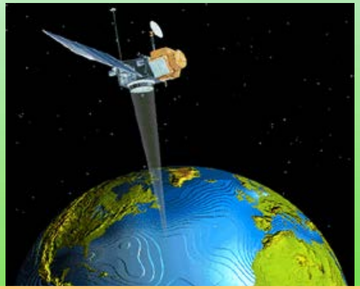


Example 6.4 (continued)

- Solving we get:

$$m = 1500\,kg\,,\, r = 35\,m\,,\, \mu_s = 0.5$$

$$\because \sum \boldsymbol{F_x} = m a_x \qquad (1)$$

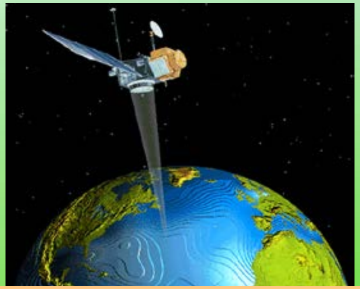
$$\therefore f_s = m\frac{v^2}{r} \qquad (2)$$

$$\because f_s = \mu_s n = \mu_s (mg) \qquad (3)$$

$$\therefore \mu_s (\cancel{m} g) = \cancel{m}\frac{v^2}{r}$$

$$\Rightarrow v = \sqrt{r\,\mu_s\, g} \qquad (4)$$

$$\therefore v = \sqrt{(35)(0.5)(9.8)} = 13.1\text{m/s}$$

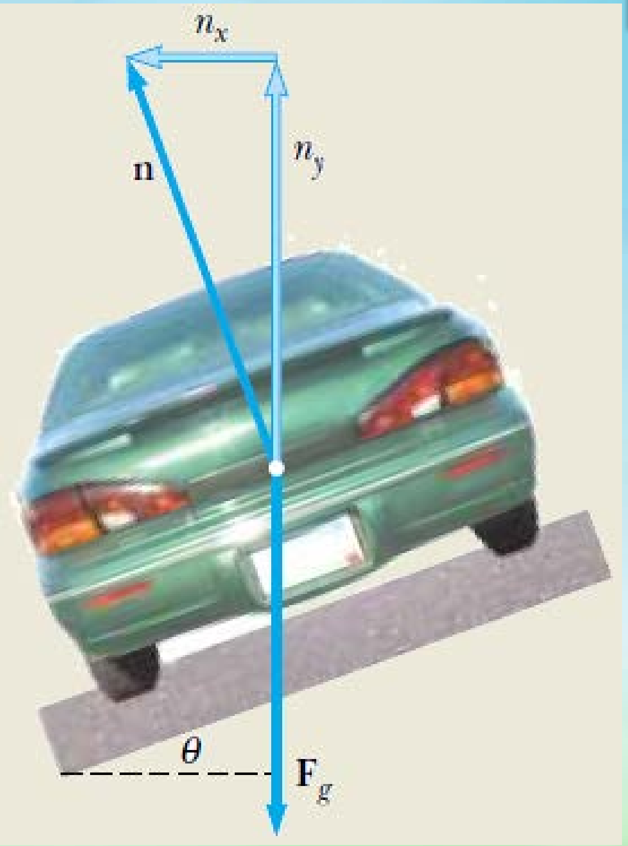


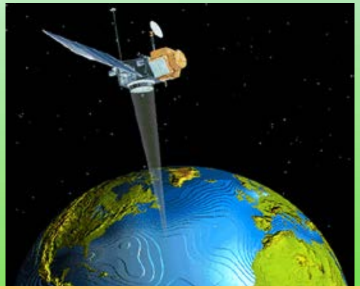
Example 6.5 The Banked Exit Ramp

- A civil engineer wishes to design a curved exit ramp for a highway in such a way that a car will not have to rely on friction to round the curve without skidding. In other words, a car moving at the designated speed can negotiate the curve even when the road is covered with ice. Such a ramp is usually *banked*. Suppose the designated speed for the ramp is to be 13.4 and the radius of the curve is 50.0 m. At what angle should the curve be banked?
- ***Solution***: We shall apply Newton's 2nd law:

$$\sum \boldsymbol{F_x} = ma_x \qquad (1)$$

$$\sum \boldsymbol{F_y} = ma_y \qquad (2)$$





Example 6.5 (continued)

- Solving we get:

$$r = 50\,m, v = 13.4\,m/s$$

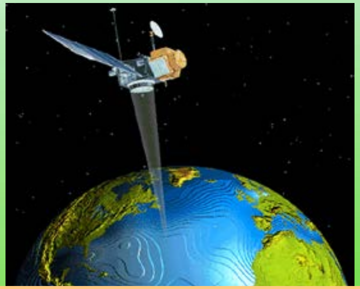
$$(1) \Rightarrow n \sin\theta = m\frac{v^2}{r} \qquad (3)$$

$$(2) \Rightarrow n \cos\theta = mg \qquad (4)$$

$$(3) \div (4) \Rightarrow: \tan\theta = \frac{v^2}{gr}$$

$$\therefore \theta = \tan^{-1}\left(\frac{v^2}{gr}\right) = \tan^{-1}\left(\frac{13.4^2}{(50)(9.8)}\right) = 20.1^o$$

- A driver who attempts to negotiate the curve at a speed greater than 13.4 m/s has to depend on friction to keep from sliding up the bank.



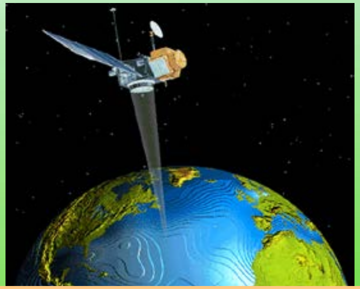
Lecture Summary

- Newton's second law applied to a particle moving in uniform circular motion states that the net force causing the particle to undergo a centripetal acceleration is:

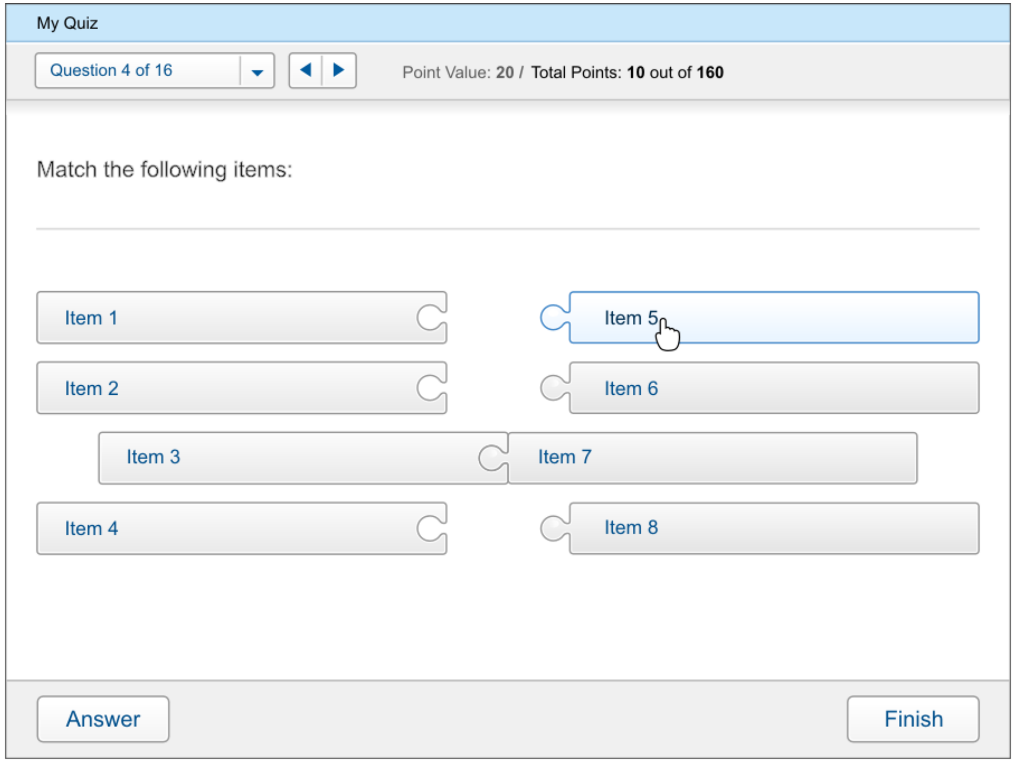
$$\sum \mathbf{F} = ma_c = m\frac{v^2}{r} \qquad (6.1)$$

- A particle moving in a uniform circular motion has the centripetal acceleration give by:

$$a_c = \frac{v^2}{r} \qquad \text{(centripetal acceleration)}$$



Interactive Quiz



Click the **Quiz** button on
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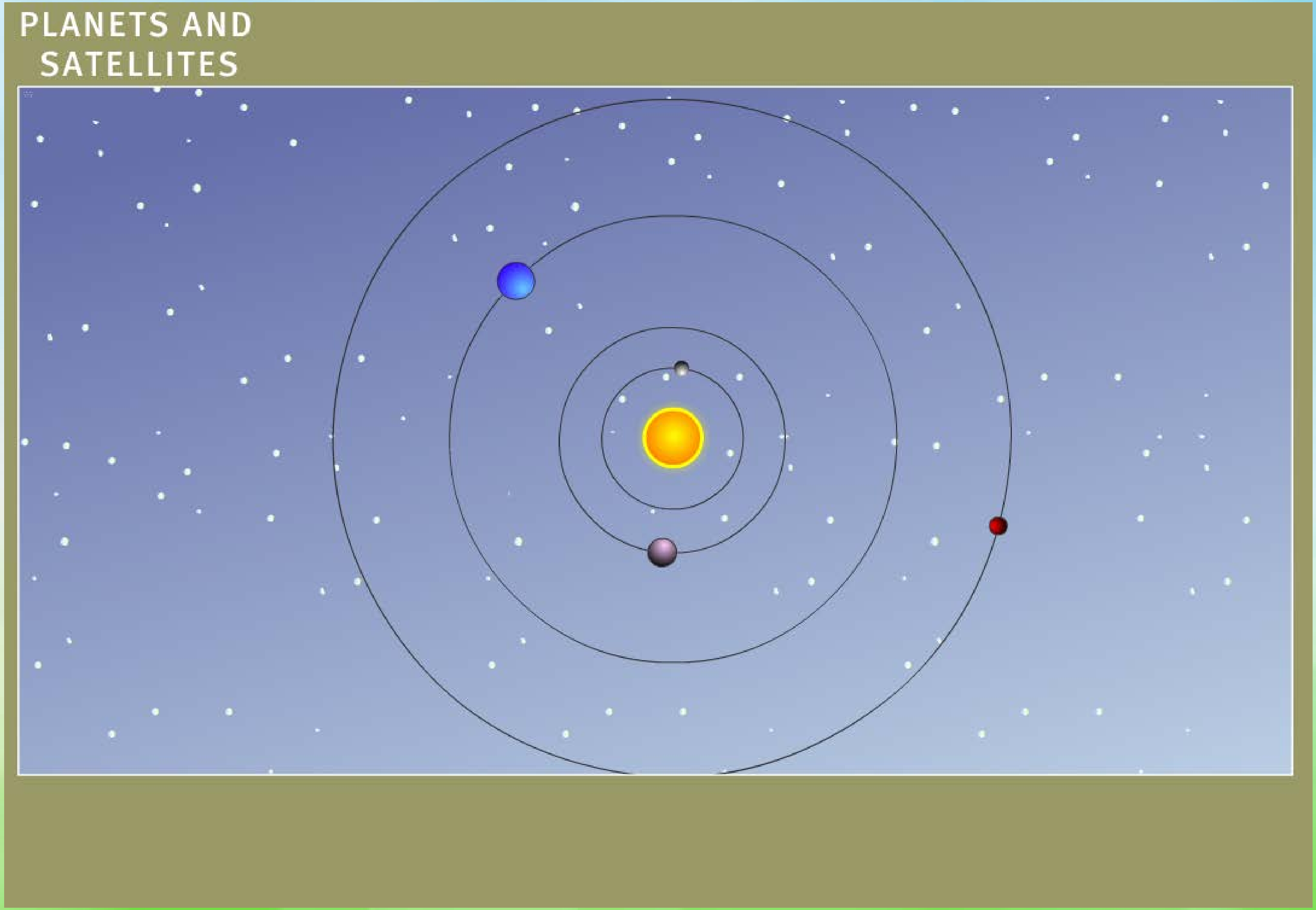
Interactive Flash

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