SPH4U Unit 1 Dynamics

Chapter 3 Uniform Circular Motion

Lesson Package

Schoolwork	Useful Links/ Videos/ Handouts	Homework
Chapter 3 Videos		
	Interactive Animations 1. Uniform circular motion 2. Horizontal Circle Simulation 3. Vertical Circle Simulation **Websites:** 1. Circular Motion and Satellite Motion **Videos** 1. Circular Motion 2. Introduction to Centripetal Acceleration	
3.1 Inertial and Non-inertial Frames of Reference		
1. Lesson 3.1 Presentation 2. Lesson 3.1 Lesson Package	**Video:** 1. 3.1 Inertial and non-inertial frames of reference	1. 3.1 Check Your Understanding 2. 3.1 Check Your Knowledge 3. Textbook pg. 113 #1-8
3.2 Centripetal Acceleration		
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3.3 Centripetal Force		
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3.4 Rotating Frames of Reference		
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Lesson 5 Additional Problems		
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1. Chapter 3 Self- Quiz pg. 139 (attempt all) 2. Chapter 3 Review pg. 140 #1-74 3. Uniform Circular Motion Communication Questions (lesson package)		1. Chapter 3 Self- Quiz pg. 139 (attempt all) 2. Chapter 3 Review pg. 140 #1-64 3. MC questions on Schoology 4. Uniform Circular Motion Communication Questions (lesson package)

Lesson 3.1 Inertial and Non-inertial Frames of Reference

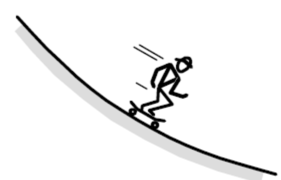
Lesson Goal: Solve problems related to objects in a non-inertial frame of reference

Success Criteria: At the end of this lesson, I will be able to:

- ✓ Define what a frame of reference is.
- ✓ Differentiate between inertial and non-inertial frame of reference
- ✓ Understand that fictitious forces help explain motion in a non-inertial frame of reference
- ✓ Distinguish between weight and apparent weight
- ✓ Outline the process of calculating apparent weight

Now that we went through PPP " Frames of Reference" let's do some examples

TIPERs B3-31 SKATEBOARD RIDER COASTING DOWN A HILL—ACCELERATION AND NET FORCE
At the instant shown, a skateboard rider is coasting down a hill and speeding up. Consider the skateboard and the rider as a single system and ignore friction.



a) Use velocity vectors to find the approximate direction of the acceleration of the system.

b) Draw a free-body diagram for the system, labelling all forces, and explain how the forces in your free-body diagram add to give a net force in the direction of the acceleration.

Example 1: Calculating the Acceleration of a Non-inertial Frame of Reference

A teacher suspends a small cork ball from the ceiling of a bus. When the bus accelerates at a constant rate forward, the string suspending the ball makes an angle of 10.0° with the vertical. Calculate the magnitude of the acceleration of the bus.

Apparent Weight

Apparent weight is the magnitude of the normal force acting on an object in an accelerated (non-inertial) frame of reference.

Suppose that you stand on a scale inside an elevator. When the elevator is at rest, the normal force is again the same as your weight. This is also true when the elevator is moving at a constant non-zero speed upward or downward. However, what happens when the elevator accelerates?

When the elevator accelerates downward, the normal force decreases, so that the magnitude of the reading on the scale is less than your weight, mg.

Similarly, when the elevator accelerates upward, the normal force increases, resulting in a greater reading on the scale. As with the bus at the beginning of this section, the elevator can be an inertial frame of reference when it has a constant velocity going up or down. It becomes a non-inertial frame of reference when it accelerates, resulting in a normal force that is either greater or less than your weight.

Other non-inertial frames of reference produce other values for apparent weight. On a free-fall ride at an amusement park, the acceleration of the ride is equal to g, and the normal force is zero (Figure 4(c)). Thus, the scale will read an apparent weight of zero. Similarly, an astronaut aboard the International Space Station is constantly in free fall. Therefore, the normal force acting on the astronaut is zero

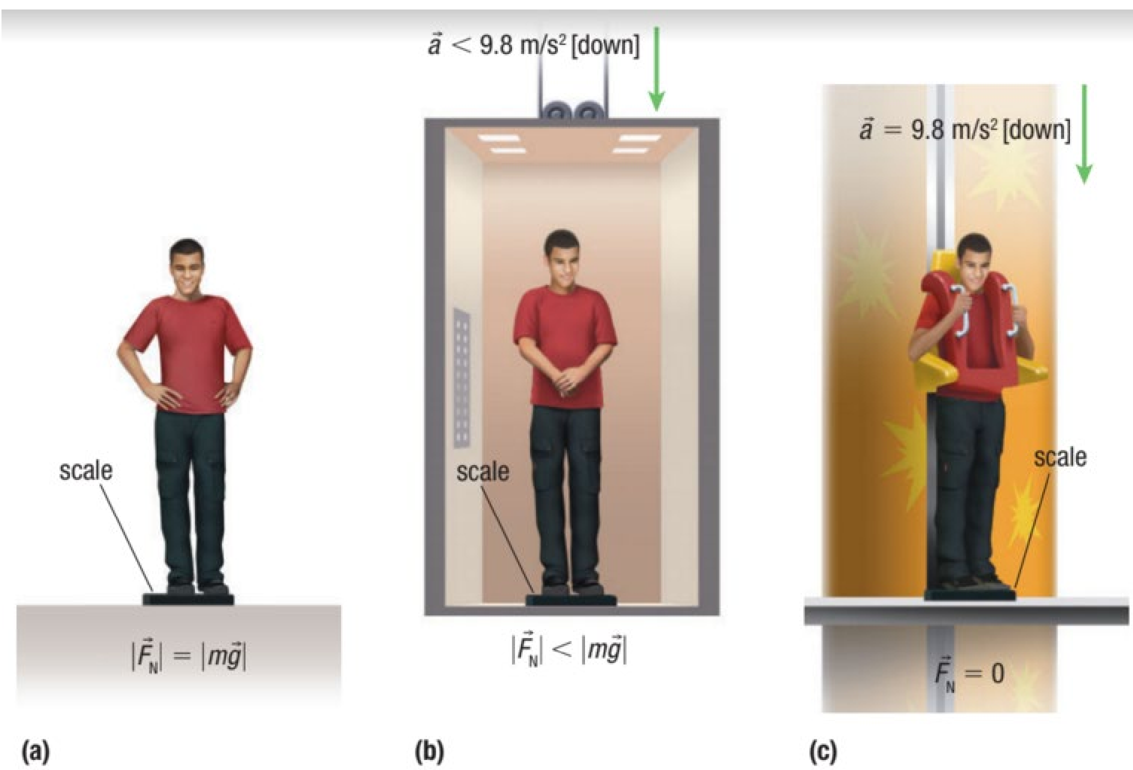


Figure 4 The readings on the scale will be (a) equal to *mg* when standing still, (b) less than *mg* when the elevator accelerates downward, (c) equal to zero in vertical free fall on an amusement park ride, and (d) equal to zero in free fall during orbit.

Apparent Weight Analysis

Example 2: Apparent Weight in an Accelerating Elevator

An elevator accelerates upward with an acceleration of magnitude 1.5 m/s^2, after which it moves with a constant velocity. As the elevator approaches its stopping point, it undergoes a downward acceleration of magnitude 0.9 m/s^2. Calculate the apparent weight of a passenger with a mass of 75 kg when

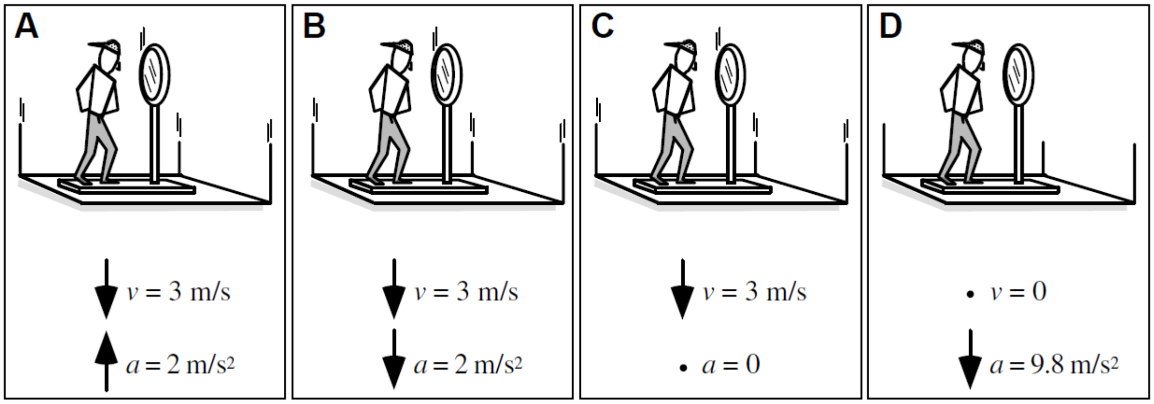
a) the elevator undergoes positive acceleration

b) the elevator moves at constant velocity

c) the elevator undergoes negative acceleration

TIPERs pg. 121 B3-RT61: Person in an Elevator Moving Downward—Scale Reading

A person who weighs 600 N is standing on a scale in an elevator. The elevator is identical in all cases. The velocity and acceleration of the elevators at the instant shown are given.



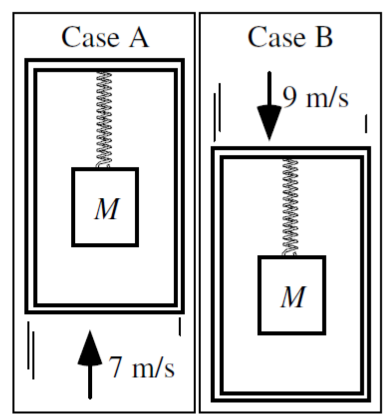
Rank the scale reading.

				OR			
1 Greatest	2	3	4 Least		All the same	All zero	Cannot determine

Explain your reasoning.

TIPERs (pg. 89 B3-09) **Ranking Problem - BLOCKS IN MOVING ELEVATORS—STRETCH OF SPRING**

A spring is attached to the ceiling of an elevator, and a block of mass *M* is suspended from the spring. The cases are identical except that in Case A the elevator is moving upward with a constant speed of 7 m/s, while in Case B the elevator is moving downward with a constant speed of 9 m/s.

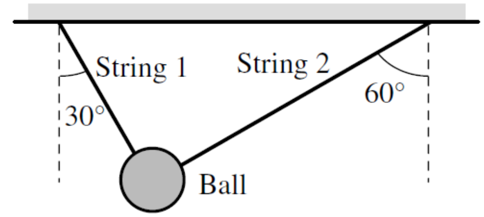


Will the spring be stretched

(i) *more* in Case A, (ii) *more* in Case B, or (iii) *the same* in both cases?

Explain your reasoning.

TIPERs (B3-77) BALL SUSPENDED FROM CEILING BY TWO STRINGS—TENSION



A 0.5-kg ball is suspended from a ceiling by two strings. The ball is at rest.

(a) Is the tension in string 1

(i) *greater than*, (ii) *less than* (iii) *the same as*

the tension in string 2?

Explain your reasoning.

Suppose that the ceiling in the picture above is the ceiling of an elevator, and that the elevator is moving *down* at a constant speed of 2 m/s.

(b) Is the tension in string 1

(i) *greater than*, (ii) *less than*, or (iii) *the same as*

the tension in string 1 in the previous question (a) where the ball was at rest?

Explain your reasoning.

Conceptual Understanding Problem 1(BFW):

Consider a person riding in an elevator that is moving vertically.

1. Draw a picture of the scenario and a free-body diagram of the person.

2. How does the normal force on the person compare to the gravitational force when the elevator is accelerating upward? Explain your reasoning.

3. How does the normal force on the person compare to the gravitational force when the person is moving at a constant speed? Explain your reasoning.

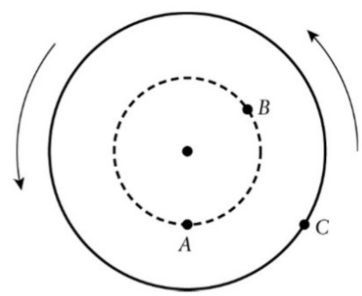
4. How does the normal force on the person compare to the gravitational force when the person is accelerating downward? Explain your reasoning.

5. A person is considered “weightless” when there is no normal force exerted on them, i.e. they are floating around in the elevator cabin. Under what motion conditions would the normal force on the person be zero? Justify your answer with reference to your free body diagrams and Newton’s Laws.

6. Based on your answer to question 5, what must you conclude about the astronauts in the space station who are “weightless?” What must be true about their motion in orbit about Earth?

Problem 2 (BFW):

The figure at right shows a disk that is rotating at a constant rate. Consider the three points A, B, and C at the locations shown.



a) Rank the points in order from greatest to least based on the period of their circular motion. In other words, rank first the point that has the greatest period and rank last the one that has the least period.

Greatest 1 ____ 2 ______ 3 ____ Least Or, all of the points have the same period ___.

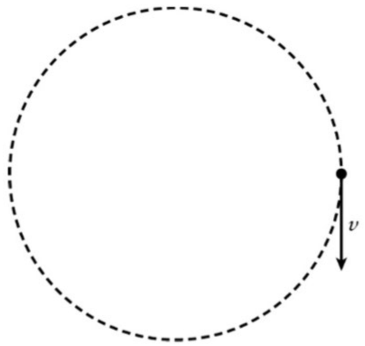
Briefly explain your reasoning.

b) Rank the points in order from greatest to least based on the linear speed of the point.

Greatest 1 ____ 2 ______ 3 ____ Least Or, all of the points have the same speed ___.

Briefly explain your reasoning.

Problem 3 (BFW): An object is moving in uniform circular motion of radius R as shown below. The velocity of the object at the position shown is given by the arrow. Draw a motion map for the object for one complete period of its motion. Include both velocity and acceleration vectors every Δt = T/8 s, where T is the period of the motion.



Check Your Knowledge – Lesson 3.1 Definitions

Term	**Definition**
____ frame of reference	1. A frame of reference that that accelerates with respect to an inertial frame; the law of inertia does not hold
____ inertial frame of reference	2. The magnitude of the normal force acting on an object in an accelerating (non-inertial) frame of reference
____ non-inertial frame of reference	3. A coordinate system relative to which motion is described or observed
____ fictitious force	4. A frame of reference that moves at a zero or constant velocity; the law of inertia holds
____ apparent weight	5. An apparent but non-existent force invented to explain the motion of objects within an accelerating (non-inertial) frame of reference

Check Your Understanding - Lesson 3.1

1. Why did we invent the idea of fictitious force?

2. What is the difference between an inertial frame of reference and a non-inertial frame? Give an example of each.

3. Outline the forces that balance an object moving in a circle at a constant speed if it is being spun on the end of a string.

4. In an inertial frame of reference, is there experiment that can be done that will allow you to determine if you are moving at a constant velocity or if you are at rest?

5. A student is riding a bus and a ball roll forward at 2 m/s in a bus travelling backward at 5 m/s. Is the ball moving forward or backward?

6. Explain how you could see a ball you throw upward in a glass elevator moving downward, but to someone outside the elevator, the ball could appear to be not moving at all.

7. Use apparent weight to explain how you feel at a variety of positions during a roller coaster ride.

8. At what points do you feel the lightest and at what points do you feel heaviest on the roller coaster ride?

9. On the roller coaster ride, when is the force felt an absolute maximum and when is it an absolute minimum?

10. Would you classify motion in a circle at constant speed as an inertial or non-inertial frame of reference? Explain your answer.

3.2 Centripetal Acceleration

Lesson Goal: Solve problems with objects moving with centripetal acceleration

Success Criteria: At the end of this lesson, I will be able to:

- ✓ Understand that uniform circular motion involves any object following a circular path at a constant speed
- ✓ Know that centripetal acceleration is directed toward the centre of the circle
- ✓ Know that centripetal acceleration is the instantaneous acceleration of an object toward the centre of a circular path
- ✓ Relate the three equations for centripetal acceleration to each other through the relationship

Now that we went through the PPP, let's work through a few examples

Video: Centripetal Acceleration

Example 1: Calculating the Magnitude of Centripetal Acceleration

A child rides a carousel with a radius of 5.1 m that rotates with a constant speed of 2.2 m/s. Calculate the magnitude of the centripetal acceleration of the child.

Centripetal Acceleration in terms of frequency and period

Example 2: Calculating the Magnitude and Direction of Centripetal Acceleration

A salad spinner with a radius of 9.7 cm rotates clockwise with a frequency of 12 Hz. At a given instant, the lettuce in the spinner moves in the westward direction. Determine the magnitude and direction of the centripetal acceleration of the piece of lettuce in the salad spinner at this particular instant. Draw a diagram of the situation.

Example 3: Calculating Frequency and Period of Rotation for a Spinning Object

The centripetal acceleration at the end of an electric fan blade has a magnitude of $1.75*10^3$ m/s^2. The distance between the tip of the fan blade and the centre is 12 cm. Calculate the frequency and the period of rotation of the fan.

Check Your Knowledge – Lesson 3.2 Definitions

Term	Notation	Definition
____ uniform circular motion		1. the number of rotations, revolutions, or vibrations of an object per unit of time; the inverse of period
____ centripetal acceleration		2. the time required for a rotating, revolving, or vibrating object to compete one cycle
____frequency		3. the motion of an object with a constant speed along a circular path of constant radius
____ period		4. the instantaneous acceleration that is directed toward the center of a circular path

Check Your Understanding – Lesson 3.2

1. In uniform circular motion, what factors affect the circular motion?

2. At a constant radius, when the speed of the object moving with uniform circular motion is large, direction changes rapidly. Why is this true?

3. Consider a rotating vinyl record on an old turntable. Along a marking for the radius, think of two points: one close to the centre of the rotation and one close to the rim of the record. Clearly the outer point will travel a greater distance to get back to its starting point than the point closer to the centre of the circle. Both points take the same amount of time to make one complete revolution, so they each have a different speed. Does this mean that the two points have a different centripetal acceleration?

3.3 Centripetal Force

Lesson Goal: Solving problems related to centripetal force

Success Criteria: At the end of this lesson, I will be able to:

- ✓ Describe the idea of Newton's second law and how the centripetal force is equal to the mass of the object multiplied by the centripetal acceleration
- ✓ Relate the banking of a turn to the safe speed at which a car can travel the curve
- ✓ Outline how other forces such as gravity and tension factor into the net force associated with centripetal force

The net force $\overrightarrow{F_{net}}$ that causes centripetal acceleration is called **the centripetal force**, $\overrightarrow{F_c}$. Without such a force, the object cannot move in uniform circular motion.

Forces That Cause Centripetal Acceleration

Watch Out!

"Centripetal force" is not a special *kind* of force—it describes the *direction* of the net force.

The force that points toward the inside of an object's curving trajectory and produces the centripetal acceleration is sometimes called the **centripetal force**. Keep in mind, however, that this is not a separate kind of force that you need to include in a free-body diagram. The word *centripetal* simply describes the direction of the force. Just as we might write F_x to denote the *x* component of a force, we write F_{cent} to denote the component of a force directed toward the center of an object's circular trajectory (although sometimes we will just define toward the center at some instant *x*, and still call it F_x). As we'll see in the following examples, in different circumstances different forces play the role of the centripetal force.

Example 1: Determining Centripetal Acceleration and Identifying the Centripetal Force

Suppose a bug is sitting on the edge of a horizontal DVD. The bug has a mass of 5.0 g, and the DVD has a radius of 6.0 cm. The DVD is spinning such that the bug travels around its circular path three times per second. Calculate the centripetal acceleration of the bug and the net force on the bug. Also, identify the force or forces responsible for the centripetal force.

Example 2: Calculating Speed Using Apparent Weight

A roller coaster car is at the lowest point on its circular track. The radius of curvature is 22 m. The apparent weight of one of the passengers in the roller coaster car is 3.0 times her true weight. Determine the speed of the roller coaster.

TIPERs B3-CT101: SKATEBOARDER ON CIRCULAR BUMP—WEIGHT AND NORMAL FORCE

A skateboarder is skating over a circular bump. At the instant shown, she is at the top of the bump and is moving with a speed of 5 m/s.

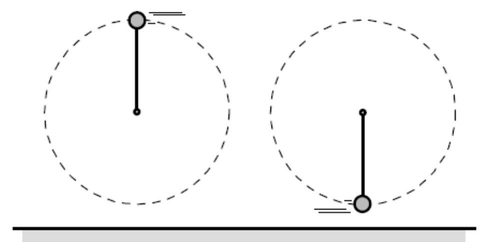
Is the normal force exerted on the skateboarder by the bump

(i) *greater than,* (ii) *less than,* or (iii) *equal to* the weight of the skateboarder? _____

Explain your reasoning.

TIPERs B3-SCT100: BALL WHIRLED IN VERTICAL CIRCLE—NET FORCE ON BALL

A ball with a weight of 2 N is attached to the end of a cord of length 2 m. The ball is whirled in a vertical circle counterclockwise. The tension in the cord at the top of the circle is 7 N, and at the bottom it is 15 N. (The speed of the ball is not the same at these points.)



(a) Three students discuss the net force on the ball at the top.

Angelica: "The net force on the ball at the top position is 7 N since the net force is the same as the tension."

Bo: "The net force on the ball at the top position is 9 N. Both the tension and the weight are acting downward so you have to add them."

Charles: "No, you are both wrong. You need to figure out the centripetal force (mv^2/r) and include it in the net force."

With which, if any, of these students do you agree?

Angelica _____ Bo _____ *Charles* _____ None of them _____

Explain your reasoning.

(b) Now the students discuss the net force on the ball at the bottom.

Angelica: "The net force on the ball at the bottom position is 15 N since the net force is the same as the tension."

Bo: "The net force on the ball at the bottom position is 17 N, since you need to add the weight of 2 N to the tension of 15 N."

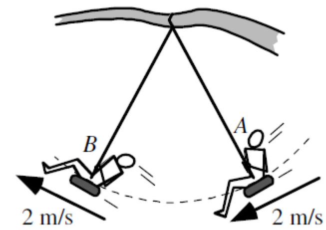
Charles: "The net force on the ball at the bottom position is 13 N. I agree that you need to take into account both the weight and the tension, but they are in different directions so they will subtract."

With which, if any, of these students do you agree?

Angelica _____ Bo _____ *Charles* _____ None of them _____

Explain your reasoning.

TIPERs B3-SCT102: CHILD ON A SWING—TENSION



A child is swinging back and forth on a tire swing that is attached to a tree branch by a single rope. Shown are two positions during a swing from right to left. Three students are discussing the tension in the rope at the bottom of the swing.

Alia: “At the bottom of the swing, she will be moving exactly horizontally. Since she is not moving vertically at that instant, the vertical forces cancel. The tension in the rope at that instant equals the weight.”

Brian: “Just looking at the velocity vectors, the change in velocity points upward between A and B. So that is the direction of the acceleration, and also of the net force. To get a net force pointing upward, the tension would have to be greater than the weight.”

Clara: “But there aren’t just two forces acting on her at the bottom of the swing. Since she’s moving in a circle, there’s also the centripetal force, which acts toward the center of the circle. Since both the tension and the centripetal force point upward, and the weight points downward, to get zero net force the tension actually has to be less than the weight. The tension plus the centripetal force equals the weight.”

With which, if any, of these students do you agree?

Alia _____ *Brian* _____ *Clara* _____ None of them_____

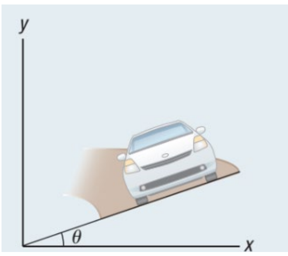
Explain your reasoning.

Problem 1 (BFW): A Turn on a Level Road

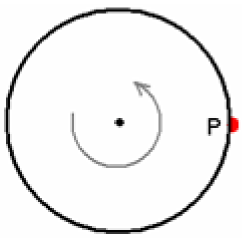
A car of mass m_{car} exits the freeway and travels around a circular off-ramp at a constant speed of 15.7 m/s. The ramp is level (it is not banked), so the centripetal force has to be provided by the force of friction exerted by the road on the tires. If the coefficient of static friction between the car's tires and the road is 0.55 (a typical value when the road surface is wet), what radius of curvature is required for the -off-ramp so that the car does not skid?

Example 3: Calculating Speed on a Banked Turn

A car making a turn on a dry, banked highway ramp is experiencing friction (refer to the figure below). The coefficient of static friction between the tires and the road is 0.60. Determine the maximum speed at which the car can safely negotiate a turn of radius $2.0 * 10^2$ m with a banking angle of 20.0°.



Problem 2: A drum is spinning at a constant speed with its axis vertically. A drop of water at a point P on its surface detaches and flies off. Looking from the top, what is the most likely path followed by the drop?

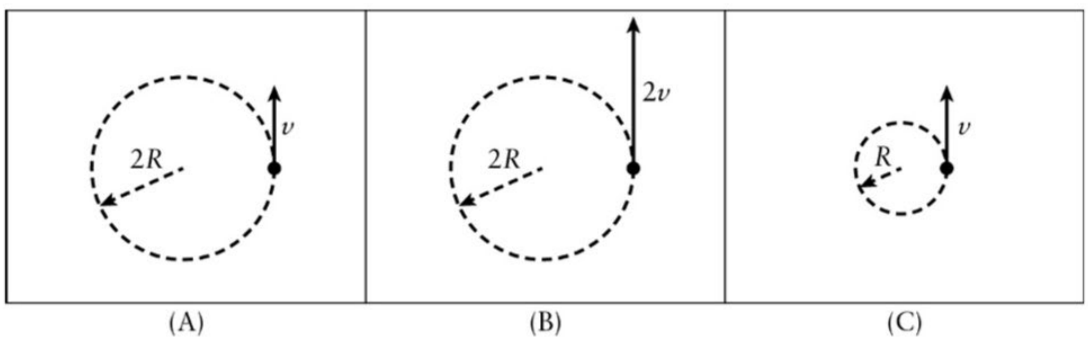


Problem 3 (BFW): A student twirls a ball at the end of a string in a vertical circle at a constant speed. Is the tension in the string greater at the top of the circle or at the bottom of the circle?

Greater at the top ______ Greater at the bottom ________ Same at top and bottom _______

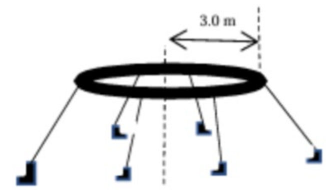
Justify your claim by reasoning from evidence and using physics principles.

Problem 4 (BFW): Consider three objects moving at constant speed in circles in the diagrams below. The radius and the speed of the objects are given in the diagrams. The three objects all have the same mass. Rank the three objects based on the net centripetal force that must act on each to maintain the circular motion shown. Justify your ranking.



Problem 5 (BFW): Chair Swing Ride

A chair swing ride consists of chairs suspended from a rotating circular frame by 4.0-m-long cables. The circular frame, with a radius of 3.0 m, begins to spin and the chairs move outward and upward until the hanging cable makes a 40° angle with the vertical. Calculate the linear speed of the rider in the chair.



Problem 6 (BFW): Vertical Circle

A ball is swung in a vertical circle. Students observe it starts to fall out of the circular path near the top when it is moving slowly. The circular path has a radius of 0.75 m.

a) Calculate the minimum speed of the ball to make it fully around the vertical circle.

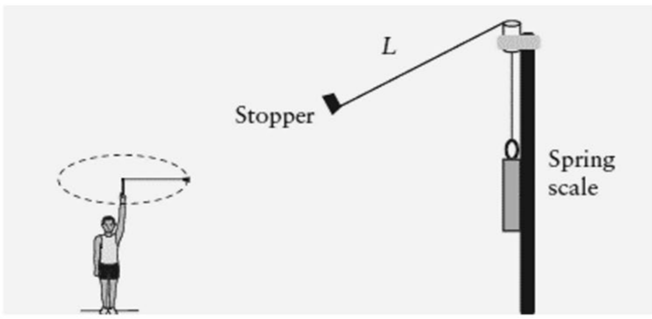
b) Calculate the period of the ball's motion when it is moving at the minimum speed.

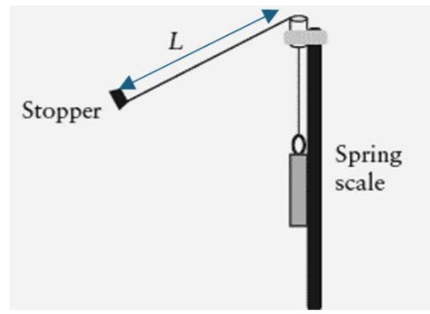
Problem 7 (BFW): Minimum Speed

A stunt sometimes performed at carnivals consists of a person riding a motorcycle inside a cylindrical structure known as the “wall of death.” The driver starts on the ground and rides the motorcycle up a ramp onto the wall itself. When the motorcycle is going fast enough, it can move around the vertical axis in a uniform circular motion, with no part of it or the rider touching the ground. If the structure has a radius of 5.50 m and the coefficient of static friction between the motorcycle tires and the wall is 0.80, what is the minimum speed needed to maintain this motion?

Problem 8 (BFW): Stopper in Circular Motion

A rubber stopper with mass m is swung in a horizontal circle overhead using a spring scale to measure the tension in the string. The string is attached to the stopper, passes through a small glass tube, and is tied to the spring scale, as shown in the figure. The tension, , in the string is varied and the period, T, of the circular motion and the length, L, of the string from the tube to the stopper are measured. The length, L, of the string is kept constant, but the angle that the string makes with the vertical varies with the speed of the stopper.





a) Draw a free-body diagram of the stopper in the position shown in the figure.

b) Derive an expression for the tension in the string. Express your answer in terms of m, L, and fundamental constants, as appropriate.

c) On the axes below, sketch the tension in the string vs. the period.

d) As the tension increases, how does the frequency of the stopper's rotation change?

_______It increases. _______It decreases. _______It remains the same.

Justify your answer by using at least one feature of parts b or c.

Check Your Understanding – Lesson 3.3

1. When studying forces acting on a vehicle as it moves around a banked curve, what forces exist that hold the path of the vehicle as it travels around the curve?

2. Refer to the example 3. If the speed of the car were to increase, would the car move up the banked curve or down, assuming no change to the steering of the vehicle?

3. How does your answer in question 2 change if the car were to slow down?

3.4 Rotating Frames of Reference

Lesson Goal: Understand the difference between centrifugal and centripetal forces

Success Criteria: At the end of this lesson, I will be able to:

- ✓ Describe the operation of a centrifuge and explain the theoretical concepts
- ✓ Recognize that the Coriolis force is a fictitious force that acts perpendicular to the velocity of an object in a rotating frame of reference.
- ✓ Recognize that the fictitious force that is centrifugal force is used to explain the outward force observed in a rotating frame of reference (i.e., a non-inertial frame)

Video: [Centrifugal and Centripetal Forces]

Example 1: Designing a Space Station

Consider a rotating space station similar to the one in the figure below. The radius of the station is 40.0 m. How many times per minute must the space station rotate to produce a force due to artificial gravity equal to 30.0 % of Earth's gravity?

Check Your Understanding – Lessons 3.4

1. If a rotating circular frame of reference is a non-inertial frame, why do we not sense that Earth is rotating?

2. How would your answer change if Earth's spin were to suddenly speed up or slow down?

3. What do you know about the Coriolis force.

4. How does a centrifuge work?

Check Your Knowledge – Lessons 3.3 and 3.4 Definitions

Term	**Notation**	**Definition**
____ centripetal force		1. a rapidly rotating device used to separate substances and stimulate the effects of gravity
____ centrifugal force		2. a situation in which the value of gravity has been changed artificially to more closely match Earth's gravity
____centrifuge		3. the fictitious force in a rotating (accelerating or non-inertial) frame of refence
____ Coriolis force		4. the net force that causes centripetal acceleration
____ artificial gravity		5. a fictitious force that acts perpendicular to the velocity of an object in a rotating frame of reference

Lesson 5 – Circular Motion Additional Problems

1. (BFW) You tie one end of a lightweight string around a rock of mass *m* so that the distance from the point at which hold the string to the centre of the rock (which you can treat as an object) is a length *L*. You make the rock swing in a horizontal circle at a constant speed. As you swing the rock the string makes an angle θ with the vertical. Derive an expression for the speed at which the rock moves around the circle in terms of m, L, θ, and relevant physical constants. Ignore the effect of drag force.

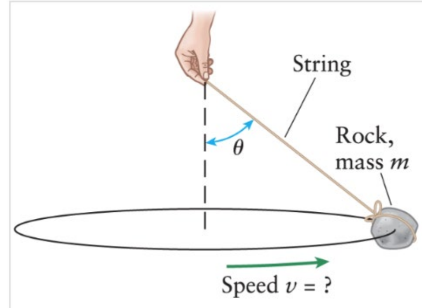


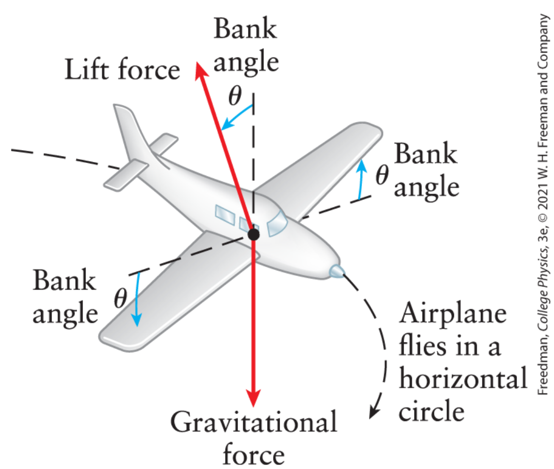
Figure 6-8 Moving in a circle How fast must the rock move to make the string hang at an angle θ from the vertical?

2. (BFW – p249eg6-4) An airplane banks (dips its wings) to one side in order to turn in that direction. By banking the plane, the *lift force* — a force exerted perpendicular to the direction of flight due to differences in the motion of air over and under the airplane's wings — ends up with both a vertical component and a horizontal component (see the figure below). The horizontal component of this force is directed toward the centre of the desired circular path (centripetally), causing the airplane to move in a circular path.

a) If the airplane of mass $m_{airplane}$ is travelling at speed *v* and is banked at an angle θ derive the expression for the radius of the turn.

b) The pilot of the airplane has mass m_{pilot} and weight $F_{g,pilot} = m_{pilot}$*g. Derive an expression for the force that the seat exerts on the pilot as the airplane makes its banked turn.

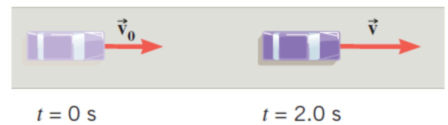
c) Find the radius of the banked turn that the airplane makes.



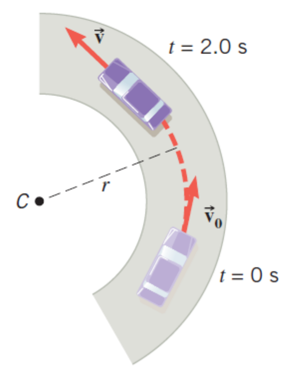
3. Unlike the level off-ramp, many freeway off-ramps are banked (angled downwards toward the inside of the curved path). The same is true for corners at racetracks. As an example, each corner at the Indianapolis Motor Speedway is banked by 9.20° and has a radius of 256 m. What is the fastest speed at which a race car could take one of these corners if the coefficient of static friction is 0.550?

4. (C-pg140eg6) In a circus, a man hangs upside down from a trapeze, legs bent over the bar and arms downward holding his partner. Is it harder for the man to hold his partner when the partner hangs straight down and is stationary or when the partner is swinging through the straight-down position?

5. (C pg152eg15) At time t = 0 s, automobile A is travelling at a speed of 18 m/s along a straight road and is picking up speed with an acceleration that has a magnitude of 3.5 m/s^2 (see the figure on the right). At time t= 0 s, automobile B is travelling at a speed of 18 m/s in a uniform circular motion as it negotiates a turn (see the figure on the right). It has a centripetal acceleration whose magnitude is also 3.5 m/s^2.



(a) Automobile A



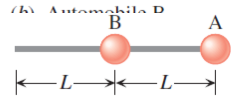
(b) Automobile B

a) Which automobile has a constant acceleration?

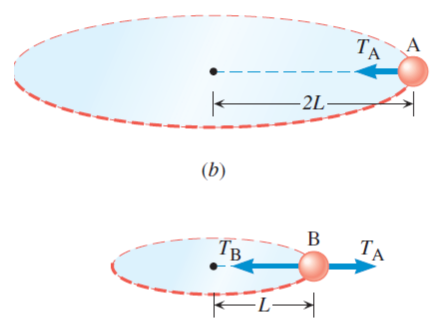
b) For which automobile do the equations of kinematics apply?

c) Determine the speed of each automobile when t = 2.0 s.

6. (C pg153eg16) Ball A is attached to one end of a rigid massless rod, while an identical ball B is attached to the center of the rod, as in the figure on the right. Each ball has a mass of m = 0.50 kg, and the length of each half of the rod is L = 0.40 m. This arrangement is held by the empty end and is whirled around in a horizontal circle at a constant rate, so each ball is in uniform circular motion.



(a)



(b)

(c)

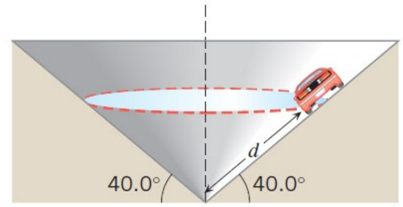
a) How many tension forces contribute to the centripetal force that acts on ball A?

b) How many tension forces contribute to the centripetal force that acts on ball B?

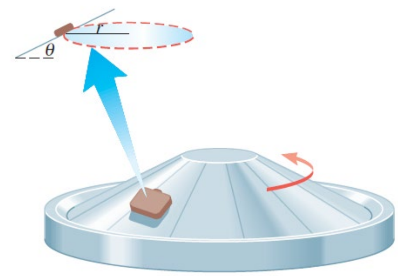
c) Is the speed of ball B the same as the speed of ball A?

d) Ball A travels at a constant speed of v_A = 5.0 m/s. Find the tension in each half of the rod.

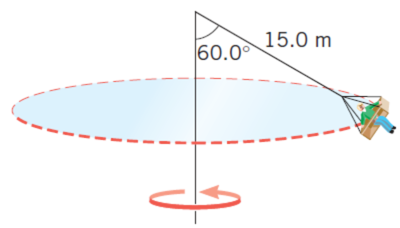
7. (Cpg157#24) A racetrack has the shape of an inverted cone, as the figure shows. On this surface the cars race in circles that are parallel to the ground. For a speed of 34.0 m/s, at what value of the distance *d* should a driver locate his car if he wishes to stay on a circular path without depending on friction? (Ans = 184m)



8. (Cpg157#26) The drawing shows a baggage carousel at an airport. Your suitcase has not slid all the way down the slope and is going around at a constant speed on a circle (r = 11.0 m) as the carousel turns. The coefficient of static friction between the suitcase and the carousel is 0.760, and the angle θ in the drawing is 36.0°. How much time is required for your suitcase to go around once? (Ans: 45s)



9. (Cpg159#53) A “swing” ride at a carnival consists of chairs that are swung in a circle by 15.0-m cables attached to a vertical rotating pole, as the drawing shows. Suppose the total mass of a chair and its occupant is 179 kg.

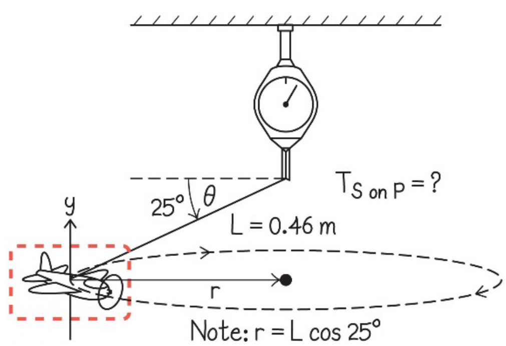


a) Determine the tension in the cable attached to the chair. (Ans: 3510N)

b) Find the speed of the chair. (Ans: 14.9m/s)

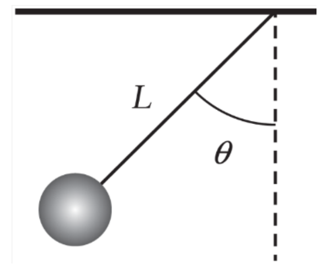
10. (Epg127eg4.2) When a fighter pilot pulls out from the bottom of a power dive, his body moves at high speed along a segment of an upward-bending approximately circular path. However, while his body moves up, his blood begins to fill the easily expandable veins in his legs. This can deprive the pilot's brain of blood and cause a blackout if the radial acceleration is 4 g or more and lasts several seconds. Suppose during a dive, an airplane moves at a modest speed of v = 80 m/s through a circular arc of radius r = 150 m. Is the pilot likely to blackout?

11. (Epg132eg4.5) A toy airplane flies around in a horizontal circle at a constant speed. Our airplane is attached to the end of a 46-cm string, which makes a 25° angle relative to the horizontal while the airplane is flying. A scale at the top of the string measures the force that the string exerts on the airplane. Predict the period of the airplane’s motion.



12. (Epg132eg4.6) A 62-kg woman is a passenger in a rotor ride. A drum of radius 2.0 m rotates at a period of 1.7 s. When the drum reaches this turning rate, the floor drops away but the woman does not slide down the wall. Imagine that you were one of the engineers who designed this ride. Which characteristics of the ride would you ensure that the woman remains stuck to the wall? Justify your answer quantitatively.

13. (BFW pg278#19) A ball swings from a cord attached to the ceiling, as shown in the figure.



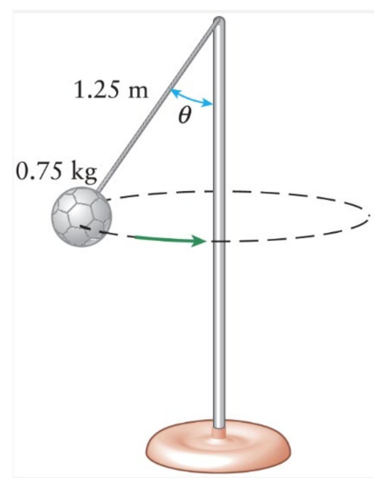
a) Construct a FBD representing the forces exerted in the ball at the moments it is released from rest in the position shown.

b) Draw an FBD representing the forces exerted on the ball when the string is vertical, and the ball has reached its maximum speed and is just beginning to swing upward.

c) Apply Newton's second law to express the mathematical relationship between the horizontal and vertical components of the acceleration and corresponding components of the net force at the position described in parts a) and b).

d) Explain why the equation describing circular motions caused by a central force, $F=mv^2/r$, is consistent with the instant in the motion of the swinging ball described in part b).

14. (BFW pg278#20) In the game of tetherball, a 1.25 m rope connects a 0.750 lg ball to the top of the vertical pole so that the ball can revolve around the pole, as shown in the figure.



a) Draw a FBD of the tetherball when the angle θ of the rope is 35° with the vertical?

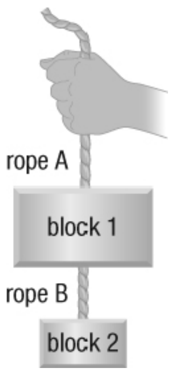
b) Apply Newton's second law to calculate the tension in the rope

c) Calculate the speed of the ball as it rotates around the pole

d) As the ball passes one of the players, the player slaps the ball to exert a force in the direction in which the ball was moving. Explain why the angle between the rope and the vertical increases.

Chapter 3 – Uniform Circular Motion: Communication Questions

1. A pair of blocks is connected to an upward force with two ropes, as shown. The acceleration upward is increased until at least one of the ropes breaks. Which will break first? Explain your answer. (3.1)



2. A passenger standing in an elevator feels an apparent weight three times normal. Determine the state of motion of the elevator. Explain your answer. (3.1)

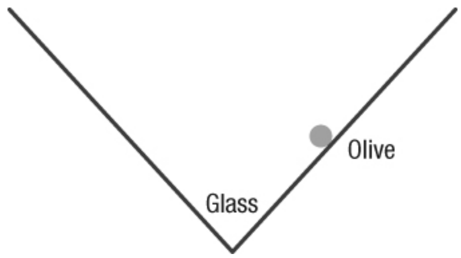
3. A cork ball is suspended from the roof of a fighter jet by a light string. What is the minimum acceleration required for the jet such that the string swings back until it is horizontal? (3.1)

4. Gaspar was riding in a car when the car hit a parked vehicle and came to an abrupt stop. Gaspar said, "the force of the seat pushed me against the seatbelt so hard that I cracked three ribs." Is his statement correct? Explain your answer. (3.1)

5. One rider on a carousel sits on a zebra near the edge of the carousel. A second rider sits on a camel half the distance from the centre as the first rider. Which experiences the greater centripetal acceleration? Explain your answer. (3.2)

6. An airplane turns by banking the wings such that part of the lift supplies the centripetal force needed for the turn. Use a FBD to help you explain what is happening. Assume that the forward and backward forces on the airplane are balanced and need not be included. (3.3)

7. A magician spins an olive around the inside of a slippery glass, as shown. For a short time the olive appears to defy gravity, spinning around without falling into the glass. Explain how this trick works. (3.3)



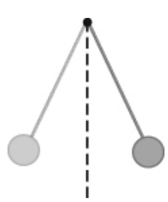
8. If an object going in a circle is always accelerating, explain why its speed never changes. (3.3)

9. A jet pilot in a centrifuge experiences an apparent weight 5 times normal. Explain why the factor of 5 does not depend on the mass of the pilot. (3.4)

10. Reflect on your learning. How has learning about uniform circular motion changed the way you think about things that are part of your everyday life? (3.4)

11. A long-range artillery weapon can shoot projectiles up to 50.0 km. If the target is due north of the gun, the gun must be aimed to one side of the target in order to hit it. Explain why this is necessary in terms of rotating frames of reference. (3.4)

12. A pendulum clock is manufactured at the north pole, and adjusted to keep correct time. It is sold to a customer who lives on the equator. Will the clock keep correct time on the equator? Explain your answer. (3.4)



13. Describe how a clothoid loop differs from a circular loop. (3.5)

14. How does a clothoid loop improve comfort for riders on a roller coaster? (3.5)

15. Summarize how technology has improved athletic performance in the sport of tennis. (3.6)

16. Outline some of the improvements in athletic performance which are not due to improvements in sport technology itself. (3.6)

18. Is it fair to compare current results to those of previous sporting events? (3.6)