SI Physics - Full Discipline Demo

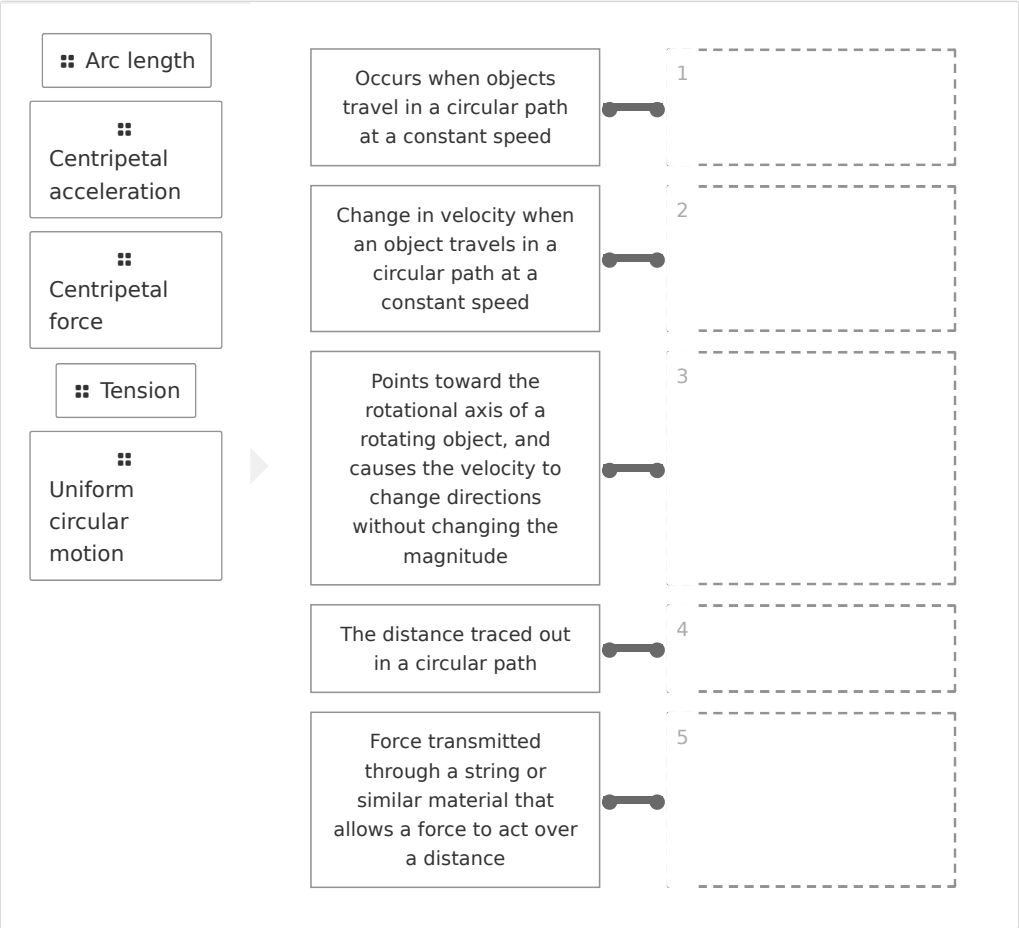
Centripetal Acceleration

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Physics - Full Discipline Demo
Course	SI Physics - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Match each term with the best description.



Correct answers:

1 Uniform circular motion 2 Centripetal acceleration 3 Centripetal force

4 Arc length 5 Tension

Typesetting math: 100%

Identify each statement as true or false.

- The arc length is equal to the subtended angle divided by the radius.
- The magnitude and direction of the tangential velocity of an object in uniform circular motion change over time.
- The speed of an object undergoing uniform circular motion can be determined using the circumference and the period of the motion.
- The tension of a swinging string can provide the centripetal force needed to keep an object on its circular path.

True	False
1	2

Correct answers:

1

The speed of an object undergoing uniform circular motion can be determined using the circumference and the period of the motion.

The tension of a swinging string can provide the centripetal force needed to keep an object on its circular path.

2 The arc length is equal to the subtended angle divided by the radius.

The magnitude and direction of the tangential velocity of an object in uniform circular motion change over time.

Exploration

During uniform circular motion, the magnitude and direction of the velocity change.

- True
- False ✔

The term centripetal means _____.

- circular
- center-seeking ✔
- towards the margin
- None of the above

_____ velocity is the velocity of an object moving in a circular path in uniform circular motion.

- Tangential ✔
- Centripetal
- Circular
- None of the above

The centripetal force always points in the same direction as the centripetal acceleration.

- True ✔
- False

For circular motion calculations, the angle is measured in units of _____.

- degrees
- radians ✔
- revolutions
- None of the above

The _____ of an object undergoing uniform circular motion can be determined using the circumference and the period of the motion.

- acceleration
- radius
- speed ✔
- None of the above

_____ provides the centripetal force needed to keep an object swinging on a string on its circular path.

- Gravity
- Tension ✔
- Velocity
- None of the above

Exercise 1

What effect does radius have on the velocity of a rotating object?

Assuming the centripetal force is constant, an object rotating at a larger radius will have a larger magnitude of velocity.

What effect does the velocity of a rotating object have on the centripetal force exerted on it?

The larger the magnitude of velocity, the larger the centripetal force.

The Moon orbits Earth at an average distance of 3.84 x 10^8 m in a path that takes 27.3 days to complete. What is the centripetal acceleration of the Moon? (Remember, you must convert time into seconds.)

Centripetal acceleration is $a_c=v^2/r$. $v=2\pi r/T$, where r=3.84 x 10^8 m and T=2,358,720 s (or 27.3 days * 24 hrs/day * 60 min/hr * 60 s/min). Thus, v=(2 * π * 3.84 x 10^8 m)/ 2,358,720 s=1.02 x 10^3 m/s. This results in a centripetal acceleration of $a_c=(1.02 \times 10^3 \text{ m/s})^2/(3.84 \times 10^8 \text{ m})=2.72 \times 10^{-3}$ m/s^2.

When a bucket of water is swung in a vertical circle, the water will remain in the bucket if the velocity is high enough. If you let the bucket slow down too much, the water will spill out. The critical velocity is the slowest velocity necessary to keep the water in the bucket.

What is the critical velocity if the formula is velocity =$\sqrt{rg}$, where r is the radius (the radius of your arm swing including the bucket) and *g* is the acceleration of gravity (*g*=9.81 m/s^2)?

Hint: *You must measure or estimate the length from your shoulder to the center of the bucket to determine the radius.*

The average length of a human arm is between 70 and 75 cm. Taking into account the bucket, we can assume r~80 cm, or 0.80 m. Using the provided equation, $v = \sqrt{0.80 \times 9.81} = 2.8$m/s.

Data Table 1: Constants for Varying Radius
(SAMPLE ANSWER BELOW)

Number of Washers	5
Mass of all Washers (kg)	0.0374
Average Mass of Single Washer (kg)	0.00748
Rotating Mass (kg)	0.0180
Hanging Mass (kg)	0.0299

Data Table 2: Varying Radius – Measurements and Calculations
(SAMPLE ANSWER BELOW)

Trial	Radius (m)	Time - 10 rev (s)	Time T - 1 rev (s)	Circumference (m)	Velocity (m/s)	F_c (N)	F_g (N)	% Error
1	0.580	9.40	0.940	3.64	3.88	0.466	0.294	58.92%
			0.848	2.89	3.41	0.455	0.294	54.87%

3	0.340	7.81	0.781	2.14	2.74	0.396	0.294	34.96%
4	0.210	7.01	0.701	1.32	1.88	0.303	0.294	3.06%

Exercise 2

What was the effect of increasing the hanging mass on the centripetal force in Part 1 of this exercise?

As the hanging mass increases, the magnitude of the centripetal force increases proportionately.

Did increasing the mass of the rotating object affect its velocity in Part 2 of this exercise? Explain your answer by referencing Data Table 4.

The hanging mass determines the experimental centripetal force. Thus, the centripetal force is constant in Part 2. Due to the relationship $F_c=mv^2/r$, if the mass increases, the velocity must decrease to maintain the constant centripetal force provided by the hanging mass.

What effect did increasing the radius of the rotating mass have on its velocity? Reference Data Table 5 in your answer. How do these results compare to those recorded in Exercise 1?

Increasing the radius increases the velocity of the rotating mass. These results are consistent with what was found in Exercise 1, where it is found that shortening the radius decreases the velocity.

What factors introduced error in both Exercise 1 and Exercise 2? How could the error have been reduced?

In Exercise 1, error can be introduced in measurement of the time (which depends on accurate counting of revolutions and reaction time), measurement of the radius (which must be measured from the rod to the center of the rubber stopper and may be difficult to find), and maintaining a constant radius while swinging and limiting the motion of your hand. These all contribute to errors in calculations. In Exercise 2, the possibility of the last two factors is eliminated, but the possible error in timing is still present, introducing error in calculations.

5. How did using the simulations in Exercise 2 contribute to your understanding of centripetal acceleration? Did you find them more or less effective than the physical experiment in Exercise 1? Explain your answer.

Student answers will vary but should include a comparison of the two methodologies.

Data Table 3: Varying Hanging Mass - Measurements and Calculations
(SAMPLE ANSWER BELOW)

Rotating Mass (kg)	0.025	Radius (m)	2.00	Circumference (m)		12.57	
Trial	Hanging Mass (kg)	Time - 10 rev (s)	Time T - 1 rev (s)	Velocity (m/s)	F_c (N)	F_g (N)	% Error
1	0.070 Note: due to the nature of this sim, student answers will vary	17.0	1.70	7.39	0.683	0.687	0.54
2	0.110	13.5	1.35	9.31	1.083	1.079	0.37
3	0.150	11.6	1.16	10.83	1.467	1.472	0.31
4	0.200	10.1	1.01	12.44	1.935	1.962	1.37

Data Table 4: Varying Rotating Mass - Measurements and Calculations
(SAMPLE ANSWER BELOW)

Hanging Mass (kg)	0.140 Note: due to the nature of this sim, student answers will vary	Radius (m)	2.00	Circumference (m)		12.57	
Trial	Rotating Mass (kg)	Time - 10 rev (s)	Time T - 1 rev (s)	Velocity (m/s)	F_c (N)	F_g (N)	% Error
1	0.025	12.0	1.20	10.47	1.371	1.373	0.19
2	0.057	18.2	1.82	6.90	1.359	1.373	1.07
3	0.079	21.3	2.13	5.90	1.375	1.373	0.11
4	0.116	25.9	2.59	4.85	1.365	1.373	0.59

Data Table 5: Varying Radius - Measurements and Calculations
(SAMPLE ANSWER BELOW)

Rotating Mass (kg)		0.025 Note: due to the nature of this sim, student answers will vary	Hanging Mass (kg)		0.140			
Trial	Radius (m)	Time - 10 rev (s)	Time T - 1 rev (s)	Circumference (m)	Velocity (m/s)	F_c (N)	F_g (N)	% Error
1	0.27	4.6	0.46	1.70	3.69	1.259	1.373	8.30
2	0.42	5.6	0.56	2.64	4.71	1.322	1.373	3.76
3	0.68	6.9	0.69	4.27	6.19	1.410	1.373	2.64
4	0.99	8.4	0.84	6.22	7.41	1.385	1.373	0.83

Competency Review

Uniform circular motion occurs when objects travel in a circular path at a constant _____.

- velocity
- direction
- speed ✔
- All of the above

The centripetal acceleration points towards the center of the circle.

- True ✔
- False

The centripetal acceleration is always _____ to the tangential velocity.

- perpendicular ✔
- tangential
- central
- All of the above

Typesetting math: 100%

The centripetal force is proportional to the _____.

- mass
- velocity squared
- inverse of the radius
- All of the above ✔

The _____ force provides the tension force in the centripetal force apparatus.

- spring
- gravitational ✔
- incline
- All of the above

The tension force is greater than the centripetal force in the centripetal force apparatus.

- True
- False ✔

An object moving in uniform circular motion with a radius of 0.6 m and a period of 0.4 s has a tangential velocity of _____ m/s.

- 2
- 4
- 9 ✔
- None of the above

The centripetal force acting on a 0.30 kg object moving with a tangential velocity of 12 m/s in a 0.80 m radius circle is _____ N.

- 4.5
- 54 ✔
- 380
- None of the above

The centripetal acceleration acting on a 0.30 kg object moving with a tangential velocity of 12 m/s in a 0.80 m radius circle is _____ m/s^2.

- 15
- 180 ✔
- 480
- None of the above

In Exercise 1, the theoretical centripetal force was calculated from the _____.

- tension
- velocity
- weight ✔
- None of the above

Extension Questions

For each of the following scenarios, describe the force providing the centripetal force for the motion:

a. a car making a turn
b. a child swinging around a pole
c. a person sitting on a bench facing the center of a carousel
d. a rock swinging on a string
e. the Earth orbiting the Sun.

(SAMPLE ANSWER BELOW)

a. static friction between the car tire and the road
b. the pulling force of the child's arms
c. the normal force of the bench and the person's back and/or the friction force of the bench seat and the person's bottom
d. the tension of the string
e. the gravitational force of the Sun on the Earth.