Mechanics: Circular Motion and Gravitation

Circular Motion and Gravitation: Problem Set

Problem 1:

During their physics field trip to the amusement park, Tyler and Maria took a rider on the Whirligig. The Whirligig ride consists of long swings which spin in a circle at relatively high speeds. As part of their lab, Tyler and Maria estimate that the riders travel through a circle with a radius of 6.5 m and make one turn every 5.8 seconds. Determine the speed of the riders on the Whirligig.

Ans: 7.0 m/s

Problem 2:

The tallest Ferris wheel in the world is in Singapore. Standing 42 stories high and holding as many as 780 passengers, the Ferris wheel has a diameter of 150 meters and takes approximately 30 minutes to make a full circle. Determine the speed of riders (in m/s and mi/h) on the Singapore Flyer. (**GIVEN**: 1.00 m/s= 2.24 mi/h)

Ans: 0.26 m/s or 0.59 mi/h

Problem 3:

During the spin cycle of a washing machine, the clothes stick to the outer wall of the barrel as it spins at a rate as high as 1800 revolutions per minute. The radius of the barrel is 26 cm.

a. Determine the speed of the clothes (in m/s) which are located on the wall of the spin barrel.
b. Determine the acceleration of the clothes.

Ans: **a.** 49 m/s
b. 9.2×10^3 m/s/s

Problem 4:

Elmira, New York boasts of having the fastest carousel ride in the world. The merry-go-round at Eldridge Park takes riders on a spin at 18 mi/h (8.0 m/s). The radius of the circle about which the outside riders move is approximately 7.4 m.

a. Determine the time for outside riders to make one complete circle.
b. Determine the acceleration of the riders.

Ans: **a.** 5.8 s
b. 8.7 m/s/s

Problem 5:

A manufacturer of CD-ROM drives claims that the player can spin the disc as frequently as 1200 revolutions per minute.

a. If spinning at this rate, what is the speed of the outer row of data on the disc; this row is located 5.6 cm from the center of the disc?
b. What is the acceleration of the outer row of data?

Ans: a. 7.0×10^{2} cm/s or 7.0 m/s
b. 8.8×10^{4} cm/s/s or 8.8×10^{2} m/s/s

Problem 6:

In the display window of the toy store at the local mall, a battery-powered plane is suspended from a string and flying in a horizontal circle. The 631-gram plane makes a complete circle every 2.15 seconds. The radius of the circle is 0.950 m. Determine the velocity of, acceleration of, and net force acting upon the plane.

Ans: velocity: 2.78 m/s; acceleration: 8.11 m/s/s; net force: 5.12 N

Problem 7:

Dominic is the star discus thrower on South's varsity track and field team. In last year's regional competition, Dominic whirled the 1.6 kg discus in a circle with a radius of 1.1 m, ultimately reaching a speed of 52 m/s before launch. Determine the net force acting upon the discus in the moments before launch.

Ans: 3.9×10^{3} N

Problem 8:

Landon and Jocelyn are partners in pair figure skating. Last weekend, they perfected the death spiral element for inclusion in their upcoming competition. During this maneuver, Landon holds Jocelyn by the hand and swings her in a circle while she maintains her blades on the ice, stretched out in a nearly horizontal orientation. Determine the net force which must be applied to Jocelyn (m=51 kg) if her center of mass rotates in a circle with a radius of 61 cm once every 1.9 seconds.

Ans: 340 N

Problem 9:

In an effort to *rev up* his class, Mr. H does a demonstration with a bucket of water tied to a 1.3-meter long string. The bucket and water have a mass of 1.8 kg. Mr. H whirls the bucket in a vertical circle such that it has a speed of 3.9 m/s at the top of the loop and 6.4 m/s at the bottom of the loop.

a. Determine the acceleration of the bucket at each location.
b. Determine the net force experienced by the bucket at each location.
c. Draw a free body diagram for the bucket for each location and determine the tension force in the string for the two locations.

Ans: a. TOP: 12 m/s/s, down BOTTOM: 32 m/s/s, up

b. TOP: 21 N, down BOTTOM: 57 N, up

c. TOP: 3.4 N BOTTOM: 74 N

Problem 10:

A 76-kg pilot at an air show performs a loop de loop with his plane. At the bottom of the 52-m radius loop, the plane is moving at 48 m/s. Determine the normal force acting upon the pilot.

Ans: 4.1×10^3 N

Problem 11:

Alexis is in her Toyota Camry and trying to make a turn off an expressway at 19.0 m/s. The turning radius of the level curve is 35.0 m. Her car has a mass of 1240 kg. Determine the acceleration, net force and minimum value of the coefficient of friction which is required to keep the car on the road.
Ans: 1.05

Problem 12:

Sheila (m=62 kg) is riding the Demon roller coaster ride. The turning radius of the top of the loop is 12 m. Sheila is upside down at the top of the loop and experiencing a normal force which is one-half of her weight. Draw a free body diagram and determine Sheila's speed.

Ans: 13 m/s

Problem 13:

In 2002, professional skateboarder Bob Burnquist became the first to successfully navigate a 360° full pipe turn. Determine the minimum speed which would be required at the top of the circular loop to make it through the 1.8-m radius pipe.

Ans: 4.2 m/s

Problem 14:

Justin is driving his 1500-kg Camaro through a horizontal curve on a level roadway at a speed of 23 m/s. The turning radius of the curve is 65 m. Determine the minimum value of the coefficient of friction which would be required to keep Justin's car on the curve.

Ans: 0.83

Problem 15:

A loop de loop track is built for a 938-kg car. It is a completely circular loop - 14.2 m tall at its highest point. The driver successfully completes the loop with an entry speed (at the bottom) of 22.1 m/s.

a. Using energy conservation, determine the speed of the car at the top of the loop.
b. Determine the acceleration of the car at the top of the loop.
c. Determine the normal force acting upon the car at the top of the loop.

Ans: a. 14.5 m/s
b. 30. m/s/s
c. 1.9×10^4 N

Problem 16:

Tyrone and Mia have masses of 84 kg and 59 kg respectively. They sit 1.0 m apart in the front center of Mr. H's Physics class. For some time, they each have been sensing a sort of electricity in their growing relationship. And now, six units into their Physics course, they have learned that they are gravitationally attracted to each other. Determine the magnitude of this force of gravitational attraction.

Ans: 3.3×10^{-7} N

Problem 17:

Determine the force of gravitational attraction between the Earth and the moon. Their masses are 5.98×10^{24} kg and 7.26×10^{22} kg, respectively. The average distance separating the Earth and the moon is 3.84×10^8 m. Determine the force of gravitational attraction between the Earth and the moon.

Ans: 1.96×10^{20} N

Problem 18:

Determine the force of gravitational attraction between the Earth and the sun. Their masses are 5.98×10^{24} kg and 1.99×10^{30} kg, respectively. The average distance separating the Earth and the sun is 1.50×10^{11} m. Determine the force of gravitational attraction between the Earth and the sun.

Ans: 3.53×10^{22} N

Problem 19:

Determine the acceleration of the moon about the Earth. (GIVEN: $M_{Earth} = 5.98 \times 10^{24}$ kg and Earth-moon distance = 3.84×10^8 m)

Ans: 2.71×10^{-3} m/s/s

Problem 20:

Determine the acceleration of the Earth about the sun. (GIVEN: M_{sun} = 1.99 x 10^{30} kg and Earth-sun distance = 1.50 x 10^{11} m)

Ans: 5.90 x 10^{-3} m/s/s

Problem 21:

Use Newton's law of gravitation to determine the acceleration of an 85-kg astronaut on the International Space Station (ISS) when the ISS is at a height of 350 km above Earth's surface. The radius of the Earth is 6.37 x 10^{6} m. (GIVEN: M_{Earth} = 5.98 x 10^{24} kg)

Ans: 8.84 m/s/s

Problem 22:

Determine the orbital speed of the International Space Station - orbiting at 350 km above the surface of the Earth. The radius of the Earth is 6.37 x 10^{6} m. (GIVEN: M_{Earth} = 5.98 x 10^{24} kg)

Ans: 7.69 x 10^{3} m/s

Problem 23:

Determine the orbital speed of the Earth as it orbits the Sun. (GIVEN: M_{sun} = 1.99 x 10^{30} kg and Earth-sun distance = 1.50 x 10^{11} m)

Ans: 2.98 x 10^{4} m/s

Problem 24:

Hercules is hoping to put a baseball in orbit by throwing it horizontally (tangent to the Earth) from the top of Mount Newton - 97 km above Earth's surface. With what speed must he throw the ball in order to put it into orbit?
(GIVEN: M_{Earth} = 5.98 x 10^{24} kg; R_{Earth} = 6.37 x 10^{6} m)

Ans: 7.86 x 10^{3} m/s

Problem 25:

Scientists determine the masses of planets by observing the effect of the gravitational field of those planets on nearby objects - mainly upon their moons. By measuring the orbital period and orbital radius of a moon about a planet, Newton's laws of motion can be used to determine the mass of the planet. Phobos, a moon of the planet Mars, was discovered in 1877. Its orbital radius is 9380 km and its orbital period is 0.319 days (2.77 x 10^{4} seconds). Determine the mass of Mars based on this data.

Ans: 6.36 x 10^{23} kg

Problem 26:

Geostationary satellites are satellites which are orbiting the Earth above the equator and make one complete orbit every 24 hours. Because their orbital period is synchronized with the Earth's rotational period, a geostationary satellite can always be found in the same position in the sky relative to an observer on Earth. (GIVEN: $M_{Earth} = 5.98 \times 10^{24}$ kg)

a. Determine the orbital radius of a geostationary satellite.
b. Determine the orbital speed of a geostationary satellite.
c. Determine the acceleration of a geostationary satellite.

Ans: **a.** 4.23×10^{7} m
b. 3.07×10^{3} m/s
c. 0.223 m/s/s

Problem 27:

In 2009, NASA's Messenger spacecraft became the second spacecraft to orbit the planet Mercury. The spacecraft orbited at a height of 125 miles above Mercury's surface. Determine the orbital speed and orbital period of Messenger.
(GIVEN: $R_{Mercury} = 2.44 \times 10^{6}$ m; $M_{Mercury} = 3.30 \times 10^{23}$ kg; 1 mi = 1609 m)

Ans: Speed: 2.89×10^{3} m/s
Period: 5.75×10^{3} s