Name: ______________________________

Central Force Particle Model

Worksheet 1: Horizontal and Vertical UCM

First, some warm-ups:

1. A bowling ball rolls down the hallway.
   a. Throcky wants to make the ball have a smooth circular turn to the right. Draw a picture to indicate how he should push on the ball to make that turn happen.

   b. While the ball's path is curving, are the forces on the ball balanced? Draw an FBD for the ball.

   c. Is the ball accelerating? If so, how (in what way) is the velocity changing?

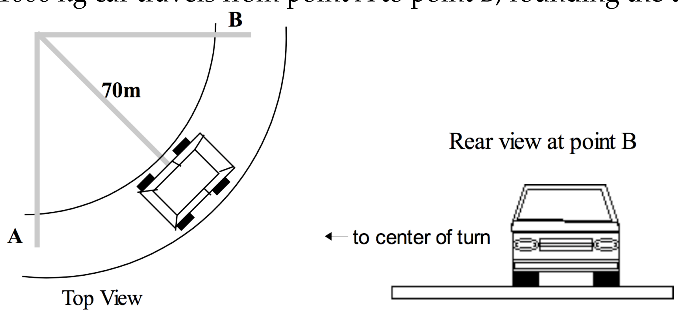
2. An airplane banks and makes a wide circle.
   Draw an FBD for the head-on view of the banking plane.

3. A car enters a circular turn. Draw an FBD for the car from a head-on perspective.

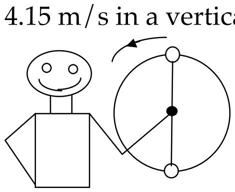
4. The international space station orbits the earth once every 90 minutes. Why doesn't the space station crash to Earth? Draw an FBD and also a sketch of the path of the station's orbit.

Now it's time to solve some problems:

5. A 1000 kg car travels from point A to point B, rounding the turn of radius 70 m with a constant speed of 60 km/h.

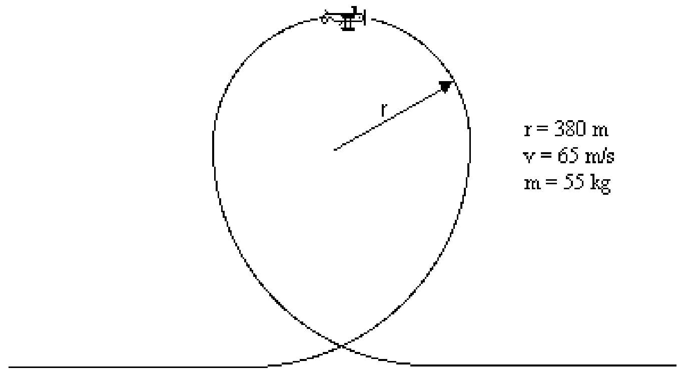


6. A 0.300 kg yo-yo on the end of a string goes "round the world" as it is cleverly revolved at a uniform speed of 4.15 m/s in a vertical circle of radius 85.0 cm.



Worksheet 2: Solving problems with UCM

7. A woman flying aerobatics executes a maneuver as illustrated:

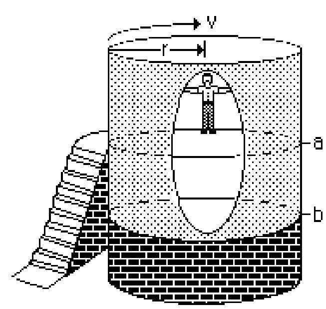


   a. Determine the value of the net force acting on the woman flying the airplane when at the top of the loop. Also find her acceleration.

   b. Construct a quantitative free body diagram for the woman.

   c. Does the woman feel lighter or heavier than normal at this position? Explain.

8. A popular amusement park ride operates as follows: riders enter the cylindrical structure when it is stationary with the floor at the point marked "a". They then stand against the wall as the cylinder then begins to rotate. When it is up to speed, the floor is lowered to the position marked "b", leaving the riders "suspended" against the wall high above the floor.

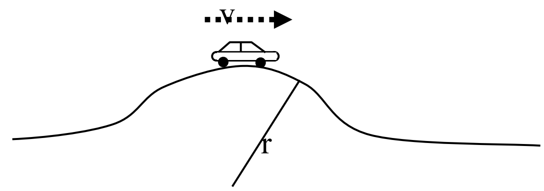


   What is the maximum period of rotation necessary to keep the riders from sliding down the wall when the floor is lowered from point "a" to point "b"? (Show all of your work and explain your reasoning.)

9. The next few problems are similar; we'll split them up so that one group does each of them and then we share when we're done. If you have time, you should work on more than just your problem before the other groups present.

a. The 1200 kg car moves with a constant speed of 43 km/h as it rounds the top of the circular hill of radius r = 25 m.

What happens to the normal force the road exerts on the car if the car goes over the hill at a faster speed? (Draw a free body diagram to illustrate this change.) Is there a speed at which the car would be going over the hill "too fast?" Explain.

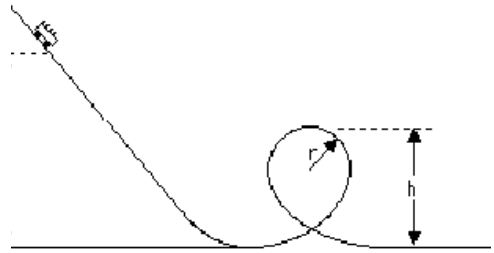


b. A teacher swings a 1 kg pail of water with a period of 1.08 seconds in a vertical circle of radius 90 cm.

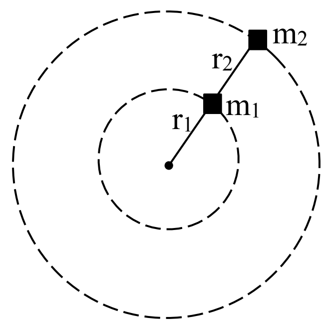
What happens to the force the pail exerts on the water if the teacher spins it more slowly. (Draw a free body diagram to illustrate this change.) Is there a speed at which the teacher would be spinning the pail "too slowly?" Explain.

c. A 1000 kg roller coaster travels with a constant speed of 8.0 m/s as it goes around a circular vertical loop of radius r = 5.0 m, with the riders upside down.

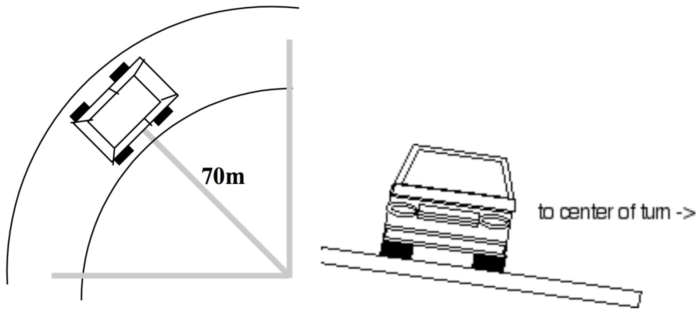
What happens to the force the track exerts on the coaster if its speed is slower. (Draw a free body diagram to illustrate this change.) Is there a speed at which the coaster is going "too slowly?" Explain.

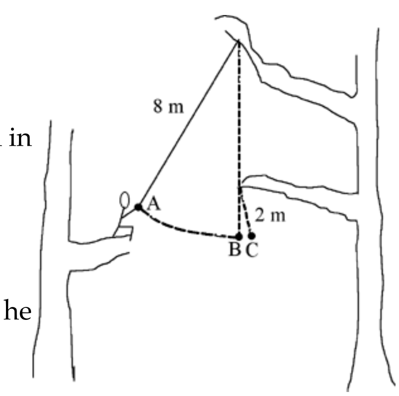


10. Two masses, m_1 = 3 kg and m_2 = 2 kg, connected to each other and to a central post by cords, as shown, rotate about the post with the same period of 3.0 seconds. The horizontal surface is frictionless , and $r_1 = r_2$ =10 cm, so that m_2 is 20 cm from the post. Determine the tension in each cord.



11. The 1000 kg car below rounds the 70 m radius banked turn at a constant speed of 30 km/h even though the road is icy, making friction negligible. Determine the banking angle.





12. Tarzan (mass = 80 kg) grabs a vine to swing to another tree.
As Tarzan swings from point A to point B, describe qualitatively how the tension in the vine changes and why.

At point B he is swinging at 7 m/s and the vine is 8 meters long. How hard does he have to hang on to the vine to keep from slipping off?

A moment later, at point C, the vine catches on a branch, reducing the radius of the swing to 2 m. If Tarzan is still traveling at 7 m/s, how hard does he now have to hold on to the vine?

Worksheet 3: Orbital Motion

13. Suppose you are at mission control on the moon, in charge of launching a moon-orbiting communications satellite.
    a. First, how much would a 1500 kg satellite weigh at the surface of the moon? (The gravitational field strength on Earth's moon is 1.6 N/kg.)

    b. The satellite is to have an altitude of 100 km above the moon's surface. What is the radius of the orbit of the satellite? (The radius of the moon is 1.74×10^6 m.)

    c. Find the required orbital velocity for the satellite.

    d. How long will it take the satellite to orbit the moon? (This time is called the orbital period.)

    e. Is this satellite accelerating while in orbit? If so, what is the direction and magnitude of the acceleration?

14. The radius of the Earth is about 6.38×10^3 km. The orbital radius of the Earth is about 1.5×10^8 km. What is the mass of the Earth?

15. What is the mass of the Sun?

16. Why do astronauts float aboard the international space station? What sensation does an astronaut feel while in orbit?

17. Are astronauts in orbit really "weightless"? What might be a better description?

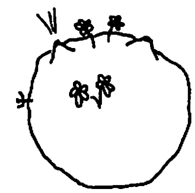
18. The space shuttle aims for an orbit about 250 km above the surface of the earth. In orbit, the mass of the space shuttle is about 95,000 kg.
    a. Calculate the orbital speed of the space shuttle.

    b. Calculate the orbital period of the space shuttle.

19. Back in Galileo's day, one of the objections to the heliocentric model of the solar system is that if the earth is spinning, we should all be "thrown off the earth." Actually, you do weigh a bit less on the equator than you would at the poles. Calculate how much.

20. How fast would you have to run to escape the Earth and never come back?

21. In "The Little Prince", the Prince visits a small asteroid called B612.
    a. If Asteroid B612 has a radius of only 20.0 m and a mass of 1.00×10^4 kg, what is the magnitude of the gravitational field on Asteroid B612?



    b. What is the speed needed to escape the gravitational pull of Asteroid B612?

    c. What would happen if you jumped up on Asteroid B612?

CFPM Model Summary

Concept Map