Physics 1408/1420 – General Physics 1

Week of September 12th, 2022

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Hello Fellow Physicists,

I am Jorge Martinez, the Master Tutor for Physics this semester. To help you on your journey to learn about this wonderful branch of science and the understanding it gives us of the world around us, I will be preparing this resource every week to give you an additional tool to better prepare for your week. I will also be conducting Group Tutoring sessions every week, the information for which will be given below. If you are unable to attend group tutoring, the tutoring center also offers one-on-one tutoring session, so be sure to visit the tutoring center or visit https://baylor.edu/tutoring.

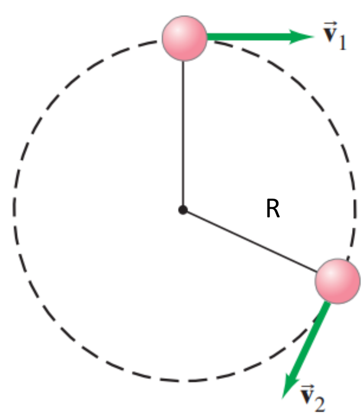
PHY 1408/1420 General Physics 1 Group Tutoring sessions will be held every Wednesday from 6:30-7:30 pm in the Sid Richardson building basement, Room 75. See you there!

In the past two weeks, your professors will have covered Projectile Motion and Forces. This week, you will finish studying Forces and begin exploring uniform circular motion.

Keywords: Centripetal Force, Uniform Circular Motion, Gravitational Force

Important Notes
Important Conventions

Important Topic 1: Uniform Circular Motion



An object is said to be uniform circular motion when the object is moving in a circular path at constant speed. If you have ever seen movies, videos, and cartoons about cowboys in the old west, you've seen the classic lasso move where they move it over their head, that is uniform circular motion (we consider no air resistance in these scenarios). If you have ever been on a Ferris wheel, you've been an object in circular motion. in uniform circular motion, the distinction between speed and velocity is paramount. In uniform circular motion, the SPEED is CONSTANT but NOT the VELOCITY. When an object is in Uniform circular motion, the magnitude of the velocity does not change, but the direction does. An object can participate in uniform circular motion if there is a centripetal force acting on the object. This is a force that exerts acceleration on the moving object toward the center of the circular path. This acceleration changes the direction of the velocity, which is tangential to the path, as you can see in the figure on the right. This is very important to remember for conceptual questions. This acceleration is called centripetal or radial acceleration, which is defined by the formula below

$$a_c = v^2/ R \qquad \text{(centripetal acceleration)}$$

This formula determines the magnitude of the objects acceleration. From this and the F = ma relation of force, we can define the formula of centripetal force as

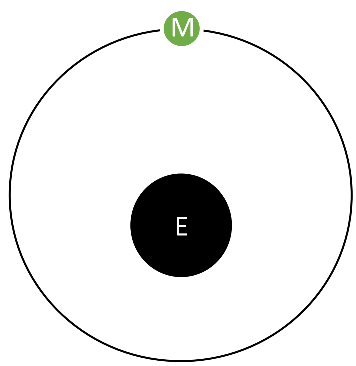
$$F_c = mv^2/ R$$

Two other terms you must also be aware of are Period (T) and Frequency (f). Period (T) is the time it takes the object in motion to complete one cycle or revolution. Frequency (f) is the amount of cycles completed in a second. Their relation to each other and velocity for uniform circular motion are as follows.

$$f = 1/T \qquad v = 2\pi Rf = 2\pi R/T$$

Example 1: The Moon revolves around the Earth in a circular orbit of radius 384,000 km and a period of 27.3 days. What is the acceleration of the Moon toward the Earth.

<u>Solution:</u>



Radius = 384000 km = 384000000 m

Period = 27.3 days = 27.3x24x60x60 = 2360000 s

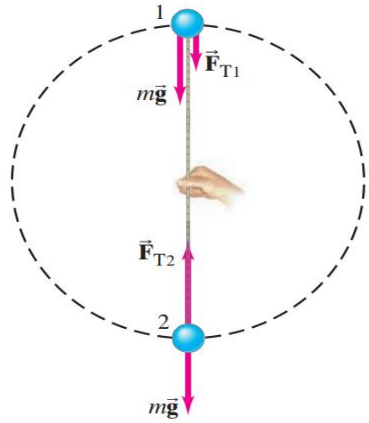
$a_c = v^2/R$

$= (2\pi R)^2/RT^2$

$= (2\pi(384000000))^2/ (384000000)(2360000)$

$= 0.0027\ m/s^2$

Example 2: a 0.150-kg ball on the end of a 1.1 m long cord is swung in a vertical circle. Determine the minimum speed the ball must have at the top of its arc so that it can continue its circular motion and calculate the tension in the cord at the bottom of the path, assume the ball is moving at twice the speed at the top.



Solution:

$m = 0.15$ kg $R = 1.1$ m

At 1

$\sum F = m\,a_c$

$F_{t1} + F_g = m\,(v^2/R)$

At the top, for minimum speed F_{t1} will be 0.

$mg = m\,(v^2/R)$

$9.8 = v^2 / 1.1$ $v = 3.28$ m/s

At 2

$\sum F = m\,a_c$

$F_{t2} + F_g = m\,((2v)^2/R$

$F_{t2} = (0.15)\,((2x3.28)^2/\,(1.1)) - (0.15)\,(9.8)$

$F_{t2} = 7.35$ N

Important Topic 2: Gravity

If you are a fan of Star Wars, guess what, you have the force in you. We call this force gravity. All matter in existence exerts a gravitational force on all other matter. Einstein describes it as a sort of depression in space time. Theoretically, you make a weird ditch in the fabric of space and time, which is what attracts all matter to you. The bigger the object, the more gravitational force it exerts. We don't magically fly to one another because earth has a stronger and deeper spacetime ditch. Newton studied the behavior of gravity not only on Earth, but also out there in space between planets. He proposed the law of universal gravitation, which states: every particle in the universe attracts every other particle with a force that is proportional to the product of their masses and inversely proportional to the square of the distance between them. From his statement, we derive the formula for gravity as

$$F_G = G\, m_1 m_2 / R^2 \qquad \text{where } G = 6.67 \times 10^{-11}\ \text{N.m}^2/\text{kg}^2$$

The relation between the force of gravity and the distance between the particles is called the inverse square law. It is essential to understand how the changes in distance between particles affects the gravitational force between the particles. The relation above changes the closer we get to the surface of a planet due to this law. For earth, you can equate

$$m\,g = (GMm)/(R_{earth})^2 \quad \text{where } M = \text{mass of earth, } m = \text{mass of object}$$

Another relation that is important is the relationship between gravity and centripetal force. This relation is what creates orbits. Centripetal acceleration occurs when a force is pulling the object in motion toward the center of the circular path. For satellites, it is gravity. We use the following when dealing with such a situation

$$G\, m_{satellite}\, m_{planet} / R^2 = m_{satellite}\, v^2 / R$$

Example 3: A geosynchronous satellite is one that stay above the same point on the earth on the equator. What is the height of the satellite above the Earth and the speed of the satellite?

Solution:

$G\, m_{satellite}\, m_{planet} / R^2 = m_{satellite}\, v^2 / R$

$G\, m_{planet} / R^2 = (2\pi R/T)^2 / R$

$G\, T^2\, m_{planet} / 4\pi^2 = R^3$

$R = (\,6.67 \times 10^{-11} \times (\,24 \times 60 \times 60\,)^2\, (5.98 \times 10^{24}) / 4\pi^2\,)^{1/3}$

$= 4.22 \times 10^7$ m

Remember, this is the distance of the satellite from the center of the earth, it is NOT you answer. You want the height. So,

Height of Satellite = $R - R_{earth} = 4.22\text{x}10^7 - 6.38\text{x}10^6 = 3.58\text{x}10^7$ m

For velocity of satellite

$v = 2\pi R/T$

$= 2\pi(4.22 \times 10^7)/ (24\text{x}60\text{x}60)$

$= 3070$ m/s

CHECK YOUR LEARNING

1. **1.** A proposed space station consists of a circular tube that will rotate about its center (like a bicycle tire). The circle formed by the tube has a radius of 1 km. What must be the rotation speed (revolutions per day) if an effect equal to gravity at the surface of the Earth is to be felt?
2. **2.** Can a 1000 kg car can round a turn of radius of 50 m on a flat road with the coefficient of friction of 0.4 if it is travelling at 80 mph?
3. **3.** A hypothetical planet has an acceleration due to gravity of 5g ($g = 9.8\ m/s^2$) on the surface but has the same radius as earth. How much larger is the mass of the planet compared to earth?
4. **4.** Jimmy's weight is 800 N but when Jimmy stands on a scale on the elevator, it reads that his weigh is 700 N. Is the elevator accelerating up or down? What is the acceleration of the elevator?

THINGS YOU MAY STRUGGLE WITH

1. **1.** Remember, the magnitude for the tangential velocity for a body in uniform circular motion does not change. Only the direction of the velocity for the body changes, which is due to the centripetal acceleration.
2. **2.** The centripetal acceleration experienced by a body in unform circular motion always points toward the center of the circular path of the motion, so the direction of centripetal motion changes relative to other forces depending on what point in the circular path the body is located. This is extremely important when looking at vertical uniform circular motion where gravity will also be acting on the object.
3. **3.** The gravitational force between two objects is inversely proportional to the square of the distance between them. Remember that if you increase or decrease the distance between the objects, the change in force will not be linear.
4. **4.** Objects in orbit around a larger body is due to the gravitational force exerted by the bodies on one another. The object stays in uniform circular motion because the gravitational force also acts as a centripetal force. Which means that in the case of satellites, we can analyze the system as a centripetal force and a gravitational force!!

It is fascinating how these laws govern everything we see out there. The next time you look at the sky, take a moment to think about how everything you have learned applies to everything out there and how the laws of physics make up the most beautiful masterpiece we call the universe.

I hope you have a wonderful week! Please feel free to reach out to me if you have any questions and check out all the resources the Tutoring Center has to offer at: https://baylor.edu/tutoring

Answers: 1) 1362 rev/day ,2) No, 3) 5 times larger, 4) down, $1.23 m/s^2$