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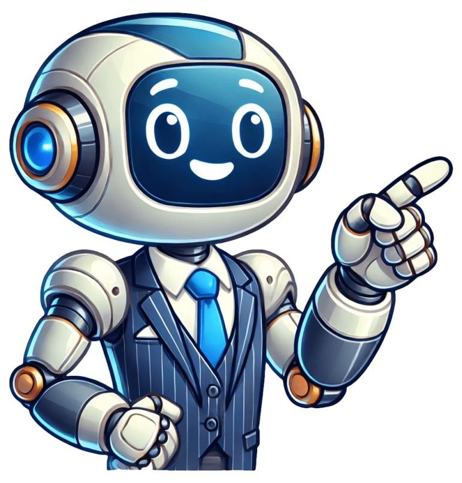

0 ratings0% found this document useful (0 votes)2K viewsThis document provides examples of problems involving uniform circular motion and their step-by-step solutions. Problem 1 calculates the centripetal acceleration and net force on an object mAI-enhanced title and descriptionSaveSave Uniform Circular Motion Problems with Answers For Later0%0% found this document useful, undefined Welcome to the Physics Library. This Living Library is a principal hub of the LibreTexts project, which is a multi-institutional collaborative venture to develop the next generation of open-access texts to improve postsecondary education at all levels of higher learning. The LibreTexts approach is highly collaborative where an Open Access textbook environment is under constant revision by students, faculty, and outside experts to supplant conventional paper-based books. Campus BookshelvesBookshelvesLearning Objects Home is shared under a not declared license and was authored, remixed, and/or curated by LibreTexts. DSA to Development: A Complete GuideBeginner to AdvanceJAVA Backend Development - LiveIntermediate and AdvanceTech Interview 101 - From DSA to System Design for Working ProfessionalsBeginner to AdvanceFull Stack Development with React & Node JS - LiveBeginner to AdvanceJava Programming Online Course [Complete Beginner to Advanced]Beginner to AdvanceC++ Programming Course Online - Complete Beginner to AdvancedBeginner to AdvancePage 2Our website uses cookiesWe use cookies to ensure you have the best browsing experience on our website. By using our site, you acknowledge that you have read and understood our Cookie Policy & Privacy Policy Energy, Work and Circular Motion Learn Work is defined as the force () applied to move an object some displacement(): . As force and displacement are vectors, we correctly say that it is only thecomponent of the force in the direction of motion that contributes to the work being done. This now results in the equation for work becoming: One of the features of circular motion, is that the centripetal force is always directed into the centre of the circle that is the path for the object. Even though the object is constantly changing direction, the motion at any instant is always tangential to the circle. This gives us the situation where the angle,, between the force and the direction of motion is 90. If we apply this to our equation for work:Therefore, we conclude that no work is being done on an object in uniform circular motion. Work is also defined as the change in kinetic energy. As the work done on an object in uniform circular motion is 0, there is no change in kinetic energy for the object in uniform circular motion. Kinetic energy is given by:The kinetic energy depends only on the magnitude of the velocity and not on its direction. In uniform circular motion, only the direction of the velocity is changing, because the force is at right angles to the movement. Since the speed (i.e. the magnitude of the velocity) is constant, no work is being done and the energy remains constant. For an object in uniform circular motion:No work is being done on the objectThere is no change in the objects kinetic energyThe kinetic energy remains constantA car of mass 100 kg is traveling in a circle of radius 20 m. There is a frictional force of 500 N on the car's wheels (in the direction of the center of the circle, to keep the car going in a circle). Draw a free body diagram for the car and find the velocity of the car.Uniform Circular MotionEasyVideoUniform Circular Motion ProblemsA student is swinging a mass, m = 2.0 kg, in a uniform vertical circle of radius R = 2.5 m. The period of the rotation is 2.8 seconds. Draw a free body diagram for the mass at the top of the circle and find the tension of the string (ignore friction and the mass of the string.) Repeat for the mass at the bottom of the rotation.Uniform Circular MotionMediumVideoA 1.2 kg mass, m, is swinging on a string pendulum of length 80 cm (the string has negligible mass). As shown in the figure below, when \theta is 10 degrees the velocity of the mass is 0.6 m/s. Find the tension in the string and the acceleration of the mass at this moment.Uniform Circular MotionHardVideoGiven that the radius of orbit for the moon is 3.8 x 108^88 m, the period of the moon's orbit is 2.36 x 106^66 s, and the radius of the earth is 6.38 x 106^66 m; Find the altitude of a geostationary satellite.(hint: use Kepler's third law.)Uniform Circular MotionMediumVideoPhysics Satellite ProblemFind the period of a satellite at an altitude of 200 km.RE_EE = 6.38 x 106^66 mME_EE = 5.98 x 1024^{24}24 kgG = 6.67 x 1011^{-11}11 Nm2kg2\frac{Nm^2}{kg^2}kg2Nm2Uniform Circular MotionMediumVideoPage 2Simple Harmonic OscillatorAn oscillator consists of a block of mass 0.500 kg connected to a spring. When set into oscillation with amplitude 35.0 cm, the oscillator repeates its motion every 0.500 s. Find the:A. periodB. frequencyC. angular frequencyD. spring constantE. maximum speedF. magnitude of maximum force on the block from the springSimple Harmonic MotionHardVideoNeeds SolutionAn oscillator consists of a block attached to a spring(k = 400 N/m). At some time t, the position (measured from the system's equilibrium location), velocity, and acceleration of the block are x = 0.100m, v = -13.6 m/s, and a = -123 m/s2^22 . Calculate the A. frequency of oscillationB. mass of the blockC. amplitude of the motionSimple Harmonic MotionEasyVideoNeeds SolutionSimple Harmonic Motion ExampleA block is on a horizontal surface (a shake table) that is moving back and forth horizontally with simple harmonic motion of frequency 2.0 Hz. The coefficient of static friction between block and surface is 0.50. How great can the amplitude of the simple harmonic motion be if the block is not to slip along the surface?Simple Harmonic MotionEasyVideoNeeds SolutionSimple Harmonic Motion ProblemTwo blocks (m = 1.8 kg and M = 10 kg) and a spring (k = 200 N/m) are arranged on a horizontal frictionless surface. The coefficient of static friction between the two blocks is 0.40. What amplitude of simple harmonic motion of the spring-block system puts the smaller block on the verge of slipping over the larger block?Simple Harmonic MotionMediumVideoNeeds SolutionHarmonic Oscillator EnergyA 10 g particle undergoes simple harmonic motion with an amplitude of 2.0 mm, a maximum acceleration of 8 x 103^33 m/s2^22 , and an unknown phase constant. What areA. the period of the motion?B. the maximum speed of the particle?C. the total mechanical energy of the oscillator?D. the magnitude of the force on the particle at its maximum and half its maximum displacement?Simple Harmonic MotionHardVideoNeeds SolutionA block of mass M, 5.4 kg, at rest on a horizontal frictionless table is attached to a rigid support by a spring constant k, 6000 N/m. A bullet of mass m, 9.5 g, and velocity of magnitude 630 m/s strikes and is embedded in the block. Assuming the compression of the spring is negligible until the bullet is embedded, determine:B. the amplitude of the resulting simple harmonic motionSimple Harmonic MotionHardVideoNeeds SolutionAn ideal spring is hung from the ceiling and a pan of mass M is suspended from the end of the spring, stretching it a distance D as shown above. A piece of clay, also of mass M, is then dropped from a height H onto the pan and sticks to it. Express all algebraic answers in terms of the given quantities and fundamental constants.E. The clay is now removed from the pan and the pan is returned to equilibrium at the end of the spring. A rubber ball, also of mass M, is dropped from the same height H onto the pan, and after the collisions is caught in mid air before hitting anything else. Indicate whether the period of the resulting simple harmonic motion of the pan is greater than, less than, or the same as it was in part (C).Simple Harmonic MotionEasyVideoNeeds SolutionPage 3A 2kg car is traveling east at 3 m/s and a 4kg car is traveling west at 6 m/s. Assume the cars collide and stick together. Find the direction and velocity of the cars after they collide.Impulse and MomentumHardVideoA 2kg car is traveling east at 3 m/s and a 4kg car is traveling west at 6 m/s. Now assume the cars bounce off each other in a perfectly elastic collision. The final velocity of the 2kg car is -4 m/s. Find the direction and velocity of the other car after the collision.Impulse and MomentumEasyVideoA champagne bottle of mass 90 g has a 2 g cork in it. The pressure built up in the bottle causes the cork to shoot out, as shown below. If after the explosion, the bottle is moving directly to the left at 4 m/s, what is the velocity of the cork?Impulse and MomentumHardVideoThe red ball (4 kg) hits the blue ball (5 kg) moving at 2 m/s, and the balls move as shown in the figure below. \theta = 30 degrees. After the impact, the red ball is measured moving at 1.8 m/s. What is the velocity of the blue ball, and at what angle relative to the horizontal is the ball moving after the impact?Impulse and MomentumEasyVideoA crash test car of mass 1,000 kg moving at a constant speed of 12 m/s collides completely inelastically with an object of mass M at time t = 0. The ojbect was initally at rest. The speed v in m/s of the car object system after the collision is given as a function of time t in seconds by the expressionv=81+5tv = \frac{8}{1 + 5t}v=1+5t8A. Calculate the mass M of the object B. Assuming an initial position of x = 0, determine an expression for the position of the car object system after the collision as a function of time t.C. Determine an expression for the resisting force on the car object system after the collision as a function of time t.D. Determine the impulse delivered to the car object system from t = 0 to t = 2.0 s.Impulse and MomentumHardVideoNeeds SolutionIn a laboratory experiment, you wish to determine the initial speed of a dart just after it leaves a dart gun. The dart of mass mmm is fired with the gun very close to a wooden block of mass M0M_0M0 which hangs from a cord of length lll and negligible mass as shown below. Assume the size of the block is negligible compared to lll and the dart is moving horizontally when it hits the left side of the block at its center and becomes embedded in it. The block swings up to a maximum angle max\theta_{max}max from the vertical. Express your answer to the following in terms of mmm , M0M_0M0 , lll , max\theta_{max}max , and ggg .C. The dart is now shot into a block of wood that is fixed in place. The block exerts a force F on the dart that is proportional to the dart's velocity v and in the opposite direction, that is F = -bv, where b is a constant. Derive an expression for the distance L that the dart penetrates into the block in terms of m, v0v_0v0 , and b.Impulse and MomentumMediumVideoNeeds SolutionPage 4The 100 kg box shown below is being pulled along the x-axis by a student. The box slides across a rough surface, and its position xxx varies with time ttt according to the equation x=0.5t3+2tx = 0.5t^3 + 2tx=0.5t3+2t , where xxx is in meters and ttt is in seconds.C. Calculate the net work done on the box in the interval ttt = 0 to ttt = 2 s would be greater than, less than, or equal to the answer in part (C). Justify your answer.Work and EnergyEasyVideoNeeds SolutionThe figure below depicts a roller coaster. Assume the roller coaster starts at a velocity of 0 m/s from 70 m.B. Determine the height of the track at point x. It is known that the roller coaster has a velocity of 30 m/s at x.Conservation of Energy ProblemsA 20 kg student is about to go down a slide. There is a 3 N frictional force opposing his movement. Assume his velocity at the top of the slide is 0 m/s. Find his velocity at the bottom of the slide.Work and EnergyMediumVideoA student is about to be launched from a spring loaded canon. The student weighs 60 kg and the spring constant is 200 N/kg. Find the students velocity the moment he leaves the canon if the spring is compressed, x = 3 m. Also find the students velocity after the spring has decompressed to x = 2 m.Potential Energy of a SpringA marble, m, of mass 100 g is placed onto a platform attached to a spring. The weight of the marble compresses the spring 2 cm, as shown below. A force is then applied to the platform to compress the spring an additional 3 cm. When the force is taken away, the spring decompresses and launches the marble upward. What is the maximum height the marble obtains above the unstretched spring (the spring with no mass on it).Work and EnergyMediumVideoA nonlinear spring is compressed various distances x, and the force Frequired to compress it is measured for each distance. The data are shown in the table below.Work and EnergyHardVideoNeeds SolutionCalculate Spring ConstantIn an experiment to determine the spring constant of an elastic cord of length 0.60 m, a student hangs the cord from a rod and then attaches a variety of weights to the cord. For each weight, the student allows the weight to hang in equilibrium and then measures the entire length of the cord. The data are recorded in the table below:iii. Calculate the maximum speed of the object. Work and EnergyMediumVideoNeeds SolutionTerminal Velocity PhysicsA rubber ball of mass mmm is dropped from a cliff. As the ball falls, it is subject to air drag (a resistive force caused by the air). The drag force on the ball has a magnitude bv2bv^2bv2 , where bbb is a constant drag coefficient and vvv is the instantaneous speed of the ball. The drag coefficient bbb is directly proportional to the cross-sectional area of the ball and the density of the air and does not depend on the mass of the ball. As the ball falls, its speed approaches a constant value called the terminal speed.A. Draw and label all the forces on the ball at some instant before it reaches terminal speed.B. State whether the magnitude of the acceleration of the ball of mass mmm increases, decreases, or remains the same as the ball approaches terminal speed. Explain.C. Write, but do NOT solve, a differential equation for the instantaneous speed vvv of the ball in terms of time ttt , the given quantities, and fundamental constants.D. Determine the terminal speed vtv_tvt in terms of the given quantities and fundamental constants.E. Determine the energy dissipated by the drag force during the fall if the ball is released at height hhh and reaches its terminal speed before hitting the ground, in terms of the given quantities and fundamental constants.Work and EnergyEasyVideoNeeds SolutionA small sphere is moving at a constant speed in a vertical circle. Which of the following quantities is changing?i. kinetic energy ii. potential energy iii. momentumi and ii onlyi and iii onlyi and ii onlyii onlyiii onlyii and iii onlyWork and EnergyMediumVideoNeeds SolutionPotential Energy ProblemsIn the system of two blocks and a spring shown below, blocks 1 and 2 are connected by a string that passes over a pulley. The initially unstretched spring connects block 1 to a ridged wall. Block 1 is released from rest, initially slides to the right, and is eventually brought to rest by the spring and the friction on the horizontal surface. Which of the following is true of the energy of the system during the process?E. The potential energy lost by block 2 is greater in magnitude than the potential energy gained by the springWork and EnergyEasyVideoNeeds SolutionIn the situation above, after block 1 comes to rest, the force exerted on the rope must be equal in magnitude toA. ZeroB. the frictional force on block 1C. the vector sum of the force on block 1 due to the friction and tension in the springD. the sum of the weights of the two blocksE. Shiang doesn't care, he just wants to sleepF. the difference in the weights of the two blocksWork and EnergyMediumVideoNeeds SolutionA rope of length LLL is attached to a support at point C. A person of mass m1m_1m1 sits on a ledge at position A holding the other end of the rope so that it is horizontal and taut, as shown below. The person then drops off the ledge and swings down on the rope toward position B on a lower ledge where an object of mass m2m_2m2 is at rest. At position B the person grabs hold of the object and simultaneously lets go of the rope. The person and object then land together in the lake at point D, which is a vertical distance LLL below position B. Air resistance and the mass of the rope are negligible. Derive expression for each of the following in terms of m1m_1m1 , m2m_2m2 , LLL , and ggg.E. The total horizontal displacement x of the person from position A until the person and object land in the water at point D.Work and EnergyEasyVideoNeeds SolutionA spherical non rotating planet has a radius R and a uniform density hohoho throughout its volume. Suppose a narrow tunnel were drilled through the planet along one of its diameters as shown in the figure below, in which a small ball of mass m could move freely under the influence of gravity. Let r be the distance of the ball from the center of the planet. Suppose the ball is dropped into the tunnel from rest at the planet's surface.F. Write an equation that could be used to calculate the time it takes the ball to move from point P to the center of the planet.Work and EnergyHardVideoNeeds SolutionA solid brass block of mass m slides along a frictionless track when released from rest along the straight section. The circular loop has a radius R.B. Assume the block is released at height h = 6.0 R, what are the magnitude and direction of the horizontal force competent acting on the block at point Q?Work and EnergyMediumVideoNeeds SolutionA 50 kg object is to be launched 7 x 106^66 m out into space (not into orbit, it will fall back to earth). Given that the radius of the earth is 6.4 x 10 6^66 m and the mass of the earth is 6.0 x 10 24^{24}24 kg, find:A. The work done to put the object that far into space. B. The total kinetic energy of the object required to put the object that far into space.C. The binding energy. D. The escape velocity.A 60 kg object is to be launched into orbit, 7 x 106^66 m above the Earth's surface. Given that the radius of the earth is 6.4 x 10 6^66 m and the mass of the earth is 6.0 x 10 24^{24}24 kg, find:A. The work done to put the object into orbit.B. The velocity required to put the object into orbit.C. The velocity of the object once it is in orbit. Page 5Draw the vector and find the X and Y components.A\vec{A}A = 8m[E 30^\circ N] Find the X and Y components of the vectorA\vec{A}A = 8m[S 40^\circ W]Given Fx_xx = -5 N and Fy_yy = +8 N find F\vec{F}FAdd the following vectors to find R\vec{R}RR\vec{R}R = 5[N] + 7 [E 30 S] + 4 [S 20 W] + 3 [N 60 W]Subtract the following vectors to find R\vec{R}RR\vec{R}R = 6.0 ws\frac{w}{s}sw [E 30 ^\circ N] - 8.0 ws\frac{w}{s}sw [S 20 ^\circ W]A car drives at 8 m/s [E 30 N], turns the corner and travels 5 m/s [E]. What was it's acceleration if this took 2 s?Page 6Kinematics Acceleration ProblemA ball is thrown off a building. If the ball is thrown up at 5 m/s and lands 3 seconds laterFind the height of the buildingFind the impact velocity of the ballPhysics Kinematics ProblemA key falls from a bridge that is 45 m above the water. It falls directly onto a model boat moving with constant velocity that is 12 m in front of the point of impact when the key is released. What is the speed of the boat? KinematicsHardVideoNeeds SolutionAn object is projected straight upward from the ground level with a velocity of 50 m/s. Ignoring air resistance, it will return to the ground in approximately how many seconds?KinematicsMediumVideoNeeds SolutionA Jogger runs with constant speed vvv through a forest of pine trees. A pine cone starts to fall from a height hhh when the jogger is directly below it. How far behind the jogger will the pine cone land?KinematicsEasyVideoNeeds SolutionPhysics Kinematics ExampleA ball is thrown upward from the ground with an initial speed of 25 m/s; at the same instant, another ball is dropped from a building 15 m high. After how long will the balls be at the same height?A projectile is launched off a click at an angle. The cliff is 15m high, the projectile is launched at 25 degrees above horizontal. How much time is the projectile in the air before hitting the ground?A swimmer is capable of swimming 0.60 ni/s in still water. (a) If she aims her body directly across a 55-m-wide river whose current is 0.50 m/s, how far downstream (from a point opposite her starting point) will she land? (b) How long will it take her to reach the other side?Answers to Physics ProblemsIn a rescue attempt, a hovering helicopter drops a life preserver to a swimmer being swept downstream by a river current of a constant velocity v. The helicopter is at a height of 9.8 m. The swimmer is 6.0 m upstream from a point directly under the helicopter when the life preserver is released. It lands 2.0 m in front of the swimmer. How fast is the current flowing? Neglect air resistance.13.7 m/s9.8 m/s6.3 m/s2.8 m/sKinematicsEasyVideoNeeds SolutionHow long to swim across a riverA river is 300 m wide and the water flows downstream, exactly south, at 4 m/s. If a swimmer, moving at exactly 6 m/s, attempts to swim across the river:At what direction should the swimmer orient himself to swim straight across the river in the east direction?How long will it take the swimmer to across the river?A pilot flys a plane at 120k km/h [E] with the wind from [W 30 S] @ 60 km/h. Find the resulting velocity.A pilot flys a plane to a town that is 600km [N 30 E] and wants to arrive in 3 hours. The wind is from the west @ 60 km/h. What is the air speed and heading?A pilot want to fly to a town 500km [N 38 E]. The plane is designed to fly at 170 km/h. The wind is from the west @ 60km/h. Find the heading, ground speed, and E.T.A.A child tosses a ball directly upward. Its total time in the air is T. Its maximum height is H. What is its height after it has been in the air at time T/4? Neglect air resistance.H/4H/3H/22H/33H/4KinematicsEasyVideoNeeds SolutionA whiffle ball is tossed straight up, reaches its highest point, and falls back down. Air resistance is not negligible. Which of the following statements are true?i. The balls speed is zero a the highest pointii. The balls acceleration is zero at the highest point.iii. The ball takes a longer time to travel up to the highest point than to fall back down.i onlyii onlyi & ii onlyi & iii onlyi, ii, and iiiKinematicsHardVideoNeeds SolutionA truck driver travels three-fourths the distance of his run at once velocity, v, and then completes his run at one half his original velocity (1/2)*v. What was the truckers average speed for the trip?0.85 v0.80 v0.75 v0.70 v0.66 vKinematicsHardVideoNeeds SolutionOn a good dry road, a car with good tires may be able to brake with a constant deceleration of 4.92 m/s2^22 . How long does such a car initially traveling at 24.6 m/s take to stop? How far does it travel this time?KinematicsMediumVideoNeeds SolutionAn airplane traveling at 90 m/s at an elevation of 300 m drops a box of supplies to skiers stranded in a snowstorm.At what horizontal distance from the skiers should the supplies be dropped?Find the magnitude of the velocity of the box as it reaches the ground.KinematicsHardVideoNeeds SolutionHorizontal Velocity ProblemA student stands at the edge of a cliff and throws a stone horizontally over the edge with a speed of 18.0 m/s. The cliff is 50.0 m above a flat, horizontal beach as shown in the figure. (a) What are the coordinates of the initial position of the stone? (b) What are the components of the initial velocity? (c) Write the equations for the x- and y-components of the velocity of the stone with time. (d) Write the equations for the position of the stone with time, using the coordinates in the figure. (e) How long after being released does the stone strike the beach below the cliff? (f) With what speed and angle of impact does the stone land?Page 7The wheel shown below has eight equally spaced spokes and a radius of 30 cm. It is mounted on a fixed axle and is spinning at 2.5 rev/sec. You want to shoot a 20 cm long arrow without hitting any of the spokes. Assume the arrow and the spokes are very thin.B. Does it matter where between the axle and the rim of the wheel you aim? If so what is the best location?Rotational DynamicsMediumVideoNeeds SolutionA flywheel turns through 40 rev as it slows from an angular speed of 1.5 rad/s to stop.A. Assuming constant angular acceleration find the time for it to come to rest.B. What is its angular acceleration?C. How much time is required for it to complete its first 20 of the 40 revolutions?Rotational DynamicsHardVideoNeeds SolutionA massless string is wrapped around a disk of rotational inertia I = 12mR2\frac{1}{2} m R^221mR2 . The disk falls and spins as it falls, unraveling the rope. Determine the tension in the string and the acceleration of the disk.Rotational DynamicsMediumVideoNeeds SolutionA solid brass sphere of mass m and radius r m) are pushed by a force F in both Case I and Case II. The surface is horizontal and frictionless. Let R1 be the force that m exerts on M in Case I and RII be the force that m exerts on M in Case II. Which of the following statements is true?Free Body DiagramsHardVideoNeeds SolutionFrictionless Pulley ProblemTwo boxes with masses 17 kg and 15 kg are connected by a light string that passes over a frictionless pulley of negligible mass as shown in the figure below. The surfaces of the planes are frictionless. The blocks are released from rest. T1 and T2 are the tensions in the strings. Which of the following statements is correct?Free Body DiagramsHardVideoFree Body Diagram ProblemAn Object with mass m and initial velocity v is brought to rest by a constant force F acting for a time t and through a distance d. Possible expressions for the magnitude of the force F are: i. mv22d\frac{mv^2}{2d}2dmv2 ii. 2mdt2\frac{2md}{t^2}t22md iii. mvt\frac{mv}{t}tmv ii onlyiii onlyi and ii onlyii and iii onlyi, ii, and iiiFree Body DiagramsMediumVideoNeeds SolutionA toy car of mass 6 kg moving in a straight path, experiences a net force given by the function F = -3t. At time t=0, the car has a velocity of 4 m/s in the positive direction and is located +8 m from the origin. The car will come instantaneously to rest at time t equal to2/3 ssqrt(4/3) ssqrt(8/3) ssqrt(8) s4 sFree Body DiagramsHardVideoNeeds SolutionA block of mass M1 on a horizontal table is connected to a hanging block of mass M2 by a string that passes over a pulley, as shown in the figure below. The acceleration of the blocks is 0.6g. Assume that friction and the mass of the string are negligible. The tension T in the string isFree Body DiagramsEasyVideoNeeds SolutionFree Body Physics ExampleHercules and Carlos horizontally push in the same direction on a 1200 kg crate. Hercules pushes with a force of 500 N and Carlos pushes with a force of 300 N. If a frictional force provides 200 N of resistance, what is the acceleration of the crate?1.3 m/s21.0 m/s20.87 m/s20.75 m/s20.5 m/s2Free Body DiagramsHardVideoNeeds SolutionTwo sleds are attached by a rope and are being pulled by an applied force, Fa= 100 N. There is 40 N of frictional force opposing movement on each sled. Draw a free body diagram to help find:Free Body DiagramsHardVideoNormal Force Example ProblemFree Body Diagram ExampleA block of mass M = 5kg is placed on an incline of \theta = 30 degrees. There is a frictional force of 15 N opposing the movement of the block. Determine the acceleration of the block. Draw a free body diagram to help find the answer.Free Body DiagramsMediumVideoCoefficient of Friction ProblemA block of mass M = 5kg is placed on an incline of \theta = 30 degrees. There is a frictional force opposing the movement of the block with a coefficient of friction, \mu = 0.2. Determine the acceleration of the block. Draw a free body diagram to help find the answer.Free Body DiagramsEasyVideoDetermine the acceleration of the system if M = 5 kg and m = 10 kg and \theta = 30 degrees. There is also a coefficient of friction, \mu = 0.2. Use a free body diagram to determine the tension in the rope and the acceleration of the system.Free Body DiagramsHardVideoThe large block M is 20 kg, and the smaller block, m, is 1 kg. The coefficient of kinetic friction is 0.2. Determine the acceleration of the system and the tension in the cords. The angle of the inclined plane is 60 degrees to the horizontal. Also draw a free body diagram for both blocks.Free Body DiagramsHardVideoNeeds SolutionBlock M = 5 kg and block m = 6 kg. The coefficient of friction is 0.5. Determine the acceleration of the system and the tension in the cord. The angle of the inclined plane is 20 degrees to the horizontal. Draw a free body diagram for the 5 kg block to help find the answer.Free Body DiagramsHardVideoFree Body Diagram PhysicsBlock M = 5 kg and block m = 3 kg. The coefficient of static friction is 0.2. Determine the acceleration of the system and the tension in the cord. The angle of the inclined plane is 30 degrees to the horizontal. Draw a free body diagram for the 5 kg block to help find the answer.Free Body DiagramsEasyVideoDetermine the acceleration of the system if m1_11 = 5 kg and m2_22 = 10 kg and the pulley has no mass. Determine the tension in the rope as well.Free Body DiagramsMediumVideoDetermine the acceleration of the system if m1_11 = 3 kg and m2_22 = 8 kg and the pulley has no mass. Determine the tension in the rope as well.Free Body DiagramsHardVideoA 3 kg box is pushed on a surface with a force of F = 15 N. The coefficient of static friction, s\mu_ss is 0.3, and the coefficient of kinetic friction, k\mu_kk is 0.1.A. Does the box move?B. If it does move, calculate the acceleration of the box.Free Body DiagramsHardVideoNeeds SolutionHome / Problems and Solution Circular Motion / Solved Problems in Basic PhysicsProblem #1An object rotates horizontally on a circular road at a speed of 10 m / s and does 120 turns in one minute. (a) Determine the frequency and period of the object, and (b) Look for changes in the speed vector when rotating 600, 900 and 1800!Answer:(a) frequency and periodn = 120 rounds, t = 1 minute = 60 seconds, thenf = n/t = 120 rounds / 60 seconds = 2 put / secondT = 1/f = second(b) change in velocity vectorIf an object moves from point A and rotates through 600 at point B, thenv = vB - vAv = 2v.cos 1200/2 = 2.10.cos 600= 20/2 = 10 m/sIf the object rotates to 900;v = vC vAv = (vA2+ vC2)1/2= [(10)2+ (10)2]1/2= 102 m/sIf the object rotates 1800;v = vD vA= 10 m / s 10 m/s = 20 m/sProblem #2A dish rotates 1800 turns for 6 minutes. The fingers are 8 cm long. Determine (a) the frequency and period of the disk, (b) the speed of the disk angle, (c) the linear velocity of a point at 3 cm from the edge of the dish and (d) the centripetal acceleration of the dish!Answer:(a) Frequency and period of diskf = n/t = 1800 turns/(6 x 60 seconds) = 5 HzT = 1/f = 0.2 seconds(b) the speed of the disk angle = 2f = 2 x 5 Hz = 10 rad/s(c) the linear speed of the point at 3 cm from the edge of the disk isv = R = (10 rad/s) (5 cm) = 50 cm/s = 0.5 m/s(d) centripetal accelerationas= v2/R = 2R = (10 rad/s)2(8 cm) = 8000 cm/s2= 80 m/s2Problem #3A wall clock must have seconds, minutes and clock hands. Determine the ratio of seconds to seconds, minutes and hours!Answer:In 1 round = 3600 = 2 radians, the second hand takes 1 minute = 60 seconds, while the minute hand takes 1 hour = 3600 seconds and the clock needs 12 hours = 12 x 3600 seconds, thens(second hand) = 2/(60 s) = /30 rad / sm(minute hand) = 2/(3600 s) = /1800 rad / sh(hour hand) = 2/(12 x 3600 s) = /21600 rad / sthen s: m: h= (/30): (/1800) : (/21600) =720 : 12: 1Problem #4You design an aircraft propeller that rotates at 2400 rpm like the picture. The speed of the forward plane is 75.0 m/s and the tip speed of the air propeller blades must not exceed 270 m/s. (This is about 80% of the sound speed in the air. If the propeller speed is greater than this, they will produce a lot of noise.) (A) What is the maximum radius of the propeller? and (b) With this radius, what is the speed of the propeller?Answer:Changing the angular speed of the propeller in the rad / s is = 2400 put/minute = 2400 (2 rad)/(60 seconds) = 80 rad/s = 251 rad/s(a) from the picture we wrote,vT2= v2tan+ v2pesawat= r22+ v2plane(270 m/s)2= r2(251 rad/s)2+ (75.0 m/s)2(251 rad/s)2r2= (270 m/s)2 (75.0 m/s)2= 67275r = 1.03 m(b) The acceleration of centripetal particles isas= 2r = (251 rad/s)2(1.03 m) = 6.5 x 104m/s2= 6600gProblem #5A wheel rotates 150 revolutions in 30 seconds. What is the angular speed?Answer:(a) revolutions per minute (rpm)150 revolutions /30 seconds = 150 revolutions /0.5 minute = 300 revolutions/minute = 300 rpm(b)degrees per second (o/s)1 revolution = 360o, 300 revolutions = 54000o150 revolutions/30 seconds = (150) (360o)/30 seconds = 54000o/30 seconds = 1800o/second(c)radians per second (rad/s)1 revolution = 6.28 radians150 revolutions/30 seconds = (150)(6.28) radians/30 seconds = 942 radians/30 seconds = 31.4 radians/second. In this article, we explore various problems related to uniform circular motionwith detailed answers. These questions are designed to be highly beneficial for both high school and college students, aiding in their understanding and mastery of the concepts involved in circular motion. Save time, boost your score! Get our comprehensive 31-page equation sheet and ace the AP Physics 1 Exam in 2025. Limited time offer for just $\$ 10$! (Download free PDF sample). Circular Motion Problems Problem (1): A5-kg object moves around a circular track with a radius of 18 cm at a constant speed of 6 m/s. Find(a) The magnitude and direction of the acceleration of the object.(b) The net force acting upon the object causing this acceleration. Solution: When an object moves around a circular path at a constant speed, the only acceleration it experiences is centripetal acceleration or radial acceleration. This kind of acceleration is always toward the center of the circle, and its magnitude is found by the following formula: \[a_c=\frac{v^2}{r}\] where v is the constant speed with which the object revolves the circle, and r is the radius of the circle. (a) The track is circular and the speed of the object is constant, so a centripetal acceleration directed toward the center is applied to the object, whose magnitude is as follows \[a_c=\frac{6^2}{0.18\,{\rm m}}=200\,{\rm \frac{m}{s^2}}\] In the figure below, a top view of the motion is sketched. (b) By applying Newton's second law along the direction of the centripetal acceleration, we can find the magnitude of the net force causing the acceleration as follows \[F_{net}=m\frac{v^2}{r}\] Therefore, \[F_{net}=5\times 200=1000\quad {\rm N}\] Note: At each point along the circular path, the instantaneous velocity of the revolving object is tangent to the path. The direction of this velocity changes, but its magnitude remains constant. Problem (2):Two figure skaters, each with a mass of 60.0 kg, grab hands and spin in a mutual circle. They complete one full revolution every 2.0 seconds. Assuming the distance between them (the combined length of their arms) is 1.6 meters, calculate the force they exert on each other. Solution: Since these two skaters are moving around a circle, they exert a centripetal force inward on each other, whose magnitude is found by the following formula: \[F_c=m\frac{v^2}{r}=mr\omega^2\] where v is the linear velocity, ω is the angular velocity, and r is the radius of the circle, which in this case is half the distance between the skaters, $r=0.8\,\rm m$. The angular velocity is calculated as follows: \begin{align*} \omega&=\frac{2\pi}{T} \\\\ &=\frac{2\pi}{2} \\\\ &=\pi\quad \rm rad/s \end{align*} Here, 2π represents one full revolution in radians (since 2π radians is equal to 360 degrees), and T is the period (time for one full revolution). The centripetal force is also calculated as follows: \begin{align*} F_c &=mr\omega^2 \\ &=60\times 0.8 \times (\pi)^2 \\ &\approx 474\quad\rm N\end{align*} Each skater exerts a force of approximately 474 N on the other to keep spinning in the circle. Problem (3):A particle moves in a uniform circular motion with a radius of 3 cm. The net force radially acting on the object is 30 N. If the mass of the object is 6 kg,(a) What is centripetal acceleration?(b) What is the particle's linear speed?(c) What is the acceleration if the radius is doubled without changing the particle's speed?(d) What is the acceleration if the angular velocity is doubled without changing the circle's path? Solution: Centripetal acceleration is defined as the accelerationthat an object experiences when it turns around a circular path. This acceleration points radially inward toward the center of the circular path and is related to the corresponding centripetal force, F_c, by the following formula \[F_c=ma_c=m\frac{v^2}{r}\] where r is the radius of the circular path and v is the linear speed of the revolving object. (a) According to the above explanation, a_c can be found as\begin{gather*} F_c=ma_c \\ 30=6\times a_c \\ \Rightarrow a_c=5\,\rm m/s^2\end{gather*}(b) Centripetal acceleration and linear speed are related by $a_c= \frac{v^2}{r}$. Substituting the numerical values into that and solving for v get \begin{gather*} a_c=\frac{v^2}{r} \\\\ 5=\frac{v^2}{0.03} \\\\ \rightarrow v^2=0.15 \\\\ \Rightarrow \boxed{v=\sqrt{0.15}\,\rm m/s} \end{gather*}(c) According to the centripetal acceleration formula, $a_c=\frac{v^2}{r}$, acceleration is inversely proportional to the radius of the circular path, $a_c\propto 1/r$. Therefore, we have \begin{gather*} \frac{a_c}{a'_c}=\frac{r'}{r} \\\\ \frac{5}{a'_c}=\frac{2\times 3}{3} \\\\ \Rightarrow \boxed{a'_c=2.5\,\rm m/s^2} \end{gather*}(d) We can also express the centripetal acceleration a_c in terms of the angular velocity ωusing formula \[a_c=r\omega^2\] Substituting the given numerical values into that equation gives \begin{gather*} a_c=r\omega^2 \\ 5=0.03 \times \omega^2 \\\\ \omega=\sqrt{\frac{5}{0.03}}\ \rm rad/s \end{gather*} I independently provide all the content on this site and cover its costs. Your support means a lot to me. If you find value in this article, please consider donating $5 or purchasing our AP Physics 1 Equation Sheet PDF. Problem (4): A crankshaft of radius 8 cm rotates at 2400 rpm (revolutions per minute). What is the speed of a point at its surface? Solution: The aim of this circular motion problem is the conversion of rpm into SI units of speed (m/s), which is done as below: \begin{align*} 1 \frac{rev}{minute}&=\frac{\text{circle's circumference}}{60\,\text{seconds}}\\\\&=\frac{2\pi r}{60}\\\\&=\frac{\pi r}{30}\end{align*} Hence, to convert rpm to m/s, we can use the following conversion ratio \[\rm{1\,rpm}=\frac{\pi r}{30}\,{\rm \frac ms}\] In this problem, the circular motion has a radius of $r=0.08\,{\rm m}$ and an angular speed of 2400 rpm, so we get \[2400\,{\rm rpm}=2400\times\frac{\pi(0.08)}{30}=20.1\,{\rm \frac ms}\] Problem (5): A 20-kg child sits in a cart to which a 2-m rope is attached. The rope is tied to a motor that rotates the cart. At the instant that the tension in the rope is 100 N, how many revolutions per minute does the cart make? Solution:This circular motion question aims to find the method of conversion of m/s into $\rm rpm$. The child revolves in a circular path, so the net centripetal force it experiences is determined by $F_c=\frac{mv^2}{r}$. First, use the above equation and solve for the constant speed v as below \[v=\sqrt{\frac{rF_c}{m}}=\sqrt{\frac{2\times 100}{20}}=\sqrt{10}\,{\rm \frac ms}\] Next, convert the above linear speed in ($\rm \frac ms$) into angular speed in revolutions per minute ($\rm rpm$). The simple relation between the two speeds is as $v=r\omega$, where ω is the angular speed measured in radians per second. \[\omega=\frac{v}{r}=\frac{\sqrt{10}}{2} \,{\rm \frac {rad}{s}}\] Next, as shown below, convert $\rm \frac{rad}{s}$ into $\rm rpm$\[\frac{1\,rad}{s}=\frac{\frac{1}{2\pi}\,rev}{\frac {1} {60}\,min}=\frac {30}{\pi}\, \rm rpm\] In the above, we used this fact that each revolution around a circle is equal to 2π radians.As a result, we have \[\frac{\sqrt{10}}{2}\,{\rm \frac{rad}{s}}=\frac{\sqrt{10}}{10}\left(\frac{30}{\pi}\right)\,{\rm rpm}=15.1\,{\rm rpm}\] The cart makes approximately 15 revolutions per minute. Problem (6): A 35-kg child makes a turn that is a portion of a circle with aradius of 12 meters. She covers one-quarter of the circular path in 1.6 seconds. Determine the speed, acceleration, and net force applied to the child. Solution: The child turns one-quarter of a circle in 1.6 seconds. Using the definition of speed, as distance traveled divided by time elapsed, we can find its speed. But here, the distance traveled is the circumference of one-quarter of a circle of radius 12 meters, so$L=\frac 14 (2\pi r)=\frac{\pi r}{2}$. \begin{align*} speed&=\frac{distance}{\text{time elapsed}}\\\\&=\frac{\pi r/2}{time}\\\\&=\frac{\pi\times (12/2)}{1.6}\\\\&=11.8\quad {\rm m/s}\end{align*} Because the child is moving around a portion of a circular path, centripetal acceleration is applied to the child, whose magnitude is $a_c=v^2/r$. \[a_c=\frac{v^2}{r}=\frac{(11.8)^2}{12}=11.6\quad{\rm \frac{m}{s^2}}\] The net force is also found using Newton's second law of motion as $F_{net}=ma_c$. \[F_{net}=ma_c=35\times 11.6=406\quad {\rm N}\] Problem (7): A ball of mass 2 kg is attached to a rope having a breaking strength of 1500 N and is whirled around a horizontal circle with a radius of 85 cm. Calculate the maximum speed that the ball can have. Solution: There is a circular motion, so the only radially inward force that acts upon the ball is a centripetal force whose magnitude is $F_c=mv^2/r$ where r is the radius of the circular path. Putting everything into this equation and solving for the unknown velocity, we have \[v=\sqrt{\frac{rF_c}{m}}=\sqrt{\frac{0.85\times 1500}{2}}=25.25\,{\rm \frac{m}{s}}\] The following circular motion questions are helpful for the AP Physics exam. Need more challenging problems for yourexam?Visit AP Physics 1 circular motion questions. Problem (8): The speed of a 515-kg roller-coaster at the bottom of a loop of radius 10 m is 20 m/s. Find the net vertical force pushing up on the object at this point of the circular path. Solution: Note that because of gravity, the speed of the object changes at each point of the track, so the object is not undergoing uniform circular motion. Nonetheless, we can use the centripetal acceleration formula to find the velocity at each point along the circle. At the bottom, two forces are applied to the object: the downward force of gravity(mg), and the upward tension force (T). The resultant of these two forces creates a centripetal acceleration toward the center of the circle, i.e. $F_c=T-mg$. Applying Newton's second law in this direction (by choosing upward as the positive direction since acceleration at this point is upward), we have:\begin{align*} T-mg&=\frac{mv^2}{r}\\\\ \Rightarrow T&=mg+\frac{mv^2}{r}\\\\&=(515)(10)+\frac{515\times (20)^2}{10}\\\\&=25750\quad {\rm N}\end{align*}Therefore, the tension force at the bottom of the circular track is approximately 25750 N. Problem (9): A 2000-kg car is moving around a curve with a radius of 200 m at a speed of 25 m/s. Calculate(a) The centripetal acceleration of the car.(b) The force causing this kind of acceleration.(c) The minimum coefficient of static friction between the tires and the surface of the road guarantees a safe turning. Solution: The free-body diagram below (side view) shows all forces acting on the car. (a) Centripetal acceleration is found by the following formula: \[a_c=\frac{v^2}{r}=\frac{25^2}{200}=3.125\quad {\rm \frac{m}{s^2}}\](b) The force along this direction is found using Newton's second law of motion as follows: \[F_c=ma_c=2000\times 3.125=6250\quad {\rm N}\](c) When a car turns a curve, it experiences a centripetal acceleration toward the center of the curve. The force causing this acceleration for a car around a curve is static friction force. If the static friction force is not great enough, the car will skid out of the curve and followa nearly straight line. In this situation, the static friction must be balanced with theforce needed to produce the given centripetal acceleration. On the other hand, recall that the maximum value of static friction force is given by $f_{s, max}=\mu_s N$, where N is the normal force on the car,which is equal to the weight mg (only for flat circular tracks). Thus, \begin{align*} \mu_s (mg)&=\frac{mv^2}{r}\\\\ \Rightarrow \mu_s&=\frac{v^2}{rg}\\\\&=\frac{25^2}{200\times 9.8}\\\\&=0.32\end{align*} Therefore, the car can make a safe round if the coefficient of static friction is greater than this value. Practice these questions to understand friction force:Problems on the coefficient of friction Problem (10): A 1500-kg car moves around a flat circular track with a radius of 30 m. The coefficient of friction between the car's tires and the road is 0.3. Find the maximum speed at which the car turns the track. Solution: The static friction between the car's tires and the road provides the force required for turning the car around the circular track. The maximum value of the static friction force formula is $f_{s, max}=\mu_s N$, where N is the force exerted on the car from the surface of the road,which is called the normal force. By setting Newton's second law in the vertical direction to zero (because the car does not fly!), we can find the normal force as below \[N- mg=0 \Rightarrow N=mg\] Next, apply Newton's second law of motion again to the radial direction. Because the car moves around a curve, it experiences centripetal acceleration provided by static friction. Thus, \begin{align*} f_{s,max}&=\frac{mv^2}r \\ \\\mu_s (mg)&=\frac{mv^2}r\\\\ \Rightarrow\quad v&=\sqrt{r\mu_s g}\\\\&=\sqrt{30\times (0.3)\times 9.8}\\\\&=9.4\quad {\rm \frac ms}\end{align*} Problem (11): A car is to turn a curved track with a radius of 120 m at a speed of 85 km/h. How large must the coefficient of static friction be between the car's tire and the road to maintain safe travel? Solution: The forces on the car are the downward gravity force(mg), the normal force (N) exerted upward by the road, and the static friction force due to the road. All these forces are shown in the free-body diagram below. In the vertical direction, there is no acceleration. By applying Newton's second law, we find that the gravity force equalsthe normal force. \[\Sigma F_y=0 \rightarrow N-mg=0 \Rightarrow N=mg\] In the radial direction, the net force required to keep the car on a circular path is found using the centripetal force formula, $F_c=\frac{mv^2}{r}$. This force must be balanced by the static friction force to guarantee a safe turn. Thus, the required condition for not skidding on the curve is as follows: \[F_c=f_{s,max}\] where $f_{s,max}=\mu_s N$ is the maximum value of the friction force. Therefore, \begin{align*} \frac{mv^2}{r}&=\mu_s (mg) \\\\\Rightarrow \quad \mu_s&=\frac{v^2}{r\,g}\\\\&=\frac{(23.6)^2}{10\times 120}\\\\&=0.4\end{align*} In the above, we converted "km/h" to "m/s" as follows: \[85\,{\rm \frac{km}{h}}=85\,\rm{\left(\frac{1000\,m}{3600\,s}\right)}=23.6\,{\rm \frac ms}\]Therefore, the coefficient of static friction must be at least 0.4 to maintain the safe turn. Problem (12): A 2-kg bucket at the end of a rope is circulated in a vertical plane with a radius of 1.5 m. The tension of the rope at the lowest point of the path is 30 N. Calculate(a) The speed of the bucket.(b) How fast must the bucket at the top of the path move so that the rope does not go slack? Solution: The gravity force, mg, and the tension in the rope are exerted on the bucket, which ismoving in a circular motion. A free-body diagram shows these forces below. (a) Apply Newton's second law at the lowest point of the path to find the equation governing that point. We choose the upward direction as positive because it is in the direction of centripetal acceleration (radially inward). \begin{align*} T-mg&=\frac{mv^2}{r}\\\\ 30-2(10)&=\frac{2\times v^2}{1.5}\\\\ 10\times 1.5&=2v^2\\\\\Rightarrow v&=2.8\,{\rm \frac ms}\end{align*}(b) The sum of the forces at the highest point of the circle, using Newton's second law, is written as below (down is considered as positive) \begin{align*} T+mg&=\frac{mv^2}r\\\\ \Rightarrow v&= \sqrt{\frac{r(T+mg)}{m}}\end{align*} If we set $T=0$ in the above, the rope is on the verge of going slack. Therefore, \[v= \sqrt{\frac{r(T+mg)}{m}}= \sqrt{\frac{(1.5)(0+2\times 10)}{2}}=3.8\,{\rm \frac ms}\] Problem (13): A jet plane moves around a vertical circular loop. Its speed at the lowest point of the circle is 950 km/h. Find the minimum radius of the circular path so that the (centripetal) acceleration exerted on it does not exceed 5 g's. Solution: The jet moves around a circular path and must experience centripetal acceleration. Set this acceleration to $5g$ and solve for r.Thus, we have \begin{align*} a_c&=5g \\\\\frac{v^2}{r}&=5g \\\\\Rightarrow r&=\frac{v^2}{5g}\\\\&=\frac{(950\,\frac {km}{h})\left(\frac{1000\,m}{3600\,s}\right)}{5(9.8)}\\\\&=1421\,{\rm m}\end{align*}(b) The weight of the pilot is 75 kg. What is its apparent weight at the bottom and top of the circle? The apparent weight is the normal force exerted on the pilot,which changes due to the centripetal force required to keep the pilot in circular motion. Two forces act on the pilot. One is the downward gravity force, mg, and the other is the upward normal force at the lowest point of the circular path.These two forces acting on the pilot are shown in the free-body diagram below. The vector sum of these two forces provides the centripetal acceleration around the curved path. Thus, the net force equation at the bottom is \[N-mg=m\frac{v^2}{r}\] where the direction of the acceleration (radially inward) at this point is chosenas the positive direction. Therefore, \begin{align*} N_{bottom}&=mg+mv^{2}/r\\ &=mg+m(5g)\\&=6mg\\&=6(75) (9.8)\\&=4410\,{\rm N}\end{align*} In all such vertical circular problems, the normal force is the apparent weight. At the top of the circle, the centripetal force is directed downward, and the normal force has to counteract the gravitational force and provide the centripetal force. \begin{gather*} N_{top}+mg=m\frac{v^2}{r} \\\\ N_{top}=m(5g)-mg \\\\ \Rightarrow \quad N_{top}=4mg \end{gather*}The apparent weight at the top is approximately 2940 N. Problem (14): A highway curve with a radius of 800.0 feet is to be banked so that a car traveling at 60.0 mph will not skid sideways even in the absence of friction. (a) Draw a free-body diagram of this car. (b) At what angle should the curve be banked? Solution: The following are the forces acting on the car:Gravitational Force (mg): Acts vertically downward due to the car's weight.Normal Force (N): Acts perpendicular to the surface of the banked curve, providing the support force.Centripetal Force (F_c): Acts horizontally inward towards the center of the circular path, responsible for keeping the car moving in a curve. Note that in all banked tracks, the horizontal component of the normal force provides the centripetal force, i.e., $N\sin\theta=F_c$. Thus, in your free-body diagram, F_c should not be included separately as a new force. Since we're dealing with distances in feet (radius of the curve in feet), its necessary to convert all measurements to the same unit system. Convert 60.0 mph to feet per second for consistent units as follows: \[v=\rm{60\,mph\times \frac{5280\,ft}{1\,mil}\times \frac{1\,hour}{3600\,s}=88\,ft/s}\] The components equations from Newton's second's law are: \begin{gather*} N\sin\theta=m\frac{v^2}{r} \\\\ N\cos\theta+(-mg)=0 \end{gather*} Dividing these two expressions by each other, we arrived at the well-know banked track equation \[\tan\theta=\frac{v^2}{gr}\] This equation shows the banking angle needed for a car to navigate a curve without relying on friction. Plugging in the given values and solving for θ using the inverse tangent function yields \begin{gather*} \tan\theta=\rm{\frac{(88\,ft/s)^2}{800\,ft\times 32.2\,ft/s^2}} \\\\ \Rightarrow \theta=\tan^{-1}(0.3) \approx 16.7^\circ \end{gather*} The curve should be banked at an angle of approximately 17°. Problem (15): The radius of a highway curve banked at an angle of 13° is 75 m. At what speed can a car make a turn this curve without the help of friction? Solution:To solve this problem, we can use the concept of centripetal force. When a car turns on a curved road, the centripetal force required to keep it moving in a circle is provided by the friction between the tires and the road surface. However, in this case, we are asked to find the speed at which the car can make the turn without relying on friction. This means that there is no horizontal component of friction acting on the car. Two real forces act on the car:the force of gravity, and the normal force $\vec{N}$. Establish a coordinate system suchthat the centripetal force lies in the radial direction, as depicted in the figure below. The normal force can be resolved into two components. The horizontal component of the normal force provides the necessary centripetal force in this situation. The y-component of the normal force cancels out with gravity, while the radial component provides the centripetal force. Like in the previous problem, the banked angle is given as follows: \[\tan\theta=\frac{v^2} {rg}\]Rearranging this andsolving for v, thensubstituting the given numerical values,yields: \begin{align*} v&=\sqrt{rg\tan\theta}\\\\ &=\sqrt{75\times 9.8\times \tan 13^\circ} \\\\ &=13.02\,\rm m/s\end{align*} Therefore, the car can make the turn on this curve without the help of friction at a speed of approximately 13 m/s. Problem (16): A child is swinging a ball tied to a string in a horizontal circle at a height of 3 meters above the ground. The length of the string is 1.2 meters. Suddenly, the string breaks and the ball flies off horizontally, landing 8 meters away from the point where the string broke. Solution: Once the string breaks, the stone's trajectory can be analyzed using the principles of projectile motion. The horizontal velocity remains constant throughout its flight, while the stone begins to fall under the influence of gravity. (a) How long did it take for the ball to hit the ground after the string broke? To determine the time it takes for the ball to hit the ground after the string breaks, we use the formula for the time of flight in free fall motion: \begin{gather*} h=\frac 12 gt^2 \\\\ 3=\frac 12 (9.8)t^2 \\\\ \Rightarrow \quad t=\sqrt{\frac{3}{4.9}}\approx 0.78\quad\rm s\end{gather*}(b) What was the horizontal velocity of the ball just before the string broke? After the string breaks, the ball travels a horizontal distance of 8 meters with uniform speed:\[v=\frac{d}{t}=\frac{8} {0.78}=10.26\quad\rm m/s\] This is the speed just before the string breaks when it was undergoing uniform circular motion. (c) What was the centripetal acceleration of the ball while it was in circular motion?The centripetal acceleration before the string breaks is given by: \begin{align*} a_c&=\frac{v^2}{r}\\\\ &=\frac{(10.26)^2}{1.2} \\\\ &\approx 87.72\quad\rm m/s^2 \end{align*} Therefore, The centripetal acceleration of the ball while it was in circular motion is approximately $87.73\,\rm m/s^2$. Problem (17): An electron is moving in a circular track with a radius of 2 mm at a speed of $2\times 10^{6}\,{\rm m/s}$. Find(a) The period of the revolutions;(b) The centripetal acceleration experienced by the electron. Solution: (a) An electron, moving at a speed of$2\times 10^6 \,{\rm m/s}$, covers a distance equal to thecircumference of the circle every second. Recall that the circumference of a circle with radius r is $2\pi r$. We must first determine how many times the electron revolves around this circular track. \[L=N(2\pi r)\Rightarrow N=\frac{L}{2\pi r}\] The period T is the time it takes the electron to complete one revolution. According to this definition, we have \[T=\frac{1}{N}=\frac{2\pi r}{L}\] Using this formula, we can find the period of the electron as \[T=\frac{2\pi\times (0.002)}{2\times 10^6}=6.3\times 10^{-9}\,{\rm s}\] Hence, the period of the electron is approximately $6\,{\rm ns}$ (nanoseconds). (b) The electron moves in a circular motion, and itscentripetal acceleration is calculated as follows: \[a_c=\frac{v^2}{r}=\frac{(2\times 10^6)^2}{0.002}=2\times 10^{15}\quad {\rm \frac{m}{s^2}}\] Problem (18): A 0.45-kg ball is fastened to a rope and is swung in a horizontal plane (without friction) around a circle of radius1.3 m. When the tension in the rope exceeds 75 N, the rope is broken. What is the maximum speed the ball can have at this point? Solution: In this circular motion problem, the only force causing the centripetal acceleration is tension in the rope. By applying the centripetal force formula, $F_c=mv^2/r$, and solving for unknown speed v, we get \[v=\sqrt{\frac{rF_c}{m}}=\sqrt{\frac{1.3\times 75}{0.45}}=14.7\,{\rm \frac ms}\] Problem (19): What is the acceleration of a stone attached to the end of a 2-m-long rope revolving at 45 revolutions per minute (rpm)? Solution: The stone has a circular motion with the given constant speed. In this problem, the speed of a revolving object is given in rpm or angular speed. To use the centripetal acceleration formula, $a_c=v^2/r$, we need speed in m/s. To convert angular speed (rpm) into linear speed (m/s), we proceed with the followingformula: \[v(m/s)=r\times (rpm)\times \frac{2\pi}{60}\] Therefore, the angular speed of "45 rpm" is converted into "m/s" as follows: \[v=2\times \frac{2\pi\times 45}{60}=9.5\,{\rm \frac ms}\] Now, we can plug this value into the centripetal acceleration formula: \[a_c=\frac{v^2}{r}=\frac{(9.5)^2}{2}=45.1\quad {\rm \frac{m}{s^2}}\] Problem (20): A car moves along a curved path as shown in the following figure. When the car reaches the bottom of the track, find(a) the normal force exerted on the carand(b) the effective weight (apparent weight) of the car. Solution: At the bottom of the curved path, the forces acting on the car are:the downward gravitationalforce, mg,the upward force due to the contact between the car and the surface, which is known as the normal force, N, and the centripetal force F_c acting towards the center of the circular path, which in this case is upwards as well. The car rounds a curve, so it experiences a centripetal force F_c radially inward in the same direction as centripetal acceleration. At the bottom of the track, this force is directed upward. It is better to choose the direction of the centripetal acceleration as positive and apply Newton's second law in this direction. (a) The centripetal force required to keep the car moving in a curve is provided by the net force exerted on the car. Therefore, the normal force must counteract both the gravitational force and provide the necessary centripetal force:\begin{gather*} N-mg=\frac{mv^2}{r} \\\\ \Rightarrow N=mg+\frac{mv^2}{r} \end{gather*} (b)The effective weight or apparent weight of the car is exerted by the normal force on the car at the bottom of the path. As calculated in part (a), the apparent weight is equal to the normal force N. Therefore, \[\text{apparent weight}=mg+\frac{mv^2}{r}\] Problem (21): A centripetal force F is exerted on an object moving around a circular track with a constant speed v. If the speed of the object is tripled and the radius of the track is quadrupled, what happensto the centripetal force? Solution: The centripetal force in a circular motion is given by the equation $F_c=\frac{mv^2}{r}$. As you can see, this kind of force is proportional directly to the speed of the curved path. The problem says $v_2=3v_1$ and $r_2=4r_1$. Thus, \begin{align*} \frac{F_2}{F_1}&=\left(\frac{v_2}{v_1}\right)^2 \frac{r_1}{r_2}\\&=\left(\frac{3v_1}{v_1}\right)^2 \frac{r_1}{4r_1}\\&=\frac{9}{4}\end{align*} Hence, the force becomes 2.25 times the original force. \[F_2=\frac 94 F_1\] Problem (22): A stone is attached to the end of a rope of length L and rotates in a vertical circle. At the top of the path, the tension in the rope is twice the weight of the stone.(a) Determine the net force on the stone when it reaches the highest point of the path.(b) What is the speed of the stone at this point?After a few circles, when the stone is at the top of the circle, the rope is broken.(c) Determine the time it takes the stone to hit the ground.(d) Find the horizontal distance traveled by the stone before striking the ground. Solution:This is left up to you to solve. Summary: In this article, we learned how to solve problems involving uniform circular motion.The most important notes we practiced were as follows: An object moving in a circular path of radius r at constant speed v experiences a centripetal acceleration $a_c=\frac{v^2}{r}=r\omega^2$ and its direction is toward the center of the circle. Uniform circular motion is an example that shows that acceleration and velocity are not always in the same direction. In such motions, $\vec{a}$ and $\vec{v}$ are perpendicular. Author: Dr. Ali NematiDate Published:7-31-2021Updated: Dec 12, 2024 Share copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. 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