

- 1.) Identify the following as either a scalar or a vector and give the units of each:
- Speed **scalar**, m/s
  - Acceleration **vector**, m/s<sup>2</sup>
  - Kinetic energy **scalar**, J
  - Momentum **vector**, kg m/s
  - Velocity **vector**, m/s
  - Displacement **vector**, m
  - Force **vector**, N
  - Torque **vector**, Nm
  - Distance **scalar**, m
- 2.) From the top of a cliff, a person uses a slingshot to fire a pebble straight downward. The initial speed of the pebble is 9.0 m/s. What is the acceleration of the pebble during the downward motion? Is the pebble decelerating? Explain. After 0.5 s, how far beneath the cliff top is the pebble?  
Remember to define a coordinate axis and make sure your known quantities have signs consistent with your axis!

Once the pebble has left the slingshot, it is subject only to the acceleration due to gravity. Since the downward direction is negative, the acceleration of the pebble is  $-9.8\text{m/s}^2$ . The pebble is not decelerating. Since its velocity and acceleration both point downward, the magnitude of the pebble's velocity is increasing, not decreasing.

The displacement  $y$  traveled by the pebble as a function of time  $t$  can be found from Equation 2.8. Using this we have

$$y = v_0 t + \frac{1}{2} a_y t^2 = (-9.0\text{ m/s})(0.5\text{ s}) + \frac{1}{2} [(-9.8\text{ m/s}^2)(0.5\text{ s})^2] = -5.7\text{ m}$$

Thus, after 0.50s, the pebble is 5.7 m beneath the cliff top.

- 3.) When a projectile is thrown at a speed  $v_0$  at an angle above the horizontal, which component of the launch velocity determines the maximum height reached by the projectile? Do the horizontal and vertical components of launch velocity have larger or smaller values than  $v_0$ ? If the projectile is thrown straight upward at a speed  $v_0$ , does it attain greater or lesser height than when it was thrown at an angle?

The vertical component of the launch velocity determines the maximum height attained by the projectile. The horizontal component determines the range of the projectile, not the height. The magnitudes of the components are smaller than  $v_0$ . The reason is that these components are given by  $v_0$  times the trigonometric sine or cosine function, and these functions are always less than one. When thrown straight upward at speed  $v_0$ , the projectile attains a greater height than when launched at an angle. The reason is that when the projectile is thrown straight upward, the entire velocity is directed upward, rather than just a component of it. With more of the velocity directed upward, the projectile naturally goes higher.

- 4.) The earth exerts a gravitational force on a raindrop. Does the raindrop exert a gravitational force on the earth, pulling it up? If so, is this force greater than, less than, or equal to the force that the earth exerts on the raindrop?

Yes, the raindrop exerts a gravitational force on the earth. This gravitational force is equal in magnitude to the gravitational force that the earth exerts on the raindrop. The forces that the raindrop and the earth exert on each other are Newton's third law (action-reaction) forces.

- 5.) Chapter 5, Problem 48: A 9.5 kg monkey is hanging by one arm from a branch and is swinging in a vertical circle. As an approximation, assume a radial distance of 85 cm between the branch and the point where the monkey's mass is located. As the monkey swings through the lowest point on the circle, it has a speed of 2.8 m/s. Find a) the magnitude of the centripetal force acting on the monkey and b) the magnitude of the tension in the monkey's arm.

The centripetal force is the name given to the net force pointing toward the center of the circular path. At the lowest point the net force consists of the tension in the arm pointing upward toward the center and the weight pointing downward or away from the center. In either case the centripetal force is given by Equation 5.3 as  $F_c = mv^2/r$ .

a.) The centripetal force is  $F_c = \frac{mv^2}{r} = \frac{(9.5\text{kg})(2.8\text{m/s})^2}{0.85\text{m}} = 88\text{N}$

- b.) Using T to denote the tension in the arm, at the bottom of the circle we have

$$F_c = T - mg = \frac{mv^2}{r}$$

$$T = mg + \frac{mv^2}{r} = (9.5\text{kg})(9.80\text{m/s}^2) + \frac{(9.5\text{kg})(2.8\text{m/s})^2}{0.85\text{m}} = 181\text{N}$$

- 6.) A monkey on ice skates slides down an icy roof and falls to the ground. Is the net work done by friction positive, negative, or zero? Is the net work done by gravity positive, negative, or zero? He then tries to climb the drainpipe in order to start the game again. Is the net work done by friction in this case positive negative or zero? By gravity?

In the first case, the net work done by friction is negative and the work done by gravity is positive. In the second case, the work done by friction is positive and the work done by gravity is negative. Remember that the sign is determined by comparing the direction of the force and the direction of motion. In the first case, the monkey is sliding down the roof and friction is opposing this motion by pointing in the opposite direction, thus the angle between the motion and the force is 180 degree. When the monkey is falling from the roof, gravity and motion are in the same direction, thus the angle between them is 0 degree. When the monkey attempts to climb the drainpipe (must be hard to do in ice skates) the force of friction must point upwards to keep the ice skates from slipping down the drainpipe. Thus, the force of friction points in the same direction as the motion and therefore the work done is positive. The force of gravity (always down) is opposite the direction of motion and thus the work done is negative.

- 7.) Chapter 7 Problem 54: A person stands in a stationary canoe and throws a 5.00 kg stone with a velocity of 8.00 m/s at an angle of 30 degrees above the horizontal. The person and canoe have a combined mass of 105 kg. Ignoring air resistance and effects of the water, find the horizontal recoil velocity.

The conservation of momentum law applied in the horizontal direction gives

$$m_c v_{fc} + m_s v_{fs} \cos(30.0^\circ) = 0$$

$$v_{fc} = \frac{-m_s v_{fs} \cos(30.0^\circ)}{m_c} = \frac{-(5.00 \text{ kg})(8.00 \text{ m/s}) \cos(30.0^\circ)}{105 \text{ kg}} = -0.330 \text{ m/s}$$

The magnitude of the velocity is 0.330 m/s. The minus sign indicates that the direction is opposite the horizontal velocity component of the stone.

- 8.) A volleyball is spiked so that its incoming velocity of +4 m/s is changed to an outgoing velocity of -21 m/s. The mass of the volleyball is 0.35 kg. What impulse does the player apply to the ball?

The impulse that the volleyball player applies to the ball can be found from the impulse-momentum theorem, Equation 7.4. Two forces act on the volleyball while it's being spiked: an average force  $F$  exerted by the player, and the weight of the ball. As in Example 1, we will assume that  $F$  is much greater than the weight of the ball, so the weight can be neglected. Thus, the net average force is equal to  $F$ . From the impulse momentum theorem, the impulse that the player applies to the volleyball is

$$F\Delta t = mv_f - mv_0 = 0.35 \text{ kg} [(-21 \text{ m/s}) - (+4.0 \text{ m/s})] = -8.7 \text{ kgm/s}$$

The minus sign indicates that the direction of impulse is the same as that of the final velocity of the ball.

- 9.) Chapter 8, Problem 7: A CD has a playing time of 74 minutes. When the music starts, the CD is rotating at an angular speed of 480 revolutions per minute. At the end of the music, the CD is rotating at 210 rpm. Find the magnitude of the average angular acceleration of the CD. Express your answer in  $\text{rad/s}^2$ .

Using Equation 8.4 and the appropriate conversion factors, the average angular acceleration of the CD in  $\text{rad/s}^2$  is

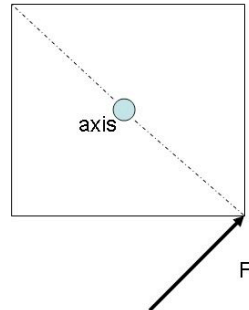
$$\bar{\alpha} = \frac{\Delta\omega}{\Delta t} = \left( \frac{210 \text{ rev/min} - 480 \text{ rev/min}}{74 \text{ min}} \right) \left( \frac{2\pi \text{ rad}}{1 \text{ rev}} \right) \left( \frac{1 \text{ min}}{60 \text{ s}} \right)^2 = -6.4 \times 10^{-3} \text{ rad/s}^2$$

The magnitude of the average angular acceleration is  $6.4 \times 10^{-3} \text{ rad/s}^2$ .

- 10.) Re-express the kinematic equations in terms of rotational motion.

See page 229; Table 8.1

- 11.) A square, 0.40 m on a side, is mounted so that it can rotate about an axis that passes through the center of the square. The axis is perpendicular to the plane of the square. A force of 15 N lies in this plane and is applied to the square. What is the magnitude of the maximum torque that such a force could produce?



The maximum torque will occur when the force is applied perpendicular to the diagonal of the square as shown. The lever arm  $l$  is half the length of the diagonal. From the Pythagorean theorem, the lever arm is therefore,

$$l = \frac{1}{2} \sqrt{(0.40\text{m})^2 + (0.40\text{m})^2} = 0.28\text{m}$$

Since the lever arm is now known, we can use Equation 9.1 to obtain the desired result directly.

$$\tau = Fl = (15\text{N})(0.28\text{m}) = 4.2\text{Nm}$$

- 12.) Chapter 9, Problem 77: Two thin rods of length  $L$  are rotating with the same angular speed about axes that pass perpendicularly through one end. Rod A is massless but has a particle of mass 0.66 kg attached to its free end. Rod B has a mass of 0.66kg, which is distributed uniformly along its length. Which has the greater moment of inertia? Which has the greater rotational kinetic energy?

According to Equation 9.6, the moment of inertia for rod A is just that of the attached particle, since the rod itself is massless. For rod A with its attached particle, then, the moment of inertia is  $I_A = ML^2$ . According to Table 9.1, the moment of inertia for rod B is  $I_B = 1/3 ML^2$ . The moment of inertia for rod A with its attached particle is greater. Since the moment of inertia for rod A is greater, its kinetic energy is also greater, according to Equation 9.9  $KE_R = \frac{1}{2} I \omega^2$ .

- 13.) One end of a meter stick is pinned to a table, so the stick can rotate freely in a plane parallel to the tabletop. Two forces, both parallel to the tabletop, are applied to the stick in such a way that the net torque is zero. One force has a magnitude of 2.00 N and is applied perpendicular to the length of the stick at the free end. The other force has a magnitude of 6.00 N and acts at a 30 degree angle with respect to the length of the stick. Where along the stick is the 6.00 N force applied? Express the distance with respect to the end that is pinned. N

Since the meter stick does not move, it is in equilibrium. The forces and the torques, therefore, each add to zero. We can determine the location of the 6.00N force, by using the condition that the sum of the torques must add to zero.

If we take counterclockwise torques as positive, then the torque of the first force about the pin is

$$\tau_1 = F_1 l_1 = (2.00\text{N})(1.00\text{m}) = 2.00\text{Nm}$$

The torque due to the second force is

$$\tau_2 = -F_2 \sin(30.0^\circ) l_2 = -(6.00\text{N}) \sin(30.0^\circ) l_2 = (-3.00\text{N}) l_2$$

The torque is negative because the force F2 tends to produce a clockwise rotation about the pinned end. Since the net torque is zero, we have

$$2.00\text{Nm} + [-(3.00\text{N}) l_2] = 0$$

$$l_2 = \frac{2.00\text{Nm}}{3.00\text{N}} = 0.667\text{m}$$