AP Physics C: Mechanics
Unit 2 Practice Exercises

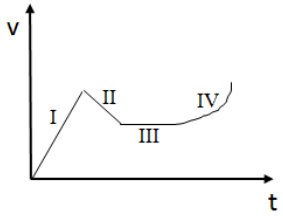
Directions: Show the steps required to arrive at the answer (if applicable). Use g = 9.80 m/s^2 and neglect air resistance unless otherwise stated. Work out the problems on separate page.

2.1 – Newton's Laws

1. A 40 kg mine-cart is rolling at a speed of 2 m/s. If the speed of the cart is doubled, what happens to the inertia of the cart? Justify you answer.

2. A car is moving with a constant velocity of 20 m/s. What is the net force acting on the car? Justify your answer.

3. Consider the velocity vs. time graph shown. List the intervals that fit each description.



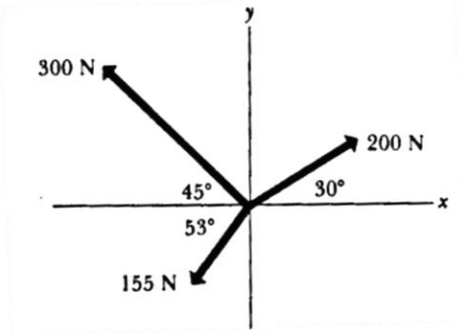
a) A constant, non-zero force is applied to the object.
b) A non-zero force acts in the direction the object is moving.
c) The net force on the object is zero.
d) A variable force is applied to the object.

4. A 35 kg mass is pulled across a nearly frictionless surface. The mass is pulled to the right by a 45 N force that makes an angle of 25° with the horizontal. The mass has a velocity of 5.0 m/s to the right at time t= 0.
a) What is the acceleration of the mass?
b) How far does the mass have to be pulled before its velocity is 12 m/s?

5. A 320 kg sailboat experiences a force of 460 N from the wind. The water exerts a force of 230 N to the east.
a) Find the magnitude and direction of the boat's acceleration.
b) If the boat starts from rest, find its velocity after 5 s.

6. Describe two examples in which the force of friction exerted on an object is in the direction of motion of the object.

7. The three forces in the diagram act on an object at the origin.



a) Find the resultant of the three forces.
b) Find the magnitude and direction of the equilibrant force.

8. An object of mass 2 kg moves in the xy plane such that it's x and y coordinates vary according to:

$$x(t) = 2\,m - (5\,\frac{m}{s^3})t^3 \qquad y(t) = (16\,\frac{m}{s^2})t^2$$

a) Calculate the resultant force in the x and y directions, as functions of time.
b) What are the magnitude and direction o the resultant force at time t = 3.0 s?

9. The force on a particle is given by $F(t) = ke^{\alpha t}$. $v(0) = 0; x(0) = 0$
a) Determine an expression for the particle's velocity over time.
b) Determine an expression for the particles position over time.

2.2 – F=ma

1. A hockey puck leaves a player's stick with a velocity of 10 m/s and slides 40 m before coming to rest. What is the coefficient of friction between the block and the ice?

2. A box of penguins weighing 60 N rests on a horizontal surface. The coefficient of static friction between the box and the surface is 0.40, and the coefficient of sliding friction is 0.20.

a) How great will the friction force be if a horizontal force of 18 N is exerted on the box?
b) How great will the friction force be if a horizontal force of 30 N is exerted on the box?
c) What is the minimum force that will start the box in motion?
d) What is the minimum force that will keep the box in motion once it is started?

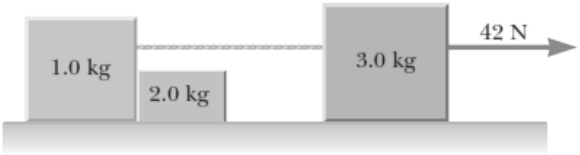
3. A woman at an airport is towing her 20.0-kg suitcase at constant speed by pulling on a strap at an angle θ above the horizontal. She pulls on the strap with a 35.0-N force, and the coefficient of kinetic friction between the ground and the suitcase is .20.

a) Draw a free body diagram of the suitcase.
b) What angle does the strap make with the horizontal?
c) What is the magnitude of the normal force that the ground exerts on the suitcase?

4. Before an upcoming Mu Alpha Theta competition, the elevator of Suncoast is overloaded with trophies and the total mass is 2000 kg. The elevator cable has a breaking strength of 24,000 N.

a) What is the maximum upward acceleration for the elevator if the cable does not break?
b) When the elevator accelerates downward at 1.2 m/s^2, what will be the apparent weight will a 50 kg student?

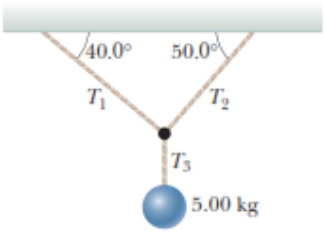
5. Assume the three blocks portrayed in the figure move on a frictionless surface and a 42-N force acts as shown on the 3.0-kg block.



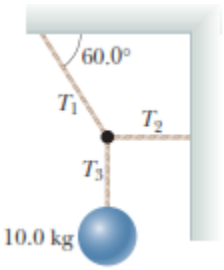
a) Determine the acceleration of the system
b) Calculate the tension connecting the 3.0-kg and the 1.0-kg blocks.
c) Calculate the force exerted by the 1.0-kg block on the 2.0-kg block.

6. The figures below shows loads hanging from the ceiling of an elevator that is moving at constant velocity. Find the tension in each of the three strands of cord supporting each load.

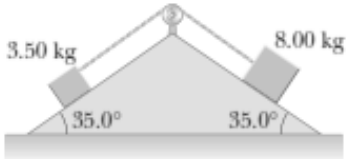
a)



b)



7. Two blocks of mass 3.50 kg and 8.00 kg are connected by a massless string that passes over a frictionless pulley. The inclines are frictionless and make angles of 35° with the horizontal as shown below.

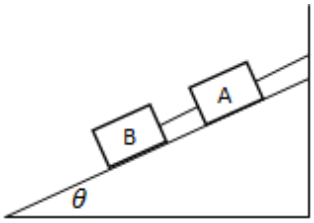


a) Find the magnitude of the acceleration of each block.
b) Calculate the tension in the rope.

8. Two blocks, each of mass M, are held in place on a frictionless incline that makes an angle of θ with the horizontal, as shown in the figure on the right.

a) Calculate the tension connecting block A to the wall.

b) Calculate the tension connecting blocks A and B.



9. A man is pushing a piano of mass 160 kg at constant velocity up a ramp that is inclined 20° above the horizontal. The coefficient of kinetic friction between the piano and incline is .30. What is the magnitude of the force required by the man if:

a) he pushes parallel to the incline?

b) he pushes directly horizontally?

10. A crate rests on an inclined plane that makes an angle θ with the horizontal. The coefficient of sliding friction is 0.50, and the coefficient of static friction is 0.75.

a) Find the minimum angle for which the crate starts to slip.

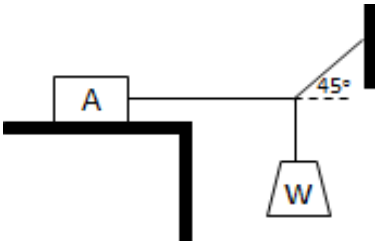
b) At this angle, find the acceleration once the crate begins to move.

c) How much time will it take the crate to slip 10 m down the incline?

11. Refer to the diagram on the right. Block A has a mass of 10.0 kg and the coefficient of static friction between the block and the surface is 0.30.

a) If the weight w is 20 N, what is the friction force exerted on block A?

b) Find the maximum weight w for which the system will remain in equilibrium.

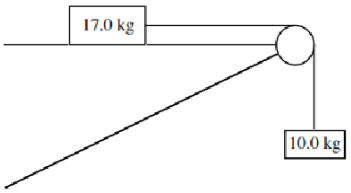


12. The coefficient of sliding friction between the block and the horizontal surface is 0.48. The initial velocity of the 17.0 kg block is 3.00 m/s to the right.

a) Draw a separate free body diagram for each block.

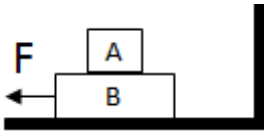
b) What is the acceleration of the 10.0 kg block?

c) What is the tensions in the rope?

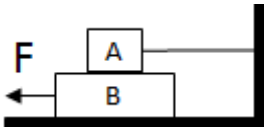


13. Block A, weighing 4.0 N, is placed on top of block B, which weighs 8.0 N. The coefficient of sliding friction between all surfaces is 0.25. Find the force F necessary to drag block B to the left at constant speed if:

a) A rests on B and moves with it?



b) if A is held at rest as shown?



2.3 – Resistive Forces

1. An object of mass m moving along the x-axis with velocity v is slowed by a force F = -kv, where k is a constant. At time t = 0, the object has velocity v_o at position x = 0, as shown above.

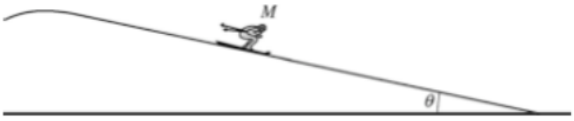
a) What is the initial acceleration (magnitude and direction) produced by the resistance force?

b) Derive an equation for the object's velocity as a function of time t, and sketch this function on the axes below. Let a velocity directed to the right be considered positive.

c) Derive an equation for the distance the object travels as a function of time t and sketch this function on the axes below.

d) Determine the distance the object travels from t = 0 to t = ∞.

2. A skier of mass M is skiing down a frictionless hill that makes an angle θ with the horizontal, as shown below. The skier starts from rest at time t = 0 and is subject to a velocity-dependent drag force $F = -bv$, where v is instantaneous velocity and b is a positive constant.



a) Write a differential equation that can be used to solve for the velocity of the skier vs. time.

b) Determine an expression for the terminal velocity of the skier.

c) Solve the differential equation from part a).

3. A rubber ball of mass m 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 magnitude bv^2, where b is a constant drag coefficient and v is the instantaneous speed of the ball. The drag coefficient b 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 a label free body diagram of all the forces on the ball at some instant before it reaches terminal speed.

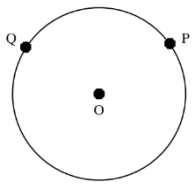
b) State whether the magnitude of the acceleration of the ball of mass m increases, decreases, or remains the same as the ball approaches terminal speed. Explain

c) Write, but do NOT solve, a differential equation for the instantaneous speed v of the ball in terms of time t, the given quantities, and fundamental constants.

d) Determine the terminal speed v_t in terms of the given quantities and fundamental constants.

2.4 – Circular Motion

1. An object is tied to a string and traveling in a counterclockwise circle path at constant speed on a frictionless surface.



a) Draw a vector representing the direction of the object's velocity at point P.

b) Draw a vector representing the direction of the object's acceleration at point P.

c) Sketch an arrow representing the path of the object if the string breaks at point Q.

2. An object of mass *m* moves in a circular path with a constant speed *v*. The centripetal force on the object is *F*. If the objects speed were halved and the mass was tripled, the centripetal force would be _____.

3. For a ball in a vertical circle, which of the following does the velocity depend on?

i) the acceleration due to gravity

ii) the mass of the ball

iii) the force the string exerts on the ball

iv) the radius of the vertical circle

4. A 3.5 kg mass is swung horizontally in a circle of radius 2.9 m. The centripetal force supplied by the rope is 17 N. What is the period of the mass's motion?

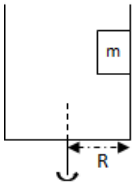
5. An object travels around a circular path 2.0 times in 8.0 seconds. What is the frequency and period of the motion?

6. What is the centripetal force exerted on a 1.5 kg object that is spinning at 250 rev/min? The object is .15 m from the axis of rotation of a centrifuge.

7. A 4000 kg train travels at 100 km/h on a circular track with a radius of 800 m. What force does the track exert on the train?

8. A flat, unbanked curve on a highway has a radius of 240 m and the car rounds a curve of 22 m/s. What must be the minimum coefficient of friction to prevent sliding?

9. The cylindrical container shown on the right rotates around an axis in its center. A small mass is pinned against the wall of the container so it does not slip. The coefficient of friction between the mass and container wall is .20 and the radius of the container is 1.2 m. What is the minimum rotation rate of the container so the mass does not slip?



10. A highway curve that has a radius of curvature of 100 meters is banked at an angle of 15°.

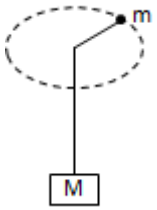
a) Determine the vehicle speed for which this curve is appropriate if there is no friction between the road and the tires of the vehicle.

On a dry day when friction is present, a car successfully negotiates the curve at a speed of 25 m/s.

b) Draw a free body diagram of the car on the curve

c) Determine the minimum coefficient of friction necessary to keep this car on the curve without sliding.

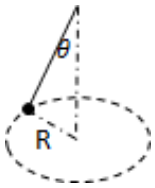
11. A stone of mass m = 1.5 kg is whirled in a horizontal circle of radius R = 2.5. The stone travels at a constant speed of 12 m/s. A mass is attached to the other end of the string and is free to move up at down.



a) What is the period of the stone's motion?

b) What is the mass of M if R is kept constant?

12. A stone travels in a horizontal circle of radius R. The stone makes f revolutions per second.



a) Write an expression for the angle with the vertical, θ.

b) Find an expression for the tension T in the rope. Do not include θ in your answer.

13. A 40.0-kg child swings in a swing supported by two chains, each 3.00 m long. The tension in each chain at the lowest point is 350 N.

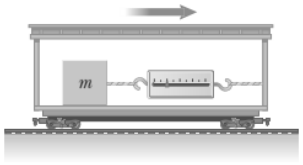
a) Find the child's speed at the lowest point.

b) Find the force exerted by the seat on the child at the lowest point.

14. A plane makes a vertical loop. At the top of the loop, an 80 kg pilot is pressed against his seat with a force of 260 N. The airspeed indicator reads 160 km/h at the top of the loop. What is the radius of the plane's loop?

2.5 – Accelerating Reference Frames

1. An object of mass 5.00 kg, attached to a spring scale, rests on a frictionless, horizontal surface as shown. The spring scale, attached to the front end of a boxcar, reads zero when the car is at rest.

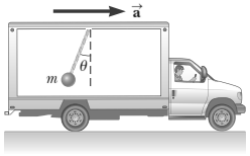


a) Determine the acceleration of the car if the spring scale has a constant reading of 18.0 N when the car is in motion.

b) What constant reading will the spring scale show if the car moves with constant velocity?

c) Describe the forces on the object as observed by i) someone in the car and ii) someone outside the car.

2. An object of mass 0.50 kg is suspended from the ceiling of an accelerating truck. The truck accelerates at a rate of 3.00 m/s^2.



a) Find the angle θ that the string makes with the vertical and

b) Find the tension T in the string.

3. A person stands on a scale in an elevator. As the elevator starts, the scale has a constant reading of 591 N. As the elevator later stops, the scale reading is 391 N. Assuming the magnitude of the acceleration is the same during starting and stopping, determine

a) the weight of the person

b) the person's mass

c) the acceleration of the elevator.

4. A truck is moving with constant acceleration a up a hill that makes an angle $/\emptyset$ with the horizontal as shown. A small sphere of mass m is suspended from the ceiling of the truck by a light cord. If the pendulum makes a constant angle θ with the perpendicular to the ceiling, what is a?