Physics 121 Homework Problems, Spring 2014

1-1. Write out your solution to all parts of this problem neatly on a piece of 8.5 \times 11-inch paper and turn it in at the slotted boxes across the hallway from N373 ESC. Do not put your name on it, only your CID number. Do this in addition to submitting the answers online.

Suppose you want to make a scale model of a hydrogen atom. You choose, for the nucleus, a small ball bearing with a radius of 1 mm. The outer radius of the hydrogen atom is 0.529 \times 10^{-10} \text{ m} and the radius of the nucleus is 1.2 \times 10^{-15} \text{ m}.

(a) What would be the outer radius of the model?
(b) Suppose that now you want to make a scale model of the solar system using the same ball bearing as in part (a) to represent the sun. How far from it would you place a sphere representing the earth? (Center to center distance please.) (See the inside cover of your textbook for data.)
(c) What would be the radius of the sphere representing the earth in part (b)?

[(a) 50, 99 \text{ m} (b) 0.200, 0.500 \text{ m} (c) 1.00 \times 10^{-5}, 2.00 \times 10^{-5} \text{ m}.]

1-2. (a) Atoms are typically spaced about 0.2 nm apart. At that spacing, how many atoms would be found in a line 1 inch long?
(b) How many kg of water are in 1 cubic inches (in^3)?

[(a) 1.0 \times 10^8, 8.0 \times 10^8 (b) 0.010, 0.099 \text{ kg}]

1-3. Consider the following formula: \( x = A \cos(Bt^2) \). \( x \) is in meters and \( t \) is in seconds.

(a) Which of the following must be the units of \( A \)?
1/m, m/rad, m/s^2, m, m s^2.
(b) Which one of the following is the least acceptable units for \( B \)?
degree/s^2, m/s^2, rad/s^2, rev/s^2.

1-4. How many significant figures are in the following numbers?

(a) 7
(b) 6.478 \times 10^{12}
(c) 0.700
(d) 0.0004
2-1. Wilma I. Ball walks at a constant speed of \(0.0\) m/s along a straight line from point A to point B and then back from B to A at a constant speed of 3.15 m/s.
(a) What is Wilma’s average speed over the entire trip?
(b) What is Wilma’s average velocity over the entire trip?
[(a) 3.00, 5.00 (b) \(-5.00, +5.00\)]

2-2. The figure shows position as a function of time for two particles, A and B, moving along parallel straight lines.
(a) Estimate from the figure, the displacement \(\Delta x\) of particle A between \(t = 0\) and \(t = 10\) seconds.
(b) Estimate from the figure, the displacement \(\Delta x\) of particle B between \(t = 0\) and \(t = 10\) seconds.
(c) Estimate the average velocity \(\bar{v}\) of particle A between \(t = 0\) and \(t = 10\) seconds.
(d) Estimate the average velocity \(\bar{v}\) of particle B between \(t = 0\) and \(t = 10\) seconds.
(e) When, approximately, are the particles at the same position?
(f) When, approximately, do the particles have the same velocity?
2-3. A particle moves in such a way that its position \( z \), in meters, is given as a function of \( t \), in seconds, by the equation \( z = c_1t^2 - c_2t^3 \) where \( c_1 = 2.12 \text{ m/s}^2 \) and 
\( c_2 = [02] \text{ m/s}^3 \).
(a) The particle is at \( z = 0 \) twice. What is the time of the second occurrence of \( z = 0 \)?
(b) What is the displacement \( \Delta z \) of the particle between the times \( t = 2.00 \text{ s} \) and \( t = 5.00 \text{ s} \)?
(c) What is the velocity of the particle at \( t = 0.657 \text{ s} \)?
(d) The velocity is also zero twice. What is the time of the second occurrence?
(e) What is the acceleration at \( t = 0.657 \text{ s} \)?
(f) When is the acceleration equal to zero?
(g) When the acceleration is zero, what is the particle’s position?

3-1. Your FHE brother claims his car will accelerate from rest to a speed of \([01] \text{ m/s} \) in 8.36 seconds. Assume the acceleration is constant.
(a) What is the car’s acceleration?
(b) How far does the car travel during that time period?
(c) What is the speed of the car after 10.5 seconds (assuming it maintains the same acceleration)?

\([a] 4.00, 6.00 \text{ m/s}^2 \) \( b) 150, 250 \text{ m} \) \( c) 50.0, 70.0 \text{ m/s} \)
3-2. Write out your solution to all parts of this problem neatly on a piece of 8.5 × 11-inch paper and turn it in at the slotted boxes across the hallway from N373 ESC. Do not put your name on it, only your CID number. Do this in addition to submitting the answers online.

The supermarket tabloids report that a (rather clumsy) person fell 2 ft from a tall building. He landed on a metal ventilator grate which was crushed 18.7 inches (suffering only minor injuries). In the following questions use a coordinate system with down being positive. Assume that the top of the ventilator grate is flush with the sidewalk at ground level.

(a) What is the person’s speed (m/s) just before colliding with the ventilator grate?
(b) What is the person’s acceleration (m/s²) while crushing the grate? Assume constant acceleration.
(c) How long did it take for the person to come to a stop after first contacting the grate?
[(a) 20.0, 30.0 m/s (b) −600, −990 m/s² (c) 30.0, 40.0 ms]

3-3. A daring ranch hand sitting on a tree limb wishes to drop vertically onto a horse galloping under the tree. (Don’t try this at home.) The speed of the horse is 9.28 m/s and the vertical distance from the limb to the saddle is 3 m.

(a) What must be the horizontal distance between the saddle and the limb when the ranch hand makes his move?
(b) How long is he in the air?
[(a) 7.00, 9.00 m (b) 0.700, 0.950 s]

4-1. A surveyor measures the distance across a straight river by the following method:
Starting directly across from a tree on the opposite bank, she walks 100 m along the river bank to establish a base line. Then she sights across to the tree. The angle between her baseline and the tree is 1 degrees. How wide is the river?
[50.0, 90.0 m]

4-2. A person walks 2 degrees north of east for 3.10 km. A. How far would he have to walk (a) due north and then (b) due east to arrive at the same location?
[(a) 1.00, 3.00 km (b) 1.00, 3.00 km]
4-3. A vector \( \vec{A} \) has a negative \( x \) component \(-0.3\) units in length and a positive \( y \) component 3.17 units in length.

The vector \( \vec{A} \) can be written in unit vector notation: \( a_1 \hat{i} + a_2 \hat{j} \). Find the value of (a) \( a_1 \) and (b) \( a_2 \)
(c) What is the magnitude of \( \vec{A} \)?
(d) What is the direction of \( \vec{A} \)?

When a vector \( \vec{B} = b_1 \hat{i} + b_2 \hat{j} \) is added to \( \vec{A} \), the resulting vector has no \( x \) component and a negative \( y \) component of 4.43 units. Find the value of (e) \( b_1 \) and (f) \( b_2 \)

\[(a) -1.00, -5.00 \quad (b) 3.00, 4.00 \quad (c) 3.00, 6.00 \quad (d) 120.0, 150.0^\circ \quad (e) 1.00, 5.00 \quad (f) -6.00, -9.00\]

4-4. A radar station locates a sinking ship at range 17.3 km and bearing 136 degrees clockwise from north. From the same station a rescue plane is at horizontal range 0.4 km, 153 degrees clockwise from north, with elevation 2.20 km.

(a) The vector displacement from plane to ship can be written in the form, \( a_1 \hat{i} + a_2 \hat{j} + a_3 \hat{k} \), where \( \hat{i} \) represents east, \( \hat{j} \) represents north, and \( \hat{k} \) represents up. Find the values of (a) \( a_1 \), (b) \( a_2 \), and (c) \( a_3 \).
(d) How far apart are the plane and ship?

\[(a) 2.00, 4.00 \text{ km} \quad (b) 3.00, 8.00 \text{ km} \quad (c) -2.00, -3.00 \text{ km} \quad (d) 5.00, 8.00 \text{ km}\]

5-1. A particle moves with position as a function of time, in seconds, given by the vector \( \vec{r} \) in meters: \( \vec{r} = 5.00t^3 \hat{i} + (3.00t - 6.00t^4) \hat{j} \). At \( t = 0.1 \) seconds, find:

The (a) \( x \) and (b) \( y \) components of position.
(c) magnitude and (d) direction of position.
The (e) \( x \) and (f) \( y \) components of velocity.
The (g) magnitude and (h) direction of velocity.
The (i) \( x \) and (j) \( y \) components of acceleration.
The (k) magnitude and (l) direction of acceleration.

\[(a) 30, 140 \text{ m} \quad (b) -80 - 500 \text{ m} \quad (c) 90, 500 \text{ m} \quad (d) -60.0, -80.0^\circ \quad (e) 50, 150 \text{ m/s} \quad (f) -100, -700 \text{ m/s} \quad (g) 100, 700 \text{ m/s} \quad (h) -70.0, -80.0^\circ \quad (i) 50, 100 \text{ m/s}^2 \quad (j) -200, -700 \text{ m/s}^2 \quad (k) 200, 700 \text{ m/s}^2 \quad (l) -70.0, -90.0^\circ\]
5-2. A particle starts at $t = 0$ at the origin of a coordinate system with a velocity of 1.32 m/s in the negative $y$ direction. There is acceleration on the particle of _______ m/s$^2$ in a direction 35 degrees above the $x$ axis.

(a) At what time does the $y$ component of the particle’s position equal 3.38 m?

(b) At that time, what is the $x$ component of position?

At that time, what are the (c) $x$ and (d) $y$ components of velocity?

[(a) 3.00, 5.00 s (b) 10.0, 15.0 m (c) 2.00, 7.00 m/s (d) 2.00, 7.00 m/s]

5-3. A projectile (a stale doughnut for instance) is launched with a speed of 50.0 m/s and an angle of _______ degrees above the horizontal, from the top of a 75.0 m high cliff onto a flat valley floor at the base of the cliff.

(a) How long does it take the projectile to reach the valley floor?

(b) What is the horizontal distance between the base of the cliff and the impact point?

What are the (c) vertical and (d) horizontal components of the velocity just before impact?

[(a) 7.00, 9.50 s (b) 300, 330 m (c) −40.0, −60.0 m/s (d) 30.0, 50.0 m/s]

5-4. A glass is slid across a table top, goes off the edge and falls to the floor below. The table is 0.860 m high and the glass lands _______ m horizontally from the edge.

(a) With what velocity did the glass leave the table top?

(b) What was the direction of the glass’s velocity as it hit the ground?

[(a) 2.00, 5.00 m/s (b) −40.0, −60.0°]
5-5. Write out your solution to all parts of this problem *neatly* on a piece of 8.5 × 11-inch paper and turn it in at the slotted boxes across the hallway from N373 ESC. Do not put your name on it, only your CID number. Do this *in addition* to submitting the answers online.

During a snowball fight, your opponent distracts you by throwing a snowball at you with a high arc. She throws snowballs with a speed of \[05\] ________ m/s and the first is thrown at 70.0 degrees. As you are watching the first snowball, she throws a second at a lower angle.

(a) If both snowballs cover the same horizontal distance, at what angle should the second be thrown?
(b) If the second snow ball is going to hit you while your attention is still focused on the first snowball, how soon after the first snowball is thrown must the second be thrown? In other words, what is the delay between the two throws that will have both arriving at the same time?
\[(a) 10.0, 30.0^\circ (b) 2.00, 4.00 \text{ s}\]

6-1. A place kicker must kick the football from a point [01] ________ m from the goal and clear a bar 3.00 m above the ground. The ball leaves the ground with a speed of 20.0 m/s at an angle of 53.0 degrees above the horizontal.
(a) By how much does the ball clear (positive value) or fall short (negative value) of the cross bar? (This is vertical distance above or below the cross bar.)
(b) When it gets to the cross bar, what is the vertical component of the ball’s velocity? (Is it rising or falling?)
\[(a) 1.0, 9.9 \text{ m} (b) -4.0, -13.0 \text{ m/s}\]
6-2. A particular Ferris wheel (a rigid wheel rotating in a vertical plane about a horizontal axis) at a local carnival has a radius of 20.0 m and it completes 1 revolution in \( \theta \) seconds.

(a) What is the speed of a point on the edge of the wheel?

Using the coordinate system shown, find the (b) \( x \) and (c) \( y \) components of the acceleration of point A at the top of the wheel.

Find the (d) \( x \) and (e) \( y \) components of the acceleration of point B at the bottom of the wheel.

Find the (f) \( x \) and (g) \( y \) components of the acceleration of point C at the edge of the wheel.

\[ (a) \ \text{10.0, 20.0 m/s} \quad \text{(b–g) -15.0, +15.0 m/s}^2 \]

6-3. A ball on the end of a string is moving in circular motion as a conical pendulum as in the figure. The length \( L \) of the string is 1.70 m, the angle \( \theta \) is 37.0 degrees and the ball completes one revolution every \( \phi \) seconds.

(a) What is the speed of the ball?

(b) What is the acceleration of the ball?

\[ (a) \ \text{2.00, 4.00 m/s} \quad \text{(b) 4.00, 9.90 m/s}^2 \]

7-1. Lance arrives early at the SLC airport (with flowers and balloons in hand) to welcome home his “friend” from a mission. Her plane is delayed. While waiting, he notices that it takes 2 minutes 47 seconds to get down the hall on the moving sidewalk. While walking (not on the moving sidewalk), it took him \( \psi \) seconds. If he walks while on the sidewalk how long will it take him?

\[ 40, 80 \text{ s} \]
7-2. Write out your solution to all parts of this problem *neatly* on a piece of 8.5 × 11-inch paper and turn it in at the slotted boxes across the hallway from N373 ESC. Do not put your name on it, only your CID number. Do this *in addition* to submitting the answers online.

The pilot of an airplane notes that the compass indicates a heading of due west. The airplane’s speed relative to the air is 150.0 km/h. If there is a wind of \([02] \) km/h toward the north, what is the (a) magnitude and (b) direction (measured from west) of the velocity of the plane relative to the ground? 
[\[(a) 150.0, 160.0 \text{ km/h} (b) 7.0, 15.0^\circ] \]

7-3. Your FHE brother’s car (if his claims are true) can accelerate from rest to \([03] \) m/s in 8.04 seconds. If the car has a mass of 815 kg, what is the strength of the average force causing the acceleration?
[4000, 5000 ± 10 N]

7-4. A freight train has a mass of \([04] \) kg. The wheels of the locomotive push back on the tracks with a constant net force of \(7.50 \times 10^5 \text{ N}\), so the tracks push forward on the locomotive with a force of the same magnitude. Ignore aerodynamics and friction on the other wheels of the train. How long, in seconds, would it take to increase the speed of the train from rest to 80.0 km/h?
[200, 600 s]

7-5. A very large box of doughnuts weighs \([05] \) N on earth.
(a) What is its mass on earth?
(b) What is its weight on Jupiter where the free-fall acceleration is 25.9 m/s\(^2\)?
(c) What is its mass on Jupiter?
[(a) 10.0, 30.0 kg (b) 200, 600 N (c) 10.0, 30.0 kg]
8-1. A train consists of a 4300-kg locomotive pulling two loaded boxcars. The first boxcar has a mass of 12,700 kg and the second has a mass of 16,300 kg. Presume that the boxcar wheels roll without friction and ignore aerodynamics. The acceleration of the train is \[01\] \( m/s^2 \).
(a) With what force, in Newtons, do the boxcars pull on each other?
(b) With what force do the locomotive and first boxcar pull on each other?
(c) With what force must the tracks push on the locomotive?
[(a) 3000, 25000 \( \pm \) 100 N (b) 3000, 25000 \( \pm \) 100 N (c) 3000, 25000 \( \pm \) 100 N]

8-2. A block starts from rest at the top of a 2.00-m long, \([02]\) \( \cdot \)degree frictionless incline.
(a) What is the acceleration of the block?
(b) How fast is it going at the bottom?
[(a) 1.00, 4.00 m/s\(^2\) (b) 2.00, 4.00 m/s]

8-3. To test your FHE brother’s claims about his car, you accept his offer of a ride about campus. Not wanting to exceed the speed limit, he claims he can only give a taste of the accelerating ability of his car and not the full proof. You notice, however, that the pine tree scented (and shaped) air freshener that hangs from his rear view mirror makes an angle of \([03]\) \( \cdot \)degrees with the vertical while he is accelerating.
(a) What is the car’s acceleration?
(b) What is the tension in the string of the 100-g air freshener (assume only one string hanging from the mirror)?
[(a) 3.00, 6.00 m/s\(^2\) (b) 1.00, 1.20 N]
8-4. Write out your solution to all parts of this problem *neatly* on a piece of 8.5 × 11-inch paper and turn it in at the slotted boxes across the hallway from N373 ESC. Do not put your name on it, only your CID number. Do this *in addition* to submitting the answers online.

Block $M = 7.50$ kg is initially moving up the incline and is increasing speed with $a = [04] \text{ m/s}^2$. The applied force $F$ is horizontal. The coefficients of friction between the block and incline are $\mu_s = 0.443$ and $\mu_k = 0.312$. The angle of the incline is 25.0 degrees.

(a) What is the magnitude of the force $F$?
(b) What is the normal force $N$ between the block and incline?
(c) What is the magnitude of the force of friction on the block?

[(a) 80.0, 120.0 N (b) 100.0, 120.0 N (c) 30.0, 40.0 N]

8-5. In the figure shown, the coefficients of friction between the two blocks are $\mu_s = [05]$ and $\mu_k = [06]$. There is no friction on the horizontal surfaces.

(a) What minimum force $F$ must be exerted on the block $M$ in order for block $m$ to not fall?
(b) What is the resulting acceleration of the blocks?

[(a) 1700, 2200 ± 10 N (b) 15.0, 20.0 m/s$^2$]

9-1. The loaded car of a roller coaster has mass $M = 320$ kg. It goes over the top “hill” with a speed $v$ of 21.4 m/s. The radius of curvature $R$ of the hill is [01] m.

(a) What is the force that the track must exert on the car? (positive is up)
(b) What must be the force that the car exerts on a 61 kg passenger?

[(a) $-5000$, $-9000 \pm 10$ N (b) $-1000$, $-2000 \pm 10$ N]
9-2. A satellite of mass $M = 02$ kg is in circular orbit around the Earth at an altitude equal to the earth’s mean radius (6370 km). At this distance, the free-fall acceleration is $g/4$.
(a) What is the satellite’s orbital speed?
(b) What is the period of revolution?
(c) What is the gravitational force on the satellite?
[(a) 5000, 6000 ± 10 m/s (b) 10000, 20000 ± 100 s (c) 400, 990 N]

9-3. An automobile moves at a constant speed over the crest of a hill traveling at a speed of $03$ km/h. At the top of the hill a package on a seat in the rear of the car barely remains in contact with the seat. What is the radius of curvature of the hill?
[50.0, 80.0 m]

9-4. A Ferris wheel has a radius $R$ of $04$ m and rotates four times each minute.
There is a rider with a mass of 41.5 kg.
(a) What is the centripetal acceleration of the rider?
Find the (b) magnitude and (c) direction of the force that the seat exerts on the rider at the lowest point of the ride. (reference angles to upward being 0 degrees)
Find the (d) magnitude and (e) direction of the force that the seat exerts on the rider at the highest point of the ride.
Find the (f) magnitude and (g) direction of the force that the seat exerts on the rider half way between top and bottom. Note: The “seat force” includes both the normal force and friction.
[(a) 1.00, 2.00 m/s² (b) 300, 500 N (c) 0.0, 20.0° (d) 300, 500 N (e) 0.0, 20.0°
(f) 300, 500 N (g) 0.0, 20.0°]

9-5. A marble with a mass $m$ of 3.00 g is released from rest in a bottle of syrup. Its terminal speed $v_t$ is $05$ cm/s.
(a) Presuming the resistive force $R = -bv$, what is the value of $b$?
(b) What is the strength of the resistive force when the marble reaches terminal speed?
(c) How long in seconds does it take for it to reach a speed of $0.600v_t$?
[(a) 1.00, 2.00 N · s/m (b) 0.0200, 0.0400 N (c) 1.00, 3.00 ms]
10-1. A 15 kg block is dragged over a rough, horizontal surface by an applied force of 10-1. A 15 kg block is dragged over a rough, horizontal surface by an applied force of 
10N acting at 20.0 degrees above the horizontal. The block is displaced 5.00 m, and the coefficient of kinetic friction is 0.300. Find the work done by
(a) the applied force,
(b) the normal force,
(c) the force of gravity,
(d) the force of friction.
((a) 500 J, (b) 500 J, (c) 500 J, (d) 500 J)

10-2. \( \vec{F} \) and \( \Delta \vec{r} \) are vectors. \( \vec{F} = F_x \hat{i} + F_y \hat{j} + F_z \hat{k} \) where \( F_x = 10 \) N, \( F_y = 62.7 \) N, \( F_z = -71.2 \) N, and \( \Delta \vec{r} = \Delta x \hat{i} + \Delta y \hat{j} + \Delta z \hat{k} \), where \( \Delta x = 44.8 \) m, \( \Delta y = 03 \) m, \( \Delta z = -10.1 \) m.
(a) What is the magnitude of \( \vec{F} \)?
(b) What is the magnitude of \( \Delta \vec{r} \)?
(c) What is the scalar product of \( \vec{F} \) and \( \Delta \vec{r} \)?
(d) What is the angle between \( \vec{F} \) and \( \Delta \vec{r} \)?
(e) How much work would be done if this force acted on a 30 kg space ship while it experienced a displacement of \( \Delta \vec{r} \)?
((a) 95.0 J, (b) 45.0 m, (c) 300 J, 1500 ± 10 J, (d) 70.0°, (e) 300 J, 1500 ± 10 J)

10-3. A spring gun is made by compressing a spring in a tube and then latching the spring at the compressed position. A 4.87-g pellet is placed against the compressed and latched spring. The spring latches at a compression of 0.04 cm, and it takes a force of 9.13 N to compress the spring to that point. Assume that the spring quits moving when it is back to its relaxed length. How much work is done by the spring when the latch is released and the pellet leaves the tube? Ignore gravity.
(0.100 J, 0.300 J)
10-4. Write out your solution to all parts of this problem *neatly* on a piece of 8.5 × 11-inch paper and turn it in at the slotted boxes across the hallway from N373 ESC. Do not put your name on it, only your CID number. Do this *in addition* to submitting the answers online.

A pendulum of length \( L = [05] \) cm and mass \( m = 168 \) g is released from rest when the cord makes an angle of 65.2° with the vertical.

(a) How far does the mass fall before reaching its lowest point?
(b) How much work is done by gravity as it falls to its lowest point?
(c) How much work is done by the string tension as it falls to its lowest point?

\[ (a) \ 0.100, \ 0.300 \text{ m}, \ (b) \ 0.100, \ 0.400 \text{ J}, \ (c) \ -0.100, \ 0.400 \text{ J} \]

11-1. A truck carrying a 65.4-kg crate accelerates from rest to \([01]\) km/hr on a flat horizontal surface in 15.2 seconds. The crate does not slip in the truck bed. The acceleration was not constant. How much work was done on the crate by the truck?

\[ 6000, \ 9900 \pm 10 \text{ J} \]

11-2. A construction crew pulls up an 87.5-kg load using a rope thrown over a pulley and pulled by an electric motor. They lift the load \([02]\) m and it arrives with a speed of 15.6 m/s having started from rest. Assume that acceleration was not constant.

(a) How much work was done by the motor?
(b) How much work was done by gravity?
(c) What constant force could the motor have exerted to cause this motion? (This would have been the average force exerted by the motor).

\[ (a) \ 2.00 \times 10^4, \ 3.00 \times 10^4 \text{ J}, \ (b) \ -1.00 \times 10^4, \ -2.00 \times 10^4 \text{ J}, \ (c) \ 1000, \ 2000 \pm 10 \text{ N} \]
11-3. Write out your solution to all parts of this problem *neatly* on a piece of 8.5 × 11-inch paper and turn it in at the slotted boxes across the hallway from N373 ESC. Do not put your name on it, only your CID number. Do this *in addition* to submitting the answers online.

A spring gun is made by compressing a spring in a tube and then latching the spring at the compressed position. A 4.97-g pellet is placed against the compressed and latched spring. The spring latches at a compression of [03] cm, and it takes a force of 9.12 N to compress the spring to that point.

(a) If the gun is fired vertically, how fast is the pellet moving when it loses contact with the spring? (Include the effect of gravity and assume that the pellet leaves the spring when the spring is back to its relaxed length.)

(b) To what maximum height will the pellet rise? (as measured from the original latched position)

[(a) 7.00, 9.99 m/s, (b) 2.00, 5.00 m]

11-4. A pendulum of length \( L = [04] \) cm and mass \( m = 169 \) g is released from rest when the cord makes an angle of 65.4° with the vertical. What is the speed of the mass upon reaching its lowest point?

[1.50, 2.50 m/s]

12-1. A ball with mass \( m = 1.72 \) kg is attached to a peg at point C using a length of massless string of \( L = 1.54 \) m. It is released from the top of a vertical circle with speed \( v_0 = [01] \) m/s as shown in the figure. Defining the angle as shown, what is the ball’s speed at \( \theta = 21.7^\circ \)?

[5.00, 7.00 m/s]

12-2. A rock is launched at an angle \( \theta = 53.2^\circ \) above the horizontal from an altitude \( h = 182 \) km with an initial speed \( v_0 = [02] \) km/s. What is the rock’s speed when it reaches an altitude of \( h/2 \)? (Assume \( g \) is a constant 9.8 m/s².)

[1500, 2500 ± 10 m/s]
12-3. A bucket of mass \( M = \) _______ kg is attached to a second bucket of mass \( m = 3.52 \) kg by an ideal string. The string is hung over an ideal pulley as shown in the figure. Mass \( M \) is started with an initial downward speed of 2.13 m/s. What then is the speed of mass \( M \) after it has moved 2.47 meters?

[3.00, 5.00 m/s]

12-4. A tall bald student (height 2.1 meters and mass \( m = \) _______ kg) decides to try bungee jumping from a bridge. The bridge is 36.7 meters above the river and the “bungee” is 25.3 meters long as measured from the attachment at the bridge to the foot of jumper. Treat the “bungee” as an ideal spring and the student as a 2.1-meter rod with all the mass at the midpoint. This particular student desires to stay dry. What is the minimum spring constant of the “bungee” that will allow the student to get as close as possible to the water but still stay dry? Assume that he begins at a standing position and “falls” from the bridge. Hint: The “bungee” spring only stretches; it can’t be compressed. Watch what the student’s center of mass does and assume that initially the bungee cord is limp and tied to his feet and that at the end the bungee cord is stretched and that his head is just touching the water.

[700, 950 N/m]

12-5. A parachutist with mass \( m = \) _______ kg jumps from an airplane traveling at a speed \( v_i = 112 \) km/hr at a height \( H = 2570 \) m. He lands with a speed of \( v_f = 5.21 \) m/s. What is the change in mechanical energy of the earth-parachutist system from just after the jump to just before landing?

\([-1.50 \times 10^6, \ -2.50 \times 10^6 \text{ J}]\)
13-1. In the system shown, the block $M$ (mass of 15.65 kg) is initially moving to the left with a speed of 3.01 m/s. The mass of $m$ is 8.26 kg and the coefficients of friction are $\mu_s = 0.411$ and $\mu_k = 0.304$. The string is massless and the pulley is massless and frictionless. How fast will $M$ be traveling when $m$ has fallen through a height $h = 2.47$ meters?\[3.00, 5.00\text{ m/s}\]

13-2. Write out your solution to this problem *neatly* on a piece of 8.5 × 11-inch paper and turn it in at the slotted boxes across the hallway from N373 ESC. Do not put your name on it, only your CID number. Do this *in addition* to submitting the answers online.

A crate of mass 0.812 kg is placed on a rough incline of angle $35.3^\circ$. Near the base of the incline is a spring of spring constant 1140 N/m. The mass is pressed against the spring a distance $x$ and released. It moves up the slope 0.02 meters from the compressed position before coming to a stop. If the coefficient of kinetic friction is 0.195, how far was the spring compressed? Hint: Do not assume that the mass and the spring are still in contact at the end.\[0.0300, 0.0600\text{ m}\]

13-3. (a) At what speed would a 1140-kg car have the same momentum as a 12,600-kg truck traveling at 40.0, 80.0 m/s?\[40.0, 80.0\text{ km/hr}\]

(b) The car and truck in (a) have a head-on collision and then stick together. What is their final common velocity? (Assume the car is going in the positive direction.)

(c) What is the car’s change in momentum in (b)?

(d) At what speed would the car have the same initial kinetic energy as the truck?

(e) The car and truck in (d) have a head-on collision and then stick together. What is their final common velocity? (Assume the car is going in the positive direction.)

(f) What is the car’s change in momentum in (e)?

\[40.0, 80.0\text{ m/s, (b) }-9.00, +9.00\text{ m/s, (c) }-5.00 \times 10^4, -9.00 \times 10^4\text{ kg·m/s, (d) }10.0, 30.0\text{ m/s, (e) }-9.00, +9.00\text{ m/s, (f) }-1.00 \times 10^4, -4.00 \times 10^4\text{ kg·m/s}\]
13-4. A superball with a mass $m = 61.6$ g is dropped from a height $h = 0.04$ m. It hits the floor and then rebounds to a new height that is 88.5% of the initial height. Use upward as the positive direction.
(a) What is the momentum change of the ball during its collision with the floor?
(b) Suppose you drop a ball of putty of the same mass from the same height and the putty sticks to the floor. What then would be the second ball’s momentum change during its collision with the floor?
[(a) 0.600, 0.900 kg·m/s, (b) 0.300, 0.500 kg·m/s]

13-5. Two objects of mass $M = 0.05$ kg and mass $m = 2.38$ kg are at rest on a flat frictionless surface. An ideal spring ($k = 51.6$ N/m) is placed between them and they are pushed together compressing the spring. At the compressed position they are held together with a piece of ideal string as in figure (a). The string is then cut and after they have moved apart as in figure (b), $M$ has a speed $V$ of 0.472 m/s.
(a) What is the velocity $v$ of mass $m$?
(b) How far was the spring compressed?
[(a) 1.00, 2.00 m/s, (b) 0.200, 0.500 m]
14-1. A bullet with mass $m = 5.21$ g is moving horizontally with a speed $v = [01] \ldots \text{m/s}$ when it strikes a block of wood with mass $M = 14.8$ kg (initially at rest). The bullet embeds itself in the block.

(a) What is the speed of the bullet-block combination immediately after the collision?
(b) What is the impulse exerted on the block?
(c) What is the final kinetic energy of the block?
(d) How much work did the bullet do on the block?
(e) What was the change in kinetic energy of the bullet?
(f) How much work was done on the bullet?

[(a) 0.100, 0.300 m/s, (b) 2.00, 4.00 kg·m/s, (c) 0.100, 0.400 J, (d) 0.100, 0.400 J, (e) $-400, -950$ J, (f) $-400, -950$ J]

14-2. A steel ball with mass $m = 5.21$ g is moving horizontally with speed $v = [02] \ldots \text{m/s}$ when it strikes a block of hardened steel with mass $M = 14.8$ kg (initially at rest). The ball bounces off the block in a perfectly elastic collision.

(a) What is the speed of the block immediately after the collision?
(b) What is the impulse exerted on the block?
(c) What is the final kinetic energy of the block?
(d) How much work did the bullet do on the block?
(e) What was the change in kinetic energy of the ball?
(f) How much work was done on the ball?

Please compare the similarities and differences between this and the previous problem.

[(a) 0.200, 0.400 m/s, (b) 3.00, 6.00 kg·m/s, (c) 0.300, 0.950 J, (d) 0.300, 0.950 J, (e) $-0.300, -0.950$ J, (f) $-0.300, -0.950$ J]

14-3. A car with mass $m = [03] \ldots \text{kg}$ is initially traveling directly east with a speed $v_i = 25.0 \text{ m/s}$. It crashes into the rear end of a truck with mass $M = 9000$ kg moving in the same direction with speed $V_i = 20.0 \text{ m/s}$. Immediately after the collision the car has a speed $v_f = 18.0 \text{ m/s}$ in its original direction.

(a) What is the speed of the truck immediately after the collision?
(b) How much mechanical energy was lost as a result of the collision?

[(a) 20.0, 25.0 m/s, (b) 7000, 9900 ± 10 J]
14-4. A bullet with a mass $m = 12.5$ g and speed $v = [04] \text{ m/s}$ is fired into a wooden block with $M = 113$ g which is initially at rest on a horizontal surface. The bullet is embedded into the block. The block-bullet combination slides across the surface for a distance $d$ before stopping due to friction between the block and surface. The coefficients of friction are $\mu_s = 0.753$ and $\mu_k = 0.659$.

(a) What is the speed of the block-bullet combination immediately after the collision?
(b) What is the distance $d$?

[(a) 7.00, 9.90 m/s, (b) 4.00, 8.00 m]

14-5. Your FHE brother (mass [05] _________ kg) is canoeing on Utah Lake with his sister (mass 81.6 kg). He had the only paddle but managed to drop it in the lake. It has drifted just out of his reach along the long axis of the canoe. His sister has taken Physics 121 and suggests that if they trade places she might be able to reach the paddle. Due to the high “slime” content of the lake and the slick surface of the canoe, the canoe moves in the water without any friction or drag. The passengers sit 2.03 meters apart and the canoe has a mass of 48.7 kg. After the passengers switch places, how much closer to the paddle (which does not move) is the end of the canoe?

[0.300, 0.500 m]

15-1. What is the angular speed, in SI units, of:

(a) The earth in its orbit about the sun every 365 days.
(b) The moon in its orbit about the earth every 27.3 days.

[(a) $1.00 \times 10^{-7}$, $3.00 \times 10^{-7}$ rad/s, (b) $1.00 \times 10^{-6}$, $3.00 \times 10^{-6}$ rad/s]

15-2. A wheel rotates with an initial angular speed $\omega_i$. It experiences a constant angular acceleration $\alpha$ and reaches a final angular speed $\omega_f = 75.9$ rad/s in $\Delta t = [01] \text{ s}$. During this time, the wheel completes 37.0 revolutions. Find the value of $\alpha$.

[8.0, 12.0 rad/s$^2$]
15-3. A centrifuge whose maximum rotation rate is \( \omega = 10,000 \) revolutions per minute (rpm) can be brought to rest in a time \( \Delta t = 0.2 \) s. Assume constant angular acceleration.

(a) What is the angular speed, in SI units, just before it begins decelerating?
(b) What is the angular acceleration in SI units?
(c) How far does a point \( R = 8.13 \) cm from the center travel during the deceleration?
(d) What is the magnitude of the radial component of acceleration of the point just as the centrifuge begins its deceleration?
(e) What is the tangential component of acceleration of the point just as the centrifuge begins its deceleration?

[(a) 1000, 2000 \( \pm \) 10 rad/s, (b) \(-200\), \(-400 \) rad/s\(^2\), (c) 100, 300 m,
(d) 80000, 90000 \( \pm \) 100 m/s\(^2\), (e) \(-10.0\), \(-30.0 \) m/s\(^2\)]

15-4. Write out your solution to all parts of this problem *neatly* on a piece of 8.5 \( \times \) 11-inch paper and turn it in at the slotted boxes across the hallway from N373 ESC. Do not put your name on it, only your CID number. Do this in addition to submitting the answers online.

A car is traveling at [03] \_\_\_\_\_\_\_\_ km/hr. The tires have a radius \( R = 38.4 \) cm.

(a) What is the angular speed of the tire (in SI units)?
(b) What is the magnitude of the centripetal acceleration of a piece of tire on the outer edge?

[(a) 50.0, 80.0 rad/s, (b) 1000, 2500 \( \pm \) 10 m/s\(^2\)]
16-1. Two objects, \( M = 15.3 \) kg and \( m = \) \[01\] \( \text{__________} \) kg are connected with an ideal string and suspended by a pulley (which rotates with no friction) in the shape of a uniform disk with radius \( R = 7.5 \) cm and mass \( M_p = 14.1 \) kg. The string causes the pulley to rotate without slipping. If the masses are started from rest and allowed to move 2.5 m:
(a) What is the final speed of mass \( m \)?
(b) What is the final angular speed of the pulley?
(c) How long did it take for the masses to move from rest to the final position?
Part (a) can be done by two methods: either use forces and torques or energy conservation. Please use the other method to check your answer.
\[(a) 2.00, 5.00 \text{ m/s}, (b) 30.0, 60.0 \text{ rad/s}, (c) 1.00, 2.00 \text{ s}\]

16-2. Your FHE brother gets a flat tire while driving up a road with a 35° slope. While changing the tire he lets go of the spare and it begins to roll down the hill. His sister has stopped her car \[02\] \( \text{__________} \) m down the slope (of course this is very late on a cloudy night so she is there with her lights on). If we model the tire as a cylindrical shell with mass \( M \) and radius \( R \) that rolls without slipping,
(a) how fast is the tire moving when it hits the sister’s car?
(b) If instead we model the tire as a solid cylinder, how fast would it be moving when it hits the sister’s car?
\[(a) 4.00, 8.00 \text{ m/s}, (b) 4.00, 8.00 \text{ m/s}\]

16-3. In each of the following cases, the mass is \[03\] \( \text{__________} \) kg and the radius is 7.5 cm.
(a) What is the moment of inertia of a solid cylinder rotating about an axis parallel to the symmetry axis but passing through the edge of the cylinder?
(b) What is the moment of inertia of a solid sphere rotating about an axis tangent to its surface?
\[(a) 0.0500, 0.0900 \text{ kg}\cdot\text{m}^2, (b) 0.0500, 0.0900 \text{ kg}\cdot\text{m}^2\]
16-4. A bicycle wheel has radius $R = 32.0 \, \text{cm}$ and mass $M = 1.82 \, \text{kg}$ which you may assume to be concentrated on the outside radius. A resistive force $f = [04] \, \text{N}$ (due to friction with the ground) is applied to the rim of the tire. A force $F$ is applied to the sprocket at radius $r$ by the bicycle chain such that the wheel has an angular acceleration of $\alpha = 4.50 \, \text{rad/s}^2$. The tire does not slip with the ground, and the lower part of the chain (not shown) exerts no force.

(a) If the sprocket radius is 4.53 cm, what is the force $F$?
(b) If the sprocket radius is 2.88 cm, what is the force $F$?
(c) What is the combined mass of the bicycle and rider? Hint: The force $F$ also acts on the front sprocket of the bicycle. Hint: The diagram shown is now the full diagram needed for part (c); carefully draw the correct free-body diagram.
[(a) 700, 1200 ± 10 N, (b) 1000, 1800 ± 10 N, (b) 60, 120 kg]

17-1. Write out your solution to all parts of this problem neatly on a piece of 8.5 × 11-inch paper and turn it in at the slotted boxes across the hallway from N373 ESC. Do not put your name on it, only your CID number. Do this in addition to submitting the answers online.

$\vec{F}$ and $\vec{r}$ are vectors. $\vec{F} = F_x \hat{i} + F_y \hat{j} + F_z \hat{k}$, where $F_x = [01] \, \text{N}$, $F_y = 60 \, \text{N}$, and $F_z = -70 \, \text{N}$, and $\vec{r} = x \hat{i} + y \hat{j} + z \hat{k}$, where $x = 40 \, \text{m}$, $y = [02] \, \text{m}$, and $z = -10 \, \text{m}$.

(a) What is the magnitude of $\vec{F}$?
(b) What is the magnitude of $\vec{r}$?
(c) What is the $x$ component of the vector product $\vec{r} \times \vec{F}$?
(d) What is the $y$ component of the vector product $\vec{r} \times \vec{F}$?
(e) What is the $z$ component of the vector product $\vec{r} \times \vec{F}$?
[(a) 90.0, 120.0 N, (b) 40.0, 60.0 m, (c) -5000, +5000 ± 10 N·m, (d) -5000, +5000 ± 10 N·m, (e) -5000, +5000 ± 10 N·m]
17-2. A ball (mass $m = 250$ g) on the end of an ideal string is moving in circular motion as a conical pendulum as in the figure. The length $L$ of the string is $[\text{03}]$ ________ m and the angle with the vertical is $37^\circ$.

(a) What is the magnitude of the torque exerted on the ball about the support point?

(b) What is the direction of the torque exerted on the ball about the support point?
   - Downward.
   - Upward.
   - Toward the support point.
   - Directly away from the support point.
   - Toward the center of the circle.
   - Directly away from the center of the circle.
   - Tangent to the circle in the direction of motion.
   - Tangent to the circle opposite to the direction of motion.
   - The torque is zero.
   - Something not listed above.

(c) What is the magnitude of the angular momentum of the ball about the support point?

(d) What is the direction of the angular momentum of the ball about the support point?
   - Downward.
   - Upward.
   - Toward the support point.
   - Directly away from the support point.
   - Toward the center of the circle.
   - Directly away from the center of the circle.
   - Tangent to the circle in the direction of motion.
   - Tangent to the circle opposite to the direction of motion.
   - The angular momentum is zero.
   - Something not listed above.

$[(a) \ 0.00, \ 3.00 \ \text{N}\cdot\text{m}, \ (c) \ 0.50, \ 2.00 \ \text{kg}\cdot\text{m}^2/\text{s}]$
A ball (mass $m = 250$ g) on the end of an ideal string is moving in circular motion as a conical pendulum as in the figure. The length $L$ of the string is [04] ________ m and the angle with the vertical is 37°.

(a) What is the magnitude of the torque exerted on the ball about the center of the circle of motion?
(b) What is the direction of the torque exerted on the ball about the center of the circle of motion?
  - Downward.
  - Upward.
  - Toward the support point.
  - Directly away from the support point.
  - Toward the center of the circle.
  - Directly away from the center of the circle.
  - Tangent to the circle in the direction of motion.
  - Tangent to the circle opposite to the direction of motion.
  - The torque is zero.
  - Something not listed above.

(c) What is the magnitude of the angular momentum of the ball about the center of the circle of motion?
(d) What is the direction of the angular momentum of the ball about the center of the circle of motion?
  - Downward.
  - Upward.
  - Toward the support point.
  - Directly away from the support point.
  - Toward the center of the circle.
  - Directly away from the center of the circle.
  - Tangent to the circle in the direction of motion.
  - Tangent to the circle opposite to the direction of motion.
  - The angular momentum is zero.
  - Something not listed above.

[(a) 0.00, 3.00 N·m, (c) 0.50, 2.00 kg·m²/s]
17-4. An airplane of mass 2180 kg located 131 km north of BYU is flying
in a 4.0 km/hr in an easterly direction.
(a) What is the magnitude of the angular momentum with respect to BYU?
(b) What is the direction of the angular momentum with respect to BYU?
  Upward
  Downward
  North
  South
  East
  West
  Something not listed above
If the plane were now flying in a northeast direction (45 degrees north of east),
(c) What is the magnitude of the angular momentum with respect to BYU?
(d) What is the direction of the angular momentum with respect to BYU?
  Upward
  Downward
  North
  South
  East
  West
  Something not listed above
[(a) 1.00 × 10^{10}, 3.00 × 10^{10} \text{ kg} \cdot \text{m}^2/\text{s}, (c) 1.00 × 10^{10}, 3.00 × 10^{10} \text{ kg} \cdot \text{m}^2/\text{s}]

18-1. A star with the same mass and diameter as the sun rotates about a central axis with a
period of about 01 ________ days. Suppose that the sun runs out of nuclear fuel and
collapses to form a white dwarf star with a diameter equal to that of the earth. Assume
the star acts like a solid sphere, that there is no loss of mass in the process, and that the
star has no external torques acting on it. Note however, that as the star cools and
gravity causes it to contract, its rotational kinetic energy changes. You will need some
data from the inside front cover of you text.
(a) What would be the new rotation period of the star?
(b) What is the ratio of final to initial kinetic energies \( \frac{K_f}{K_i} \)?
[(a) 100, 300 s, (b) 10000, 15000 ± 100]
18-2. A small motor is mounted on the axis of a space probe with its rotor (the rotating part of the motor) parallel to the axis of the probe. Its function is to control the rotational position of the probe about the axis. The moment of inertia of the probe is \[02\] ________ times that of the rotor. Initially, the probe and rotor are at rest. The motor is turned on and after some period of time, the probe is seen to have rotated by positive 32.6 degrees. Through how many revolutions has the rotor turned? [400, 700 rev]

18-3. A bullet with a mass \(m = 4.83\) g and initial speed of 330 m/s passes through a wheel which is initially at rest as in the figure. The wheel is a solid disk with mass \(M = 2.29\) kg and radius \(R = 18.6\) cm. The wheel rotates freely about an axis through its center and out of the plane shown in the figure. The bullet passes through the wheel at a perpendicular distance 14.8 cm from the center. After passing through the wheel it has a speed of \[03\] ________ m/s.

(a) What is the angular speed of the wheel just after the bullet leaves it?
(b) How much kinetic energy was lost in the collision?
[(a) 1.00, 3.00 rad/s, (b) 100, 200 J]

18-4. A long thin rod of mass \(M = 2\) kg and length \(L = 75\) cm is free to rotate about its center as shown. Two identical masses (each of mass \(m = [04]\) ________ kg) slide without friction along the rod. The two masses begin at the rod’s point of rotation when the rod is rotating at 10 rad/s.

(a) When they have moved halfway to the end of the rod, how fast is the rod rotating?
(b) When the masses are halfway to the end of the rod, what is the ratio of the final rotational kinetic energy to the initial rotational kinetic energy \((K_{r f}/K_{r i})\)?
(c) When they reach the end, how fast is the rod rotating?
[(a) 6.00, 8.00 rad/s, (b) 0.600, 0.800, (c) 3.00, 5.00 rad/s]
19-1. A 1540-kg truck has a wheel base of 3.13 m (this is the distance between the front and rear axles). The center of mass of the truck is [01] ________ m behind the front axle.  
(a) What is the force exerted by the ground on each of the front wheels?  
(b) What is the force exerted by the ground on each of the back wheels? Hint: Remember that the truck has four wheels.  
[(a) 2000, 6000 ± 10 N, (b) 2000, 6000 ± 10 N]  

19-2. The figure shows a cross member of a bridge lying in the xy plane of the page. The mass of the member is $M = [02] ________$ kg and its center of mass is at its geometrical center. Two forces, (1) $\vec{F}$ (with $x$ and $y$ components) acting at A and (2) $\vec{R}$ (also with $x$ and $y$ components) acting at O, represent the contacts at the ends of the member. The angle $\theta = 41.7^\circ$ and $R_y = +2Mg$.  
(a) What is $R_x$?  
(b) What is $F_x$?  
(c) What is $F_y$?  
[(a) −3000, +3000 ± 10 N, (b) −3000, +3000 ± 10 N, (c) −3000, +3000 ± 10 N]  

19-3. A uniform beam with mass $M = 62.4$ kg has two ‘loads’ represented by the blocks, one with mass $M$ (equal to the mass of the beam) and the other with mass $m = [03] ________$ kg, as shown in the figure. $\ell = 5.04$ m and $d = 1.28$ m. What distance $x$ would put the system in equilibrium such that no force would be required at point O?  
[3.00, 6.00 m]
19-4. Write out your solution to this problem *neatly* on a piece of 8.5 × 11-inch paper and turn it in at the slotted boxes across the hallway from N373 ESC. Do not put your name on it, only your CID number. Do this *in addition* to submitting the answers online.

A shelf bracket is mounted on a vertical wall by a single screw as sketched in the figure. The vertical dimension of the bracket is 12.3 cm and the screw is at the midpoint. A downward force $F = \[04\] \text{ N}$ is applied to the bracket 5.2 cm from the wall.

Ignore the mass of the bracket. What is the horizontal component of the force that the screw exerts on the bracket? Hint: Imagine that the bracket is slightly loose and tilts a little so that the wall exerts a horizontal force acting at the bottom of the bracket.

20-1. A planet with mass $m = 2.00 \times 10^{24}$ kg and a second with mass $M = 5.00 \times 10^{24}$ kg are separated by a distance $d = \[01\] \text{ m}$.

(a) What is the strength of the gravitational force which $m$ exerts on $M$?
(b) What is the strength of the gravitational force which $M$ exerts on $m$?
(c) What is the net gravitational force (magnitude) on $m_3$ due to the other two planets?
(d) Is the net force toward or away from the smaller mass ($m$)?
(e) Where could the third planet be positioned (distance from the larger planet $M$) so that the net gravitational force is zero?

[(a) $2.00 \times 10^{15}, 8.00 \times 10^{15} \text{ N}$, (b) $2.00 \times 10^{15}, 8.00 \times 10^{15} \text{ N}$, (c) $1.00 \times 10^{15}, 5.00 \times 10^{15} \text{ N}$, (e) $1.00 \times 10^{11}, 4.00 \times 10^{11} \text{ m}$]

20-2. Four stars with equal masses $m = 1.99 \times 10^{30}$ kg are located at the corners of a square, each side of which is $\ell = \[02\] \text{ m}$.

The configuration and coordinate system is shown in the figure.

(a) What is the direction (angle from the $x$ direction) of the net force on the star at the origin?
(b) What is the magnitude of the net force on the star at the origin?

[(a) $0.0, 90.0^\circ$, (b) $2.00 \times 10^{17}, 6.00 \times 10^{17} \text{ N}$]
20-3. Your FHE brother observes an artificial satellite orbiting the earth. He estimates it is at an altitude \( h = [03] \) \( \text{km} \) above the earth’s surface and has a mass \( m = 3500 \text{ kg} \). He wishes to show it off to his FHE group. He asks you to help him calculate when the satellite will be back in the same position. From the second law of motion and the gravitational force law, calculate the following:

(a) What is the satellite’s velocity? (m/s)
(b) What is the period of the satellite’s motion?

\[(a) 7000, 8000 \pm 10 \text{ m/s}, (b) 5000, 7000 \pm 10 \text{ s}]\]

21-1. Write out your solution to this problem *neatly* on a piece of 8.5 \( \times \) 11-inch paper and turn it in at the slotted boxes across the hallway from N373 ESC. Do not put your name on it, only your CID number. Do this *in addition* to submitting the answers online.

A binary star system consists of two equal mass stars that revolve in circular orbits about their center of mass. The period of the motion, \( T = [01] \) \( \text{days} \), and the orbital speed \( v = 220 \text{ km/s} \) of the stars can be measured from telescopic observations. What is the mass of each star? Note: The stars orbit on the same circle, opposite each other, with their center of mass at the center of the circle. Kepler’s third law, as given in your book, does not work in this situation.

\[1.00 \times 10^{32}, 3.00 \times 10^{32} \text{ kg}\]

21-2. A projectile is launched vertically from the surface of the earth with an initial speed \( v_0 = [02] \) \( \text{km/s} \).

(a) What is its acceleration \( [03] \) \( \text{km} \) above the surface of the earth?
(b) At what height will it stop and begin to fall back to the surface of the earth?

\[(a) 5.00, 7.00 \text{ m/s}^2, (b) 2000, 7000 \pm 10 \text{ km}]\]
22-1. A particle moves so that position $x$ in meters is given as a function of time $t$ in seconds by the equation $x(t) = c_1 \cos(c_2 t + c_3)$, where $c_1 = [01] \text{_____ m}$, $c_2 = [02] \text{_____ s}^{-1}$, $c_3 = [03] \text{______}$. Give numerical values for the following:

(a) Amplitude (m)
(b) Angular frequency (rad/s)
(c) Frequency (Hz)
(d) Period (s)
(e) Phase constant (rad)
(f) What is the position of the particle at $t = 3.00 \text{ ms}$?
(g) What is the velocity of the particle at $t = 3.00 \text{ ms}$?
(h) What is the acceleration of the particle at $t = 3.00 \text{ ms}$?

[(a) 0.0200, 0.0400 m, (b) 300, 400 rad/s, (c) 40.0, 70.0 Hz, (d) 0.0100, 0.0300 s,
(e) 1.00, 1.50 rad, (f) $-0.0400$, $+0.0400$ m, (g) $-20.0$, $+20.0$ m/s,
(h) $-7000$, $+7000 \pm 10 \text{ m/s}^2$]

22-2. Write out your solution to this problem neatly on a piece of $8.5 \times 11$-inch paper and turn it in at the slotted boxes across the hallway from N373 ESC. Do not put your name on it, only your CID number. Do this in addition to submitting the answers online.

A particle oscillates in simple harmonic motion with a period of [04] ________ s and an amplitude of [05] ________ cm. At $t = 0$, it is at $z = -2.0$ cm and it is moving toward $z = 0$. We wish to write the position of the particle as a function of time in the following form, $z(t) = c_1 \cos(c_2 t + c_3)$.

(a) What is $c_1$?
(b) What is $c_2$?
(c) What is $c_3$? (Give the answer in the range $-\pi$ to $\pi$.)

[(a) 3.00, 6.00 cm, (b) 2.00, 4.00 rad/s, (c) $-3.14$, $+3.14$ rad]
22-3. A piston (with mass $M = 2.0$ kg) in a car engine is in vertical simple harmonic motion with amplitude $A = 5.0$ cm. If the engine is running at $60$ rev/min,
(a) What is the maximum velocity of the piston?
(b) What is the maximum acceleration of the piston?
Suppose a small 100 g piece of metal were to break loose from the upper surface of the piston when it (the piston) is at the lowest point ($z = -5.0$ cm and $v = 0$).
(c) At what position does the piece of metal lose contact with the piston?
(d) What is the velocity of the metal piece when it loses contact with the piston?
Hint: Let the piston be at its lowest point at $t = 0$ and use $z = -A \cos \omega t$ to answer (c) and (d).

$[(a) 10.0, 30.0 \text{ m/s}, (b) 4000, 9000 \pm 10 \text{ m/s}^2, (c) 5.00 \times 10^{-5}, 9.99 \times 10^{-5} \text{ m},$
$\text{(d) 10.0, 30.0 m/s}]$

23-1. A block with mass $M = 3.4$ kg is connected to two springs with force constants $k_1 = 50$ N/m and $k_2 = 100$ N/m. The mass moves on a frictionless horizontal surface where it is displaced from equilibrium and released. In both cases below, the motion can be described not only by all the individual forces acting in the problem but also by an equivalent or effective spring constant $k_{\text{eff}}$.
In the case shown as 'a' in the figure,
(a) What is the effective spring constant $k_{\text{eff}}$?
(b) What is the period of the motion?
In the case shown as 'b' in the figure,
(c) What is the effective spring constant $k_{\text{eff}}$?
(d) What is the period of the motion?
Hint: Both springs stretch when the block moves such that the forces at point P balance.

$[(a) 20, 200 \text{ N/m}, (b) 0.50, 2.50 \text{ s}, (c) 20, 200 \text{ N/m}, (d) 0.50, 2.50 \text{ s}]$
23-2. A simple pendulum has a period \( T = \) [02] _________ s in a location where \( g = 9.80000 \text{ m/s}^2 \).
(a) What is its length?
(b) What would be its period on the moon where \( g = 1.67 \text{ m/s}^2 \)?
(c) What is the difference in the period between a location where \( g = 9.80000 \text{ m/s}^2 \) and a location where \( g = 9.79000 \text{ m/s}^2 \)?
[(a) 1.00000, 2.50000 m, (b) 5.00, 8.00 s, (c) \( 1.00 \times 10^{-3}, \ 2.00 \times 10^{-3} \) s]

23-3. A block of mass \( m \) is attached to a spring with spring constant \( k \) and is observed to execute damped harmonic motion (no driving force) with its position \( x \) given by \( x = Ae^{-\gamma t} \cos (\omega t + \phi) \), with \( \gamma = 7.0 \text{ s}^{-1} \) and \( \omega = 27.0 \text{ s}^{-1} \). Note that \( \gamma = b/2m \).
(a) If the mass of the block is [03] _________ kg, find the value of the spring constant \( k \).
(b) The block and spring are now changed to \( m = 0.5 \text{ kg} \) and \( k = 389 \text{ N/m} \) with the damping the same as in part (a). The block is now driven with a force given by \( F = (1.25 \text{ N}) \cos (\Omega t + \phi) \) with \( \Omega = [04] \) _________ \text{s}^{-1} \). Find the amplitude of the block in meters after the force has been driving the block for several minutes.
[(a) 2000, 9000±10 \text{ N/m}, (b) \( 4.00 \times 10^{-3}, \ 7.00 \times 10^{-3} \) m]