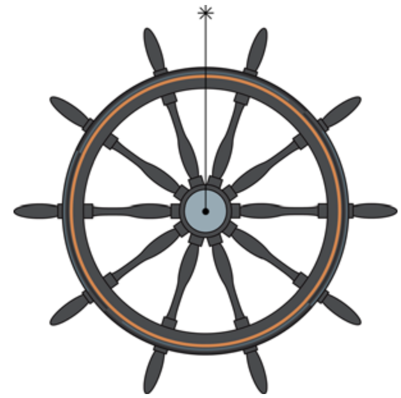
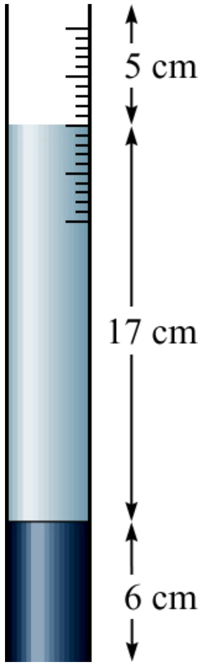
Physics 135-1 Sample Final Questions



1) (10 points) You are in a maritime museum. An old ship's wheel, hanging by its center axis from a cord 1.8 meters long, is swaying very gently in the breeze. You count 17 oscillations in one minute. A sign below the wheel says it has a mass of 20 kg. What is the moment of inertia of the ship's wheel around its center axis?

Solution. The angular frequency of a physical pendulum is $\omega = (mgd/I)^{1/2}$, so $I = mgd/\omega^2$. The frequency is $f = 17$ swings / 60 sec, so $\omega = 2\pi f = 2\pi(17/60) = 1.78$ rad/s. Inserting the other values gives $I = (20\text{ kg})(9.8\text{ m/s}^2)(1.8\text{ m})/(1.78\text{ rad/s})^2 = 111.3\text{ kg m}^2$. However, this I is around the pendulum's *pivot*, not around the wheel's *axis*, which is what the problem asked for. To find that we use the parallel axis theorem: $I = I_{CM} + md^2$, or $I_{CM} = I - md^2 = 111.3\text{ kg m}^2 - (20)(1.8)^2 = 46.5\text{ kg m}^2$.

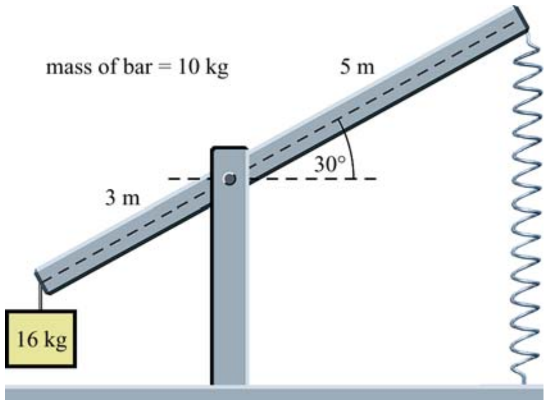


2) (10 points) You have a Physicsland® test tube whose walls have no thickness and no mass. Its radius is 1.2 cm. The test tube contains 6 cm of a tar-like sludge with a density $\rho = 1.4$ g/cm^3. Above that it contains 17 cm of a light oil with a density $\rho = 0.9$ g/cm^3. The top 5 cm of the test tube are empty. If I float the test tube in water, how far below the top lip of the test tube will the waterline be?

Solution. For the test tube to float, its weight must equal the buoyancy force. Since $m = \rho V$, the mass of the test tube is $m = \rho_{tar} V_{tar} + \rho_{oil} V_{oil} = \rho_{tar}\, \pi r^2 (6 \text{ cm}) + \rho_{oil}\, \pi r^2 (17 \text{ cm})$, where we used $V = \pi r^2 h$ for the volume of a cylinder. The given densities yield $m = \pi r^2 [(1.4)(6) + (0.9)(17)] = 23.7\, \pi r^2$. The weight is $W = mg = 23.7\, \pi r^2 g$.

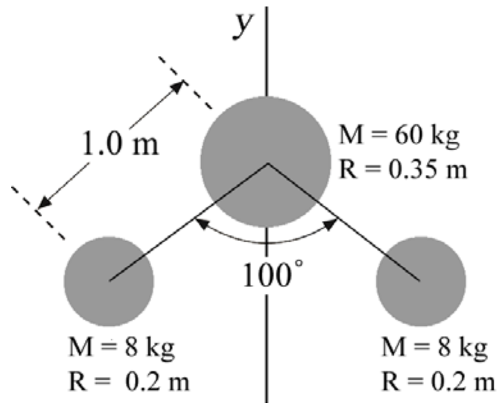
Buoyancy equals the weight of displaced fluid. The displaced water's mass is $m = \rho_{H2O} V_{H2O} = (1 \text{ g/cm}^3) \pi r^2 d$, where d is the length of the tube under water. The buoyancy is then $F_B = W = mg = \pi r^2 dg$. Equating this force to the weight of the test tube yields $d = 23.7$ cm. The waterline will be $(5 + 17 + 6 - 23.7) = 4.3$ cm below the lip. (Note that we did not need to use the values of $\pi r^2 g$).

3) (10 points) A uniform bar that is 8 meters long, with a mass of 10 kg, is attached to a frictionless pivot 3 meters from one end. It is slanted at 30° from the horizontal. A mass of 16 kg is hanging from the short end at shown at right, and a vertical spring is attached to the other end. Nothing is moving. What force is the spring exerting on the bar, and is the spring compressed or stretched? (You do not need to know either the spring constant *k* or the spring's equilibrium length.)



Solution. We have four torques acting around the pivot which must add to zero. The 16 kg mass is acting at –3 m from the pivot, the short end of the bar is acting at –1.5 m (its center of mass), the long end of the bar is similarly acting at +2.5 m, and the spring is at +5 m. We see that the short end of the bar has a mass of (10 kg)(3 m)/(8 m) = 3.75 kg; the long end has m = 6.25 kg. The net torque is $\tau = r \times F = 0 = (-3\text{ m})(16\text{ kg})g\sin\theta + (-1.5\text{ m})(3.75\text{ kg})g\sin\theta + (2.5\text{ m})(6.25\text{ kg})g\sin\theta + (5\text{ m})F\sin\theta$, where F is the spring force we want. All the forces are acting at the same angle to the beam, so $\sin\theta$ is the same for all and cancels out. Inserting numbers, $5F = g(48 + 5.625 - 15.625)$, or F = 74.5 N. The long end of the bar is trying to rise, thus the spring has been stretched.

4) (10 points) The figure shows three spheres connected by two stiff, massless rods. The large sphere has M = 60 kg and R = 0.35 m. Two identical smaller spheres have M = 8 kg and R = 0.2 m. The center-to-center length of the rods is 1 m and they are 100° apart. What is the moment of inertia of this system around the y-axis?



Solution. The larger sphere is centered on the rotation axis, so it has $I = {}^2/_5\,MR^2 = (0.4)(60\text{ kg})(0.35\text{ m})^2 = 2.94\text{ kg m}^2$. For the moment of inertia of either of the smaller spheres, we must use the parallel axis theorem. We have $I = I_{CM} + md^2 = {}^2/_5(8\text{ kg})(0.2\text{ m})^2 + (8\text{ kg})[(1.0\text{ m})\sin(50°)]^2 = 4.82\text{ kg m}^2$, where we have remembered that d refers to the *perpendicular* distance from the CM of a small sphere to the rotation axis. The total moment of inertia is $I = 2.94 + 2 \times 4.82 = 12.58\text{ kg m}^2$.

5) (10 points) For the same spheres as in Problem 5, suppose I place a point mass of 1 kg on a line directly below the large sphere at a distance of 2 m as measured from the large sphere's center, i.e., at (x, y) = (0, –2) if the coordinate origin is at the large sphere's center. What is the direction and magnitude of the gravitational force acting on the point mass, due to the three spheres?

Solution. By symmetry, the gravitational force will act upward along the y-axis. The large sphere will contribute $F = GMm/r^2 = G\ (60\text{ kg})(1\text{ kg})/(2\text{ m})^2 = 15\ G$, because its center is on the y-axis.

Either of the small spheres will contribute $F_Y = GMm/r^2$, where F_Y means only the y-axis force component is used. (The x-components from the small spheres cancel each other.) We can use the x-y coordinates of the right sphere to calculate r: $x = (1.0)\sin(50°) = 0.766$, and $y = -(1.0)\cos(50°) = -0.6428$. This means $\Delta x = 0.766 - 0$ and $\Delta y = -0.6428 - (-2)$, or $\mathbf{r} = 0.766\ \mathbf{i} + 1.357\ \mathbf{j}$. The magnitude of this vector is $r^2 = (0.766)^2 + (1.357)^2$, or $r = 1.56$ m. The unit vector is $\mathbf{r} / 1.56$, or $\underline{\mathbf{r}} = 0.492\ \mathbf{i} + 0.871\ \mathbf{j}$. (We don't need the x-component, but I include it anyway for esthetics.)

This yields a force of $F_Y = G(0.871)(8\text{ kg})(1\text{ kg})/(1.56\text{ m})^2 = 2.87\ G$. By symmetry, the force from the other small sphere is the same, so the total gravitational force is $F = 15\ G + (2)(2.87\ G) = (20.74)(6.67 \times 10^{-11}) = 1.38 \times 10^{-9}$ N = 1.38 nano-newtons.

6) (5 points) I have a rocket whose mass is 100 kg, when it is unfueled. Fully fueled, it has a mass of 160 kg. When the fuel is ignited, it will completely burn out in 10 seconds. Assume that the fuel burns at a constant rate and exits the rocket at a speed of 600 m/s. If the rocket is setting on a launch pad on Mars, what is its instantaneous acceleration (relative to the Martian surface) at the instant the fuel is ignited?

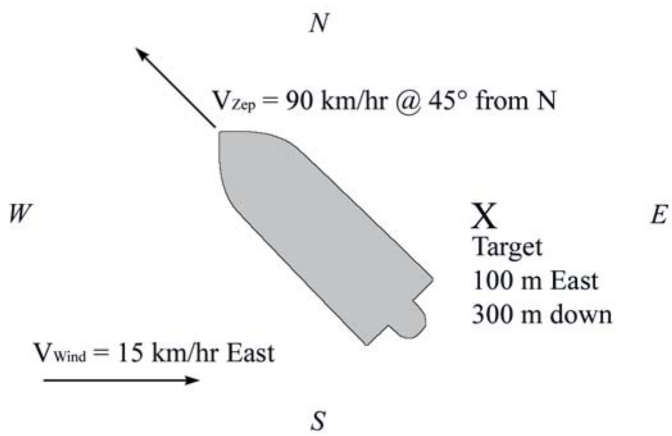
A) 3.8 m/s^2
B) 22.5 m/s^2
C) 36 m/s^2
D) zero (too massive to rise)
E) 26.4 m/s^2
F) 18.7 m/s^2
G) 60 m/s^2
H) 2.4 m/s^2

Solution. The rocket's thrust is $F = v(dm/dt) = (600 \text{ m/s})(60 \text{ kg}/10 \text{ s}) = 3600 \text{ N}$. Its acceleration is thus $a = F/m = 3600/160 = 22.5 \text{ m/s}^2$, and subtracting Mars' gravity gives a net $22.5 - 3.8 = 18.7 \text{ m/s}^2$.

7) A Zeppelin airship is flying at a speed of 90 km/hr on a heading 45° counter-clockwise of North, relative to the surrounding air. A wind is blowing East at 15 km/hr, relative to the ground. The figure shows a "top" view of the Zeppelin.

a) (5 points) At what speed and in what direction (angle from North) is the Zeppelin moving relative to the ground? Assume that counter-clockwise is a positive angle.

A) 80 km/hr @ +37°
B) 75 km/hr @ +45°
C) 85 km/hr @ –4°
D) 95 km/hr @ +35°
E) 101 km/hr @ +51°
F) 80 km/hr @ –53°
G) 90 km/hr @ –45°
H) 64 km/hr @ +15°



b) (5 points) The Zeppelin is 300 meters above the ground. It must drop a packet of medical supplies on a point ("X" marks the spot) that is 100 meters east of its present position. Assume that the initial velocity of the packet has no z-component (no "up" or "down" initial velocity) relative to the Zeppelin. What velocity vector in North/South and East/West components (i.e., in x- and y-components, where x is E-W and y is N-S) must the packet have relative to the Zeppelin to hit the "X" target? You may assume zero air friction.

All answers have units of m/s. Positive is East and North, respectively.

A) $\mathbf{v} = 15.0\,\mathbf{i} - 17.7\,\mathbf{j}$	B) $\mathbf{v} = 1.6\,\mathbf{i} + 17.7\,\mathbf{j}$	C) $\mathbf{v} = 26.3\,\mathbf{i} - 17.7\,\mathbf{j}$
D) $\mathbf{v} = -15.1\,\mathbf{i} + \text{zero}\,\mathbf{j}$	E) $\mathbf{v} = 11.9\,\mathbf{i} + \text{zero}\,\mathbf{j}$	F) $\mathbf{v} = -11.9\,\mathbf{i} + \text{zero}\,\mathbf{j}$
G) $\mathbf{v} = -11.9\,\mathbf{i} - 63.6\,\mathbf{j}$	H) $\mathbf{v} = 26.3\,\mathbf{i} + 63.6\,\mathbf{j}$	I) $\mathbf{v} = -0.7\,\mathbf{i} - 63.6\,\mathbf{j}$
J) $\mathbf{v} = 0.7\,\mathbf{i} + 17.7\,\mathbf{j}$	K) $\mathbf{v} = 48.6\,\mathbf{i} - 17.7\,\mathbf{j}$	L) $\mathbf{v} = 35.8\,\mathbf{i} + 17.7\,\mathbf{j}$

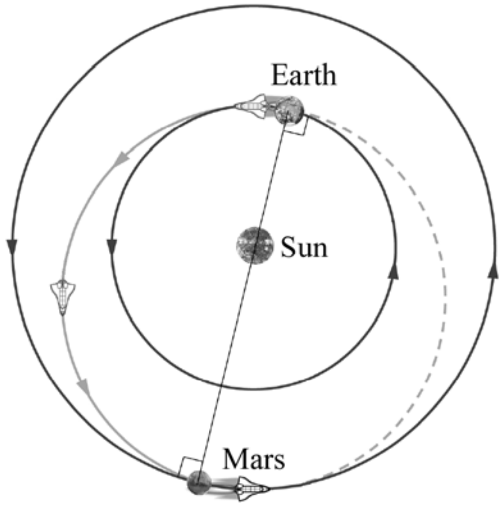
Solutions

7a) The velocity of the Zeppelin relative to the air is $\mathbf{v} = (90 \text{ km/hr})[-\sin(45°)\,\mathbf{i} + \cos(45°)\,\mathbf{j}]$, with $\sin(45°) = \cos(45°) = 0.7071$. Relative to the ground, we must add the wind's velocity to that of the Zeppelin, or $\mathbf{v} = [-(0.7071)(90) + 15]\,\mathbf{i} + (0.7071)(90)\,\mathbf{j} = -48.6\,\mathbf{i} + 63.6\,\mathbf{j}$. The speed relative to the ground is $s = (48.6^2 + 63.6^2)^{1/2} = 80$ km/hr. The angle is given by $\tan\theta = 48.6/63.6$, or $\theta = 37°$ ccw of North.

7b) We have $z = z_0 + v_0 - ½\,gt^2$ for a falling object. Here, $z = -300$, $z_0 = 0$, and $v_0 = 0$. This gives $t^2 = (2)(300)/(9.8)$, or $t = 7.8$ sec for the packet to fall. The packet's motion in the x-direction will be at contant speed. It must move 100 m east as measured from the ground, so $x = v_0 t$ gives $v_0 = x/t = 100/7.8 = 12.8$ m/s to the east, relative to the ground. The Zeppelin is flying at –48.6 km/hr = –13.5 m/s relative to the ground, so the packet must be thrown at 12.8 – (–13.5) = 26.3 m/s east, relative to the Zeppelin. (We have assumed that the packet is unaffected by either air friction or the wind, after it is thrown from the Zeppelin.)

The Zeppelin is moving north at 63.6 km/hr = 17.7 m/s relative to both the air and the ground, so the packet must be thrown south at 17.7 m/s relative to the Zeppelin if it is to move directly eastward. The velocity of the packet relative to the Zeppelin is thus $\mathbf{v} = 26.3\,\mathbf{i} - 17.7\,\mathbf{j}$, in m/s.

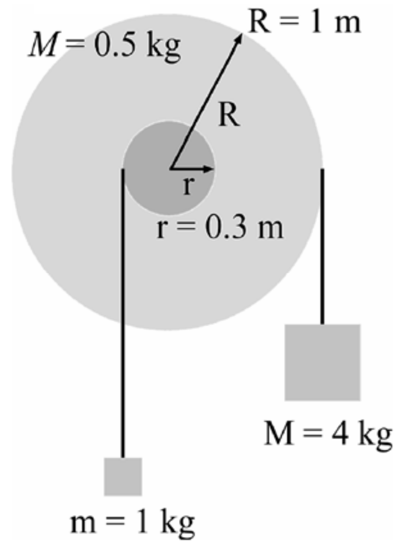
8) (10 points) In the solar system shown schematically at right, the USS Iceskater is launched tangentially to Earth's orbit at 1.82 miles/sec relative to the Earth. The Iceskater coasts in orbit around the Sun until it intersects the orbit of Mars, also at a tangent. Earth, Mars, and the spacecraft are all rotating counter-clockwise. How fast is the Iceskater moving relative to Mars, in miles/sec, when their paths intersect?



Radius of Mars orbit = 1.52 X radius of Earth's orbit
Orbital speed of Earth = 18.51 miles/sec
Orbital speed of Mars = 14.96 miles/sec

Solution: We can solve this problem with conservation of angular momentum. $\mathbf{L} = \mathbf{r} \times \mathbf{p} = mvr$ when the spacecraft is at Earth and Mars, because v is perpendicular to r there. Using E and M subscripts to indicate each planet: $m\, v_E\, r_E = m\, v_M\, r_M$ gives us $v_M = v_E(r_E/r_M) = (1.82 \text{ mi/s} + 18.51 \text{ mi/s})(1.00/1.52) = 13.38 \text{ mi/sec}$. (Note that I added the Earth's speed to Iceskater's speed, because we need its speed relative to the Sun.) The spacecraft's speed relative to Mars is $13.38 - 14.96 = -1.58$ mi/sec. That is, Mars is moving faster than the spacecraft, which has to launched so as to reach the rendezvous point just *before* Mars does.

9) (15 points) A Physicsland® pulley that can rotate with no friction has two masses attached to it. The larger mass (M = 4 kg) is attached to the outside of the wheel at R = 1 m. The smaller mass (m = 1 kg) is attached to a small sleeve of negligible mass located near the center of the wheel at r = 0.3 m. Both are attached with massless cords that wrap perfectly around the wheel without slipping. The wheel can be assumed to be a perfect disk with a mass of *M* = 0.5 kg. As the larger mass falls, what is the linear acceleration of the smaller mass?



Solution: We start with the torques acting on the wheel, $\boldsymbol{\tau} = \boldsymbol{r} \times \boldsymbol{F}$. Here $\tau = rF$ because the weights are pulling at 90° to the radius. Using the sign convention that counter-clockwise rotation of the wheel is positive, then the net torque on the wheel is $\tau_{net} = rT_1 - RT_2$, where T_1 and T_2 are the tensions in the left and right cords, respectively. (That is, T_1 is above m and T_2 is above M.) Note that T_1 is <u>not</u> equal to mg, nor T_2 to Mg, for the simple reason that the masses are accelerating. This can only happen if there are <u>unbalanced</u> forces acting, ergo, $T_1 \neq mg$ and $T_2 \neq Mg$. (The tension can equal the weight only if the system is "bolted down" and isn't moving.) So, we do not know what the tensions are, but we do know that they are unlikely to be equal because the wheel <u>is</u> accelerating! (Yes, we assume $T_1 = T_2$ all the time in problems that have phony massless wheels, but massless wheels have zero moment of inertia.) Our wheel has $I = \frac{1}{2} M_w R^2$, and this requires an unbalanced torque, i.e., $rT_1 \neq RT_2$. In short, we suddenly have three unknowns: a, T_1, and T_2.

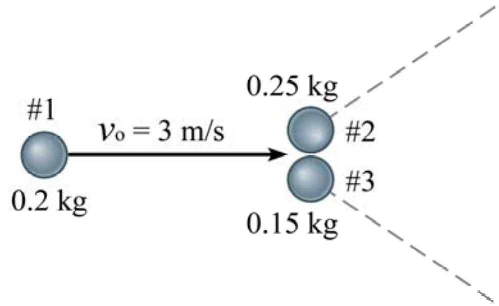
No problem. All we need is three equations. Using $\tau = I\alpha$ gives us one: $\tau_{net} = rT_1 - RT_2 = I\alpha = \frac{1}{2} M_w R^2 \alpha$. For the first mass we have $ma_1 = mg - T_1$, where I thoughtfully note that $a_1 = r\alpha$, and for the second mass we have $Ma_2 = T_2 - Mg$, where $a_2 = R\alpha$. The sign conventions for the gravitational forces and tensions are dictated by whether they are pulling clockwise or counterclockwise.

The algebra can be done in a dozen ways. If we change a_1 and a_2 to α, solve the two shorter equations for T_1 and T_2, then substitute into the equation for τ_{net}, we have $r(-mr\alpha + mg) - R(MR\alpha + Mg) = \frac{1}{2} M_w R^2 \alpha$, where M_w is the mass of the wheel. A little rearrangement yields $mgr - MgR = \alpha(\frac{1}{2} M_w R^2 + MR^2 + mr^2)$. We need the acceleration of the small mass, so $a_1 = r\alpha = rg(mr - MR)/(\frac{1}{2} M_w R^2 + MR^2 + mr^2)$. With numbers: $a_1 = (0.3\text{ m})(9.8\text{ m/s}^2)[(1\text{ kg})(0.3\text{ m}) - (4\text{ kg})(1\text{ m})]/[\frac{1}{2}(0.5\text{ kg})(1\text{ m})^2 + (4\text{ kg})(1\text{ m})^2 + (1\text{ kg})(0.3\text{ m})^2)] = (0.3)(9.8)(0.3 - 4)/(0.25 + 4 + 0.3^2) = -2.51\text{ m/s}^2$. The minus sign means the small mass is rising.

10) (10 points) An overhead view of three billiard balls on a pool table is shown at right. The masses of the balls are:

$m_1 = 0.2$ kg, $m_2 = 0.25$ kg, $m_3 = 0.15$ kg.

Ball #1 is moving at $v_0 = 3$ m/s along the x-axis; the other balls are stationary. Then ball #1 collides *perfectly elastically* between the other balls and stops. It transfers **$^1/_2$** of its momentum to ball #2 and **$^1/_2$** to ball #3. What are the velocity vectors of balls #2 and #3 after the collision (in **i** and **j** notation)?



Solution: Using subscripts 1,2,3 for each ball, and x,y for the vector components, we need the four unknowns v_{x2}, v_{y2}, v_{x3}, and v_{y3}. We know ball #1 transfers half of its momentum to ball #2. Since ball #1 has only x-momentum, we have $\frac{1}{2} m_1 v_0 = m_2 v_{x2}$, or $\frac{1}{2}(0.2 \text{ kg})(3 \text{ m/s}) = (0.25 \text{ kg}) v_{x2}$, or $v_{x2} = 1.2$ m/s. Likewise, we get $v_{x3} = 2$ m/s.

To find v_{y2} and v_{y3} we need two equations. For one we can use momentum conservation along the y-axis: $0 = m_2 v_{y2} + m_3 v_{y3}$, or $v_{y2} = -(0.15 \text{ kg}) v_{y3} / (0.25 \text{ kg}) = -0.6\, v_{y3}$. For the second we use conservation of kinetic energy: $\frac{1}{2} m_1 v_1^2 = \frac{1}{2} m_2 v_2^2 + \frac{1}{2} m_3 v_3^2$. Substituting the various vector components into the kinetic energy equation yields: $(0.2 \text{ kg})(3 \text{ m/s})^2 = (0.25 \text{ kg})[(1.2 \text{ m/s})^2 + (0.6\, v_{y3})^2] + (0.15 \text{ kg})[(2 \text{ m/s})^2 + v_{y3}^2]$, or $1.8 = [0.36 + 0.09\, v_{y3}^2] + [0.6 + 0.15\, v_{y3}^2]$, or $0.24\, v_{y3}^2 = 0.84$, or $v_{y3} = -1.87$ m/s.

We used a negative sign for the square root for v_{y3} because ball #3 is moving downwards. This then gives us $v_{y2} = -(0.6)(-1.87 \text{ m/s}) = 1.12$ m/s.

The velocity vector for ball #2 is: $(1.2\,\mathbf{i} + 1.12\,\mathbf{j})$ m/s

The velocity vector for ball #3 is: $(2\,\mathbf{i} - 1.87\,\mathbf{j})$ m/s

11) (4 points) Titan, the largest moon of Saturn, is 80% more massive than our Moon and has a radius 48% larger than our Moon. If the surface gravity on the Moon is 1.63 m/s^2, what is the surface gravity on Titan?

A) 2.92 m/s^2 B) 1.98 m/s^2 C) 2.41 m/s^2 D) 0.74 m/s^2 E) 1.34 m/s^2 F) 1.01 m/s^2

Solution: $F = GMm/r^2$, so taking the ratio of the forces on a 1-kg object on Titan's surface and the Moon's, we have $F_T/F_M = (M_T/ M_M)/(R_T^2/R_M^2) = 1.8/1.48^2 = 0.82$, or $g_T = 0.82(1.63) = 1.34\ m/s^2$.

12) (4 points) The following objects are rolling along the floor with equal linear velocities. They all have the same mass and radius, but different shapes. Which one has the most kinetic energy?

A) hoop B) long cylinder C) thin disk D) sphere E) spoked wheel F) short cylinder

Solution: Since $E_K = ½ I\omega^2$, the object with the largest I has the most kinetic energy, which is the hoop.

13) (3 points) If you take a spinning gyroscope and drop it off a tall building (neglect air friction), it will:

A) precess all the way down at constant ω
B) precess all the way down with ω gradually decreasing
C) not precess, but tumble randomly
D) precess all the way down with ω gradually increasing
E) not fall at all
F) neither precess nor tumble, but point in one direction

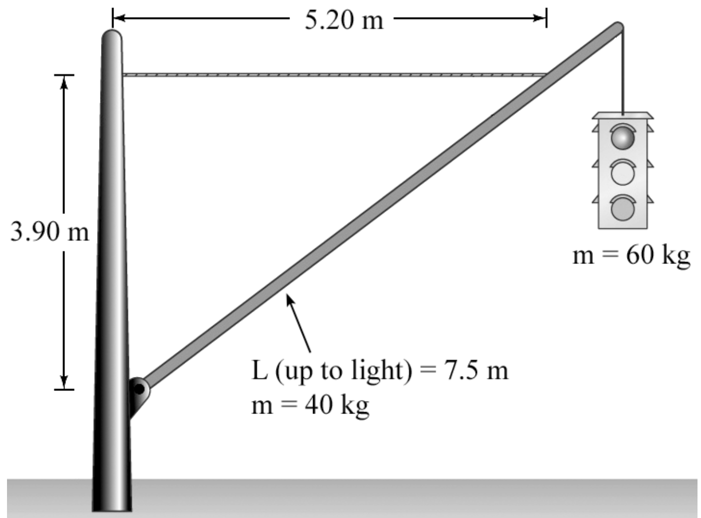
Solution: Conservation of angular momentum will keep the rotation axis pointing one way.

14) (3 points) What is the gravitational force between two 100 kg football players who are 0.5 m apart?

A) 2.67×10^{-6} N B) 6.67×10^{-11} N C) 6.67×10^{-7} N
D) 1.34×10^{-6} N E) 2.67×10^{-8} N F) 1.33×10^{-10} N

Solution: $F = Gm_1m_2/r^2 = (6.67 \times 10^{-11})(100)(100)/(0.5)^2 = 2.67 \times 10^{-6}$ N.

15) (10 points) Suppose we have a traffic light hanging from the end of a boom of mass = 40 kg, length = 7.5 m. The boom is of uniform width and density, and is free to pivot around a frictionless pin at the bottom. A 5.2 m cord is tied to the boom at a height of 3.9 m above the pivot. The traffic light is connected to the very end of the boom, and has a mass of 60 kg. What is the tension in the cord?



A) 980 N
B) 905 N
C) 678 N
D) 1045 N
E) 123 N
F) 1206 N
G) 510 N
H) 600 N
I) 723 N
J) 434 N

Solution: The torques trying to rotate the boom around its pivot must add to zero. There are two torques acting clockwise: the weight of the boom and the weight of the stop light. The weight of the boom acts at its center of mass, (7.5 m)/2 = 3.75 m from the pivot. The weight of the stop light acts at the end, 7.5 m from the pivot. The component of the gravitational force perpendicular to the boom can be obtained by using a bit of trigonometry. Pythagoreas gives the hypotenuse of the part of the beam that goes up to the cord as $h = (3.9^2 + 5.2^2)^{1/2} = 6.5$, so the angle in the cross-product $\mathbf{r} \times \mathbf{F} = rmg \sin\theta$ (i.e., the angle between the perpendicular and the beam) is $\sin\theta = 5.2/6.5 = 0.8$ for either mass. The combined torque from the mass of the boom and the stop light is: $\tau = (0.8)(40\text{ kg})g(3.75\text{ m}) + (0.8)(60\text{ kg})g(7.5\text{ m}) = (0.8\ g)(600\text{ kg-m})$. This must equal the torque supplied by the cord in the counterclockwise direction. The cord is attached to the boom 6.5 m from the pivot, and similar trig to that above gives $\sin\theta = 3.9/6.5 = 0.6$ for the $\mathbf{r} \times \mathbf{F}$ of the tension T in the cord. We have $(0.6)T(6.5\text{ m}) = (0.8\ g)(600\text{ kg-m})$, or T = 1206 N.

16) (4 points) A standard bowling ball is 21.6 cm in diameter and has a mass of 7.26 kg. If a bowler releases a bowling ball which rolls without slipping at a velocity of 13.7 m/s, how much kinetic energy does the bowling ball have?

A) 6.81 J	B) 273 J	C) 1022 J	D) 954 J	E) 545 J
F) 681 J	G) 408 J	H) 1226 J	I) 341 J	J) 1362 J

Solution: The ball will have translational and rotational kinetic energy. The translational part is $E_T = {}^1/_2 mv^2 = (0.5)(7.26)(13.7)^2 = 681$ J. The rotational part is $E_R = {}^1/_2 I\omega^2$, where $I = {}^2/_5 MR^2$ and $v = R\omega$. This gives $E_R = {}^1/_5(MR^2)(v^2/R^2) = {}^1/_5 Mv^2 = (0.2)(7.26)(13.7)^2 = 273$ J. Finally, $E_T + E_R = 681 + 273 = 954$ J.

17) (5 points) Mars has two tiny moons, Deimos and Phobos (aka Panic and Fear). Deimos orbits 23,436 km from Mars with a period of 1.262 Earth days. Phobos orbits 9377 km from Mars. How long does Phobos take to make one orbit?

A) 1.98 days	B) 0.319 day	C) 0.506 day	D) 3.13 days	E) 0.685 day
F) 0.632 day	G) 0.251 day	H) 1.58 days	I) 2.32 days	J) 0.430 day

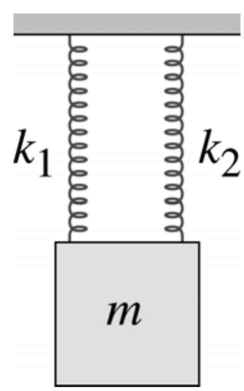
Solution: We can use Kepler's Third Law, $T^2 = (4\pi^2/GM)R^3$. Taking the ratio, $(T_P/T_D)^2 = (R_P/R_D)^3$ gives us $(T_P/1.262 \text{ day})^2 = (9377 \div 23{,}436)^3$, or $T_P = (1.262 \text{ day})(9377 \div 23{,}436)^{3/2} = 0.319$ day.

18) (4 points) The "large" Martian moon, Phobos, has a radius of about 11 km and a mass of 1.08×10^{16} kg. If you stood on the surface of Phobos, how fast would you have to throw a baseball to place it into orbit around Phobos (assuming the orbit is barely above the ground)?

A) 8.1 m/s	B) 8.1 km/s	C) 256 m/s	D) 4.0 m/s
E) 66 m/s	F) 128 m/s	G) 16.2 m/s	H) 7.0 km/s

Solution: For a stable orbit, the gravitational force must equal the centrifugal force acting on the baseball. We have $GMm/r^2 = mv^2/r$, or $v = (GM/r)^{1/2} = [(6.67 \times 10^{-11})(1.08 \times 10^{16})/(11{,}000)]^{1/2} = 8.1$ m/s. This is only 18 miles per hour! There are people who could launch themselves from Phobos by running up a ramp.

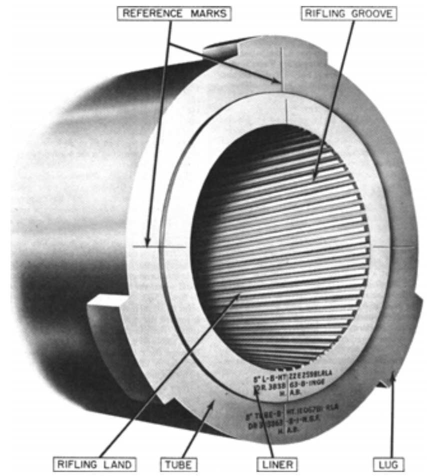
19) (5 points) We have a 500-gm mass and two springs with constants k_1 and k_2. If only the first spring (k_1) is connected to the mass, then its oscillation frequency is 5 Hz. If only the second spring (k_2) is connected to the mass, then its oscillation frequency is 10 Hz. What is the oscillation frequency when both springs are connected to the mass?



A) 5.4 Hz	B) 8.7 Hz	C) 11.2 Hz	D) 15 Hz
E) 7.5 Hz	F) 10.5 Hz	G) 14.4 Hz	H) 12.5 Hz

Solution: With both springs attached to the mass, $F = -k_1x - k_2x = -(k_1 + k_2)x$. This is just the standard harmonic oscillator equation with $\omega = [(k_1 + k_2)/m]^{1/2}$. Since $\omega_1 = 2\pi f_1 = (k_1/m)^{1/2}$, solving for k_1 gives $k_1 = 4\pi^2 f_1^2 m$, and likewise for k_2. Substituting: $\omega = [(k_1 + k_2)/m]^{1/2} = [(4\pi^2 f_1^2 m + 4\pi^2 f_2^2 m)/m]^{1/2} = 2\pi(f_1^2 + f_2^2)^{1/2}$. This yields $f = (5^2 + 10^2)^{1/2} = 11.2$ Hz. (Note that you never need to know the mass.)

20) (4 points) Prior to the end of the eighteenth century, most firearms had smooth bores – that is, their barrels were perfectly smooth cylinders on the inside. After that time, arms makers increasingly moved to "rifled" barrels, which were barrels that had fine lines or grooves engraved on the inside in a shallow spiral (see illustration at right). The purpose of the grooves was to put a lot of spin on the bullet. The question is, why would you want to put a lot of spin on a bullet?



A) Spin makes the bullet give off a frightening whine.
B) The added rotational kinetic energy makes the bullet more destructive.
C) The angular momentum vector keeps it pointed ahead for better accuracy.
D) The centrifugal force helps the bullet maintain its shape.
E) A spinning bullet experiences less air friction.
F) All of the above
G) None of the above.

Solution: The rapidly spinning bullet acts like a tiny gyroscope, so the angular momentum vector directed out of its nose helps to keep it pointed straight forward rather than tumbling. This stabilizes it against erratic flight due to the severe buffeting it receives as it pushes its way through the air at high speed. The bullet's path is thus more predictable and the weapon is more accurate.