XF.10

205

State Any Assumptions You Need To Make – Show All Work – Circle Any Final Answers
Use Your Time Wisely – Work on What You Can – Be Sure to Write Down Equations
Feel Free to Ask Any Questions   ☐☆2a ☐☆2b ☐☆2c ☐☆2e

Safety First (50,000 points)

1.) (a) A small car, $m = 1350\ kg$, is moving at only 5.00 mph (2.23 m/s). How much kinetic energy K does it have?

(b) The small car is equipped with 5 mph safety bumpers, basically a rigid piece of steel on a spring with constant k. The spring is compressed 4.00 cm when the car runs into a brick wall at 5.00 mph (2.23 m/s). Find the spring constant k.

(c) If the car didn't have the safety bumper, find the average acceleration a needed to bring the car to a stop from 5.00 mph (2.23 m/s) in a distance of 4.00 cm.

(d) Smashing the 5.00 kg of steel of the front of the car will result not just in bending and making a noise, but raising its temperature. Find the temperature change ΔT of 5.00 kg of steel when it absorbs a heat energy $Q = 2250\ J$. The specific heat of steel is $c_{steel} = 448\ J/kg \cdot {}^\circ C^{-1}$.

(e) A shelf of width D is made from a uniform slab of wood with mass m. It is attached to the wall at Point 1 with a force $\vec{F}_1$ and is propped up at the end by another piece of wood which exerts a force $\vec{F}_2$ on the shelf at Point 2. Draw the Free Body Diagram and Free Rotation Diagram of the shelf. Identify which way all the components of $\vec{F}_1$ and $\vec{F}_2$ point. *Hint: Should the prop piece be in tension or compression?*
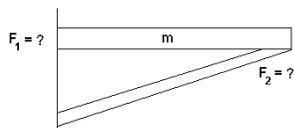
Star Points – The Tasty New Breakfast Sensation   (50,000 points)

2.) ☆(a) An experimental high speed car (m=4100. kg) is traveling at 400. mph (179 m/s) and needs to be stopped. But the car tends to flip if the brakes are applied too hard too early. So the driver uses a force equal to $F_1 = C x^3$, where x is how far the car has traveled while braking, and brings the car to a stop in 2450 m. Set up an integral to find the work done by the force and solve for the constant C.

☆(b) The speed of an object can be described by the following equation. Find the position of the object at the time t = 1.23 sec.
$$v(t) = 7.00\ m/s + 7.00\ m/s^2\ t + 7.00\ m/s^4\ t^3$$

☆(c) The angular speed of an object can be described by the following equation. Find the angular acceleration of the object at the time t = 1.23 sec.
$$\omega(t) = 7.00\ rad/s + 7.00\ rad/s^2\ t + 7.00\ rad/s^4\ t^3$$

(d) Vector $\vec{C} = \vec{A} + \vec{B} = 131.5m\ @\ 35°$ and Vector $\vec{B}$ has components $B_x = 62.3m\ \hat{i}$ and $B_y = -42.7\ m\ \hat{j}$. What is the standard angle θ of Vector $\vec{A}$?

☆(e) The wreck of the *RMS Titanic* lies 3821 meters below the surface of the ocean, where the pressure on it is 48,240,000 Pa. We can's just use $P = \rho\,g\,h$ because ρ is not constant. While water is fairly incompressible, it does increase somewhat from its surface value of $\rho_0 = 1030\ kg/m^3$. If we let the mass-to-volume ratio for sea water to be $\rho(y) = \rho_0\left(1 + \dfrac{C}{h}y\right)$, then integrate $P = \int_0^h \rho(y)\,g\,dy$ where $h = 3821\ m$ to find the constant C. *To eliminate minus signs, we are defining y-positive as down.*

Dr. Phil Marvels That ANYONE Can Afford a Boat! (50,000 points)

3.) The $114,121 Hydra-Sports 2796 Vector cc uses twin Evinrude outboard motors, each with 250 h.p., to move a 6900 pound boat (m = 3130 kg) at speeds up to 54.5 mph (24.4 m/s). At top speed, the engines are generating 500. h.p. total. That's 373,000 W. (a) If we neglected all air and water resistance forces, how long (time) would it take for this boat to get to 54.5 mph (24.4 m/s) using the power of 373,000 W?

(b) However there are resistive forces, and it would not only take longer, but limit the top speed. Find the constant force that a power of 500. h.p. generates at 54.5 mph (24.4 m/s).

(c) At 54.5 mph (24.4 m/s), the boat can't go any faster due to hydrodynamic resistance – water drag. This is similar to the drag due to air resistance. Use the high speed drag equation, $F = c v^2$, and find the constant c. *If you didn't get an answer to (b), then use F = 10,000 N.*

(d) How many Joules/second of Useful Work (per time) is 500. h.p.?

The fuel economy at top speed is 1.23 miles per gallon, since the boat can travel 333 miles on 270 gallons of gas, when traveling at 54.5 mph for 6.11 hours. This results in 1.62×10^6 J of total energy available per second. (e) Find the Actual Efficiency, ε_{actual} , of the engines.

Whirling Physicists (50,000 points)

4.) Consider a merry-go-round on a children's playground, mass $M = 277\ kg$ and radius $R = 3.00\ m$, that we can treat as a uniform solid disk to find it's moment of inertia I. The merry-go-round is spinning at a constant $\omega = 1.50\ rad/sec$ with four large adult men ($m_1 = m_2 = m_3 = m_4 = 175\ kg$) having just hopped onto the edge of the merry-go-round. (a) What was the men's linear speed just before they jumped onto the merry-go-round?
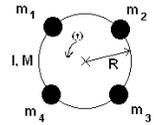
(b) Find the frequency f and the period T of the merry-go-round is spinning at a constant $\omega = 1.50\ rad/sec$.

(c) If the men all move 2.00 meters closer to the central pivot point, what is the new angular velocity of the merry-go-round? *Hint: What rotational quantity can we conserve in this problem?*

(d) A squirrel in a tree 15.0 meters above the ground watches this show, and laughing, rushes to go tell his brothers about these stupid humans. Leaping from one branch with $v_{0x} = 7.80\ m/s$, the squirrel unfortunately misses the next branch and falls all the way to the ground. How far away from his release point does he hit the ground? *Assume he begins to free-fall immediately.*

(e) Lying on the ground, catching his breath, the surprised squirrel contemplates that his weight and his normal force exactly cancel each other, so that he doesn't move. What principle of Physics is in play here? *Short Answer!*