Physics 10154 - Exam #4b

Partial credit will be given provided you show all work and are solving parts of the problem correctly. Points will be deducted if you don't show your work (or if some parts are incorrect) even if you get the right answer. Clearly indicate your answer with a circle or box and remember to include correct units and significant figures.

1. A 35 kg horizontally oriented, uniform cylinder of radius 22 cm is set in motion by wrapping a thin string around the rim of the cylinder and pulling on the string so that the string is tangent to the rim of the cylinder. A frictional torque of 1.4 N-m opposes any motion of the cylinder.

If the cylinder starts from rest and reaches an angular speed of 3.0 rev/sec in 8.0 seconds, answer the following:

a) (25 pts) What is the applied force pulling on the string?

$I = \frac{1}{2}(35)(.22)^2 = 0.847\ kg\cdot m^2$

$\Delta\theta = ?$

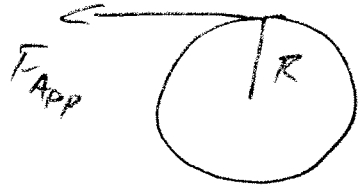
$\omega_0 = 0$

$\omega = 18.85\ rad/s$

$\alpha = ?$

$t = 8.0\ s$

$\alpha = \frac{18.85}{8} = 2.356\ rad/s^2$



$\Sigma\tau = \tau_{App} - \tau_{Fric} = I\alpha$

$+(.22)F_{App}\sin 90 - 1.4 = (.847)(2.356)$

$.22F_{App} = 1.99 + 1.4$

$F_{App} = 15\ N$

b) (15 pts) The instant the cylinder reaches its final speed, the string is released (and we can now ignore friction), and a 4.0 kg piece of putty is dropped vertically 15 cm from the center of the cylinder, where it sticks and moves with the cylinder. What is the new angular speed of the cylinder?

$I_{1i} = I_{1f} = .847\ kg \cdot m^2$

$I_{2i} = I_{2f} = MR^2 = (4.0)(.15)^2 = .090\ kg \cdot m^2$

$\omega_{1i} = 18.85\ rad/s$ $\qquad \omega_{1f} = \omega_{2f} = \omega_f$

$\omega_{2i} = 0$

$I_{1i}\omega_{1i} + I_{2i}\omega_{2i} = I_f\omega_{1f} + I_2\omega_{2f}$

$.847(18.85) + (.090)(0) = (.847 + .090)\omega_f$

$\boxed{\omega_f = 17\ rad/s}$

c) (10 pts) How much kinetic energy is lost when the putty is dropped onto the cylinder?

$K_i = \frac{1}{2} I_{1i}\omega_{1i}^2$

$= \frac{1}{2}(.847)(18.85)^2 = 150\ J$

$K_f = \frac{1}{2}(I_1 + I_2)\omega_f^2$

$= \frac{1}{2}(.937)(17)^2 = 135\ J$

$\boxed{\Delta K = 15\ J}$

2. A 22-kg block of wood floats on the surface of a water tank (water has a density of 1000 kg/m^3) with 63% of the block's volume submerged.

a) (15 pts) What is the density of the block of wood?

$$\frac{V_f}{V_0} = 0.63 \qquad \Sigma F_y = F_B - F_{grav} = 0$$

$$\rho_f V_f g - \rho_0 V_0 g = 0$$

$$\rho_f V_f = \rho_0 V_0$$

$$\rho_0 = \rho_f \left(\frac{V_f}{V_0}\right) = \boxed{630 \text{ kg/m}^3}$$

b) (15 pts) How much additional mass can be placed on the block of wood before it begins to sink?

$$\Sigma F_y = F_B - F_{grav} - m_{extra} g = 0$$

$$V_0 = 22/630 = .03492$$

$$F_B = \rho_f V_0 g = 342.2 \text{ N}$$

$$F_{grav} = (22) g = 215.6 \text{ N}$$

$$342.2 - 215.6 = m_{extra} g$$

$$m_{extra} = \frac{126.6}{9.8} = \boxed{13 \text{ kg}}$$

c) (20 pts) Assume the water tank is open to the air and a hole is poked into the tank at a level 7.5 meters below the surface. Water flows out of the hole and fills up a 1.0 gallon milk jug in 45 seconds. What is the diameter of the hole? Ignore the block of wood for this part.

$$P_{top} + \rho g y_{top} + \frac{1}{2}\rho v_{top}^2 = P_{bot} + \rho g y_{bot} + \frac{1}{2}\rho v_{bot}^2$$

Assume $P_{top} = P_{bot}$

$$v_{top} = 0$$

$$\rho g (y_{top} - y_{bot}) = \frac{1}{2}\rho v_{bot}^2$$

$$v_{bot} = \sqrt{2gh} = 12.12 \text{ m/s}$$

$$q = \frac{1.0 \text{ gal}}{45 \text{ s}} \cdot \frac{3.786 \times 10^{-3} \text{ m}^3}{1 \text{ gal}} = 8.40 \times 10^{-5}$$

$$8.40 \times 10^{-5} = Av$$

$$A = 6.93 \times 10^{-6} = \frac{\pi d^2}{4}$$

$$d^2 = 8.83 \times 10^{-6}$$

$$\boxed{d = 2.97 \text{ mm}}$$