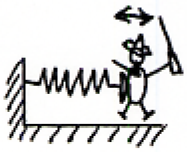
1. (8pts) Short Answer Questions

(a) At the end of an unsuccessful rabbit hunt Elmer Fudd of mass $m = 75kg$ runs into a bumper of spring constant $k = 2.5 \cdot 10^4 \frac{N}{m}$ and gets stuck. At what frequency is Elmer vibrating?

(4)



$f = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = 2.9\ Hz$

(b) Disappointed with the rabbit hunt Elmer Fudd is going after ducks. Elmer is trying to attract Daffy Duck with a duck mating call. The call is a sound at a frequency of $1.1kHz$ and the speed of sound is $343\frac{m}{s}$. What is the wavelength of the call?

(4)

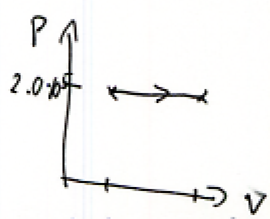
$v = f\lambda$

$\rightarrow \lambda = \frac{v}{f} = 0.31m = 31cm$

2. (10pts) An ideal monatomic gas has an initial volume of $0.10m^3$ and a pressure of $2.0 \cdot 10^5 Pa$. It undergoes an isobaric expansion to a volume of $0.30m^3$.

(a) Draw a P-V-diagram for this process.

(4)



(b) Calculate the work done on the gas, the change of internal energy and the heat transfered to the gas.

(6)

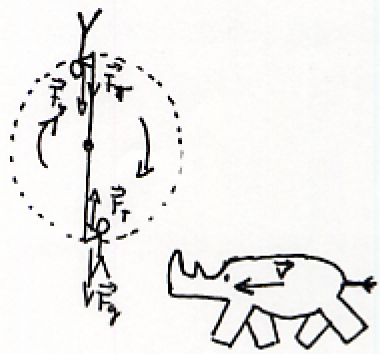
$W = -P\Delta V = -2.0 \cdot 10^5 Pa \cdot 0.20m^3 = -4.0 \cdot 10^4 J$

$\Delta U = \frac{3}{2} nR\Delta T = \frac{3}{2} P\Delta V = 6.0 \cdot 10^4 J$

$Q = 10 \cdot 10^4 J.$

3. (22pts) Once again, on one of those terrible days where everything goes wrong, Tarzan (of mass $m_T = 95kg$) miscalculated a jump and is dangling on a $5.0m$ long vine from a tree. In order to get out of this unfortunate situation he calls Rinaldo the rhino. However, Rinaldo (of mass $m_E = 2500kg$) is running too fast and collides with Tarzan.

(7) (a) If Rinaldo bumps into Tarzan with a velocity of $9.5\frac{m}{s}$ and the collision is elastic, what is Tarzan's velocity right after the collision? (Alternative result: $19\frac{m}{s}$)



$m_R \cdot v_{R/i} = m_R v_{R/f} + m_T v_{T/f}$

$v_{R/i} + v_{R/f} = \cancel{v_{T/i}} + v_{T/f} \longrightarrow v_{R/f} = v_{T/f} - v_{R/i}$

$m_R v_{R/i} = m_R v_{T/f} - m_R v_{R/i} + m_T v_{T/f}$

$v_{T/f} = \frac{2m_R}{m_R + m_T} v_{R/i} = \underline{\underline{18 \frac{m}{s}}}$

(b) Tarzan holds on to the vine and loops in a vertical circular orbit around the tree branch. What is his speed at the highest point of the orbit? (Alternative result: $13\frac{m}{s}$)

(5)

$\frac{1}{2} m_T v_{T/b}^2 = \frac{1}{2} m_T v_{T/t}^2 + 2 g r m_T$

$v_{T/t}^2 = v_{T/b}^2 - 4gr \longrightarrow v_{T/t} = 11.8\frac{m}{s} \approx \underline{\underline{12\frac{m}{s}}}$

(4) (c) Draw all the forces acting on Tarzan at the highest and the lowest points of the orbit.

(d) What is the tension in the vine at the highest and the lowest points of the orbit? The vine can only support a tension of $7000N$. Will Jane see an ungraceful exit once again?

(6)

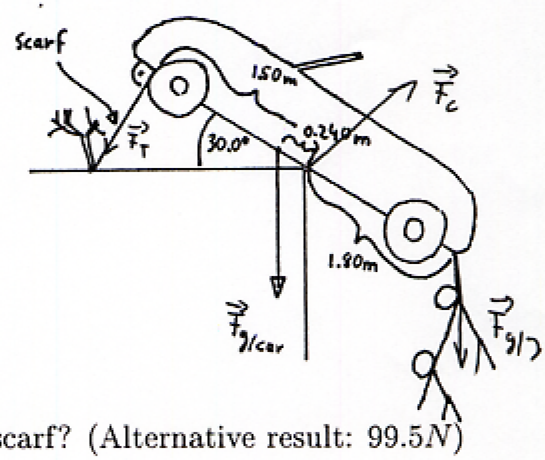
$F_{T/t} = m \cdot \left(\frac{v_t^2}{r} - g\right) = 1.7kN$

$F_{T/b} = m\left(\frac{v_b^2}{r} + g\right) = 7.3kN \longrightarrow$ ungraceful exit.

4. (20pts) At the end of a high speed car chase along the Côte d'Azur James Bond's car (of weight $9.80kN$) is hanging over a cliff about to fall. James Bond and his female companion (of a combined weight of $1.40kN$) are hanging on the bumper of the car as shown in the figure. The car is only held by a lady's scarf which got caught by accident in a bush as shown in the figure. Assume that the car cannot slip at the point A of contact with the cliff (You could imagine a hinge at this point A.). Also assume that the weight of the car is acting as indicated in the figure.

(a) Draw all the forces acting on the car and an axis A of rotation.

(5)



(b) What is the tension in the scarf? (Alternative result: $99.5N$)

(5)

$$1.50m \cdot F_T + 9.80kN \cdot 0.240m \cos 30.0° - 1.80m \cdot 1.40kN \cdot \cos 30.0° = 0$$

$$F_T = \underline{97.0\,N}$$

(c) What are the components of the force of the cliff acting on the car? (You could imagine the force on the hinge.)

(5)

$$F_{c/x} = F_T \cdot \sin 30.0° = \underline{48.5}\,N$$

$$F_{c/y} = F_{g/car} + F_{g/J} + F_T \cdot \cos 30.0° = \underline{11.3\,kN}$$

(d) If the scarf extended from its original length of $1.50m$ by $25.0cm$ and the cross section area of the scarf is $1.00cm^2$, what is the Young's modulus of the scarf?

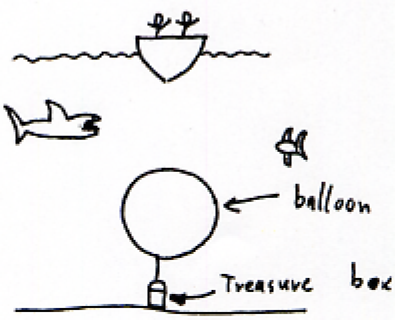
(5)

$$Y = \frac{\frac{F_T}{A}}{\frac{\Delta L}{L_0}} = \frac{97.0N \cdot 1.50m}{1.00 \cdot 10^{-4}m^2 \cdot 0.250m} =$$

$$= \underline{5.82 \cdot 10^6\,Pa}$$

5. (15pts) A treasure box of Spanish doubloons of weight $8.50kN$ is lifted off the ground of the ocean with the help of an air balloon.

(a) What volume of air has to be pumped into the balloon in order for the treasure to lift off the ground? Assume that the water displacement of the treasure and the weight of the air can be neglected. ($\rho_{Water} = 1.00 \cdot 10^3 \frac{kg}{m^3}$. Alternative result: $0.910m^3$)



(5)

$$\rho_w \cdot V \cdot g = 8.50kN$$

$$V = \frac{8.50 \cdot 10^3 N}{1000 \frac{kg}{m^3} \cdot 9.80 \frac{m}{s^2}} = 0.8673 \, m^3 \approx \underline{\underline{0.867 m^3}}$$

(b) The air balloon is at $25.0m$ depth and the pressure inside the balloon is the same as the pressure of the surrounding water. Calculate the pressure inside the balloon. (Alternative result: $3.50 \cdot 10^5 Pa$)

(5)

$$p = p_0 + \rho_w \cdot g \cdot h = 3.463 \cdot 10^5 \, Pa \approx \underline{\underline{3.46 \cdot 10^5 Pa}}$$

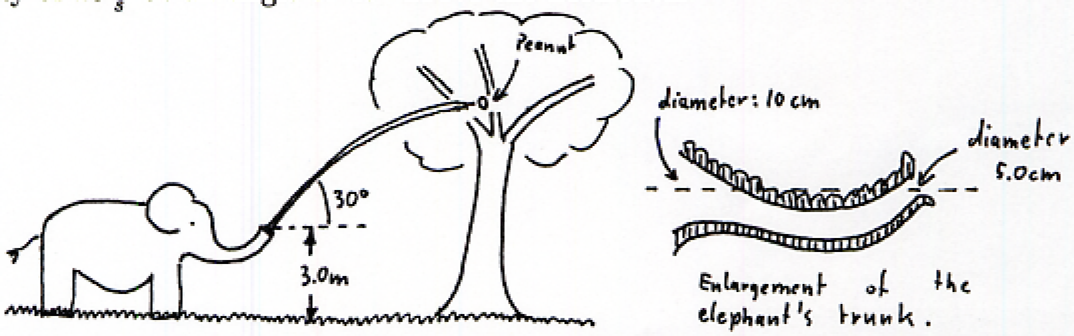
(c) The water temperature is $15°C$. How many moles of air are inside the balloon? (Assume that air is an ideal gas.)

(5)

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{0.8673 m^3 \cdot 3.46 \cdot 10^5 Pa}{8.31 \frac{J}{mol\,K} \cdot 288 K} = 125 \, mol \approx \underline{\underline{1.3 \cdot 10^2 mol}}$$

6. (25pts) An elephant is trying to blow some peanuts off a tree with a fountain of water spraying from his trunk. The end of the elephant's trunk is at a height of 3.0m above the ground and the water is coming out with a velocity of $10\frac{m}{s}$ at an angle of 45° above the horizontal.



(a) The opening of the elephant's trunk has a diameter of 5.0cm whereas in the beginning the diameter of the trunk is 10cm. (Think of the trunk of the elephant as a pipe with a diameter of 10cm at the beginning and a diameter of 5.0cm at the end.) Use the continuity equation to determine the flow speed of the water at the beginning of the trunk. (Alternative result: $2.5\frac{m}{s}$)

(5)

$A_1 v_1 = A_2 v_2$

$d_1^2 v_1 = d_2^2 v_2$

$\rightarrow v_1 = \frac{d_2^2}{d_1^2} v_2 = \frac{1}{4} v_2 = \underline{\underline{2.5 \frac{m}{s}}}$

(b) The beginning and the end of the elephant's trunk are at the same height. Use Bernoulli's equation to determine the pressure of the water at the beginning of the elephant's trunk.

(5)

$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$

$P_1 = \underbrace{P_2}_{= P_{atm}} + \frac{1}{2}\rho v_2^2 \left(1 - \left(\frac{1}{4}\right)^2\right) = \underline{\underline{1.5 \cdot 10^5 \, Pa}}$

(c) Use projectile motion for the spraying water to determine how high above the ground the water will shoot and what the speed of the water at the highest point is? (Alternative result: $v_{top} = 8.0\frac{m}{s}$)

(5)

$0 = (v_0 \sin 45°)^2 - 2 g \Delta y$

$v_t = v_0 \cos 45° = 7.1 \frac{m}{s}$

$\rightarrow \Delta y = 2.55 m$

$\rightarrow y_t = 2.55 m + 3.0 m \approx 5.6 m$

(d) What is the mass of the water leaving the elephant's trunk per second? ($\rho_{Water} = 1.0 \cdot 10^3 \frac{kg}{m^3}$. Alternative result: $\frac{\Delta m}{\Delta t} = 18\frac{kg}{s}$)

(5)

$\frac{\Delta m}{\Delta t} = \rho A v = 19.6 \frac{kg}{s} \approx 20 \frac{kg}{s}$

(e) The water hits the peanuts at the highest point and comes to rest. What is the change in momentum of the water per second at this point? What force does the water exert on the peanuts? (Use the impulse-momentum theorem!)

(5)

$\frac{\Delta p}{\Delta t} = \frac{\Delta m}{\Delta t} \cdot v = 139 N \approx 1.4 \cdot 10^2 N$

$F = \frac{\Delta p}{\Delta t} = 1.4 \cdot 10^2 N$