INSTRUCTIONS DO Problems 1,2 and 3, then any 5 of the remaining 9 problems. Clearly indicate those problems that you want graded by crossing out any work that you don't want graded . Otherwise I grade the first five (5) that have any work.

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Borough of Manhattan Community College — Course ***Physics 215***

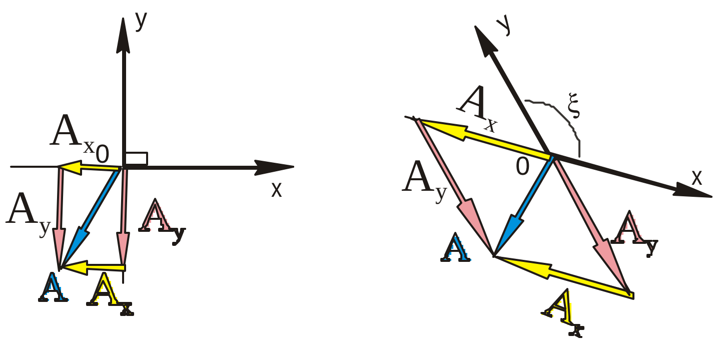
Instructor: ***Dr. Hulan E. Jack Jr.*** — Date **December 19 , 2002**

Final Exam - My Solutions

1. [12 pts Total]

a. What is a vector? Describe its defining features. **[4 pts]**

A vector is a quantity that is described by both a magnitude and a direction.

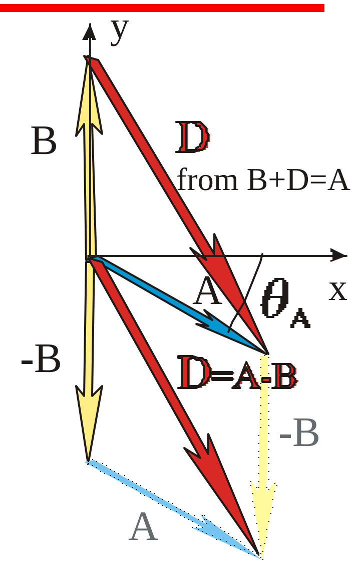


b. The vector A is shown in two coordinates systems. On each coordinate system sketch the x and y components of A for that system. **Briefly** explain the reason for your solutions. **[8 pts]** (4 pts each)

In both situations on the diagrams A_x is parallel to the x-axis;
A_y is parallel to the y-axis;
and $A = A_x + A_y$ as required for components.

2. [16 pts Total] The figure shows two vectors **A** and **B** .
A = 15 units, **B**=10 units and $\theta_A = 30^o$.

a. Sketch the vector **D** = **A** -**B** *directly on the figure*. **[3 pts]**



b. Write the components of the two vectors **[4 pts]**

Symbols	**Values**	**Symbols**	**Values**
A_x	$=A\cos\theta_A = 15\cos 30^0$	B_x	$= B\cos\theta_B = 10\cos 90^o = 0$
A_y	$= A\sin\theta_A = -15\sin 30^o$	B_y	$= B\sin\theta_B = 10\sin 90^o = 10$

c. Write the expressions for the components, magnitude and direction of the vector **D** = **A** - **B** in terms of A_x, A_y, B_x , and B_y.

[9 pts total] **SYMBOLS ONLY**

$D_x = A_x - B_x$ $D_y = A_y - B_y$ $D = \mathrm{sqrt}(D_x^2 + D_y^2) = \mathrm{sqrt}(A_x-B_x)^2 + (A_y-B_y)^2)$

$\theta_D = \arctan (D_y /D_x) = \arctan((A_y - B_y/(A_x - B_x))$.

3. **[12 pts Total]** Using the information 1 Cal = 1kcal = 1000cal , 1 cal = 4.18J, 1 watt = 1J/s, 1 day = 24 hr, 1 hr = 60 min, 1 min = 60 s.

a. Set up the program to go from 1000 Cal/day to watt (1000 Cal/day = (?) watts) using **all** of the above information (**no numbers yet - just units**) [**4 pts**]

pseudo program Cal -> cal -> J and day -> hr -> min -> s.

$$1000\frac{Cal}{day}=\frac{Cal(\,)\frac{kcal}{Cal}(\,)\frac{cal}{kcal}(\,)\frac{J}{cal}}{day(\,)\frac{hr}{day}(\,)\frac{\min}{hr}(\,)\frac{s}{\min}}=1000\frac{xxx\ J}{yyy\ s}=1000\,zzz J/s(\,)\frac{watt}{J/s}$$

b. Explain by illustrating how to check the correctness of the setup program. [**2pts**]

The units must be in a above/below , numerator/denominator, sequence such that all cancel leaving only the desired final unit. For example, in the cal -> J conversion , cal cancels cal.

c. Fill in the numbers **in the above setup program**. [**2 pts**] **(OK, now numbers)**

$$1000\frac{Cal}{day}=\frac{Cal(\,)\frac{kcal}{Cal}(1000)\frac{cal}{kcal}(\,4.18)\frac{J}{cal}}{day(24)\frac{hr}{day}(60)\frac{\min}{hr}(60)\frac{s}{\min}}=1000\frac{1000*4.18\,J}{24*60*60s}=1000*0.0484\ J/s(1)\frac{watt}{J/s}=48.4watts.$$

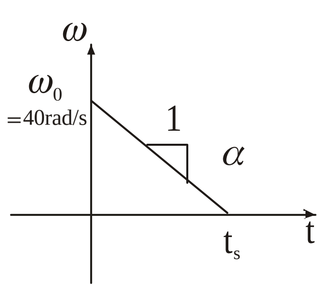
d. Explain by illustrating how to check the numbers for correct positions. **[4 pts]**

On substituting Cal =100cal, if the 1000's cancel, then position is OK. If they don't, as on the right, invert to correct it.

$$\frac{1000cal=kcal(\frac{1}{1000})}{kcal}\qquad\frac{1000cal=kcal(\frac{1000}{1})}{kcal}$$

4. **[12 pts Total]** A body initially rotating at a constant angular velocity ω_0 = 40 rad/s comes to rest (ω=0) in time t_s after rotating 80 rad (radians). Assuming constant angular acceleration α, find t_s and α.

Sketch the angular velocity vs time, ω vs t, curve [4pts]



State The Principle(s) [4pts] with equations

$\Delta\theta$ = area under the ω vs t curve.

α = slope of the ω vs t curve.

Solve for t_s and α [2pts each] symbols then numbers

$$\Delta q=\frac{1}{2}w_0t_s \text{ so, } t_s=\frac{2\Delta q}{w_o} \quad (1)$$

$$(=\frac{2*80rad}{40rad/s}=4.0s)$$

$$a=\frac{\Delta w}{\Delta t}=\frac{0-w_0}{t_s}=\frac{-w_0}{t_s} \quad (2)$$

$$(=\frac{-40\frac{rad}{s}}{4.0s}=-10\frac{rad}{s^2})$$

Combining (1) and (2) gives

$$a=\frac{-w_0}{t_s}=\frac{-w_0}{2\Delta q/w_o}=-\frac{w_o^2}{2\Delta q} \quad (3)$$

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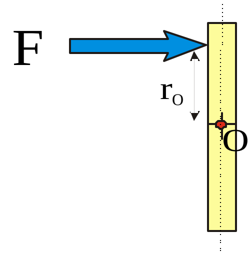
5. **[12 pts Total]** The rod with mass m = 2.0 kg, length L = 1 m, and Moment of Inertia about O I_O = 0.167 kg m^2, is held in vertical position as shown. It is released and hit with a swift horizontal force **F =** 5N, as shown in the picture. Imagine that it is space so there is no gravity acting.

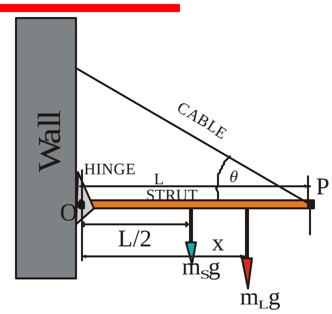


a. Describe the motion of the stick when the force hits on the center of mass O;

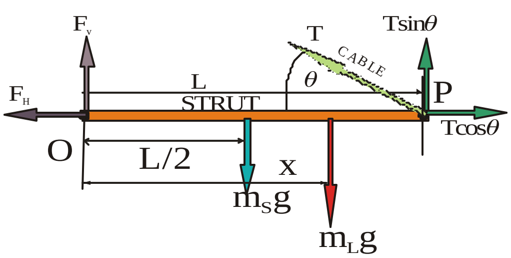
b. when it hits a distance r_O = 0.50 m from O.

State the Physical Principle (s) [2pts each]	**Fill in the Details [2 pts each]**	**Describe the motion.[2pts each]**
a. F = ma	a = F/m	Stick will undergo horizontal linear acceleration in the direction of F.
b. F=ma and $\tau = I_O\alpha$	a = F/m and $\alpha = \tau/I_O$	Stick undergoes horizontal linear acceleration as above, AND SIMULTANEOUSLY, angular acceleration about the center O.

6. **[12 pts Total]** A horizontal uniform strut of mass m_S and length L is supported by a hinge at O and a cable at P. The cable makes an angle θ with the horizontal, A load of mass m_L is a distance x from O. Find the tension T in the cable in terms of m_S , m_L , L, x and θ.



Sketch FBD of the strut. 3 pts



State Physical Principle (s) 4 pts **Fill in the details and solve**.5 pts

ccw$+\Sigma\tau_O = 0$;	$T\sin\theta L - m_L g x - m_S g L/2 = 0$	(1)
$+\wedge\Sigma F_V = 0$;	$T\sin\theta - m_L g - m_S g + F_V = 0$	(2)
$+\!-\!>\Sigma F_H = 0$;	$T\cos\theta - F_H = 0$	(3)

Fill in the details and solve.5 pts

Eq. (1) has all we need. It gives us $T = \frac{m_S gL/2 + m_L gx}{L\sin q} = \frac{m_S g/2 + m_L g(x/L)}{\sin q}$

7. **[12 pts Total]** The absolute potential energy due to gravity of a small body of mass m a distance R from the center of a another large body of mass M, like a planet, is $E_P = - GMm/R$, where G is the Universal Gravitational Constant, $G = 6.67 \times 10^{-11}$ Nm^2/kg^2. Show that the escape velocity, v_e , of m from M is v_e = sqrt(2GM/R).

Write the total energy of m if it is moving with velocity v. 4 pts

$E_{Total} = E_K + E_P \quad = ½ mv^2 \quad - GMm/R$

What is meant by escape velocity v_e? How is it defined. 4 pts

The escape velocity , v_e , is that velocity that m has at R that will allow m to just reach $R = \infty$ with v = 0. So, at infinity $E_P = E_K = 0$. Hence $E_{total} = 0$.

Solve for the escape velocity v_e. 4 pts

Since $0 = E_{Total} = E_K + E_P \quad = ½ mv^2 \quad$ - GMm/R. Then $½ mv_e^2 =$ GMm/R.
Hence v_e^2 = GM/R. So, v_e = sqrt(2M/R).

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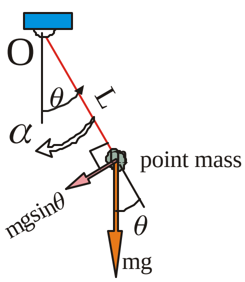
8. **[12 pts Total]** A simple pendulum consists of a mass m = 1 kg of very very small radius hanging at the end of a metal wire of length of $L_0 = 1$ m at T = 30° C. The temperature is raised to 100° C. The wire material has a coefficient of linear expansion $\alpha = 2.0 \times 10^{-5}$ /°C.

a. Show that the **period , P**, of the pendulum at T= 30 °C is P = 2πsqrt(L_0/g).

Sketch a picture of the pendulum to get P. 2 pts.

State Physical Princple(s) 2 pts

Do it. 2pts



Newton's 2nd Law of Motion(Rot)

$\Sigma\tau_O = I_O\alpha$; (1)

(τ_O = Fr)

From the math model for

$\theta = \theta_0\sin(2\pi t/P)$

$\alpha = -(2\pi/P)^2\theta$ (2)

F=mgsinθ , r=L, $I_O = mL^2$

(mgsinθ) L = $- mL^2 \alpha$ (3)

small angle approx sinθ->θ as θ->0.

So, mgLθ = $-mL^2 \alpha$. (4)

Gives $\alpha = - g/L$

Comparing (2) and (4) gives

$(2\pi/P)^2 = g/L$ or P= 2πsqrt(L/g). (5)

b. Find the expression for the **period P** in terms of L_0 , α and ΔT, that is P(L_0, α, ΔT).

State Physical Principle(s) 3 pts.

Get P(L_0, α, ΔT). 3 pts

$\Delta L = L_0\alpha\Delta T$,

so, $L=L_0 + L_0\alpha\Delta T$. (6)

Using (6) in (5) gives

P =2πsqrt(L/g) = 2πsqrt(($L_0 + L_0\alpha\Delta T$)/g).

So, **P(L_0, α, ΔT)** =2πsqrt(($L_0 + L_0\alpha\Delta T$)/g).

=2πsqrt(L_0 (1 + $\alpha\Delta T$)/g).

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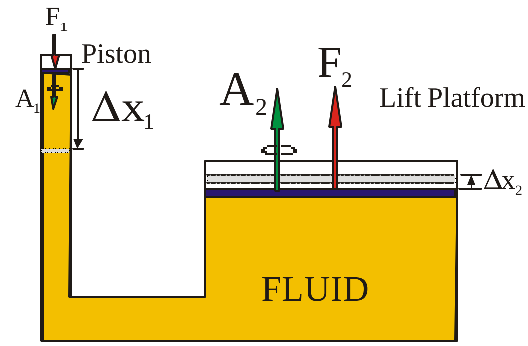
9. **[12 pts Total]** A hydraulic lift is schematically shown in the picture. The piston has area $A_1 = 0.01 m^2$ and the Lift platform area $A_2 = 4\ m^2$. A force $F_1 = 100$ N pushes the piston down by a displacement $\Delta x_1 = 10$ m.

SYMBOLS ONLY! NO NUMBERS!

a. Find the relationship between F_1, F_2, A_1 and A_2 .



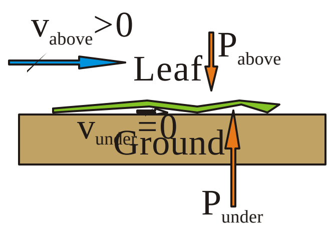
State Physical Principle (s) 2 pts	**Details and Results** 4 pts
$P = F/A$ and P is the same throughout	So, $F_1/A_1 = F_2/A_2$.

b. Find relationship between F_1, F_2, Δx_1 and Δx_2 .

State Physical Principle (s) 2 pts	**Details and Results** 4 pts
Conservation of Energy $Work_{in} = Work_{out}$ $Work = F\Delta x$	So, $F_1\Delta x_1 = F_2\Delta x_2$

10. **[12 pts Total]** On initially a windless day a leaf rests on the ground. Then a gentle breeze of air starts moving across the leaf with velocity v = 5 m/s. What happens to the leaf . Explain.

Add whatever is needed to explain what happens when the breeze starts to blow. 3 pts.



State Physical Princple (s) 3 pts

Bernoulli's Principle

$P_{under}/\rho + ½\, v_{under}^2$

$= P_{above}/\rho + ½\, v_{above}^2$.

Expalin what happens and why. 6 pts

This give

$P_{net} = P_{under} - P_{above}$

$= ½(v_{above}^2 - v_{under}^2)$

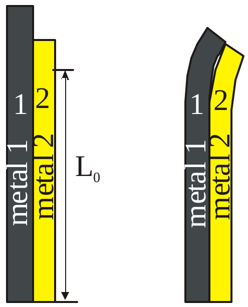
$= ½\ v_{above}^2 > 0$

$(v_{under}^2 = 0)$.

So, $P_{net} > 0$, hence tending to lift the leaf off of the ground .

11. **[12 pts total]** Total] A bimetallic strip consists of two pieces of metal of different coefficients of linear thermal expansion have been welded together. The coefficients of linear thermal expansion of the metals are α_1 and α_2 , where $\alpha_1 > \alpha_2$. At some initial temperature, T_0, the two strips have the same length, L_0 , as shown in the picture. What happens when the temperature of the strip increases by ΔT .

Sketch the strip after its temperature rises. 3 pts



If they were free

But, they are welded together

State Physical Principle (s)

4 pts

Thermal Expansion

$\Delta L = \alpha \Delta T$

Explanation 5 pts

$\alpha_1 > \alpha_2$

So, metall 1 expands more than metal 2. That is $\Delta L_1 > \Delta L_2$. But since the two strips are joined as shown, the thermal stress causes the whole strip to bend as shown.

Thermal Stress

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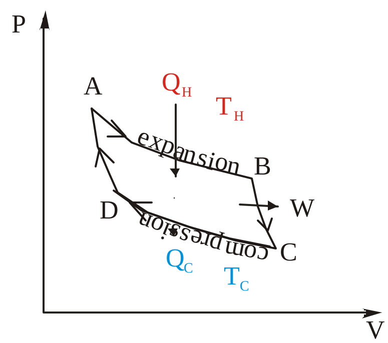
12. **[12 pts total]** Shown is the cycle of an ideal gas engine. As it expands from A to B, it absorbs heat Q_H from the hot environment which is at absolute temperature T_H . As it compresses from C to D it dumps heat Q_C into the cold environment which is at absolute temperature T_C. It does work on some external system.



How much work does it do? What Law applies? Briefly explain. **[4 pts]**

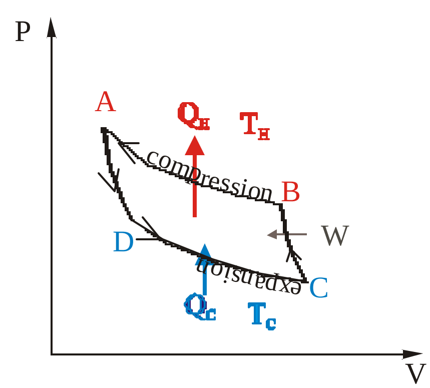
The First Law of Thermodynamics states that in any thermodynamic process $Q = \Delta U + W$, where Q is the heat absorbed (+) by the system, ΔU, (+) increase in the internal energy of the system, and W (+) the work done by the system on the environment.

U is a state function. So, in a cycle where the system returns to its initial internal energy, $\Delta U = 0$. So, in a cycle

$W = Q_{net} = Q_H - Q_C$.

How can you change this so that it operate as a refrigerator?
What does a refrigerator do. **[2 pts]**

A refrigerator absorbs heat Q_C from the low temperature, T_C, reservoir (environment), and dumps heat Q_H into the high temperature, T_H, reservior (environment).



On the diagram, sketch and label the changes in the cycle. Briefly explain what is happening [6 pts]

Reverse the direction of the cycle, as shown. Now it absorbs heat Q_C from cool environment , T_C, by the the expansion and liberates heat Q_H into hot environment, T_H, by the compression.