Suggested Problem Solving Procedure for EMA 542

The following is a suggested format for writing up homework problems in EMA 542. While it is not required that the student follow the format completely, the following steps prove to be useful to both the grader and the student. (Some more useful than others.) These steps assist in developing an organized approach to problem solving for the student. Furthermore, the steps are intended to delineate the intentions of the student in his/her solution, preventing confusion on the part of the grader. Note that the steps 7-9 are to be performed at the same time as needed.

Each problem should (ideally) contain the following:

1. Your name
2. Problem number
3. Read problem statement
4. Write problem statement:
   - Identify the given information: dimensions, constants, forces, etc.
   - Write down the quantity that the problem is asking for.
5. Provide a general diagram:
   - Diagram should portray the physical components of the structure that is being analyzed.
   - All points, dimensions, and angles that are referred to in the solution of the problem should be included in the diagram or subsequent diagrams.

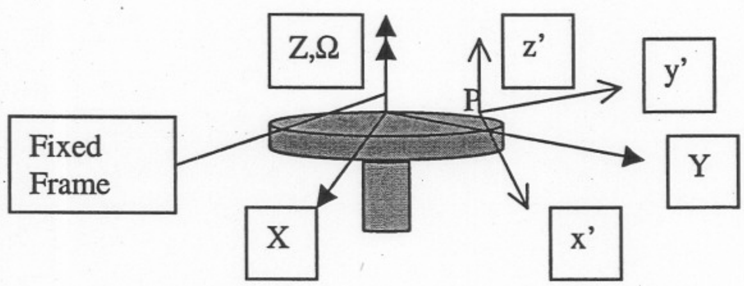
- Try not to change the notation of the problem statement, unless you really need to. (Get used to adapting to someone else's notation.)

(Note: Steps 3, 4 and 5 are intended to give the student a physical sense of the problem, as well as a sense for what is involved in the solution process.)

6. State the governing laws that define the mathematical model of the physical problem:
   - Provide the equations of motion and equations that define the kinematics of the problem.
   - List all the assumptions that make the equations valid for this physical problem. (ex. Assume that all members are rigid bodies, point P is the mass center of bar C-D, bar A-C will be idealized as a thin rod, etc.)

(Note: Assumptions that need to be made as the problem progresses can be stated as they are used. One large section of assumptions is not needed. The point here is to prove to yourself and to the grader that your methods are valid.)

7. Draw diagrams or partial diagrams of the system:
   - Free body diagrams of all of the components that require force analysis should be included.
   - A diagram of the coordinate system is **essential** along with a description of its placement and angular velocity components. (ex. "The rotating coordinate system with base vectors x', y', z' is fixed w.r.t. the platform. Therefore it rotates with the same angular velocity as the platform. This can be expressed in either the fixed coordinate system or the rotating coordinate system," $\vec{\omega}_{cs} = \Omega\vec{e}_K = \Omega\vec{e}_{k'}$. The coordinate system origin (P) also translates with $\dot{\vec{R}}_P = -\Omega b\hat{e}_{i'}$ if (b) is the radius of the platform.



   - All vectors (position, velocity, acceleration, force, moment, etc.) that are given in the problem statement should be drawn in a general configuration with respect to the coordinate system of choice. Include angles between vectors and base vectors (unit vectors in the directions of the coordinate axes). Vectors that are derived may or may not need to be shown in a diagram.
   - It is important that diagrams show a **general** configuration of the structure with all angles and position vectors labeled. (This is important because the novice analyst might forget to break up a vector into components in any general position of the coordinate system chosen to analyze the problem. Remember that a vector must be expressed in general in order to take its derivative.)

8. Clearly write out all of the vectors used in all equations. Make sure that the vector is expressed in terms of the base vectors in the coordinate system of choice. (ex.

"expressing the angular velocity of the rotating coordinate system x', y', z' in terms of the base vectors in the rotating coordinate system $e_{i'}$, $e_{j'}$, $e_{k'}$:
$\vec{\omega}_{cs} = 0\hat{e}_{i'} + 0\hat{e}_{j'} + \Omega\hat{e}_{k'}$."

9. Derive the quantity (velocity, acceleration, equation of motion, etc.) that was asked for in the problem statement:
   - Do this for any general configuration (symbolically) if possible. This technique becomes cumbersome with complicated problems though.
   - Tell a story as you proceed with the calculations. Use diagrams with labels every time that a new symbol is used in the calculations. Use phrases like: "From FBD", "Taking moments about A", "Substituting from equation 1.", "noting that pt. B is a fixed point", "the coordinate system translates with velocity Ωr and rotates...." etc.
   - Break up a large expression (such as that for acceleration) in to logical components. Calculate the components and then substitute into the large expression. (ex. $\vec{a} = \ddot{\vec{R}}_o + \vec{\omega}_{cs} \times (\vec{\omega}_{cs} \times \vec{\rho}) + \dot{\vec{\omega}}_{cs} \times \vec{\rho} + \ddot{\vec{\rho}}_r + 2\omega_{cs} \times \dot{\vec{\rho}}_r$ can be broken up unto the following components:
     $\ddot{\vec{R}}_o$, $\vec{\omega}_{cs} \times (\vec{\omega}_{cs} \times \vec{\rho})$, $\dot{\vec{\omega}}_{cs} \times \vec{\rho}$, $\ddot{\vec{\rho}}_r$, $2\omega_{cs} \times \dot{\vec{\rho}}_r$.
   - Carrying over units is always a good practice. Having units that work out to the expected unit of the answer is a necessary condition for having your answer correct.
10. Check to see if the answer makes sense physically:
    - Are the components in the direction that was anticipated?
    - Do the signs of vector components make sense?
    - Does the relationship between coordinates (degrees of freedom) and other quantities make sense?
    - If not, try to point out where the mistake is.

It is not intended that the steps should be rigorously followed for each problem. The point is that the student should have an organized plan of attack for each problem that he/she is able to justify and clearly relate to a colleague. Missing steps will certainly not result in a deduction of points. But if the student's work is not understandable by the grader, points will be taken off and it will be up to the student to see the grader and reconcile their differences.

Advice and Things to Remember

1. Read the section in the notes **before** lecture.
2. Understand the derivations of the fundamental equations.
   These suggestions will allow the student to get the most out of lectures. Instead of trying to keep up with the deluge of new information presented in lectures, the student will learn about the mathematical representations of physical quantities at his/her own pace. Derivations will be studied in order to see how the final equation has evolved from basic physical principles, and gain incite into the limitations of the equations. Lecture is then an opportunity for reinforcement of

ideas and clarification of misunderstandings. The student will be able to ask the right questions in lecture.

3. Understand derivations and equations on a mathematical and physical level. This skill will enable the student to use equations as a powerful tool, instead of just attempting to repeat a procedure learned in class.
4. Derivatives of vectors can only be taken when the vectors are expressed in the most general form.
5. Vectors such as acceleration and velocity represent physical quantities that are independent of the coordinate system that they are expressed in. Thus the velocity of a particle expressed in one frame is the same as the velocity of a particle expressed in any other frame. The vector is just written in terms of components along different base vectors. Thus the components will be different.
6. Because of 5, it may be useful to calculate the acceleration of, say, the center of a rotating frame using a fixed coordinate system. Then the acceleration vector (which is originally expressed in terms of fixed base vectors) can be written in terms of the base vectors of the rotating coordinate system by using a coordinate transformation.
7. Remember the conditions under which equations are valid. This goes hand in hand with understanding derivations.
8. Take the work you do in this class personally. As an engineer, it is up to you to be able to analyze a system correctly with the proper assumptions. Every mistake can cost lives. Take pride in the power of the material you are learning and know that some day the knowledge gained in this course will elevate the human existence.