Cornell ENGRD 1170 Quiz 2
Dec 3, 2009

No calculators, books or notes allowed.
50 minutes total. No notes. No calculators. No text messaging.

Directions. To ease your TA's grading and to maximize your score, please:

• Draw **Free body diagrams** whenever you use balance of forces or balance of moments.

A+ Be (I) neat, (II) clear and (III) well organized.

☐ **TIDILY REDUCE** and **box in** your answers (Don't leave simplifiable algebraic expressions).

>> Make appropriate **Matlab code** clear and correct.

You can use shortcut notation like “θ = 18" instead of, say, "theta = 18".
Small syntax errors will have small penalties.

↑ Clearly **define** any needed dimensions (l, h, d ...), coordinates (x, y, r, θ ...), variables (u, m, l ...),
base vectors (i, j, k, ê_r, ê_θ, ê_θ, ê_N ... and signs (±) with sketches, equations or words.

→ **Justify** your results so a grader can distinguish an informed answer from a guess.

If a problem seems **poorly defined**, clearly state any reasonable assumptions (that do not oversimplify the problem).

≈ Work for **partial credit** (from 60–100%, depending on the problem)

- Put your answer is in terms of well defined variables even if you have not substituted in the numerical values.
- Reduce the problem to a clearly defined set of equations to solve.
- Provide Matlab code which would generate the desired answer (and explain the nature of the output).

☐ Put your name on each extra sheet, fold it in, and refer to it at the relevant problem.
Note the last page is **blank** for your use. Ask for more extra paper if you need it.
1a) A car with mass $m$ has motor, gears and wheels such that the forward force the wheels can supply is

$$F_w = F_0 - c'v$$

where $F_0$ and $c'$ are constants and $v$ is the speed of the car. Also acting on the car is air drag following the law

$$F_d = \frac{1}{2} c_d \rho A v^2$$

where $c_d$ is the drag coefficient of the car, $\rho$ is the density of air and $A$ is the frontal area of the car. Answer all of the following questions in terms of some or all of the constants given above.

1a) Just when the car starts what is its forward acceleration $a_{\text{start}}$?

$$\frac{dv}{dt} = \frac{F_0}{m} - \frac{c'v}{m} - \frac{c_d \rho A v^2}{2m} \quad \text{close to } v = 0$$

1b) What is the top speed $v_{\text{top}}$ the car can reach on level ground?

$$v_{\text{peak}} = \frac{c' - \sqrt{(c')^2 - 4(-\frac{1}{2} c_d \rho A F_0)}}{c_d \rho A}$$

1c) As the car goes faster and faster, when its speed is $v$ (for some $v < v_{\text{top}}$) what is its acceleration $a$? (Answer in terms of the constants given as well as the speed $v$).

$$a = \frac{dv}{dt} = \frac{F_0}{m} - \frac{c'v}{m} - \left(\frac{1}{2} c_d \rho A v^2 \frac{1}{m}\right)$$

1d) Make a plot of $v$ vs $t$ and of $x$ vs $t$ for the car given that it starts at $x = 0$ and $v = 0$. The plots don't need to be quantitatively accurate, but just need to have the right general shapes (curved the right way with well labeled asymptotes).
1) A. \( F_w - F_d \)

\[
\frac{mdv}{dt} = F_w - \frac{1}{2} C_d P A v^2
\]

\[
\frac{mv}{dt} = F_w - C_d v^2 - \frac{1}{2} C_d P A v^2
\]

must be larger than \( b \)

\[
V_{split} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}
\]

\[
= \frac{-c(0) \pm \sqrt{(c(0))^2 + 4\left(\frac{1}{2} C_d P A v^2\right)}}{2 \left(\frac{1}{2} C_d P A v^2\right)}
\]

10/10
2) a) Assume you could change nothing but the gear box in the car from the previous problem (e.g., same motor, same wheels, same total mass, same air, same shape car). If you picked just the right dissipation-free gear box, how fast could you make the top speed of the car? Answer in terms of some or all of \( m, F_0, c', \rho, A \) and \( c_d \).

\[
F_0 = 6m_0 \int \frac{4p}{F_0} \rho \frac{1}{2} C_d PA V^2 = \rho_0 \int_c \frac{dv}{dt}
\]

b) Why not just equip cars with such a gear and no others? That is, why isn't that particular gear box not the best for all purposes? Be as specific as you can be.

If there was only one gear that output peak power/ speed, there wouldn't be enough torque in the system to start the car in the first place. Some gears allow for more torque (1st gear in a car) & others have few of a reduction as to all of a higher \( \omega \). Diff. G's allow for the same power but are specialized for torque or velocity.
\[ P_0 = \frac{M_0 \omega_f}{4} \]

\[ F_0 = GM_0 \]

\[ F_0 = c' \cdot V \]

\[ c' = \frac{\text{speed}}{c} = \frac{GM_0}{\omega_f} \]

\[ v = \frac{\omega_f}{c} \]

\[ 3/8 \]

with lot of acceleration
3) Draw any 3 bar truss that you like. Apply any non-zero load that you like. Carefully calculate the tension in any bar that you like. Your problem and solution need to be so clear that your work can be quickly evaluated and graded. You may use numbers or symbols (your choice) to define lengths, angles and loads. Draw big and clear.

Solution:

\[ \sum F_y = 0 \]

\[ F_y = A_y + B_y + C_y = 400N - 200N + C_y = 0 \]

\[ C_y = -200N \]

\[ \sum F_x = 0 \]

\[ F_x = B_x + A_x + C_x = 200N + 0 + C_x = 0 \]

\[ C_x = -200N \]

\[ \sum M_{C} = 0 \]

\[ A_y \cdot 4m + 200N \cdot 2m - B_x \cdot 2m = 0 \]

\[ B_y = \frac{1000N \cdot 2m - 1600N \cdot 2m}{2m} = -200N \]
4) A glass of water, not totally full, is on a scale. You slowly put a finger into the water without touching the glass. When you put your finger in the water does the reading on the scale go up (how much?), down (how much?) or stay the same. Your answer must include convincing reasoning. Define and variables you need (e.g., density of water, density of finger, volume of water in the glass, area of the bottom of the glass, etc).

The reading stays the same.

\[ \text{The weight of the water does not change, and by}\]

\[ \text{incorting a finger (suggested from above!), so so } F_{\text{down}}\]

\[ \text{only displaces the finger's worth of water volume,}\]

\[ mg = \rho V_w g \]

\[ mg = \rho (V_w - V_f) g + \rho V_f g \]
5) Two parallel plates with areas $A$ are separated a distance $h$ from each other with a viscous fluid in between with viscosity $\mu$. The bottom plate is fixed and the top one is dragged in its plane with speed $v$. What is the force needed to drag the plate? Assume the plates are very small, that $h$ is much smaller than that and that $v$ is small (Kirby lecture).

\[ F = \frac{h}{\mu} \text{ modulus} \]

\[ \mathcal{M} = v \cdot \cos \left( \frac{2}{5} \right) = \text{flow rate} \]

\[ v = \frac{h}{\mu} \]

\[ \sigma = [\mu] \text{ (modulus)} \]

0/10
6) Comment critically on any one point from Professor Zellman Warhaft’s lecture about Engineering and society. Explain it clearly as if to someone who did not see the lecture (e.g., Prof. Ruina who did not see the lecture). Answer the best you can in no more than 5 minutes.

There are many topics in engineering that are controversial. Examples are, bio research that allows us to clone or make glow in the dark pigs, but also things like wind power. Generally for wind power, the best wind is also in the most open/remote areas... namely those that ecowarriors also want to protect & keep human in ignorance of (e.g. windmills on tops of mountains). Prof. Warhaft advises that the progress we can make will never please everyone—some will fear how fast tech progresses while others always want more improvements.

10/10
7) Describe an experiment to measure the Young's modulus $E$ of a given material. How would you load what shape of material? What would you measure? Write a formula for $E$ in terms of the quantities you would measure. Draw clear sketches with all quantities clearly defined by the sketch or in words.

Blocks/slabs are easy to measure because they have easily defined dimensions & can be supported well. An Euler equation for a bar with $E$ in it is

$$\text{deflection} = \frac{1}{4} \frac{FL^3}{EI}$$

when a bar is supported at both ends by roller supports and loaded with masses $(M \text{grav})=F$. By measuring the deflection & deformation of the bar at the center, $E$ can be calculated.

A setup may look like

A sketch may look like

Gauge to measure deformation

Force gauge

3 loading points
8) Write Matlab commands that would draw a round circle.

```matlab
function circ
    t = 0:.01:pi;
    x = cos(t);
    y = sin(t);
    r = (x^2);
    v = (y^2);
    plot(t,r);
    hold on;
    plot(t,v);
    axis equal;
end
```

9) Circle all of the things on the following list that can be purchased from McMaster Carr: Clock, spring, valve, solder, drill bit, scissors, pulley, bicycle, tricycle, tweezers, magnifying glass, scale, coat hook, office chair, toilet plunger, the Swedish National flag, and a USB flash drive.

Parts for these... almost a whole bike