Your lab TA name, and Lab Section day:

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Cornell ENGRD 1170 Quiz 2

No calculators, books or notes allowed. Dec 3, 2009

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_7 = 18" instead of, say, "`theta7= 18`".
  Small syntax errors will have small penalties.
- Clearly **define** any needed dimensions ($\ell, h, d, \ldots$), coordinates ($x, y, r, \theta \ldots$), variables ($v, m, t, \ldots$), base vectors ($\hat{\imath}, \hat{\jmath}, \hat{e}_r, \hat{e}_\theta, \hat{\lambda}, \hat{n} \ldots$) and signs ($\pm$) 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.

10, 9, 10, 10, 10, 10, 10, 9, 10

88

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, ρ 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_{start}?

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

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

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).

10

1.) A.) $\frac{F_o}{m} = a$ ✓

B.) $F_{net} = 0$

$F_d = F_w$

$\frac{1}{2} C_d \rho A V^2 = F_o - C' V$

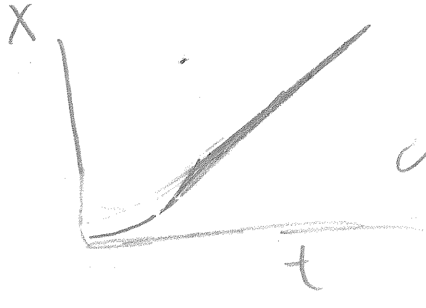
$\frac{1}{2} C_d \rho A V^2 + C' V - F_o = 0$ ✓

$\frac{-B \pm \sqrt{B^2 - 4ac}}{2a} = \frac{-C' \pm \sqrt{C'^2 + 2 C_d \rho A F_o}}{C_d \rho A} = V_{terminal}$

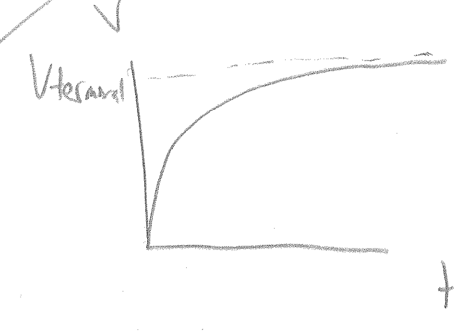
C.) $F_{net} = ma$

$a = \frac{F_{net}}{m} = \frac{F_w - F_d}{m} = \left(F_o - C'V - \frac{1}{2} C_d \rho A V^2\right)/m$ ✓

D.) X vs t



✓



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', ρ, A and c_d?

$F_w = F_d$

$F_0 G - G^2 c' V_t = \frac{1}{2} c_d \rho A V^2$ good

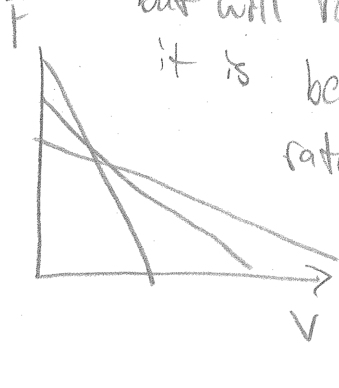
G = unitless gear ratio →

The optimum gear ratio inputted into equation will yield highest speed.

Take derivative with respect to g and solve for maximum

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.

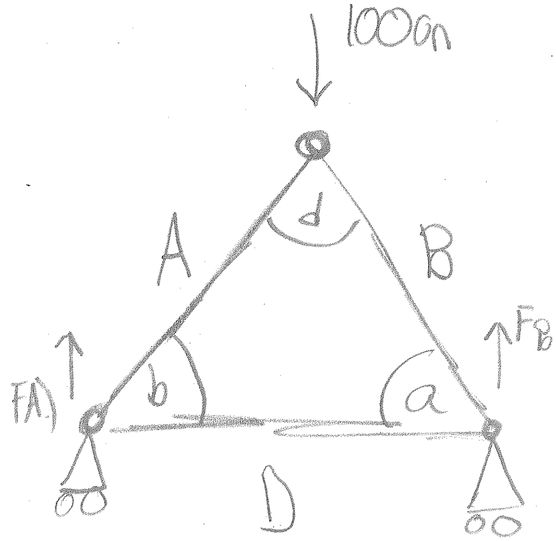
A single gear is never the best solution for all purposes because gear ratios with high terminal speeds have low accelerations because of the linear relation between Force and velocity. It would take long periods of times to travel distances with an initial velocity 0. If a car has high force it will have good acceleration but will reach a low top speed very quickly. Ideally, it is best to have a transmission that uses the best gear ratio given your scenario. The chart to the left shows how the slope of a F vs V chart is affected by a gear ratio.



$$V_{desmral} = \frac{-G^2C' \pm \sqrt{G^2C'^2 + 2GC_d\rho A F_o}}{C_d \rho A}$$

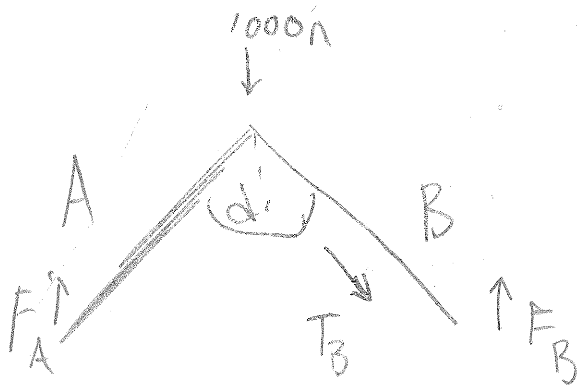
9

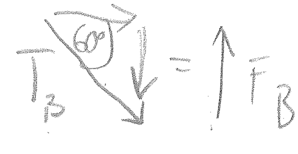
3) Draw any 3 bar truss that you like. Apply any non-zero load that you like. Carefully calculate the tension in any bar that you like. Your problem and solution need to be so clear that your work can be quickly evaluated and graded. You may use numbers or symbols (your choice) to define lengths, angles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



A = B = D = 1m

a = b = d = 60°





$T_b \sin 60 = F_b$

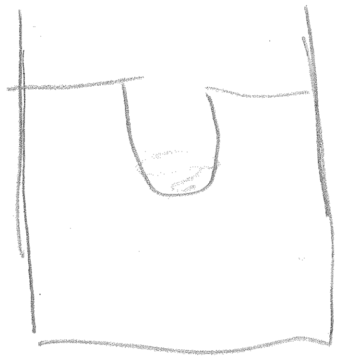
$F_{net} = ma = 0$; $1000n = F_A + F_B = 2F_B = 2T_b \sin 60$

$\tau_{net} = 0$

$$T_b = \frac{1000n}{2\sin 60}$$

(0

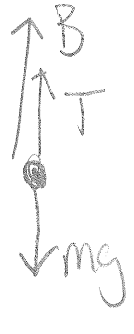
4) A glass of water, not totally full, is on a scale. You slowly put a finger into the water without touching the glass. When you put your finger in the water does the reading on the scale go up (how much?), down (how much?) or stay the same. Your answer must include convincing reasoning. Define and 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 on the scale will increase because your finger will experience a bouyant force equal to weight of the displaced water. Because of newtons third law, there is a reaction force in the opposite direction. This force is equal in magnitude and therefore equal to the bouyant force.

Bouyant force equals weight of disp

FBD of Finger



mg

The Bouyant force is equal to weight of displaced water

So

Bouyant force is equal to weight of displaced water

so $B = \rho \cdot V \cdot g$ ✓ 10

ρ = density of water

V = volume of submerged finger

g = gravity

The scale reading increases by $\rho V g$

5) Two parallel plates with areas A are separated a distance h from each other with a viscous fluid in between with viscosity μ. 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).

$\sigma = \eta \gamma$ γ = pascal-seconds

$\eta = \frac{V}{D}$

σ = stress = N/m² = $\frac{F}{A} = \frac{V\mu}{h}$

$$F = \frac{V\mu A}{h}$$

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.

One point that I took from Professor Zellman Warhafts lecture was the question of is it ethical to have planned obsolescence in a finite world. The world's engineers must be concerned about using the worlds resources and efforts should be focused on recycling rather than materialism. While it is great to invent new technology, you are utilizing resources to build a device that will have a lifespan of only a few years. Eventually this needs to stop in order to have a sustainable society.

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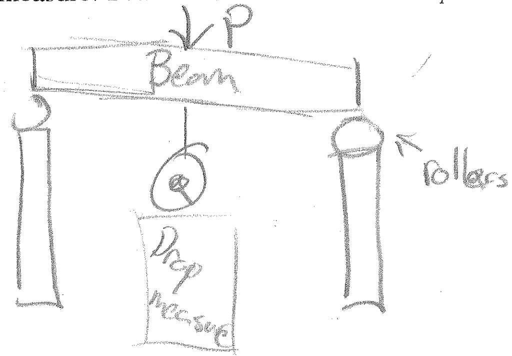
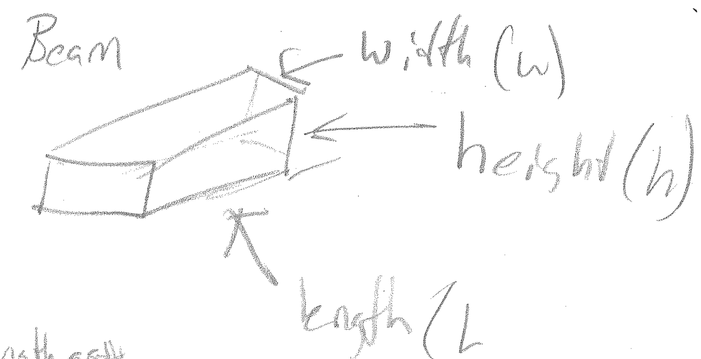
7) Describe an experiment to measure the Young's modulus E of a given material. How would you load what shape of material? What would you measure? Write a formula for E in terms of the quantities you would measure. Draw clear sketches with all quantities clearly defined by the sketch or in words.





- The Beam is exactly the same length as the distance between rollers.

You would apply a specified load (P) to a beam placed on rollers. You would then measure the displacement (Δ). The beam would have dimensions w, h, and L. The load would be applied at 1/2 from the edge

$$\Delta = \frac{P L^3 k}{4 w h^3 E}$$

k is a constant depending on geometry in this case I believe 1/4

4wh

10

$$E = \frac{P L^3 k}{4 w h^3 \Delta} =$$

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

θ = linspace(0,2π, 100)

x = cos θ

y = sin θ

plot(x,y)

axis('equal')

9

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.

✓+ 10

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