University of British Columbia
Faculty of Applied Science
Department of Mechanical Engineering

MECH

TEST #3, October 19, 2017

MECH 221

Suggested Time: 1hr 40 min **Allowed Time:** 1hr 50 min

Materials admitted: Pencil, eraser, straightedge, Mech 2 Approved Calculator (Sharp EL-510), one 3x5 inch sheet of paper for hand-written notes.

There are 5 Short Answer Questions and 2 Long Answer Questions on this test. All questions must be answered.

Provide **all** work and solutions **on this test**.

Orderly presentation of work is required for solutions to receive full credit. **Illegible work, or answers that do not include supporting calculations and explanations will NOT BE MARKED**.

FILL OUT THE SECTION BELOW. Do this during the examination time as additional time will not be allowed for this purpose.

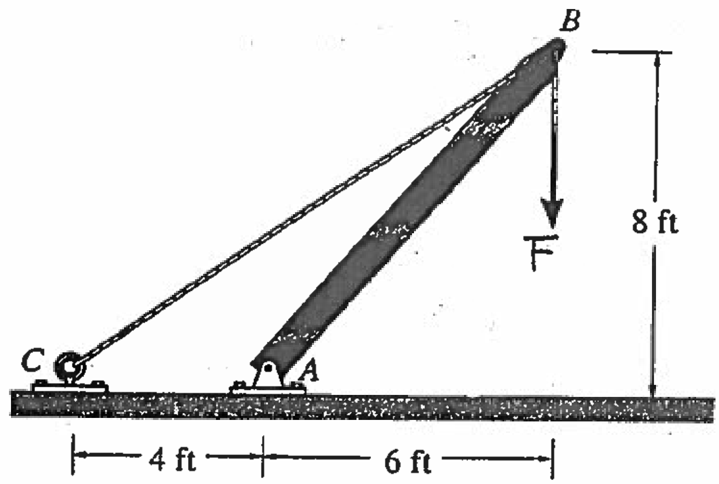
NAME:______________________________Section__________

SIGNATURE:______________________________

STUDENT NUMBER:__________________________

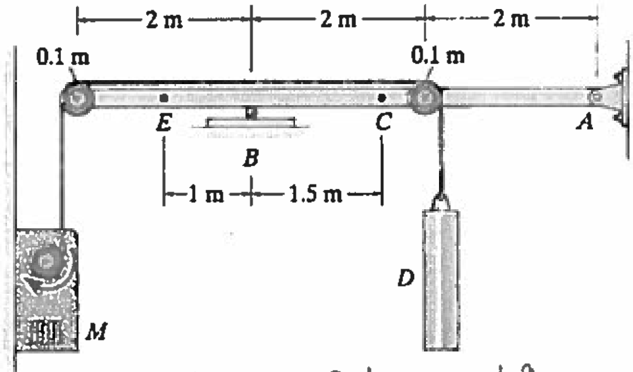
Question	Mark Received	Maximum Mark
SA 1		5
SA 2		5
SA 3		7
SA 4		5
SA 5		7
LA 1		21
LA 2		25

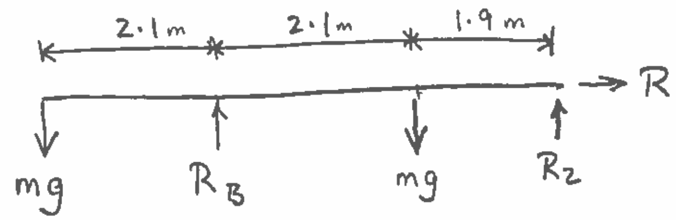
SA3. A simple crane consists of an aluminum beam AB, pinned at its lower end A, and secured at its upper end by a steel cable BC. When the crane supports a load of 1000 lb, the top of the crane, B moves down by 10 inches. When the load is increased to 2000 lb, the downward movement of B increases to 22 inches. When the load is removed, point B returns to its initial position. Use the ideas discussed in class to comment on these observations.



The crane returns to its initial position when the load is removed, so no yielding has taken place. Thus, the deformations of the metal parts are linear. However, the small angle ABC causes the large movements of B. The consequent large changes in geometry alter the internal load distribution and hence the non-linear response. This called "geometric non-linearity". The principle of superposition does not apply here.

SA4. A motor M is connected to a cylinder D of mass m by a thin flexible cable. When turned on, the motor turns and slowly lifts the cylinder. Draw a fully labeled free-body diagram of the beam A-C-E (including the part further to the left of E) and determine the resulting reaction force at B.



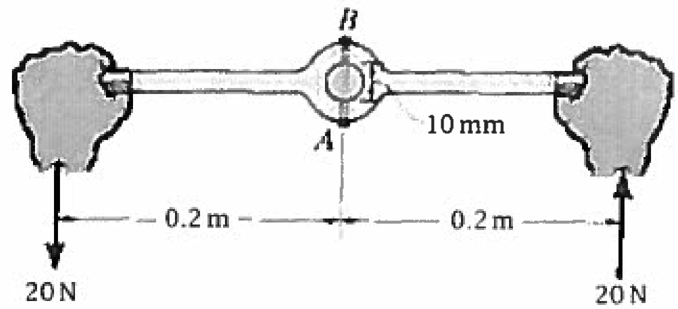


To find R_B, take moments around A (this eliminates R_1 and R_2 from the evaluation)

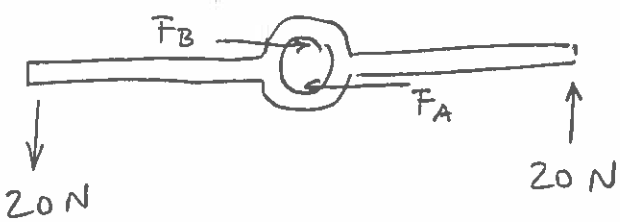
$$\Sigma M_A = 6.1\,mg - 4.0\,R_B + 1.9\,mg = 0$$

$$\longrightarrow \underline{R_B = 2mg}$$

SA 5. A control handle 0.4m long is attached at its centre to a circular shaft of diameter 10mm. The attachment bolt AB is 2mm in diameter and passes through a hole in the shaft. Calculate the minimum ultimate shear stress that is required for the bolt so that it can support the working loads of 20N.



Let τ_u = ultimate shear stress of bolt



Shear forces in bolts

$$F_A = F_B = \tau_u \cdot \frac{\pi\ 0.002^2}{4}$$

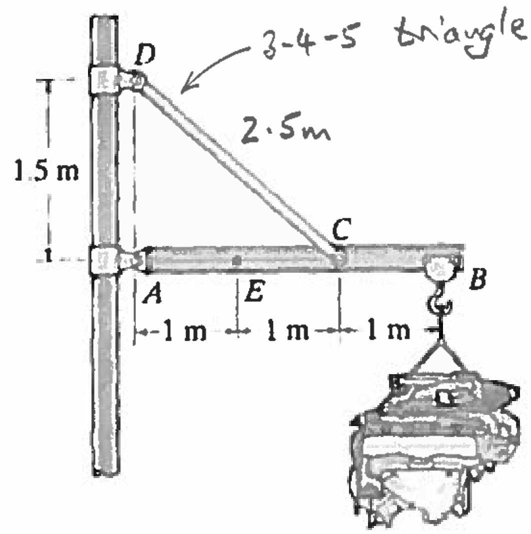
Moment balance about centre:

$$\Sigma M = 20 \times 0.2 + 20 \times 0.2 - F_A \times 0.005 - F_B \times 0.005 = 0$$

$$\rightarrow F_A = F_B = \frac{20 \times 0.2}{0.005} = 800\ N$$

$$\rightarrow \tau_u = \frac{F_A \times 4}{\pi \times 0.002^2} = \underline{255\ MPa}$$

LA1. The diagram shows an engine hoist. The vertical rod AD is securely fixed to a wall. Both rod AD and horizontal rail AB have substantial cross-sections and can be assumed to be rigid. Diagonal rod CD is made of steel 10mm in diameter and is pinned at each end. You are asked to find the downward deflection of point B that occurs when an engine of mass 300 kg is lifted.



(a) Describe in words your plan for solving this question.

(b) Draw a fully labeled free-body diagram of the engine hoist.

(c) Implement your plan described in part (a) to determine the downward deflection of point B that occurs when an engine of mass 300 kg is lifted.

(a) Draw FBD and use equilibrium to find force in CD. No need to find forces in AC or AD because we are told they are "rigid". Use Hooke's Law to find extension of CD. Use a vector diagram to determine downward displacement at C ($\rightarrow$ compatibility). Use similar triangles to find displacement at B.

(b)

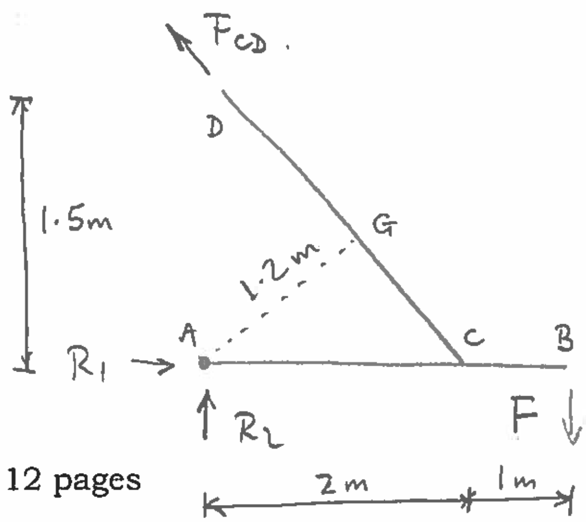
(c) Engine load $F = mg$

$F = 300 \times 9.81$ N

$F = 2943$ N

Distance AG

$L_{AG} = 0.2 \times \frac{3}{5} = 1.2$ m



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Take moments about A : $\Sigma M_A = F_{CD} \times 1.2 - F \times 3 = 0$

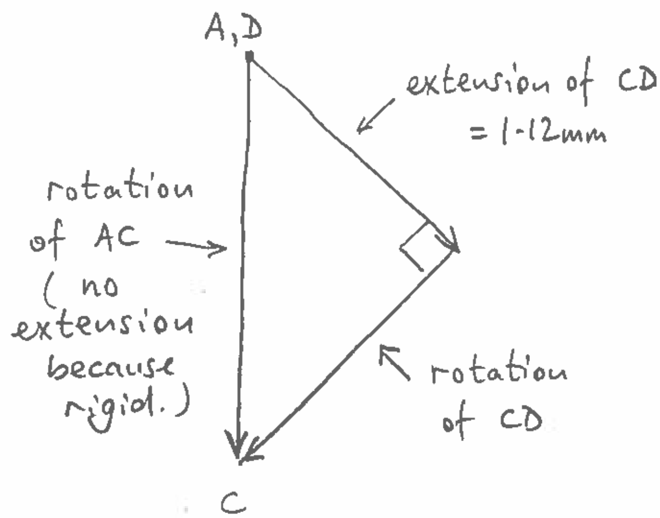
$$\rightarrow F_{CD} = \frac{2943 \times 3}{1.2} = 7360 \text{ N}$$

Hooke's Law : $\sigma = E\epsilon \rightarrow \frac{F}{A} = E\frac{\delta}{L_0}$

$$\rightarrow \delta_{CD} = \frac{F_{CD} L_{CD}}{A_{CD} E_{CD}} = \frac{7360 \times 2.5}{\pi \frac{0.01^2}{4} \times 210 \times 10^9} = 1.12 \text{mm}$$

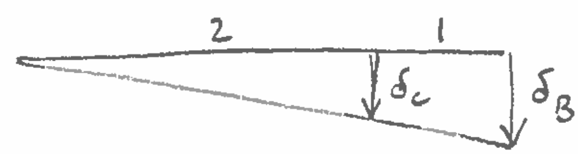
Draw vector diagram

For compatibility, CD must rotate such that C moves downwards. AC is rigid, so does not change length.



$\rightarrow$ Downward displacement of C $= \delta_C = 1.12 \times \frac{5}{3}$

$$\delta_C = 1.87 \text{mm}$$



From similar triangles:

$$\delta_B = \frac{3}{2}\delta_C = 2.8 \text{ mm}$$