Machines C - Machines C Division - Camas C-Invite - 12-12-2020

Welcome to the C division Machines test.

You may use any calculator of any form.

Please do not use any outside resources other then your designated binder..

Tie breakers: Q30, Q31, Q20, Q25, Q11, Q6, Q8, and test time.

1. (1.00 pts) An example of a second class lever is a

- A) Seesaw
- B) Wheelbarrow
- C) Tweezer
- D) Plier

2. (1.00 pts) In a third class lever, which is true?

- A) The mechanical advantage is always greater than one.
- B) The mechanical advantage is sometimes greater than one.
- C) The mechanical advantage is equal to one.
- D) The mechanical advantage is always less than one.

3. (1.00 pts)
Using a screwdriver to pry open a pain cant, and the length of the outside edge of the can to the tip of the screwdriver is 1 cm. The total length of the screwdriver is 8 cm. The lid on the paint can provide sufficient resistance. What is the ideal mechanical advantage of the system?

- A) 8
- B) 7
- C) 64
- D) 49

4. (1.00 pts) When the screwdriver is used to drive a screw, it is a

- A) a lever
- B) a wheel and axle
- C) a screw

D) an inclined plane

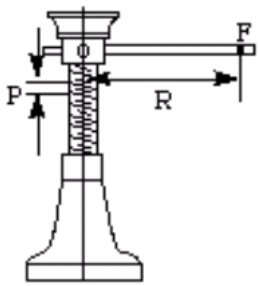
5. (1.00 pts) If a simple machine is in a frictionless environment, and it requires more effect force than resistance force, then the mechanical advantage is

A) one
B) greater than one
C) less than one
D) negative

6. (1.00 pts) A gear train has three gears with 10 teeth, 18 teeth, 16 teeth, in order. The middle gear will turn at what rate if the first gear is moving at 60 RPM?

A) 33.33 RPM
B) 108.00 RPM
C) 96 RPM
D) 17.60 RPM

7. (1.00 pts) The screw jack below is used for heavy lifting, R represents the length of the handle and P the pitch of the screw. Which principle does this apply:



A) screw
B) gear
C) lever
D) inclined plane
E) Gear chain

8. (2.00 pts)
In previous question, if R is 45.72 cm, P is 0.3175 cm, and we apply 49.9 Newton force F, what is the maximum weight that can be lifted? Select the closest estimate.

A) 49.9 ton
B) 45.4 ton
C) 14.5 ton
D) 27.7 ton

9. (1.00 pts) Ideal mechanical advantage is based on

A) Effort and resistance distances

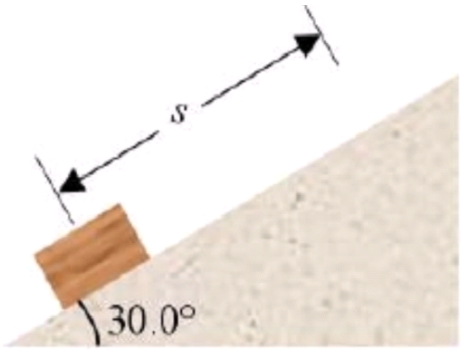
B) Effort and resistance forces

C) Static equilibrium

D) Force and distance

10. (2.00 pts)

A physics student shoves a **0.50 kg** block from the bottom of a frictionless **30.0°** inclined plane. The student performs **4.0 J** of work and the block slides a distance *s* along the incline before it stops. Determine the value of *s*.



A) 120 cm

B) 160 cm

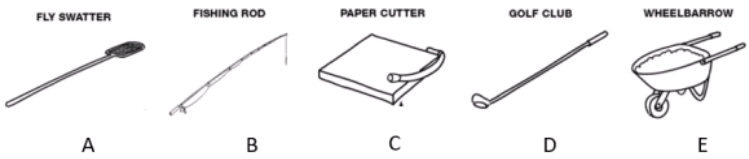
C) 80 cm

D) 8 cm

E) 16 cm

F) 320 cm

11. (2.00 pts) Identify all the class-II levers below



(Mark **ALL** correct answers)

A) A

B) B

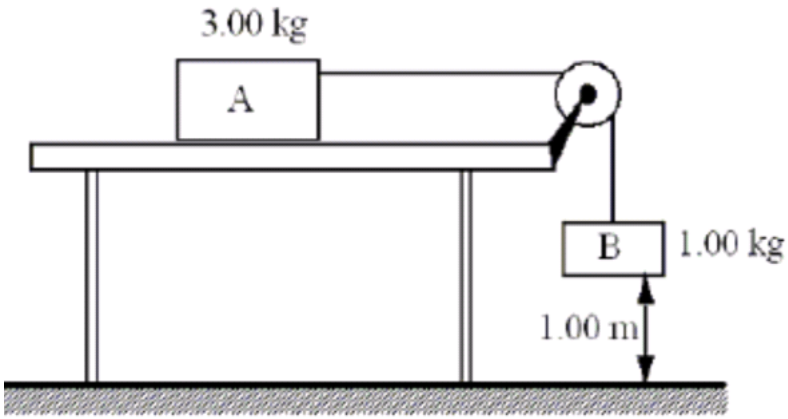
C) C

D) D

E) E

12. (2.00 pts)

Two boxes are connected to each other as shown. The system is released from rest and the **1.00 kg box** falls through a distance of **1.00 m**. The surface of the table is frictionless. What is the kinetic energy of box B just before it reaches the floor?



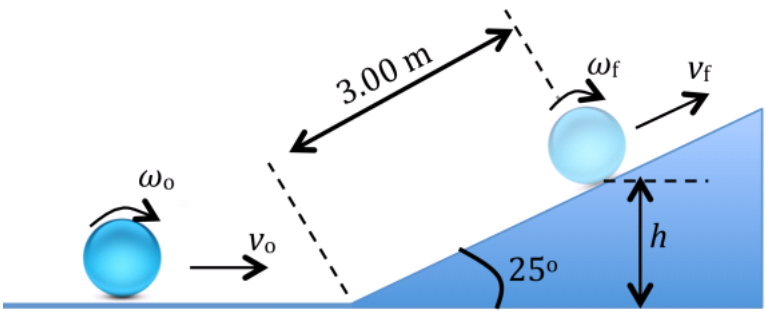
A) 2.00 J
B) 29.4 J
C) 35 J
D) 2.45 J
E) 9.8 J
F) 4.9 J

13. (2.00 pts)
A wheel of radius **0.5 m** rotates with a constant angular speed about an axis perpendicular to its center. A point on the wheel that is **0.2 m** from the center has a tangential speed of **2 m/s**.

Determine the angular speed of the wheel.

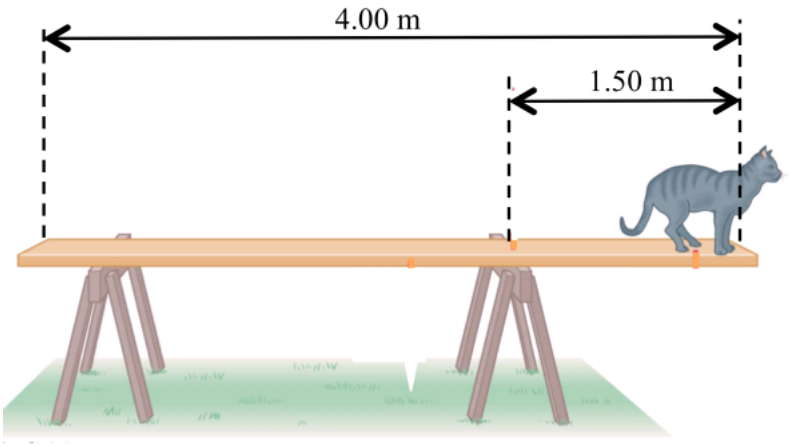
A) 1 rad/s
B) 2 rad/s
C) 20 rad/s
D) 0.4 rad/s
E) 120 rad/s
F) 10 rad/s

14. (2.00 pts)
A solid sphere is rolling without slipping along a horizontal surface with a speed of **5.50 m/s** when it starts up a ramp that makes an angle of **25.0°** with the horizontal. What is the speed of the sphere after it has rolled **3.00 m** up the ramp? Notice the sphere rises a height h as it rolls up the ramp



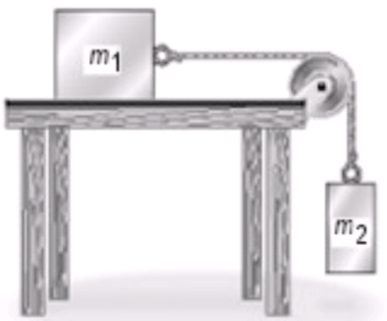
- (●) A) 3.53 m/s
- ( ) B) 2.73 m/s
- ( ) C) 5.76 m/s
- ( ) D) 1.2 m/s
- ( ) E) 2.16 m/s
- ( ) F) 4.01 m/s

15. (2.00 pts)
A cat named Schrodinger walks along a uniform plank that is **4.00 m** long and has a mass of **7.00 kg**. The plank is supported by two sawhorses, one that is **0.44 m** from the left end of the plank, and the other that is **1.50 m** from the right end. When the cat reaches the very right end of the plank, the plank starts to tip. What is Schrodinger's mass? Note: Just whe the plank begins to tip, the normal force on the plank from the sawhorse on the left will go to zero.



- ( ) A) 7.21 kg
- ( ) B) 3.08 kg
- (●) C) 2.33 kg
- ( ) D) 5.20 kg
- ( ) E) 3.41 kg
- ( ) F) 2.92 kg

16. (2.00 pts)
Two masses are connected by a string which goes over an ideal pulley as shown in the figure below. Mass **m1 = 55.0 kg**, and the coefficient of static friction between m1 and the table is **0.30.** What is the largest mass that can be hung for m2, such that the system remains in equilibrium?



- A) 162 kg
- B) 52.5 kg
- C) 18.7 kg
- D) 55 kg
- E) 16.5 kg
- F) 12.7 kg

17. (2.00 pts)

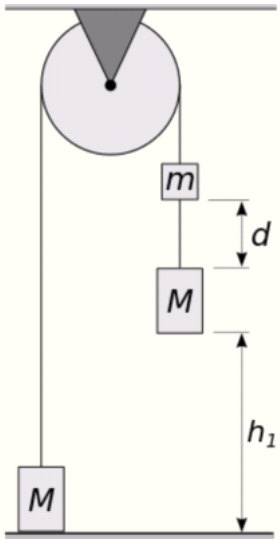
A bucket with mass *m*2 and a block with mass *m*1 are hung on a pulley system. Find the magnitude of the tension force *T* by which the rope is stressed. Ignore the masses of the pulley system and the rope. The bucket moves up and the block moves down.

- A) T=((m1)g)/(m1+2m2)
- B) T=(4m2(m1)g)/(m1+3m2)
- C) T=(3m2(m1))/(m1+4m2)
- D) T=(3m2(m1)g)/(m1+4m2)
- E) T=(m2(m1)g)/(m1+m2)
- F) T=(2m2(m1)g)/(m1+2m2)

18. (2.00 pts)

There are **two weights** of the same mass of **2.0 kg** attached to a string looped over a braked pulley. The left weight is lying on the floor, the right one is suspended **1.0 m** above the floor. There is another weight of mass **0.5 kg** attached to the string **20 cm** above the right weight. The string except the part around the pulley is stretched vertically. We then release the pulley.

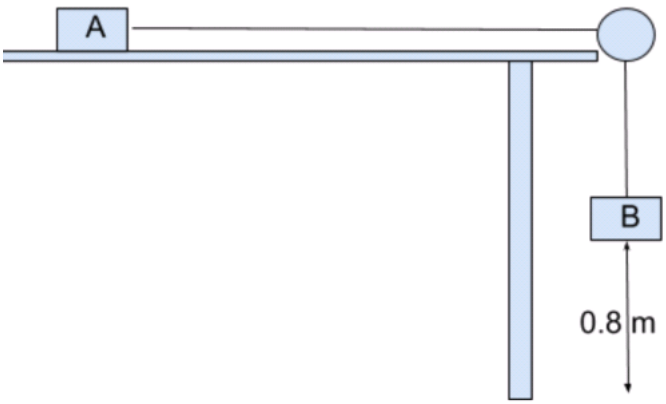
What is the height that the left weight rises to after the lower right weight falls inelastically to the floor?



- A) 0.819 m
- B) 1.185 m
- C) 2.235 m
- D) 3.145 m
- E) 1.752 m
- F) 5.528 m

19. (2.00 pts)
Two wooden blocks each of **m=0.30 kg** mass are connected by a massless string that passes over a very light frictionless pulley. One block slides on a horizontal table with **friction,** while the other hangs suspended by the string, as shown. At time **t=0**, the suspended block is at a height **h=0.80 m** above the floor, and the blocks are released from rest. after a time t=2.5s, the suspended block reaches the floor.

Determine the tension T in the rope during the motion of the blocks.



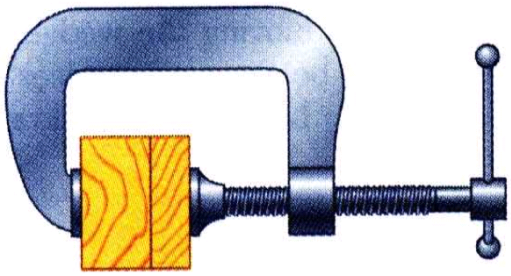
- A) 3.45 N
- B) 7.61 N
- C) 2.86 N
- D) 1.48 N
- E) 4.98 N
- F) 2.27 N

20. (2.00 pts)
The input force of **11 N** acting on the effort arm of a lever moves **0.4 m**, which lifts a **40 N** weight resting on the resistance arm a distance of **0.1 m**. What is the efficiency of the machine?

- A) 82%
- B) 75%
- C) 9%
- D) 91%
- E) 100%
- F) 97%

21. (4.00 pts)
A clamp is used to hold two pieces of wood together as shown. The clamp has a double square thread of mean diameter equal to **10 mm** with a pitch of **2 mm**. The coefficient of friction between threads is **mu s = 0.30.** If a maximum torque of **40 Nm** is applied in tightening the clamp.

Determine the torque required to loosen the clamp.

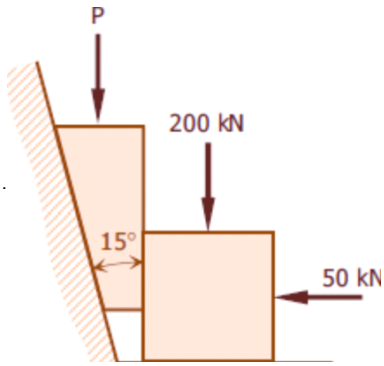


- A) 13.12 Nm
- B) 14.87 Nm
- C) 21.73 Nm
- D) 10.43 Nm
- E) 19.56 Nm
- F) 22.92 Nm

22. (1.00 pts) What is the width of a wedge with a mechanical advantage of **7** and a length of **14 inches**?

- A) 5 in
- B) 0.02 in
- C) 7 in
- D) 0.5 in
- E) 1 in
- F) 2 in

23. (0.00 pts) Determine the force P required to start the wedge shown below. The angle of friction for all surfaces in contact is **15°**

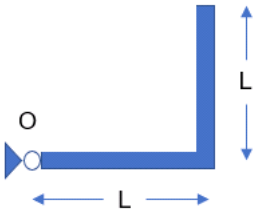


- A) 94.34 kN
- B) 81.28 kN
- C) 17.93 kN
- D) 9.54 kN
- E) 33.77 kN
- F) 110.29 kN

24. (1.00 pts)
A pulley system, made up of 3 pulleys, has a mechanical advantage of 5 and pulley diameters of 20 cm. If each pulleys diameter is doubled what will be the new mechanical advantage?

- A) The new mechanical advantage will be 2.5.
- B) The new mechanical advantage will be 5.
- C) The new mechanical advantage will be 7.5.
- D) The new mechanical advantage will be 10.
- E) The new mechanical advantage will be 15.
- F) The new mechanical advantage will be 40.

25. (3.00 pts)
The moment of inertia about the center of mass of a slender rod with mass m and length L is $I = \frac{mL^2}{12}$. Two rods with mass m are joined together to form a right-angle section as shown below.

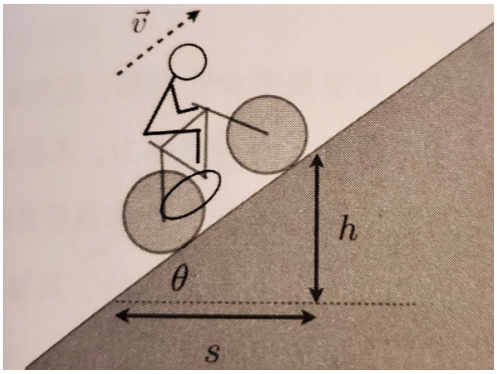


The mass moment of inertia of the right angle fixture about the point O is (assume rotation is about the axis going in/out of the screen)

- A) $I = \frac{2mL^2}{3}$
- B) $I = \frac{21mL^2}{12}$
- C) $I = \frac{5mL^2}{3}$
- D) $I = \frac{7mL^2}{6}$

26. (5.00 pts)
[FRQ] Suppose you are in Tour de France, and you are heading up Alpe d'Huez. What would be the biggest incline you can maintain a speed of 4 m/s, assuming you achieve a peak metabolic rate of 300W, and all your energy are converted perfectly to the mechanical energy?

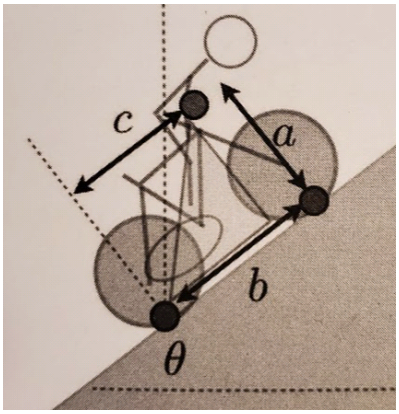
Note incline is expressed in (b/s)*100%, so a ratio of b/s = 0.1 means 10%. - Show work to get full points. You can assume your weight + bicycle is 75kg.



Expected Answer: My estimate is 10%, based on vertical velocity times the weight being limited to 300W. Original question should be asking for ratio of (h/s), instead of (b/s). During the competition the clarification was made to use next question for definition of "b", i.e. slope length. So all answers in ("b"/s) are also accepted.

27. (3.00 pts)
[FRQ] Assuming you have superpower to the degree where your metabolism is not a limitation. And you can sacrifice velocity for steepness. Then we can push to the limit where exact geometry of your bicycle and your riding stance probably matter. Shown below is an idealistic scenario, the height of your center of gravity a = 0.8m, and the distance between center of gravity and contact point of the rear wheel c = 0.75m.

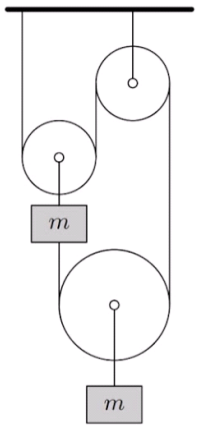
What is the maximum incline you can achieve? (note your superpower is limited to unlimited metabolism, not flying).



Expected Answer: Maximum slope is where center of gravity is aligned vertically with the rear wheel contact point. So that gives tan-1(0.75/0.8) = 43degree. This is a incline of 93.7%.

28. (7.00 pts) [FRQ] What is the acceleration of the lower pulley and its direction? Ignore pulley's mass. Show work to get full marks. [6 pts]

If we put the pulley system shown below on the moon, what would be the acceleration? [1 pt]

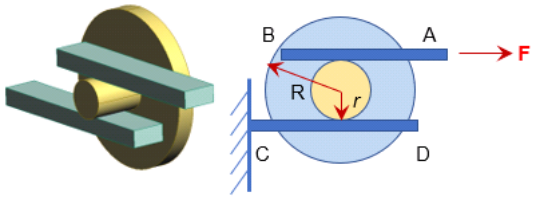


Expected Answer: Lower pulley, a = 2F/m-g, where F is the force in the line. Upper pulley has acceleration a' = F/m-g. Since rope is inelastic, a' = -2a. So a=-2/5g. Assume moon is 1/6 of 9.8, we get a = 0.653 m/s^2. Direction is downward.

29. (15.00 pts)
[FRQ] Shown below is a mechanical control device where the force applied at the terminal A is proportional to the relative acceleration of A vs. C. This is analogous to a capacitor in circuit. The force applied $F = ba$ where the acceleration a is in horizontal direction. In the design below, the disk has a mass m, radius R and a mass moment of inertia $mR^2/2$. Th axle with radius r is rigidly connected to the disk, and both axle and plate AB, CD mass can be ignored.

A) What is the unit for coefficient b in the device, assuming unit of F is Newton, a is m/s^2? [2 pts]
B) Assume there is no slip between plate AB and CD versus the axle, what is the ratio of the velocity at terminal A v_1 versus the velocity at the center of the axle v_2? [3 pts]

C) Find the expression for coefficient b, describe you steps to get full credit [10 pts]

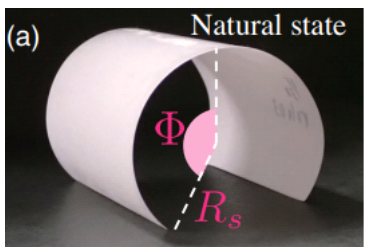


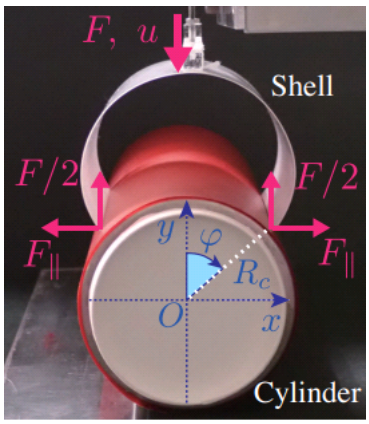
Expected Answer: A) Kilogram, mass unit ■ B) $v_1 = 2v_2$ ■ C) Balance angular momentum $I \times a/(2r)$ with the torque from the shear force $(F + F_{CD}) \times r$, and know $F - F_{CD} = ma/2$ (for the axle), one get $b = \frac{m}{4}(1 + \frac{R^2}{2r^2})$. ■

30. (15.00 pts)
[FRQ] Interlocking joint are often made of highly deformable polymeric materials that can withstand large torsion. They can be designed we hooks, knobs, protrusions, along with the parts to be joined designed as depression, dents, or openings, to facilitate assembly and disassembly. Popular example are water bottle caps, phone cover etc. The mechanism behind it is modeled in an experiment with a semi-cylindrical shell of radius R_s and thickness t, a rigid cylinder with radius R_c, and a force gauge that can measure precisely the force and displacement of the elastic shell. Shown below are (a) the cross section of the shell in an undeformed state, and (on the right) the shell-on-cylinder configuration.

A) What is the snap-fit condition, or critical opening angle Φ_{snap} that allow it to be able to fit the cylinder under reasonable initial force? Express you answer in parameter $a = R_c/R_s$, and assume a friction coefficient of $\mu = 0.3$. [10 pts]

B) What if the contact is frictionless, i.e. $\mu = 0$? - In both case you can assume quasi-static balance without worrying about deformation of the shell. [5 pts]





Expected Answer: There are three discrete points on the shell, the overall vertical force balance requires that the sum of the forces must vanish irrespective of the shape of a shell, F= 2P cos φ + 2Q sin φ, and Q = uP, where P, Q are normal and tangential force. Force F/F_parallel = $2(1 + \mu \tan\phi)/(\tan\phi - \mu)$. So at F=0, $\phi = \pi - tan^{-1}(1/\mu) = 1.862$. An

the critical opening angle Φ_s shell length $R_s\Phi_s$ must be equal or larger than $R_c\varphi$, so $\Phi_s = 1.862a$. ■. (B) In extreme case, $\Phi_s = \pi a/2$.

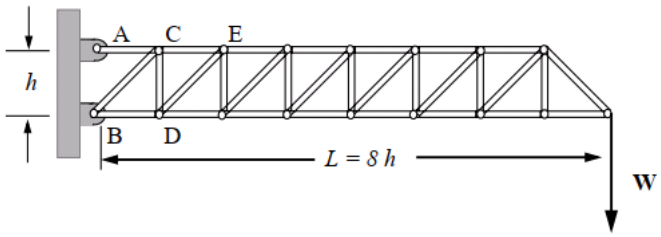
31. (15.00 pts)

[FRQ] Your buddy MW is forced to compete in Digital structure event this year, and he built a Boomilever-like truss structure in a web-based CAD tool, as illustrated below. The material he choose for all the member of the truss has the same strength, and they are equal in load capability in compression and in tension.

He is really not motivated to do more than necessary, so here are some specific things you can help him with using your Machine knowledge.

(A) Suppose he knows the truss member AC can support a maximum of 10 Newton in tension from the software. What is the load MW's Boom can carry - W= ? kg, before AC beam fails? [5 pts]
(B) If he wants to reduce the cross section of beam BD to lower the weight of the Boom, how much % can he reduce? Assume the cross section area is proportional to the load it can support. [5 pts]
(C) MW thinks the cross beam BC does not really need to be that thick. Is he correct? If so, how much % can he reduce the BC cross section? You can assume AC = BD = CD in length. [5 pts]

Describe your solution steps to get partial points. Correct answer without explaining the steps will not get full points.



Expected Answer: The easiest way is to do a free body diagram with cut across AC, BC, and BD. Then (A) Based on momentum balance at point B, W = 10x9.8 kgf/8 = 12.5 kg. ■ (B) Solve by doing force balance in horizontal and vertical direction. So BD is in compression with 7/8th of AC force, so we can reduce by 12.5% ■ (C) Same as (B), solved by same balance to get $\sqrt{2}/8$ load in BC compression. So MW can reduce by 82.3%.

Best of luck on the rest of your events, I hope you enjoyed the Machines Test!

For test feedback, please contact leijianghome@gmail.com.