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I. Multiple Choice [5 pts each] Bubble in the most correct answer on your bubble sheet and circle the correct answer here.

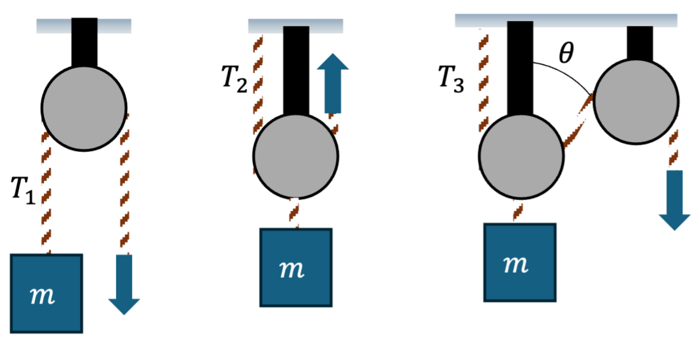
1. [5 pts] A box of mass m is placed on a horizontal flat and rough surface. When you try to push the box with a horizontal force of magnitude F_1, it does not move. If the coefficients of static and kinetic friction between the box and the surface are μ_s and μ_k. What is the magnitude of the force of friction acting on the box?
   A. $\mu_k mg$
   B. $\mu_s mg$
   C. F_1
   D. $F_1 - \mu_s mg$
   E. $F_1 - \mu_k mg$

2. [5 pts] In the previous problem, assume the box is now moving under a horizontal push of $F_2 = 120$ N. Assume $\mu_s = 0.3$, $\mu_k = 0.2$ and $m = 35$ kg. What is the acceleration of the box?
   A. 0.57 m/s^2
   B. 1.7 m/s^2
   C. 3.4 m/s^2
   D. 2.0 m/s^2
   E. 3.0 m/s^2

   Correct answer: 1.5 m/s^2

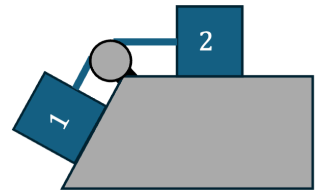
3. [5 pts] In the figure at right all blocks are stationary, all ropes are massless and inextensible, and all pulleys are massless and frictionless. The ropes are free to move around the pulleys.

   The pulleys are held in place by rigid beams that do not move.



   Choose the correct ranking of the magnitudes of the tension forces T_1, T_2 and T_3.
   A. $T_3 > T_2 > T_1$
   B. $T_2 > T_3 > T_1$
   C. $T_2 > T_1 > T_3$
   D. $T_1 > T_3 > T_2$
   E. $T_1 > T_2 > T_3$

4. [5 pts] Block 1 of mass 5.0 kg is placed on a ramp inclined at an angle of 23° and connected with a massless inextensible string to block 2 of 8.0 kg placed on the horizontal surface above the ramp, as shown at right. The string goes over a massless frictionless pulley and all surfaces are frictionless. When the string is taut, what is the magnitude of the acceleration of the system?



   A. 3.8 m/s^2
   B. 2.4 m/s^2
   C. 1.1 m/s^2
   D. 1.5 m/s^2
   E. 9.8 m/s^2

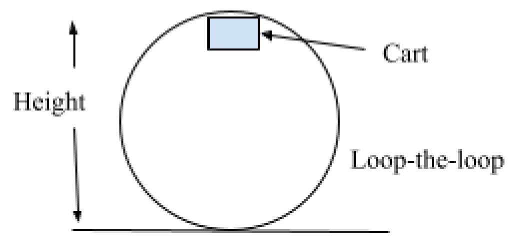
5. [5 pts] Suppose in the previous question we now make the top horizontal surface rough. Does the tension force in the string *increase*, *decrease* or *stay the same* compared to the situation described in the previous question?
   A. Increase
   B. Decrease
   C. Stay the same
   D. Information provided is not enough to answer.

6. [5 pts] Two birds are diving in the air. Bird A has a circular cross section with ½ the radius of bird B. How do the terminal velocities of the two birds compare, if everything else is the same? (All values below are terminal velocities). If needed the density of air is 1.29 kg per cubic meter and the length of the birds is ⅓ of a meter or so, and the viscosity of air is about 18 µPa s.
   A. $v_A = 2\ v_B$
   B. $v_A = 4\ v_B$
   C. $v_A = ½\ v_B$
   D. $v_A = ¼\ v_B$
   E. $v_A = v_B$

7. [5 pts] A merry-go-round of radius 2.0 m spins in a circle. If the average angular velocity is 0.40 rad/s through how many revolutions does the merry-go-round travel in one minute?
   A. 3.9
   B. 2.2
   C. 39
   D. 44
   E. None of these are correct

8. [5 pts] A person in an elevator is moving up and *slowing down*. Which is greater, the normal force on the person from the elevator or the weight of the person?
    A. Normal force on the person is greater
    B. The weight of the person is greater
    C. They are both equal
    D. Not enough information is given

9. [5 pts] A cart of mass 250 kg moves around a loop-the-loop with a constant speed of 27.5 m/s. If the total height to the top of the loop-the-loop from the ground is 35 m, what is the net force on the cart?



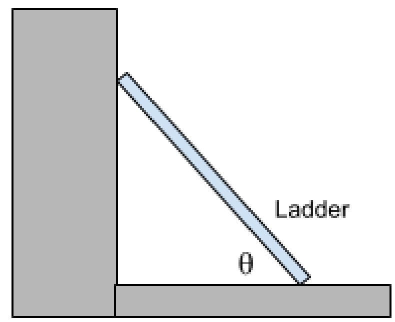
    A. 250 N
    B. 2.5 kN
    C. 4.0 kN
    D. 11 kN
    E. Not enough information is given to solve this

10. [5 pts] A long uniform board is hinged on one end and has a weight of 500 N, lying horizontal on the ground. A person can only pull with a maximum force of 260 N. Is it possible for the person to rotate the board around the hinge while lifting?

    A. No, since the maximum force is less than the weight it would be impossible to rotate.
    B. No, since the force is less than the weight you can't accelerate the body.
    C. Yes, if you apply the force near the very end the torques can be balanced and you can rotate it.
    D. Yes, the board's net weight acts on the hinge so the weight overall is less than 500 N.
    E. ~~Both apply the same torque.~~

11. [5 pts] There are three masses arranged on the x-axis: mass 1 is 5.0 kg at - 6.0 m, mass 2 is 2.0 kg at - 2.0 m, and mass 3 is 4.0 kg at x = 1.0 m. Where is the location of the center of gravity for this system of three masses?
    A. $x_{CG} = 1.0$ m
    B. $x_{CG} = 0.5$ m
    C. $x_{CG} = -1.5$ m
    D. $x_{CG} = -1.0$ m
    E. None of these are correct.

12. [5 pts] A stationary ladder of mass 25 kg makes an angle of 29 degrees from the horizontal as seen at right. The ladder has a length of 12 m. The wall has no friction, but the floor has friction. What is the magnitude of the normal force from the *floor* on the ladder?
    A. $N = 98$ N
    B. $N = 116$ N
    C. $N = 210$ N
    D. $N = 245$ N
    E. None of these could be the normal force



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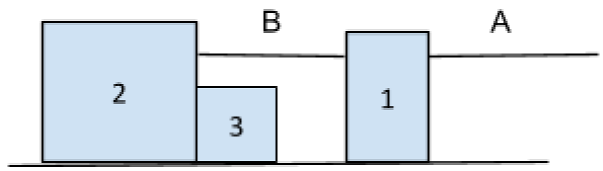
II. Lecture Free Response [20 pts total]: Show work and/or explain reasoning where indicated.

For problems 13-16 the following situation applies:
Three blocks are sliding to the right on a frictionless surface. The strings A and B are massless. Mass of block 3 < mass of block 1 < mass of block 2. The objects have been sliding for a while. String A is being pulled by a force to the right.



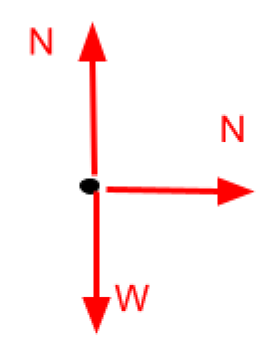
13. [5 pts] Which is *greater*, the tension on block 2 from string *B*, or the tension on block 1 from string *A*? Explain your answer.

- $T_A > T_B$ since the net force on block 1 is to the right we see both A and B act on 1, so A must be larger.
- Can also argue that A must accelerate blocks 1, 2, and 3 so must be larger.

14. [5 pts] On which object is the *net force* greatest? If they are the same state so explicitly. Explain your answer.

Block 2 must have the greatest net force since it has the largest mass. All objects have the same acceleration since they are connected.

15. [4 pts] Draw the *free body diagram* for **block 3**.



16. [6 pts] Block 1 has a mass of 3.0 kg, block 2 has a mass of 5.0 kg, and block 3 has a mass of 2.0 kg. If they are accelerating at 2.5 m/s^2, what is the normal force from block 2 on block 3?

The net force on block 3 is given by the x-direction:

$\Sigma F_x = N_{23} = m_3 a$

Which gives us 5.0 N.

N_{23}= 5.0 N

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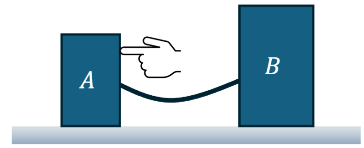
III. Tutorial Free Response [20 pts total]: Problems 17-20. Show work and/or explain reasoning where indicated.

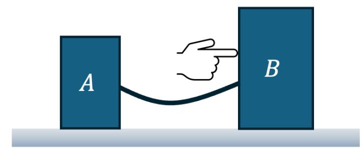
Two blocks A and B (of masses $m_A < m_B$) are connected with a uniform rope of mass M. The blocks are on a frictionless horizontal table. Consider the following two cases shown at right:

Case 1: A hand pushes with a horizontal force n_{HA} on block A moving the system with an acceleration a.

Case 2: The hand now pushes block B with a horizontal force n_{HB} moving the system with the same acceleration a.



Case 1



Case 2

17. [5 pts] Is the net force acting on block A in case 1 *greater than*, *less than* or *equal to* the net force on it in case 2? Explain briefly.

Equal to: since the masses are the same in each case for block A, and the accelerations are the same, from Newton's second law they must be equal.

18. [5 pts] Consider the following statement about case 1: "Because the m_A<m_B, the magnitude of the horizontal component of the tension by the rope on A, $T_{RA,x}$ is less than the magnitude of the horizontal component of the tension by the rope on B, $T_{RB,x}$." Do you agree or disagree with this statement? Explain your answer.

Disagree:

Newton's second law states that there must be a net force on the rope in the direction of acceleration. In this case to the left.

So in this situation the horizontal component of the tension on A must be greater than the horizontal component of the tension on B in order for the massive rope to accelerate to the left.

This can be seen by drawing a free body diagram of the rope and comparing the horizontal components of tension.

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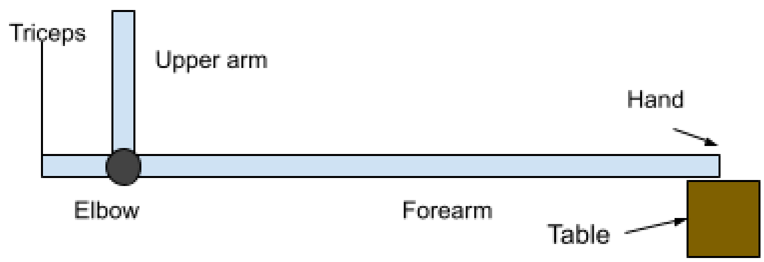
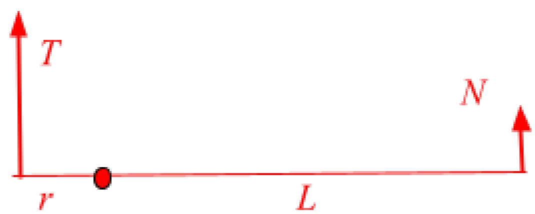
For 19. and 20. use the diagram below. The tricep muscle and tendon attach to the arm as shown in the diagram. The forearm is horizontal in this diagram.

19. [5 pts] The triceps tendon acts on the forearm 2.3 cm from the elbow as shown at right. If you assume the hand is pushing vertically down on a table with a force of 100 N, what is the force of the triceps tendon acting on the bone? Assume the distance out to the hand from the elbow is 30 cm. *Show work and/or explain reasoning for full credit*.



Extended Free Body Diagram for lower arm:



Sum torques and set to zero, solving for *T* to find force from triceps.

$$\Sigma\tau = 0 = \tau_N - \tau_T$$

$$LN - rT = 0$$

$$T = \frac{L}{r}N$$

$$T = \frac{30}{2.3}100\ N = 1.3\ \text{kN}$$

20. [5 pts] If instead of at the hand, you apply the force midway between the elbow and the hand, what would happen to the force of the triceps on the bone? Would it increase, decrease, or stay the same? *Explain your reasoning or show work for full credit.*

If we use our solution we find:

$$T = \frac{L}{2r}N = 0.65\ \text{kN},$$

substituting *L*/2, so it has **decreased.**