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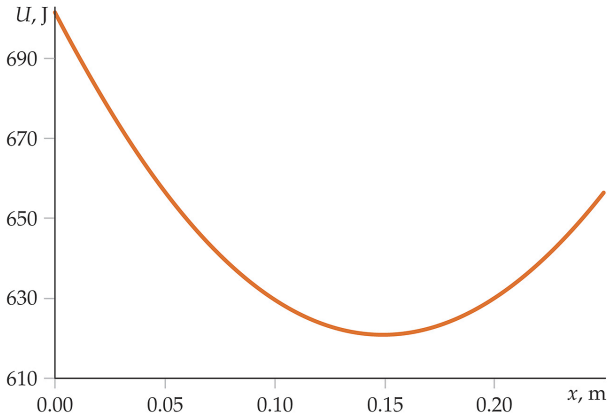
I) Lecture Multiple Choice (8 questions, 5 points each)

Use the following scenario for the next 2 questions.

The graph on the right shows the gravitational potential energy of a particle-earth system as a function of position in x as the particle undergoes a one-dimensional non-dissipative motion. The inertia of the particle is 0.13kg. At time $t = 0$, the particle is at 0.10 m, and its velocity is $-18\ \mathrm{m/s}$.



1. (5 points) Estimate the position where the particle changes its direction for the first time after this instant.
   A. 0.00 m
   B. 0.06 m
   C. 0.24 m
   D. 0.02 m
   E. 0.26 m

2. (5 points) In which direction is the particle accelerating at $t = 0$?
   A. $+x$ direction
   B. $-x$ direction
   C. The particle is accelerating in a direction other than $\pm x$ direction.
   D. The direction is not defined since the acceleration of the particle is zero.
   E. Not enough information is given.

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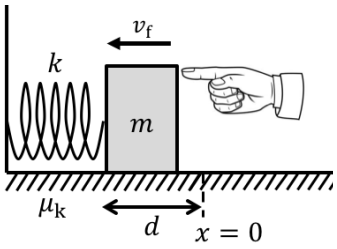
Use the following scenario for the next 2 questions.

A 2.0-kg block is initially placed at rest on rough level floor against a relaxed massless horizontal spring with a spring constant of $k = 920\ \mathrm{N/m}$. Then you push the block with a constant force of $F = 85\ \mathrm{N}$ until the spring is compressed by a distance $d = 0.13\ \mathrm{m}$ at time $t = t_\mathrm{f}$. The coefficient of kinetic friction between the block and the floor is $\mu_k = 0.75$.



3. (5 points) What is the speed of the block at $t = t_\mathrm{f}$?
   A. 1.2 m/s
   B. 1.8 m/s
   C. 2.4 m/s
   D. 3.0 m/s
   E. 3.3 m/s

4. (5 points) Suppose now that you replace the spring with another one with a larger spring constant and repeat the same procedure, pushing the box with the same constant force of $F = 85\ \mathrm{N}$ over the same distance $d = 0.13\ \mathrm{m}$. Which of the following could be true about the new experiment?
   A. The force the block pushes on your hand would be larger.
   B. The block's final speed would be the same.
   C. The thermal energy created would be greater.
   D. The work you do on the box would be greater.
   E. The change in the mechanical energy of the system containing the spring, the block, and the floor would be the same.

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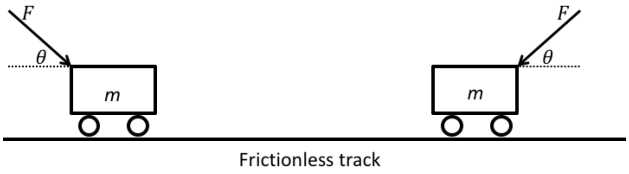
Use the following scenario for the next 2 questions.

Two 0.50-kg carts are pushed toward each other by two hands from starting positions at either end of a 5.0-m track with negligible friction. Each hand pushes each cart for a distance of 1.2 m with a force of $F =$ 4.1 N that makes an angle $\theta = 35°$ from horizontal.



5. (5 points) What is the total work done on the two-cart system by the hands?
   A. 0.0 J
   B. 4.0 J
   C. 5.6 J
   D. 8.1 J
   E. 9.8 J

6. (5 points) What is the center of mass kinetic energy at the end of this process?
   A. Zero
   B. Half of the total work done on the two-cart system by the hands.
   C. The same as the total work done on the two-cart system by the hands (and non-zero).
   D. Twice the total work done on the two-cart system by the hands.
   E. Four times the total work done on the two-cart system by the hands.

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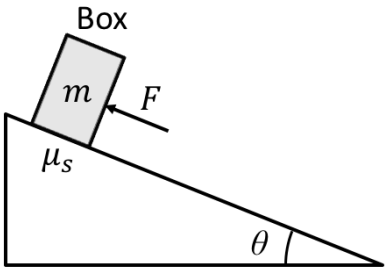
7. (5 points) A 1.5-kg ball is thrown toward a rigid wall at a speed of 14 m/s. Upon collision with the wall, the ball reverses its direction and moves away from the wall with the same speed as before the collision. What is the impulse the wall imparts on the ball during the collision?
   A. 0 kg·m/s
   B. 21 kg·m/s toward the wall
   C. 21 kg·m/s away from the wall
   D. 42 kg·m/s toward the wall
   E. 42 kg·m/s away from the wall.

8. (5 points) Suppose that you push on a 5.2-kg box with a force $F = 29$ N up along a rough incline that makes an angle $\theta = 24°$ from horizontal as shown. The box remains at rest on the incline. The coefficient of static friction between the box and the incline surface is $\mu_s = 0.75$. What is the magnitude of the static friction that the incline exerts on the box?



   A. 8.3 N
   B. 18 N
   C. 29 N
   D. 35 N
   E. 38 N

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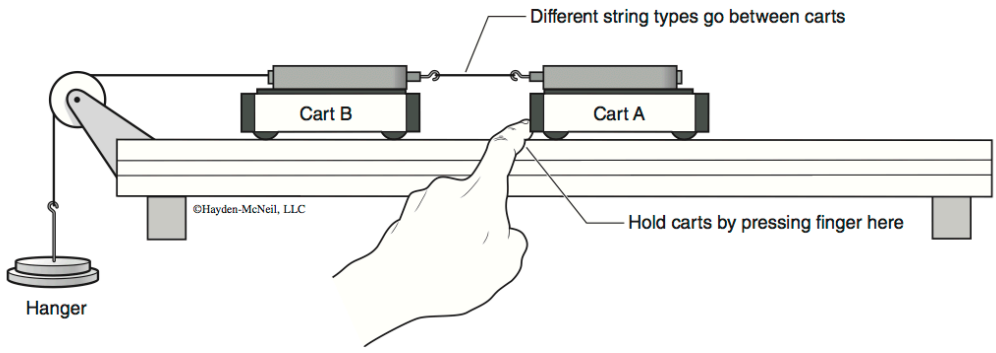
II) Lab Multiple Choice (4 questions, 16 points total)



Consider the set-up shown above for the Introduction to Force lab in which you connected two force sensors on top of carts using different materials. You measured the forces while the carts were held at rest.

9. (4 points) Do the forces measured by the force sensors on top of Cart A and Cart B constitute an interaction force pair?
    A. No, because they are different values.
    B. No, although they are approximately the same values.
    C. Yes, because they are approximately the same values.
    D. Yes, although they are different values.
    E. The answer depends on the type of material that is connecting the two sensors.

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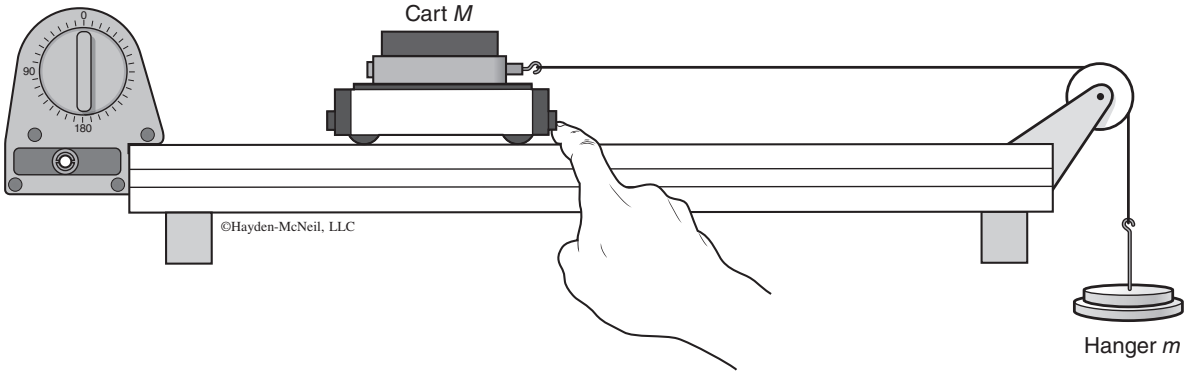
Use the following scenario for the next 2 questions.

A projectile is launched with an initial velocity of 25 m/s and a launch angle of 35° from a flat surface. Neglect air resistance.

10. (5 points) What is the magnitude of the **average velocity** of the projectile during the flight?
    A. 7.2 m/s
    B. 10 m/s
    C. 20 m/s
    D. 25 m/s
    E. 42 m/s

11. (4 points) Which of the following single changes will increase the time of flight of the projectile by a factor of 2?
    A. Decrease the inertia of the projectile by a factor of 2.
    B. Increase the launch angle by a factor of 2.
    C. Increase the initial speed by a factor of 2.
    D. Increase the initial speed by a factor of $\sqrt{2}$.
    E. More than one choice above will work.

12. (4 points) In the Newton's 2nd Law lab, you measured the tension in the string connecting a cart (with a force sensor and weight on top) on a track with negligible friction and a hanger (with a weight) as shown in the figure below. You can ignore the friction of the pulley's axle and its rotational inertia. You initially held the cart at rest, then you released the cart. Suppose that you repeated this experiment with a different cart and a different hanger so that their inertias are now different, but everything else is the same. Compare the tension in the string measured before (T) and after (T^*) the release of the cart.



A. $T - T^* > 0$
B. $T - T^* < 0$
C. $T - T^* = 0$
D. The answer depends of whether the inertia of the new cart is larger than the inertia of the new hanger.

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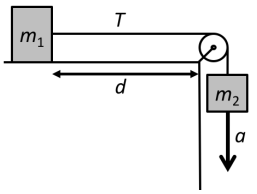
III) Lecture free response (5 questions, 26 points total)

Show all of your work. Answer all questions in terms of variables given and fundamental constants.

As shown at right, two blocks, Block 1 with inertia m_1 and Block 2 with inertia m_2, are connected by an inextensible string with a negligible inertia that goes over a pulley with negligible rotational inertia. Block 1 on a rough table is initially held at rest. When Block 1 is then released, it moves a distance d on the table with a constant acceleration a, establishing tension T in the string. Define a system containing the blocks, the string, and the table.



1. (8 points) Draw qualitatively correct free body diagrams of Block 1 and Block 2 with all the forces after Block 1 is released. Label the forces indicating the type of force and what is exerting the force.

2. (6 points) What is the coefficient of friction between Block 1 and the table in terms of the given variables?

3. (4 points) What is the change in gravitational potential energy of the system during this process in terms of given variables? If no change in gravitational potential energy occurs, state so explicitly and explain.

4. (5 points) What is the work done on the system in terms of the given variables? What does that work? If no work is done, state so explicitly and explain.

5. (3 points) If the table is frictionless instead, is the tension in the string greater than, less than, or the same as the tension in the original case? Explain.