I. INTRODUCTION

This lab will enable you to review the essentials of Newton’s three laws. Before you begin please review (a) the "Ground Rules for SDI Labs," Sec. I-C of SDI Lab #0.1; (b) operational definitions in SDI Lab #1; (c) Newton’s laws in SDI #1, 2, 6 and in your textbook.

II. STATIONARY CART

Fig. 1 on the next page shows the present setup at your table. A low-friction cart is at rest on a horizontal runway. The cart is tied to a string which connects over a low-friction pulley to a weight \( W_2 \) which is suspended vertically above the floor. The cart is held stationary by a Disk of weight \( W_3 \). The weight \( W_2 \) (not shown to scale) is a 50 g disk holder with a 50 g mass on it so that \( W_2 = m_2 g = (0.10 \text{ kg}) (10 \text{ m/s}^2) = 1.0 \text{ N} \).
Fig. 1. A low-friction cart is connected by a string to a weight $W_2$ but is held stationary by a Disk. Assume that the mass of the string, the mass of the pulley, and the friction in the pulley are all negligible.
A. DEFINITION OF TERMS

1. In Fig. 1 the cart is at rest on a horizontal runway. Can you give a meaningful definition of the word "horizontal"? {Y, N, U, NOT} ≡ {Yes, No, Uncertain, None Of These} (Here and throughout this lab, in accord with the SDI ground rules please ENCIRCLE a response and then FULLY JUSTIFY the response in the space below.)

2. Can you give a meaningful definition of the word "force"? {Y, N, U, NOT}

3. Can you give a meaningful definition of the term "net force"? {Y, N, U, NOT} (You need not redefine the word "force," just define the "net" in "net force.")

4. Can you give a meaningful definition of the term "instantaneous velocity"? {Y, N, U, NOT}
B. APPLICATION OF NEWTON’S LAWS

1. In Fig. 1, draw in ALL the forces acting ON the CART. Are the forces you have drawn in accord with Newton’s First Law (N1)? {Y, N, U, NOT}

2. Are the forces that you have drawn in Fig. 1 in accord with Newton’s Second Law (N2)? {Y, N, U, NOT}

3. In Fig. 1, show the Newton’s Third Law (N3) reaction force to each force that you have drawn in "1" above. (Show the N3 reaction forces as properly labeled dashed red (if you are using the Giancoli color code) vector arrows

4. What is the tension T in the string in terms of the mass \( m_2 \) of the weight \( W_2 \)? Please justify your answer.
5. Figure 2 shows an enlargement of the cart and the Disk of Fig 1. Can you show ALL the forces acting ON the DISK? {Y, N, U, NOT}

6. Are the forces you have drawn above in accord with Newton’s First Law (N1)? {Y, N, U, NOT}

7. Can you indicate in the drawing above the values of ALL the forces in terms of the masses \( m_1 \), \( m_2 \), \( m_3 \), \( g \), and the coefficient of static friction \( \mu_s \) between the disk and the runway? {Y, N, U, NOT}
(Here \( m_1 \) is the mass of the cart of weight \( W_1 \), of \( m_2 \) is the mass of the weight \( W_2 \), and \( m_3 \) is the mass of the disk of weight \( W_3 \).)
III. CART IN MOTION

A. CART PULLED BY A STRING ATTACHED TO A WEIGHT $W_2 = 1.0 \text{ N}$

1. Suppose you were to suddenly pull the Disk away from the cart so that the cart is free to move down the runway as shown in Fig. 3. The cart would then move with [(encircle one) decreasing, constant, increasing, none of these] speed down the runway. Please justify your answer.

2. Perform the experiment of "1" while carefully watching the motion of the cart. Are your observations in accord with your predictions? {Y, N, U, NOT}

3. Observe the motion in "2" during several trials. Simultaneously observe the motion of both the cart and the weight $W_2$ (the latter can be observed in the mirror against the wall). Fig. 3 shows "snapshot sketches" of the cart at three different instants of time: at the instant the stop is removed, near the middle of the runway, and near the end of the runway. In Fig. 3, show ALL the force vectors acting ON the CART at these 3 instants of time. Show the velocity and acceleration vectors of the cart if they exist.
Fig. 3. Snapshot sketches of the motion of the cart pulled by a string attached to weight $W_2 = 1.0 \text{ N}$. Assume as negligible (a) all frictional forces, (b) the mass of the pulley, (c) the mass and any stretching of the string.
4. The acceleration of the cart is [(encircle one) less than, the same as, greater than] the acceleration of the weight \( W_2 \). Please justify your answer.

5. In Fig. 3, considering only forces ON the cart, are there any forces in the y (vertical) -direction? {Y, N, U, NOT} If so, designate these forces in the space below in the form \( \vec{F}_{\text{on A by B}} \) where A and B are bodies.

6. Is there a net force on the cart in the y (vertical) -direction? {Y, N, U, NOT}

7. In Fig. 3, considering only forces ON the cart, are there any forces in the x (horizontal) -direction? {Y, N, U, NOT} If so, designate these forces in the space below in the form \( \vec{F}_{\text{on A by B}} \) where A and B are bodies.

8. Is there a net force on the cart in the x (horizontal) -direction? {Y, N, U, NOT}

9. Are your snapshot sketches in accord with N2? {Y, N, U, NOT}. 8
10. Do you know what the symbol "g" refers to when used in mechanics? {Y, N, U, NOT}

11. The acceleration of the cart is [(encircle one) less than, the same as, greater than] "g". Please justify your answer.

12. In Fig. 3, show the Newton’s Third Law (N3) reaction force to each force that you have drawn on the cart at the instant it is in the middle position. (Show the N3 reaction forces as properly labeled dashed red vector arrows $\vec{F}_{\text{on A by B}}$)

13. PLEASE OMIT THIS QUESTION FOR NOW, BUT RETURN TO IT AFTER COMPLETING THE REST OF THE LAB. Can you find the magnitude of the acceleration "a" of the cart in terms of the masses $m_1$ of the cart, $m_2$ of the weight $W_2$, and "g"? {Y, N, U, NOT} Please answer this question on the last page.

B. CART PULLED BY A STRING WHICH IS PULLED BY YOUR HAND.

1. Consider a thought experiment in which you pull on the string with a constant force $F_{\text{on string by hand}} = 1.0$ N in a direction vertically downward until your hand hits the floor, as shown in Fig. 4. The cart would then move with [(encircle one) decreasing, constant, increasing, none of these] speed down the runway. Please justify your answer. [You can get a "feel" for $F_{\text{on string by hand}}$ ≈ 1.0 N by pulling on the blue spring scale near the runway. (Of course, what you actually feel is $F_{\text{on hand by string}}$, the N3 reaction force to $F_{\text{on string by hand}}$.) Remember also that "quarter pounders" should be called "Newton-burgers," i.e., one Newton is the equivalent of about (1/4) pounds.]
A cart is pulled by a string on which your hand exerts a constant force $F = 1.0\text{ N}$ vertically downward until your hand hits the floor. Assume as negligible (a) all frictional forces, (b) the mass of the pulley, (c) the mass and any stretching of the string.
1. The acceleration of the cart is [(encircle one) less than, about the same as, greater than] the cart of Fig. 3, which is attached by the string to the weight $W_2 = 1.0 \text{ N}$. Justify your answer in terms of $N_2$.

If you finish this section, please return to question 13 on p. 9 (repeated below for your convenience) but do your work in the space below.

13. Can you find the magnitude of the acceleration "a" of the cart of Fig. 3 in terms of the masses $m_1$ of the cart, $m_2$ of the weight $W_2$, and "g"? {Y, N, U, NOT}