Unit-03 One Dimension of Motion Experiment I

Objective：

Place the trolley on the nearly frictionless aluminum trajectory for constant acceleration motion in order to verify the Newton's laws of motion.

Apparatus：

Aluminum trajectory, trolley, smart Pulley, photogate, digital device, weight, hook, level, electronic scales, string

Principle：

Newton's second law of motion defines that, the net force acting on an object in motion is equal to the mass of the object multiplied by the acceleration of the object. The equation can be represented as

$$\vec{F}_{net} = M\vec{a} \tag{1}$$

In Eq. (1), $\vec{F}_{net}$ is the vector sum of all forces acting on the object, provided with magnitude and direction. $\vec{a}$ is the acceleration of the object, also provided with magnitude and direction.

Fig. 1 is the schemeatic diagram of experemental set-up of Newton's laws of motion. m_1 is the total mass of the trolley and the weights on the trolley. The trolley and the trajectory are nearly frictionless. m_2 is the total mass of the hook and the weights on the hook. m_{eff} is the effective mass cause by the spinning of the pulley.

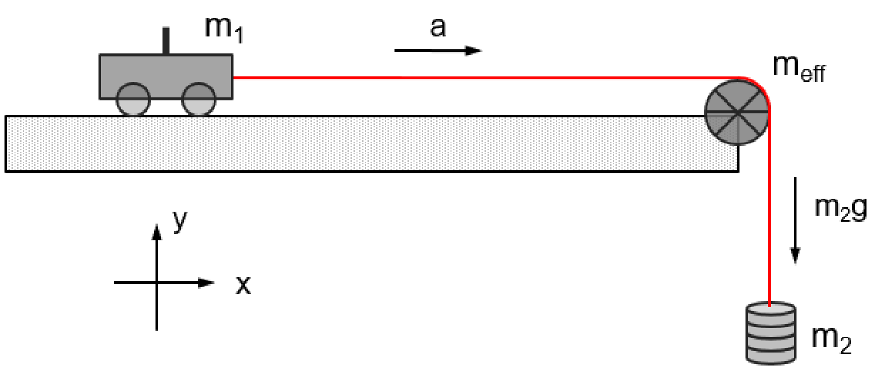

Figure 1. The schemeatic diagram of experemental set-up of Newton's laws of motion

When m_1 receive m_2g and move with constant acceleration, Eq. (1) can the changed into

$$F = Ma$$

$$\Rightarrow m_2 g - m_{eff} a = (m_1 + m_2) a$$

Remarks：

1. Make sure the trajectory is horizontal, and tighten the screws before starting an experiment.
2. The effective mass resulted from the spinning of the pulley should be accounted for the system's total mass m_{eff}.
3. The total mass of hooks and the weights on the hook should not be too heavy, otherwise the tension will be too strong which would result in breakage of strings or trolley derailment.

Procedure：

- **Preparation**
  1. Put the level on the trajectory. Adjust the screws on both sides underneath the trajectory to level it.
  2. Place the trolley on the trajectory. Observe whether the trolley slides toward one side or another of the trajectory. If so, please level the trajectory again until the trolley stops sliding. If it doesn't slide, precede the next correction.
  3. Take an appropriate length of string. Tie one end of the string on the anti-dazzling board post above the trolley, and tie the other end on the hook.
  4. Place the string on the Smart Pulley's groove and adjust the position of the trolley. Make the string paralleled to the trajectory.
  5. In this experiment the effective mass of the pulley $m_{\text{eff}} = 4.50$ g.

A. Keep the system's force *F* constant, and change the system's total mass *M*.

1. Weigh the hook and the weights on the hook with electronic scale and record the number as m_2.
2. Weigh the trolley and the weights on the trolley with electronic scale and record the number as m_1
3. Calculate the total mass M is $M = m_1 + m_2 + m_{eff}$.
4. Open the software and set the related parameters by instruction book.

5. Place the trolley on the trajectory. Make sure that the string crosses the Smart Pulley and gentley presses the pulley. Release the trolley, then you can acquire the velocity-time diagram of the trolley. The slope of the diagram is the acceleration $a_n = \overline{a_n} \pm \sigma_{a_n}$. Repeat steps above for three times. Then, record the experimental value of acceleration as $a = \bar{a} \pm \sigma_a$ (Delivering error should be considered.).
6. Keep constant the total mass of the hook and the weights on the hook. Change the total mass of the trolley and the weights (i.e. changing the system's total mass). Repeat above steps.
7. Plot $\frac{1}{a} - M$ diagram.

B. Keep the system's total mass *M* constant, and change the system's force *F*.

1. Weigh the hook and the weights on the hook with electronic scale and record the number as m_2.
2. Weigh the trolley and the weights on the trolley with electronic scale and record the number as m_1
3. Calculate the total mass *M* is $M = m_1 + m_2 + m_{eff}$.
4. Open the software and set the related parameters by instruction book.
5. Place the trolley on the trajectory. Make sure that the string crosses the Smart Pulley and gentley presses the pulley. Release the trolley, then you can acquire the velocity-time diagram of the trolley. The slope of the diagram is the acceleration $a_n = \overline{a_n} \pm \sigma_{a_n}$. Repeat steps above for three times. Then, record the experimental value of acceleration as $a = \bar{a} \pm \sigma_a$ (Delivering error should be considered.).
6. Change the weights on the trolley or the hook in the principle of keeping the total mass M constant. Repeat above steps.
7. Plot $a - m_2$ diagram.

[Note] This experiment utilizes two steps and acquires velocity-time diagram with Smart Pulley, photogate and analysis software (as shown in Fig. 2). The slope of the diagram is the system's acceleration a.

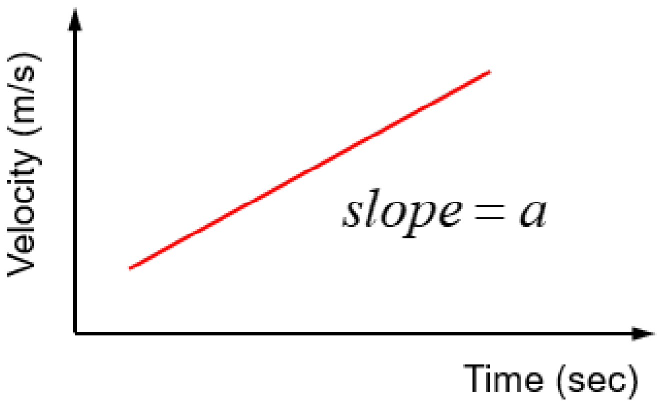

Figure 2. Velocity-Time diagram

Questions：

1. How to calculate the friction force between the trolley and trajectory? Please explain.
2. Please analyze the friction force between "string and pulley" and "pulley and bearing". Try to calculate estimate the effective mass.
3. If the experimental equipment and the same steps, respectively, in the Earth and the moon on the same experiment, the experimental results are the same. Please explain.