A01-223E-Y91

Digital Newton's Law of Motion Apparatus

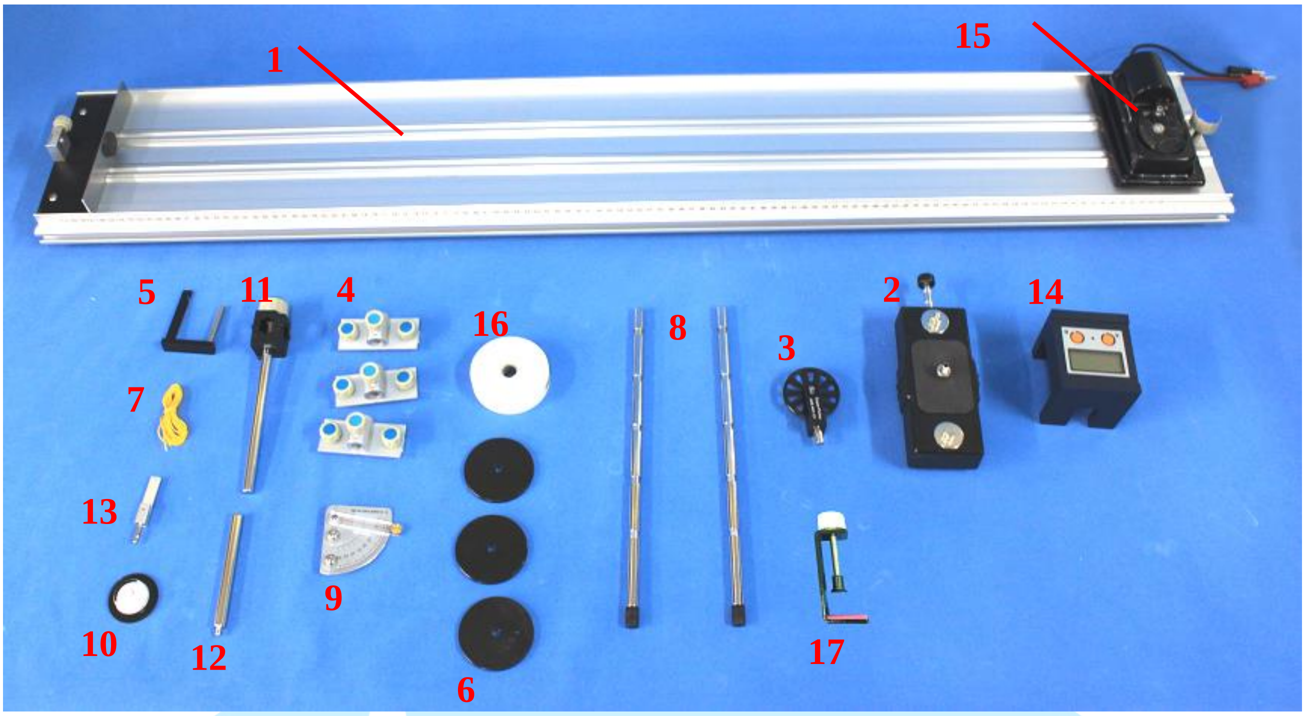
1. The purpose of the experiment

1. Calculate the acceleration through the dot timer.
2. Use a speedometer to verify Newton's second law of motion $F = ma$
3. Verify that the sliding acceleration of the object on the slope is g sinθ. That is, the sliding acceleration of the pulley is only related to the slope angle and the gravity value g, and has nothing to do with the quality of the pulley.

2. Laboratory apparatus list

No.	Item name	Qty	No.	Item name	Qty
1.	Aluminum track	1	2.	pulley	1
3.	Fixed pulley with handle	1	4.	Removable joint	3
5.	L-shaped weight hanger	1	6.	Weight 100g*3	1
7.	String	1	8.	Inclined bracket	2
9.	Angler	1	10.	Spirit level	1
11.	Connector bracket	1	12.	Speedometer bracket	1
13.	Speedometer mask	1	14.	Digital speed counter	1
15.	Communication timer (AC9V/1.5A)	1	16.	C clip	1
17.	Dot timer paper roll	1	18.	(Bring your own) Low-voltage AC power supply	1

Experimental accessories list


1
15
5
11
4
16
8
3
2
14
7
13
9
10
12
6
17

3. Experimental principle

3-1 Speed experiment:

Speed is a physical quantity that describes how fast an object moves. Speed is defined as the rate of change of displacement over time.

The definition is: v (speed) = s (displacement) / t (time)

$$\mathbf{v} = \frac{ds}{dt} \tag{3-1}$$

The most basic unit of speed in the metric system is meters per second. The international symbol is m/s. Because the speed of light in a vacuum is 299,792,458m/s, the metric system defines 1 meter as the distance that light travels in a vacuum in 1/299,792,458 seconds. In physics terms, the difference between speed and the rate of speed is that speed is a vector. Speed is directional so it can have a negative value, but the rate of speed purely refers to the speed of movement of the object. It has no directionality, so there is no negative value. But in daily language, speed and the rate of speed are almost synonymous.

3-2 Newton's second law of motion

Newton's second law of motion is the basic law of dynamics. Its content is: the acceleration “a” obtained when an object is subjected to an external force is proportional to the resultant force F received by the object and inversely proportional to the mass m of the object. Can be written as:

$$\boldsymbol{F = ma} \tag{3-2}$$

In **Figure 3-1**. Assuming that the desktop is smooth and frictionless, the quality of the slider is m_1 and the weight of the object is m_2 and the thread tension is T, then the acceleration a can be derived from the following mathematical formula

m_2 Force $\quad F-T = m_2 g - T = m_2 a$

m_1 Force $\quad T = m_1 a$

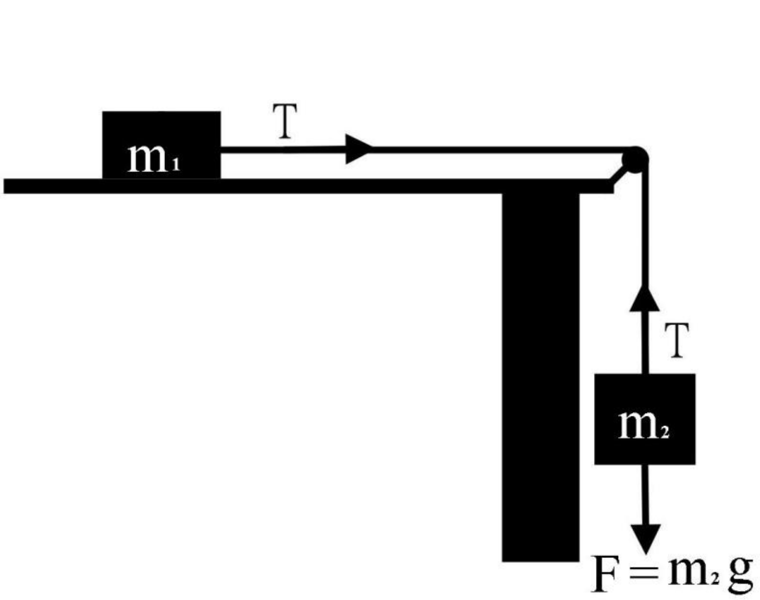


Figure 3-1

The power of the overall movement comes from the fact that m_2 is attracted by gravity and obtains $F = m_2 g$ Combine the above two formulas to get:

$$F - T = F - m_1 a = m_2 g - m_1 a$$

and

$$F - T = m_2 a$$

can get：

$$F = m_2 g = (m_1 + m_2) a$$

$$a = \frac{m_2 g}{m_1 + m_2}$$

So we can change m_1 、m_2 quality to verify Newton's second law of motion.

(3) Inclined plane experiment：

The inclined plane is an inclined plane, which can save effort but time-consuming moving objects to high places. In addition to levers, pulleys, and axles, inclined planes have also been used as a method of moving heavy objects to high places since ancient times. Many designs in daily life are related to slopes, such as: climbing stairs, barrier-free ramps, zigzag mountain roads, etc., all use slopes to achieve their goals. When using an inclined plane, if the destination height is the same and the longer the length of the inclined plane is, the more labor-saving. That is, the smaller the angle between the inclined plane and the horizontal plane, the more labor-saving. **As shown in Figure 3-2**

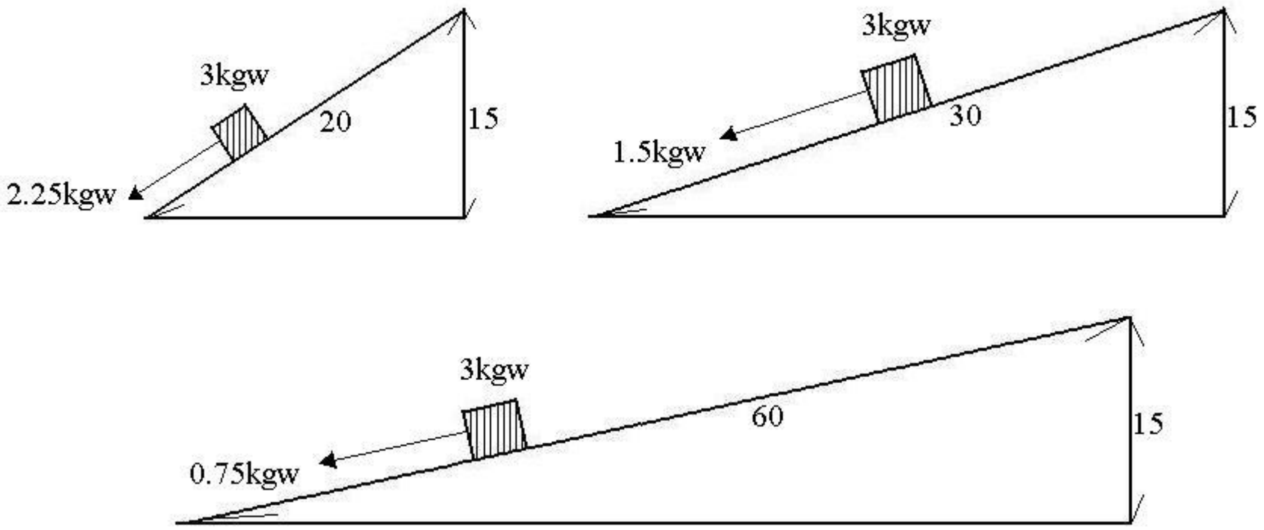
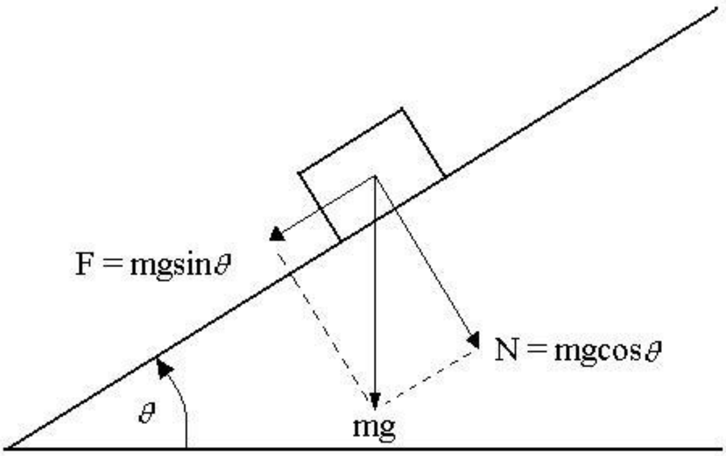


Figure 3-2

Glide force and acceleration

As shown in Figure 3-3, When an object of mass m is placed on an inclined plane with an oblique angle of θ, the gravity mg can be decomposed into parallel and vertical inclined plane forces. Force of parallel slope $F = mg \sin\theta$ becomes the force that makes the object fall and it makes the pulley move with constant acceleration. Using Newton’s second law of motion, the sliding acceleration of the pulley can be obtained $a = g \sin\theta$ 。The sliding acceleration of the pulley is only related to the angle of the slope and the gravity value g, and has nothing to do with the mass of the pulley.

Figure 3-3



4. Experimental steps：

4-1 Speed experiment：

1. The method of setting up the instrument is shown in **Figure 4-1**. Use a spirit level to adjust the level of the track, place the dot timer on one end of the track and fix it with a C-clamp.

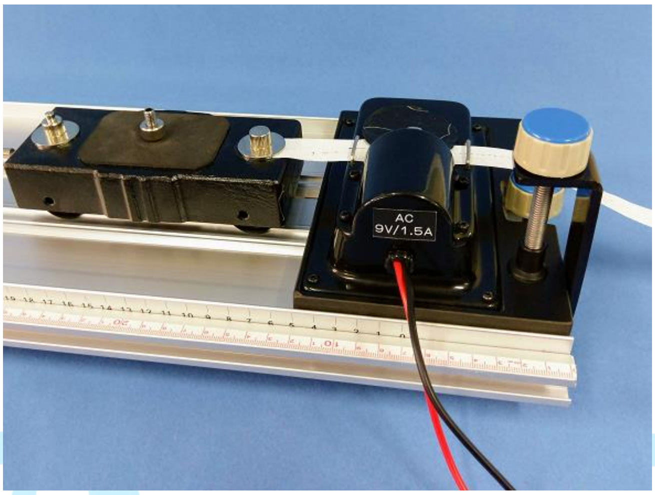


Figure 4-1 Installation diagram of the dot timer

2. Pass a piece of paper tape through the top of the dotting timer and through the carbon paper and connect to the tail of the tackle. Connect to AC9~12/1.5~1A power supply. According to the user's power supply, confirm the timing of the timing of the timing. First press the dot button switch, try to push the pulley, and observe whether the dot is clear.
3. Try to draw the x-t diagram, v-t diagram, and calculate the acceleration. Record table 1-2.
4. **4-2 Newton's second law of motion：**
5. First confirm that the slide rail is horizontal, and install the fixed pulley on one end of the slide rail, as shown in **Figure 4-2.**

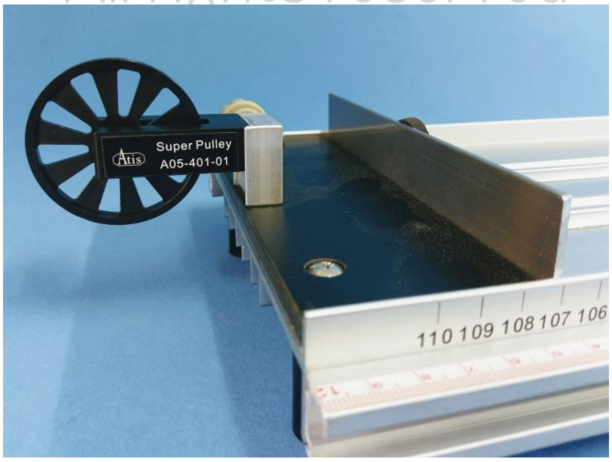
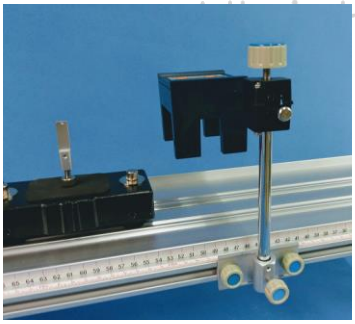


Figure 4-2 Fixed pulley device

6. Take out the L-shaped weight rack and connect the pulley and the weight rack with a rope. Crossing the fixed pulley end of the slide rail to make the weight rack hang on the side of the slide rail.
7. Make sure that the dotted paper tape is installed on the rear of the car, and the rear of the car is leaning against the dotted timer. First press the AC dotting button switch, then release the pulley. The pulley is pulled due to the weight of the L-shaped weight, and the dot timer will record the speed trajectory of the movement of the pulley.
8. Record according to the experiment sheet 2-1 ~2-3. Record the total weight of the weight rack and the total weight of the pulley.
9. Put a 100g weight on the weight rack and record the total weight of the weight rack and the total weight of the pulley. Pull the trolley to the edge and press the dotting timer button switch. Release the pulley so that the pulley is pulled by the weight of the weight. At this time, the dot timer will record the track of the trolley and calculate the speed.
10. Change the weight on the pulley or the weight on the rack, repeat steps 6~9. Verify Newton's second law of motion.

Use tachometer to measure：

11. Slide rail and trolley under constant conditions, set up a digital speedometer(The position of the speedometer is recommended to be in the middle of the slide). And insert the speedometer mask on the trolley, check that the speedometer can pass smoothly as shown in Figure 4-3 and can be detected. Also put the tail of the trolley against one end of the slide rail, confirm that the speedometer is in the B state (speed measurement). Release the trolley and record the speed and discuss whether the speed values are the same.



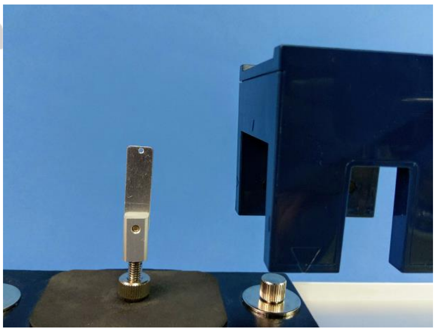


Figure 4-3 Schematic diagram of setting up the speed counter and smoothly allowing the light shield to pass the speed counter

12. Change the weight on the pulley or the weight on the rack and repeat the above steps to verify Newton's second law of motion.

4-3 Inclined movement

13. Place the movable joint and the inclined surface bracket device on the slide rail, as shown in Figure 4-4. And confirm that the movable joint is fixed in the groove of the inclined bracket to effectively prevent displacement after vibration. Install the protractor, you can know the slope angle of the slide rail, as shown in Figure 4-5.

Figure 4-4 Schematic diagram of inclined plane movement device

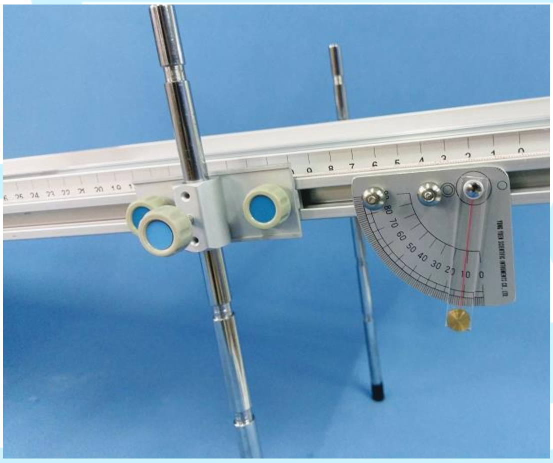


Figure 4-5 Schematic diagram of inclined plane protractor

14. Users can choose to run timer or tachometer to measure.

15. Adjust the small inclination of the track (do not exceed 30 degrees inclination), pull the trolley to the edge and let the bumper of the trolley slide forward.
16. Record the weight and speed of the pulley according to the record of the experiment.
17. Increase the weight of the pulley in sequence, repeat the above operation, and record it according to the experimental record **table 2-5.**
18. Fix the total weight of the pulley, and change the inclination of the slide rail in sequence. Record it according to the experimental record table 2-6.
19. Try to verify that the sliding acceleration of the pulley is only related to the angle of the slope and the gravity value g. It has nothing to do with the mass of the pulley.

5. Experimental results and problem discussion

Dot timer-speed test record table (1-1)					
Net weight of tackle（kg）					
Total mass of pulley m_1（kg）					
Dotting frequency (hz)					
spacing (cm)					
speed（ m/s ）					
Acceleration（ m/s^2 ）					
Average acceleration（ m/s^2 ）					

x-t

v-t

Timer - Newton's second law of motion experimental record sheet (2-1)					
Net weight of tackle（kg）		Total weight m_2（kg）			
Total mass of pulley m_1（kg）		Theoretical acceleration $\frac{m_2 g}{m_1 + m_2}$（m/s^2）			
Dotting frequency (hz)					
spacing (cm)					
speed（m/s）					
Acceleration（m/s^2）					
Average acceleration（m/s^2）					

Timer - Newton's second law of motion experimental record sheet (2-2)					
Net weight of tackle（kg）		Total weight m_2（kg）			
Total mass of pulley m_1（kg）		Theoretical acceleration $\frac{m_2 g}{m_1 + m_2}$（m/s^2）			
Dotting frequency (hz)					
spacing (cm)					
speed（m/s）					
Acceleration（m/s^2）					
Average acceleration（m/s^2）					

Timer - Newton's second law of motion experimental record sheet (2-3)					
Net weight of tackle（kg）		Total weight m_2（kg）			
Total mass of pulley m_1（kg）		Theoretical acceleration $\frac{m_2 g}{m_1 + m_2}$（m/s^2）			
Dotting frequency (hz)					
spacing (cm)					
speed（m/s）					
Acceleration（m/s^2）					
Average acceleration（m/s^2）					

Digital Speedometer-Newton's Second Law of Motion Experimental Record Sheet (2-4)					
	1	2	3	4	5
Net weight of tackle（kg）					
Total weight m_2 （kg）					
Total mass of pulley m_1 （kg）					
Theoretical acceleration $\frac{m_2 g}{m_1 + m_2}$ （ m/s^2 ）					
Speedometer acceleration （ m/s^2 ）					

Oblique movement test record sheet (2-5)					
	1	2	3	4	5
Sliding rail inclination (θ)					
Net weight of tackle（kg）					
Measured acceleration （ m/s^2 ）					
Theoretical acceleration（ m/s^2 ）					

Oblique movement test record sheet (2-6)					
	1	2	3	4	5
Net weight of tackle（kg）					
Sliding rail inclination (θ)					
Measured acceleration （ m/s^2 ）					
Theoretical acceleration（ m/s^2 ）					

Atis Scientific Instruments Co.,Ltd
Address：1F., No.18, Nanming St., South Dist.,
Tainan City 702, Taiwan (R.O.C.)
E-mail:atis@atissi.com.tw
Tel: (886) -6-2925201
Fax: (886)-6- 2611476
Mobile:+886-9-8006-1128
Website: www.atis.com.tw