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Experiment / assignment / tutorial No. 9
Grade: AA / AB / BB / BC / CC / CD /DD

Signature of the Staff In-charge with date

Title – Newton's Second Law

Objective

To verify the application of Newton's Law of Motion for bodies with acceleration.

Theory

Newton's second law of motion can be used conveniently to derive the equation of motion of a system under the following conditions.

1. The system undergoes either pure translation or pure rotation.
2. The motion takes place in a single plane.
3. The force acting on the system either have a constant orientation or are oriented parallel to the direction along which the point of application moves.

Newton's second law states that the force applied to a body produces a proportional acceleration , the relationship between the two is

$$F = ma$$

Where 'F' is the force applied, 'm' is the mass of the body, and 'a' is the body's acceleration. If the body is subject to multiple forces at the same time, then the acceleration is proportional to the vector sum (that is, the net force).

$$F_1 + F_2 + \dots\dots\dots\dots + F_n = F_{net} = ma$$

The second law can also be used to relate the net force and the momentum 'p' of the body

$$F_{net} = ma = m\frac{dv}{dt} = \frac{d(mv)}{dt} = \frac{dp}{dt}$$

Therefore, Newton's second law also states that the net force is equal to the time derivative of the body's momentum

$$F_{net} = \frac{dp}{dt}$$

Consistent with the first law, the time derivative of the momentum is non-zero when the momentum changes direction, even if there is no change in its magnitude (see time derivative). The relationship also implies the conservation of momentum. When the net force on the body is zero, the momentum of the body is constant. Both statements of the second law are valid only for constant-mass systems, since any mass that is gained or lost by the system will cause a change in momentum that is not the result of an external force. A different equation is necessary for variable-mass systems. Newton's second law requires modification if the effects of special relativity are to be taken into account, as it cannot be said that momentum is the product of inertial mass and velocity.
The equation for T, the tension of the cable in the experiment are given by,

$$T = mg - ma$$
$$T = Ma + \mu Mg$$

The acceleration of an object can be found out using the below equation that is used in the experiment for the track slider setup

$$a = (mg - \mu Mg) / (M + m)$$

a = acceleration of the cart,
m = mass of the hanging weight,
g = gravitational acceleration(simulator used earth's 9.8m/s^2,
μ= coefficient of friction,
M = mass of the wagon.

The distance can be found out by

$$s = \frac{1}{2} at^2$$

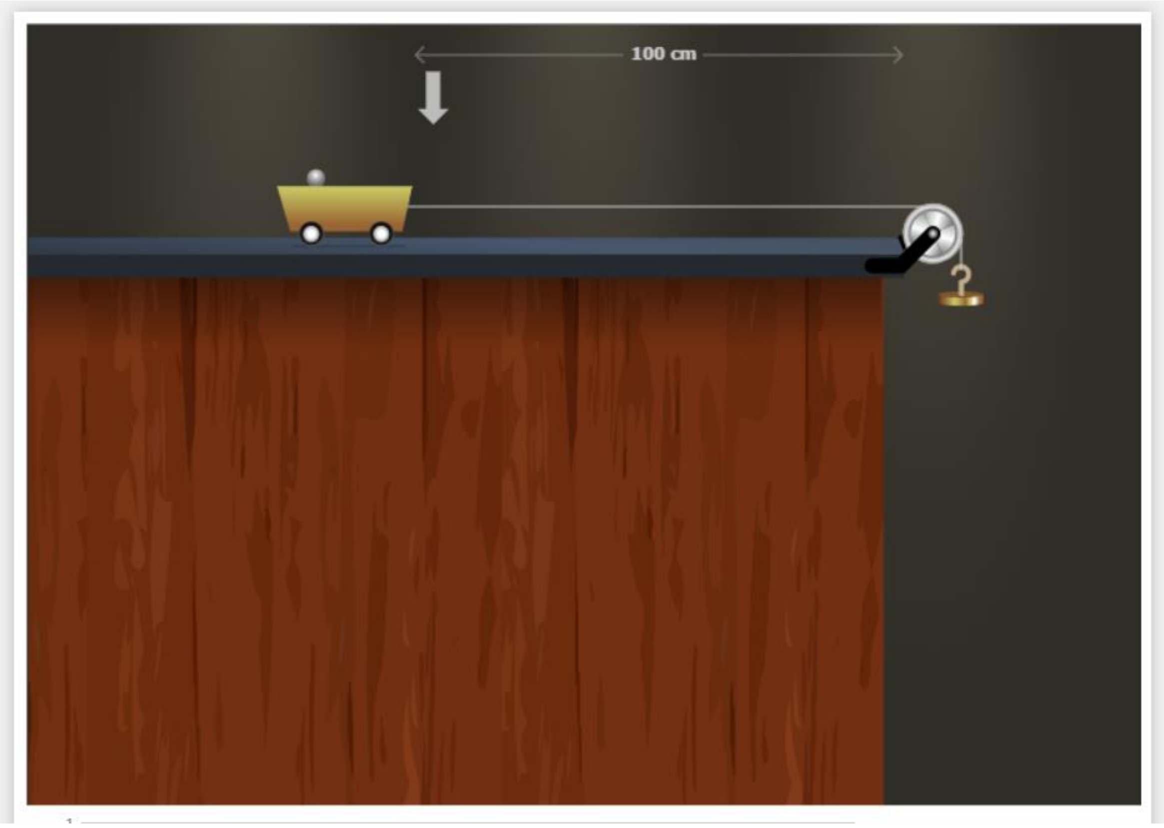
S = displacement of the cart,
a = acceleration of the cart,
t = time for the cart to travel distance S.

Applications:

- It helps to explain the mechanics behind the motion of a body using D Alembert's principle (restatement of 2^{nd} law of motion).eg:-Atwood's machine.
- Applications in biomechanics.
- It is used to explain the fundamentals of atmospheric modelling where momentum equations are derived from the second law.

- Used in quantum field theory and superconductivity.
- Applications in sports like cricket.

Setup Diagram:



PROCEDURE:

Variable Region:

1. Change Friction:

This slider helps you to change the Co efficient of Friction of the surface.

2. Change hanging weight:

This slider helps you to change the hanging weight. The change will be in grams.

3. Change cart weight:

This slider helps you to change the cart weight. The change will be in grams.

4. Change pointer position:

This slider is used to change the position of the pointer. The pointer is used to measure and calculate the time for reaching the pointer position.

5. Start Button:

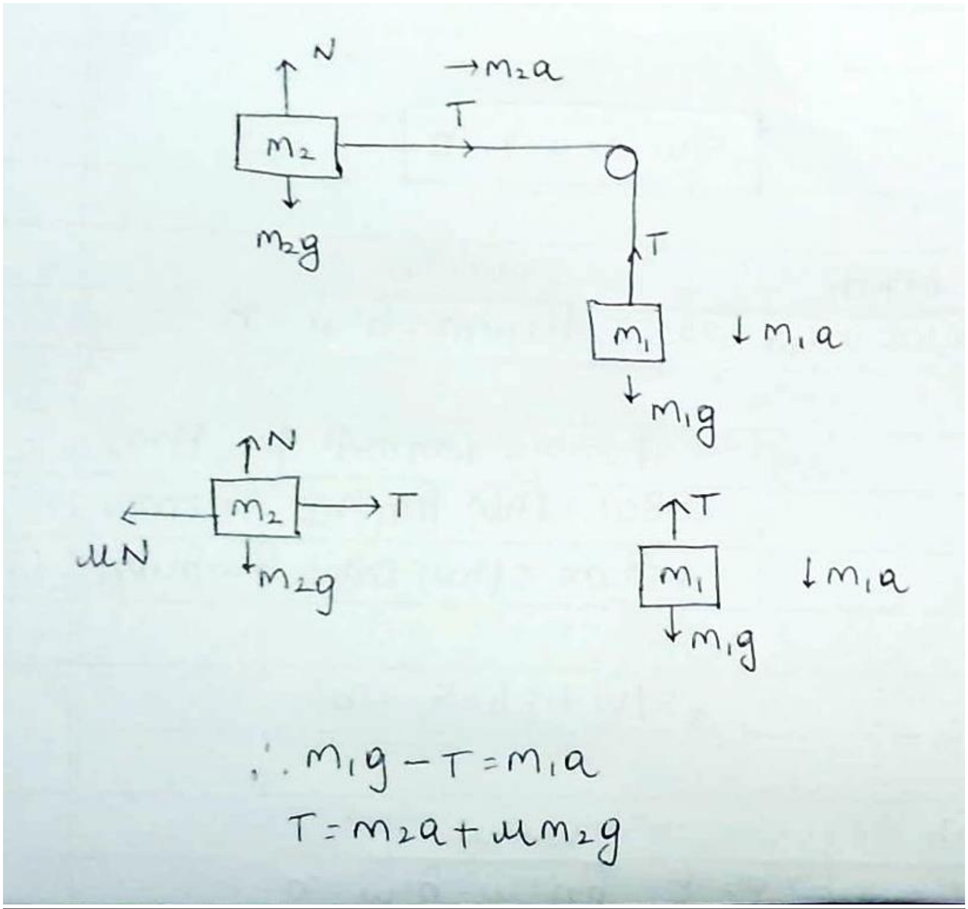
This button is used to start the movement of the cart.

6. Reset Button:

This button is used to reset the cart to the initial position.

Measurement Region:
1.Time taken to reach the pointer will show the time taken by the cart to reach the pointer position in seconds.
2.The pointer distance will show the pointer position distance.
3.The acceleration shows the acceleration of the cart.

Free Body Diagram:



Observation table:-

Set No.	Hanging mass (m1), gms.	Mass of trolley (m2), gms.	Coeff. of friction	Acceleration of body (a), m/s^2	
				Experimental	Analytical
1	40	30	0.002	5.57	5.592
2	50	40	0.003	5.431	5.434
3	20	10	0.001	6.530	6.530
4	25	60	0.002	2.869	2.869

Calculations :-

1) Hanging mass (m_1) = 40gm
Mass of trolley (m_2) : 30gm
Coeff^n of friction (μ) = 0.2

$$\therefore a = \frac{m_1 g - \mu m_2 g}{m_1 + m_2} = \frac{40 \times 9.8 - 0.002 \times 30 \times 9.8}{40 + 30}$$

$$\boxed{a = 5.592 \ m/s^2}$$

2) Hanging mass (m_1) = 50gm
Mass of trolley (m_2) = 40gm
Coeff^n of friction (μ) = 0.003

$$\therefore a = \frac{m_1 g - m_2 \mu g}{m_1 + m_2} \Rightarrow \frac{50 \times 9.8 - 40 \times 0.003 \times 9.8}{40 + 5}$$

$$a = 5.434 \ m/s^2$$

3) Hanging mass (m_1) = 20 gm

mass of trolley (m_2) = 10gm

Coeff^n of friction = 0.001

$$\therefore a = \frac{m_1 g - \mu m_2 g}{m_1 + m_2} = \frac{20 \times 9.8 - 0.001 \times 10 \times 9.8}{20 + 10}$$

$$\boxed{a = 6.530 \ m/s^2}$$

4) Hanging mass (m_1) = 25 gm

Mass of trolley (m_2) = 60 gm

Coeff^n of friction = 0.002

$$a = \frac{m_1 g - \mu m_2 g}{m_1 + m_2} = \frac{25 \times 9.8 - 0.002 \times 60 \times 9.8}{25 + 60}$$

$$\boxed{a = 2.869 \ m/s^2}$$

Self Evaluation:

1) The product of mass and velocity is called

- ○ Force ◉ Momentum
- ○ Torque ○ Work

2) When there is no external force acts on the system total linear momentum is conserved"- What is this statement

- ◉ Law of conservation of momentum
- ○ Law of conservation of force
- ○ Law of conservation of mass
- ○ Law of conservation of energy

3) Statement of Newton's second law

- ○ F = m(dv/dt) ○ F = ma
- ○ F = dp/dt ◉ All of the above

4) When a body moves over a frictional surface, its acceleration

- ◉ Decreases with increase of friction
- ○ Increases with increase of friction
- ○ Is independent of frictional force

5) In uniformly accelerated motion, the shape of the displacement- time graph is

- ○ Hyperbola ◉ Parabola
- ○ Straight line ○ No fixed shape

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Conclusion:-

As we increase the coefficient of friction, keeping the hanging weights and the cart weights constant, the acceleration of the cart decreases.

But when we increase the hanging weight. Keeping the cart weight and the coefficient of friction constant then the acceleration of the cart increases.

Hence we verify the application of Newton's Law of Motion for bodies with acceleration