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Presented by:
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- **Kinetics of particle**

5.1	Force and acceleration: Introduction to basic concepts, equations of dynamic equilibrium, Newton’s second law of motion (only rectilinear motion)

Newton's laws of motion

- The first law states that an object either remains at rest or continues to move at a constant velocity, unless it is acted upon by an external force.
- The second law states that the rate of change of momentum of an object is directly proportional to the force applied.
  - or, for an object with constant mass, that the net force on an object is equal to the mass of that object multiplied by the acceleration.
- The third law states that when one object exerts a force on a second object, that second object exerts a force that is equal in magnitude and opposite in direction on the first object.

Newton's second law

- The second law states that the rate of change of momentum of a body over time is directly proportional to the force applied, and occurs in the same direction as the applied force.
- For objects and systems with constant mass, the second law can be re-stated in terms of an object's acceleration.

$$\mathbf{F} = \frac{\mathrm{d}(m\mathbf{v})}{\mathrm{d}t} = m\,\frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t} = m\mathbf{a},$$

✓ where **F** is the net force applied, *m* is the mass of the body, and **a** is the body's acceleration.

✓ Thus, the net force applied to a body produces a proportional acceleration.

Static and Dynamic Equilibrium

- Equilibrium implies the object is at rest (static) or its center of mass moves with a constant velocity (dynamic)
- The special case in which linear and angular velocities are equal to zero, called **"static equilibrium"** :

$$v_{CM} = 0 \text{ and } w = 0$$

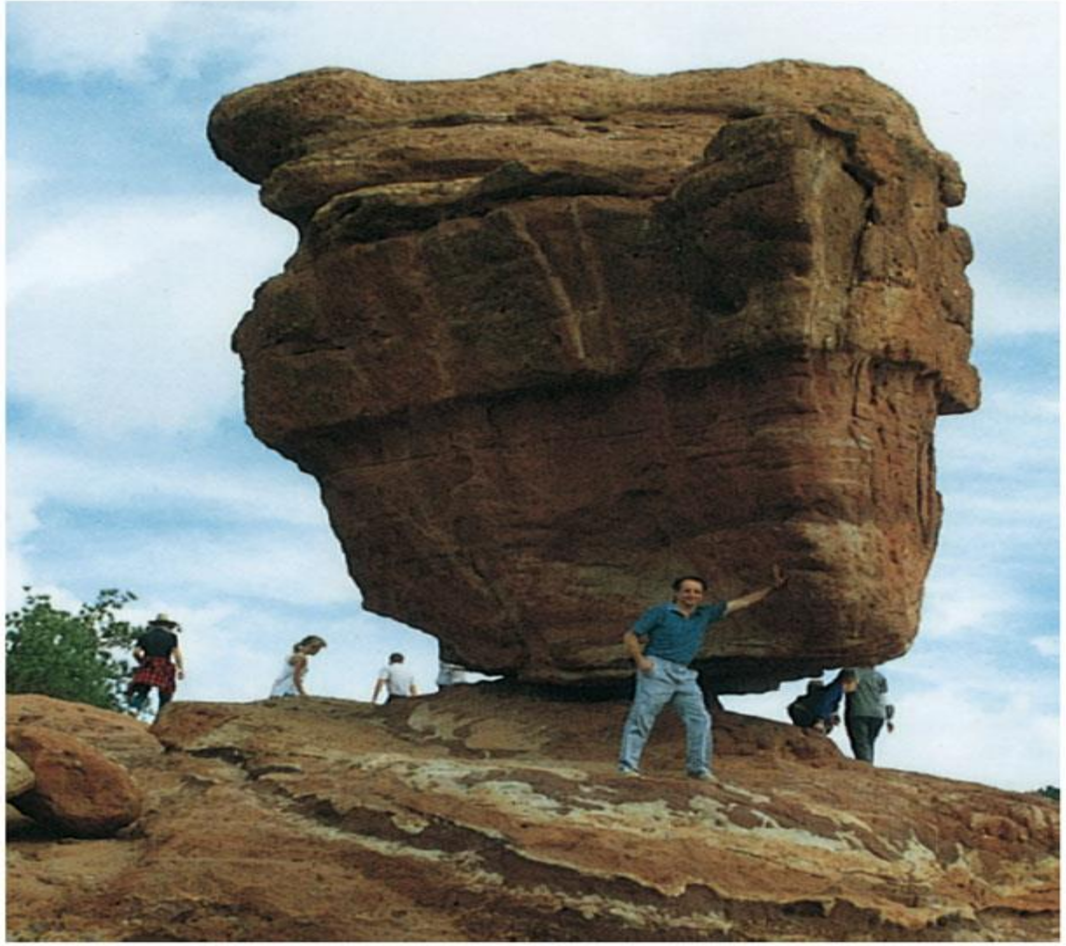
- Examples
  - *Book on table*
  - *Puck sliding on ice in a constant velocity*
  - *Ceiling fan – off*
  - *Ceiling fan – on*
  - *Ladder leaning against wall (foot in groove)*

Conditions for Equilibrium

- The first condition of equilibrium is a statement of translational equilibrium
- The net external force on the object must equal zero

$$\vec{F}_{net} = \sum \vec{F}_{ext} = m\vec{a} = 0$$

- It states that the translational acceleration of the object's center of mass must be zero



Dynamic Equilibrium (D' Alembert's Principle)

- According to Newton's second law,

$$\mathbf{F} = \frac{\mathrm{d}(m\mathbf{v})}{\mathrm{d}t} = m\frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t} = m\mathbf{a},$$

$$\Sigma F - ma = 0$$

- The vector –ma is referred to as Inertia force.
- The magnitude of Inertia force is ma.
- The direction is opposite to that of acceleration.
- If we add inertia vector to the system of forces then the state of equilibrium is created which is called **dynamic equilibrium**.

D' Alembert's Principle

- For rectangular components, the conditions are

  $\Sigma F_x = 0$

  $\Sigma F_y = 0$ including inertia force

- For tangential and normal components

  $\Sigma F_t = 0$

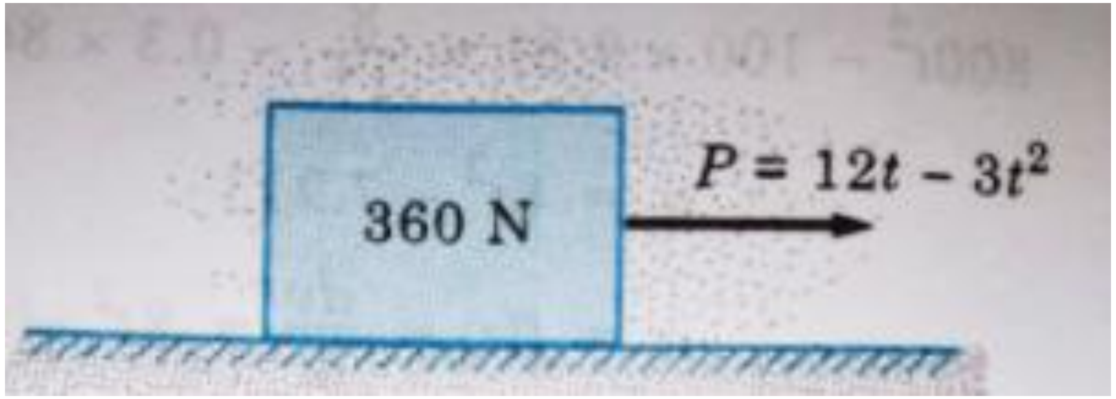
  $\Sigma F_N = 0$

Here, $-ma_t$ is tangential component of inertia vector

$-ma_N$ is normal component of inertia vector.

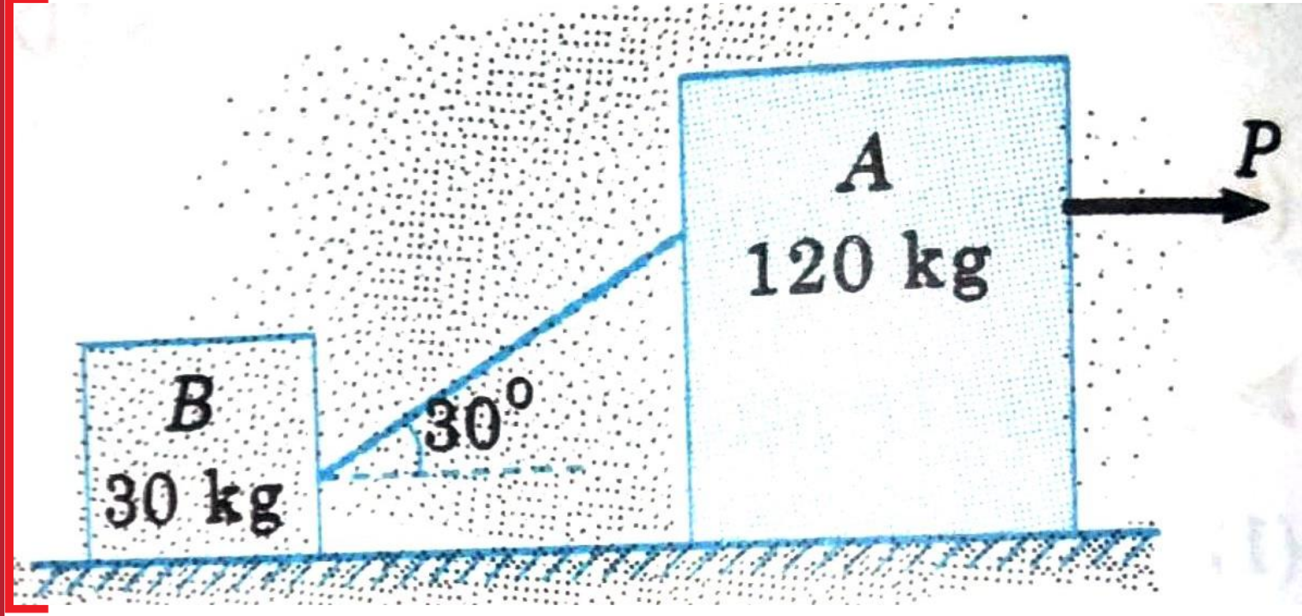
Problem No. 1:

A 360 N block is resting on a smooth horizontal surface. It is acted upon by a horizontal force P which varies according to the relation $P = 12t - 3t^2$ where P is in Newton and t is in seconds. Determine the maximum positive velocity of the block and the time when it reverses its motion.



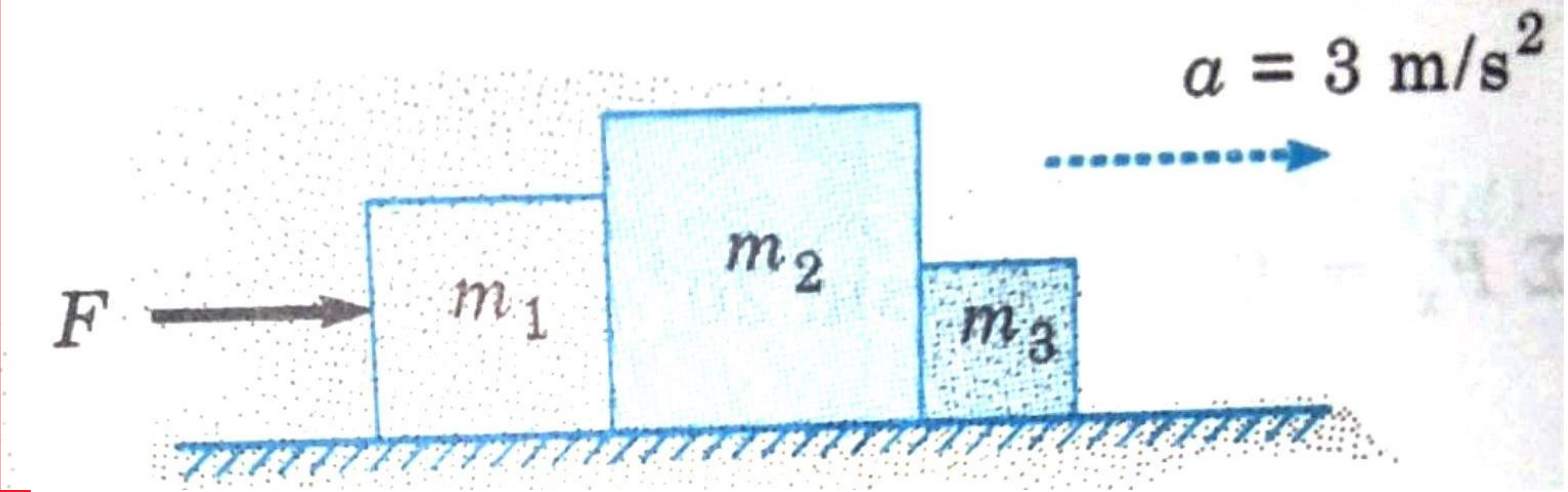
Problem No. 2:

A horizontal force P=600N is exerted on block A of mass 120 kg as shown in figure. The coefficient of friction between block A and horizontal plane is 0.25. Block B has a mass of 30 kg and the coefficient friction between it and the plane is 0.40. The wire between two blocks makes an angle 30° with the horizontal. Calculate the tension in the wire and acceleration of blocks.



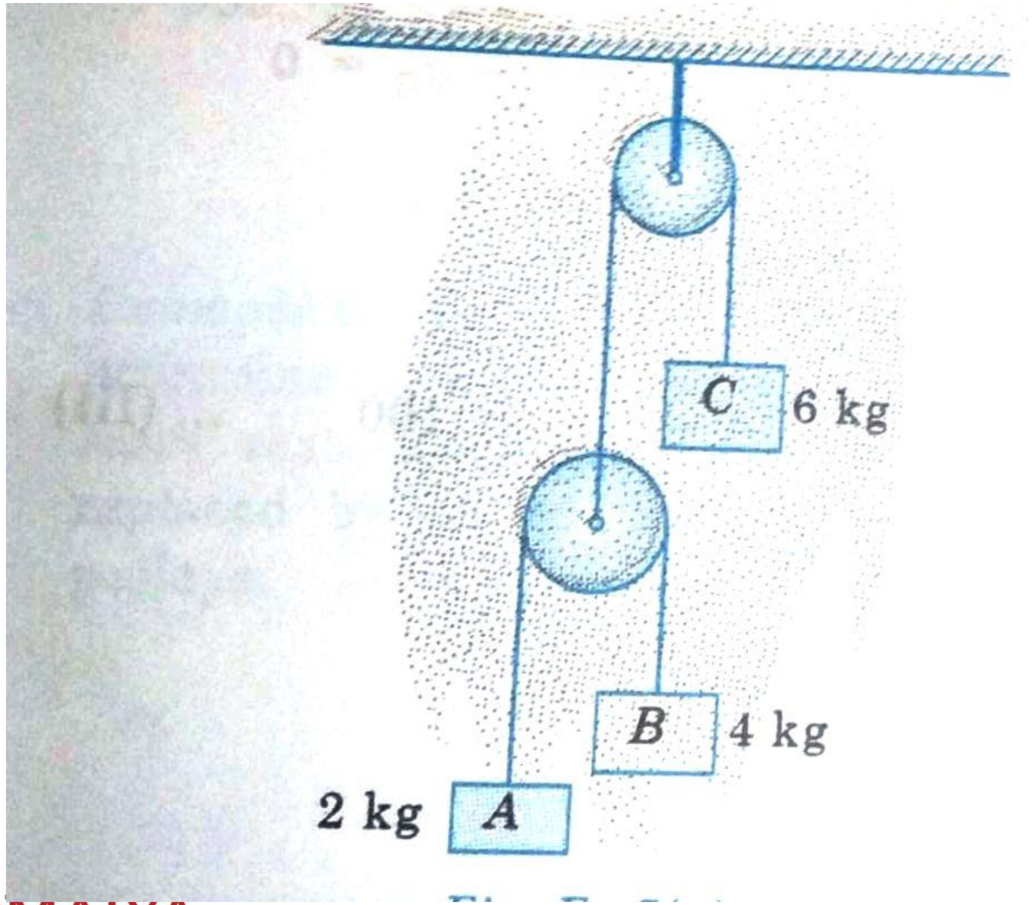
Problem No. 3:

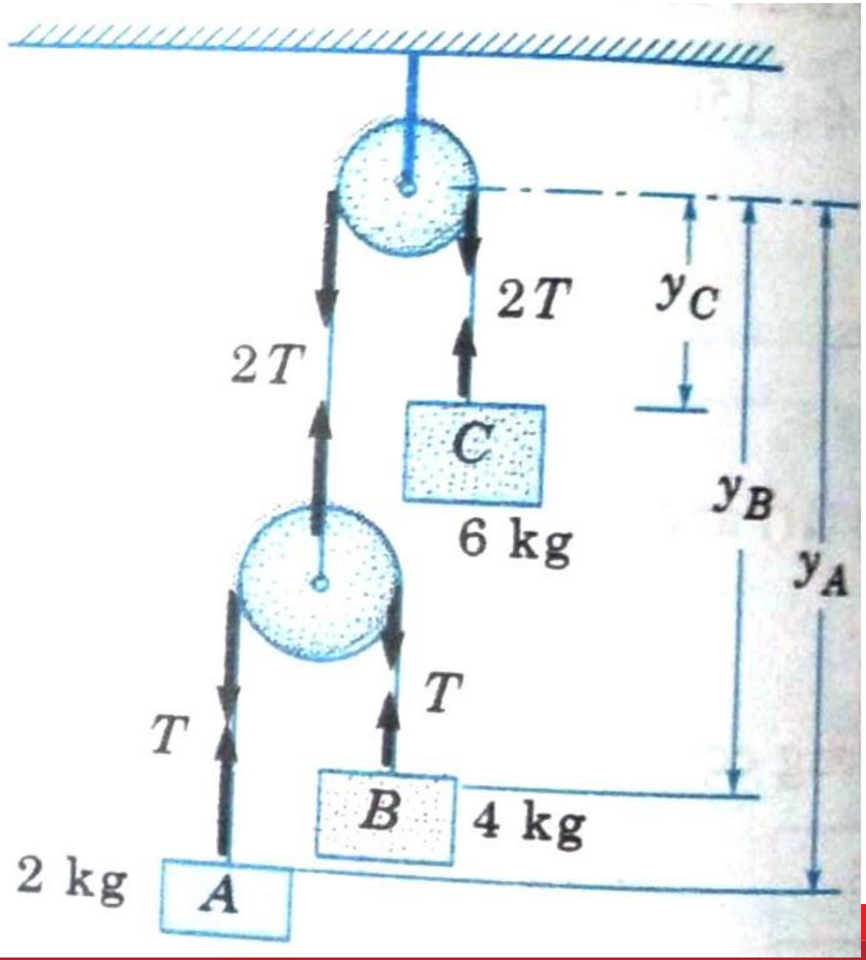
Three blocks m_1, m_2, and m_3 of masses 1.5 kg, 2 kg and 1 kg respectively are placed on a rough surface (μ=0.2) as shown in figure. If a force F is applied so as to give blocks acceleration of 3 m/s^2, then what will be the force that 1.5 kg block exerts on 2 kg block.



Problem No. 4:

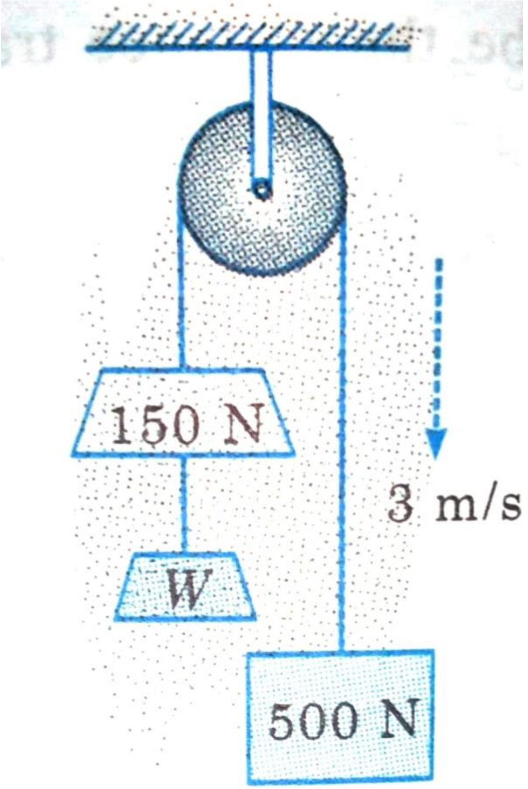
The system of pulleys, masses and connecting inextensible cables as shown in figure. Pulleys are massless and frictionless. If the system is released from the rest, find the acceleration of each of the three masses and tension in the cable.





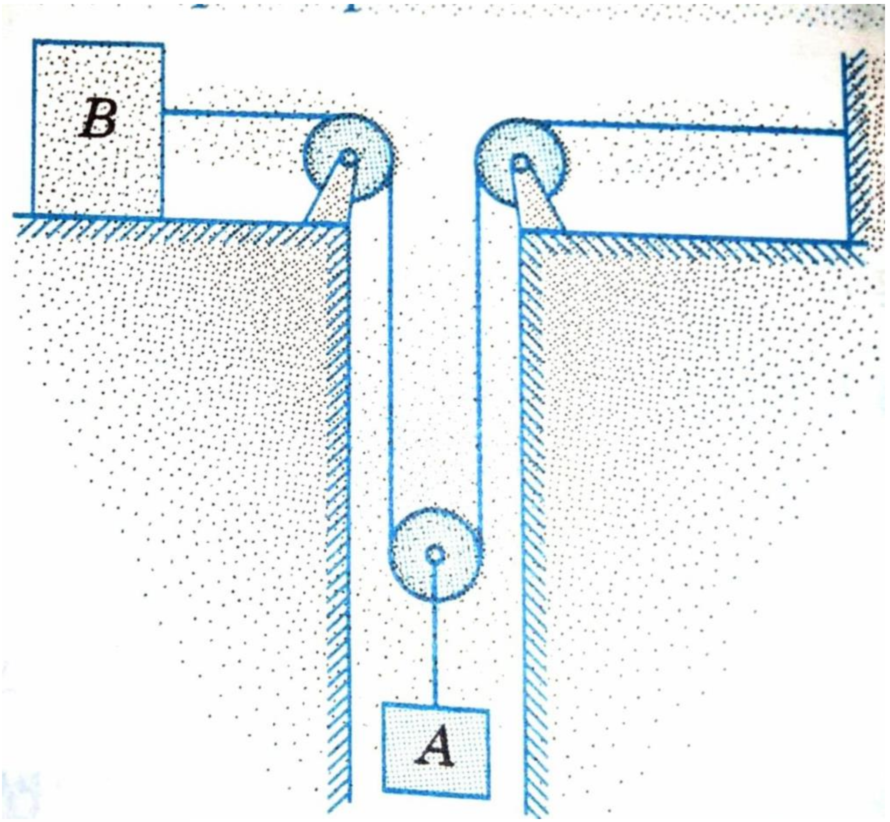
Problem No. 5:

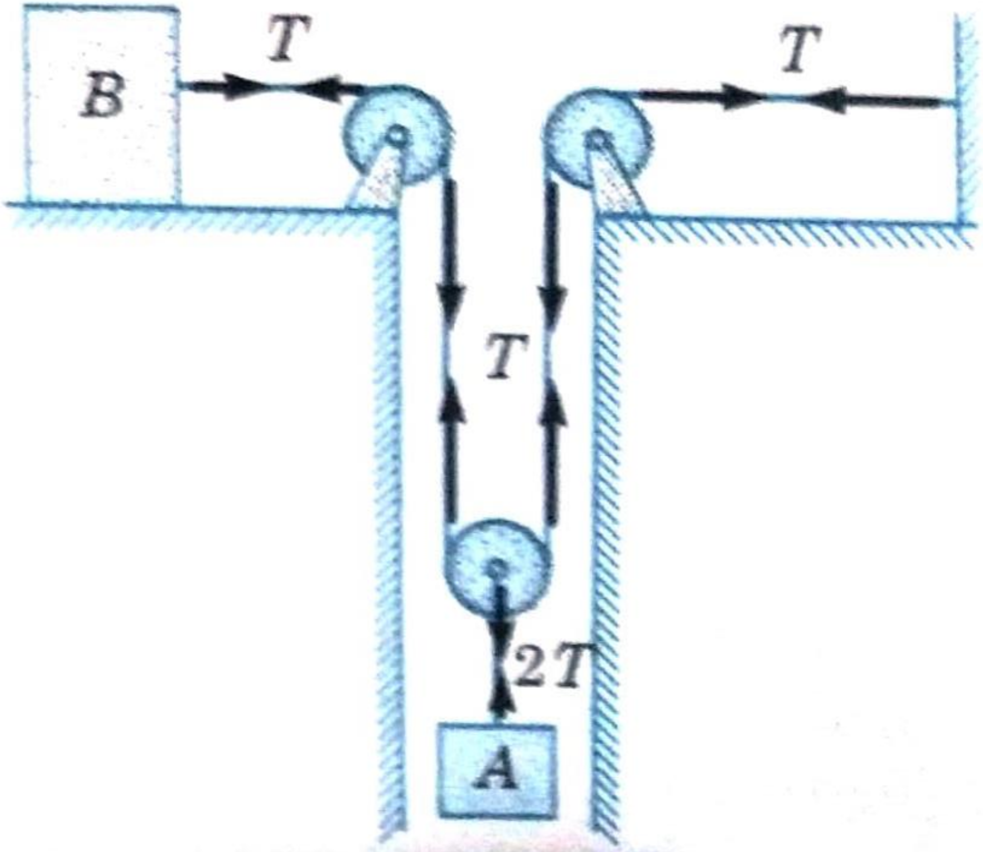
Determine the weight W required to be attached to 150 N block to bring the system as shown in figure to stop in 5 seconds if at any stage 500 N is moving down at 3 m/s. Assume pulley to be frictionless and massless.



Problem No. 6:

At a given instant the 50 N block A is moving downward with a speed of 1.8 m/s. Determine its speed 2 seconds later. Block B has a weight 20 N, and the coefficient of kinetic friction between it and the horizontal plane $\mu_k = 0.2$. Neglect the mass of pulleys and chord.





Problem No. 7:

A 100 kg crate is hoisted up the inclined plane using cable and motor M. For a short time the force in the cable is $800t^2$ N where t is in seconds. If the crate has an initial velocity vi = 2 m/s when t = 0 sec, determine the velocity when t = 2 seconds. The coefficient of kinetic friction between the crate and the inclined plane is $\mu_k = 0.3$.