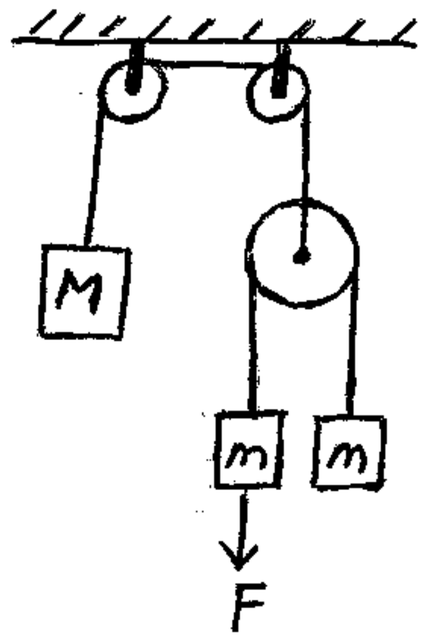
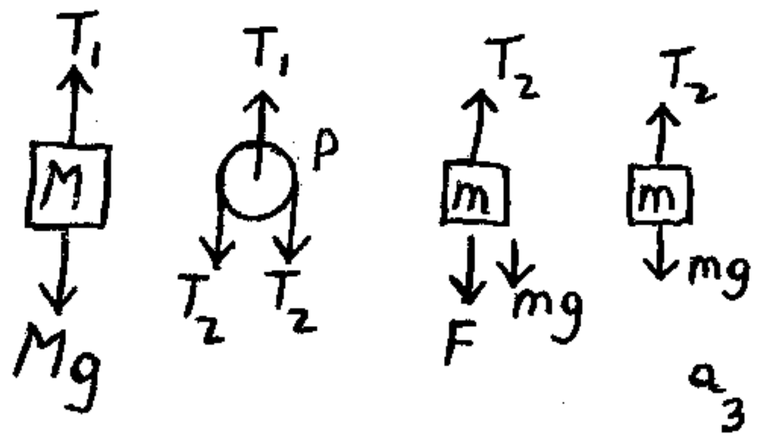
This is a force and motion problem involving pulleys.



Block M has a mass of 40 kg and both blocks m have a mass of 20 kg each. The mass of the pulleys and ropes are negligible. All blocks start from rest and the left block m moves a distance of 2 m in 1.5 s. Determine the tension in the ropes and the magnitude of the force F.

Solution:

Free-body diagrams



a_1 (direction to be determined)

a_2 (direction to be determined)

a_3 (direction to be determined)

↑ + (sign convention)

Let a_{rel} be the acceleration of the left block (m) relative to pulley P. Let a_p be the acceleration of the pulley P.

Then, $a_2 = a_p + a_{rel}$, and $a_3 = a_p - a_{rel}$

a_2: acceleration of left block relative to ground

a_3: acceleration of right block relative to ground

The acceleration of the block M (relative to ground) is:

$$a_1 = -a_p$$

Since the pulley P is assumed massless,

$$-2T_2 + T_1 = 0 \Rightarrow T_1 = 2T_2$$

Now, apply Newton's second law to the left block:

$$T_2 - F - mg = ma_2$$

$$\Rightarrow T_2 - F - mg = m(a_p + a_{rel}) \quad (1)$$

Apply Newton's second law to the right block:

$$T_2 - mg = ma_3 \Rightarrow T_2 - mg = m(a_p - a_{rel}) \quad (2)$$

Apply Newton's second law to the block M:

$$T_1 - Mg = Ma_1 \Rightarrow 2T_2 - Mg = -Ma_p \quad (3)$$

Substitute given values:

$$(1) \Rightarrow T_2 - F - 20(9.8) = 20(a_p + a_{rel})$$

$$(2) \Rightarrow T_2 - (20)(9.8) = 20(a_p - a_{rel})$$

$$(3) \Rightarrow 2T_2 - 40(9.8) = -40a_p$$

It's given that, for the left block (m), $\Delta d = +2m$ or $\Delta d = -2m$

So, $\Delta d = \underset{\uparrow \text{starts from rest}}{0} + \frac{1}{2}a_2(1.5)^2$ (kinematic equation)

If $\Delta d = +2\,m$, then

$$2 = \frac{1}{2} a_2 (1.5)^2$$

$$\Rightarrow \quad a_2 = 1.778\ m/s^2$$

If $\Delta d = -2\,m$, then

$$-2 = \frac{1}{2} a_2 (1.5)^2$$

$$\Rightarrow \quad a_2 = -1.778\ m/s^2$$

So there are two possible equations from this.

$$1.778 = a_p + a_{rel} \quad (4)$$

or

$$-1.778 = a_p + a_{rel} \quad (5)$$

First, combine equations (1), (2), (3), (4) to solve for T_2, F, a_p, a_{rel}:

$T_2 = 184.15\,N$, and $T_1 = 2T_2 = 368.3\,N$

$F = -47.41\,N$ ← a negative sign means that F is acting upward which contradicts problem statement

$a_p = 0.593\ m/s^2$

$a_{rel} = 1.185\ m/s^2$

Second, combine equations (1), (2), (3), (5) to solve for T_2, F, a_p, a_{rel}:

$T_2 = 207.85\,N$, and $T_1 = 2T_2 = 415.7\,N$

$F = 47.41\,N$ ← positive so this is consistent with problem statement

$a_p = -0.593\ m/s^2$

$a_{rel} = -1.185\ m/s^2$

(answer)