IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Moving Pulleys Problem

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Abstract- Three Pulleys System is considered so that problems of accelerated pulley can be incorporated, The problem is solved using differential principles of dynamics. D' Alembert idea of reversed effective force is utilized. Accelerations of all masses and tensions in all strings are calculated.

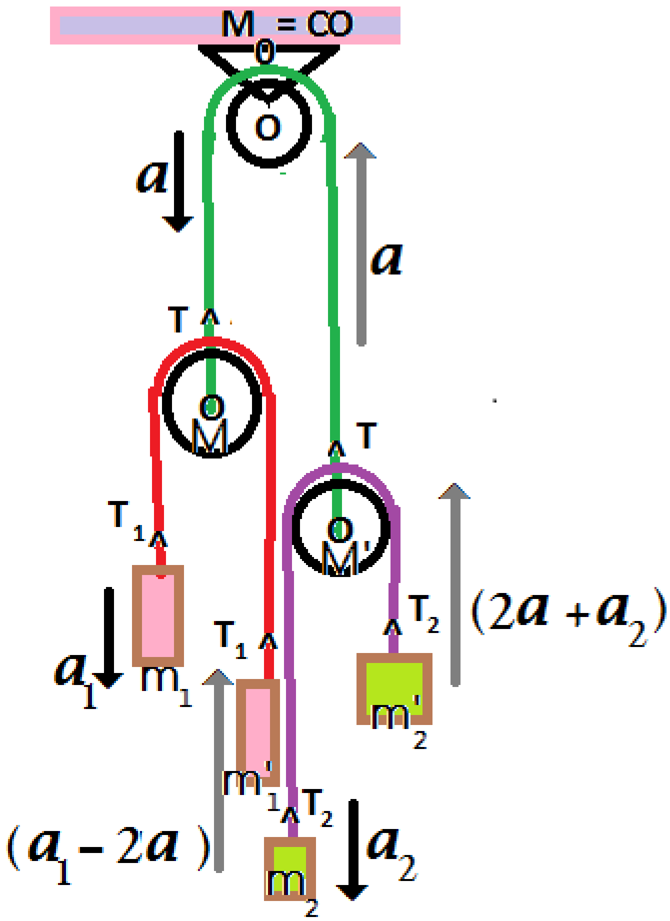
Keywords: Moving pulleys, dynamics in non inertial frames, reversed effective force

1. *Introduction*

The soul of mechanics resides in the problem solving techniques. Here we are considering a problem of moving pulleys so that readers may enjoy and experience an application of pseudo force, reversed effective force and fictitious force. Although the terms are used as synonyms but theoretical use in proper perspective is suited to theoreticians. The reversed effective force is invented to transform dynamics into statics. The pseudo force is the term irrespective of physical perception needed and fictitious force is the term with physical perception but usual origin missing. Here this complex system of pulleys incorporates such physical ideas.

2. *Solution of Moving pulleys*

Here one pulley is fixed to the ground and due to this fact its mass can be regarded as infinite. Other two pulleys, of unequal masses in general, are allowed to move around this pulley in frictionless environment. Each moving pulley is allowed to have masses moving over it. In this way we are having an interesting problem to solve.



$$2T_1 + Mg - T = Ma \qquad \ldots(1)$$

$$T - 2T_2 - M'g = M'a \qquad \ldots(2)$$

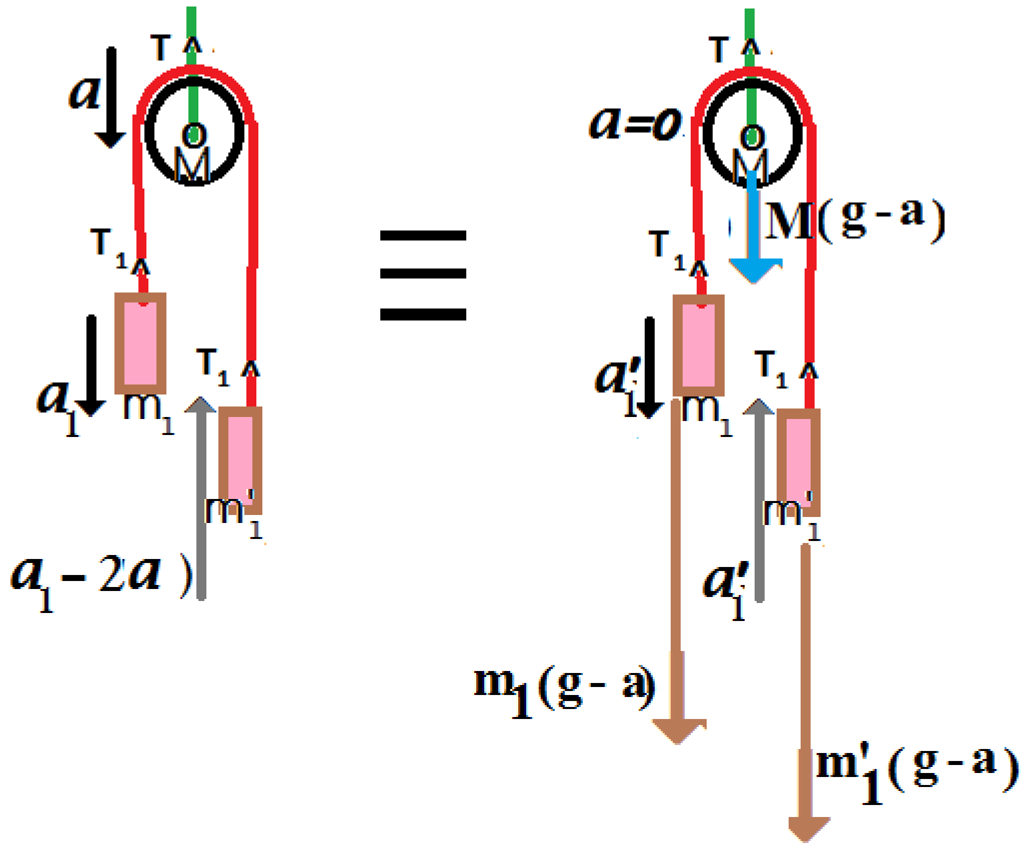
$$m_1 a_1 = m_1 g - T_1 \qquad \ldots(3)$$

$$m'_1(2a - a_1) = m'_1 g - T_1 \qquad \ldots(4)$$

$$m_2 a_2 = m_2 g - T_2 \qquad \ldots(5)$$

$$m'_2(2a + a_2) = T_2 - m'_2 g \qquad \ldots(6)$$

These *six* equations are sufficient to decide *six* unknowns "**a, a_1, a_2, T, T_1, T_2**".



$$m_1 a'_1 = m_1(g-a) - T_1$$

$$m'_1 a'_1 = T_1 - m'_1(g-a)$$

$$T_1 = \frac{2m_1 m'_1}{m_1 + m'_1}(g-a) = 2\mu_1(g-a) \qquad ..(7)$$

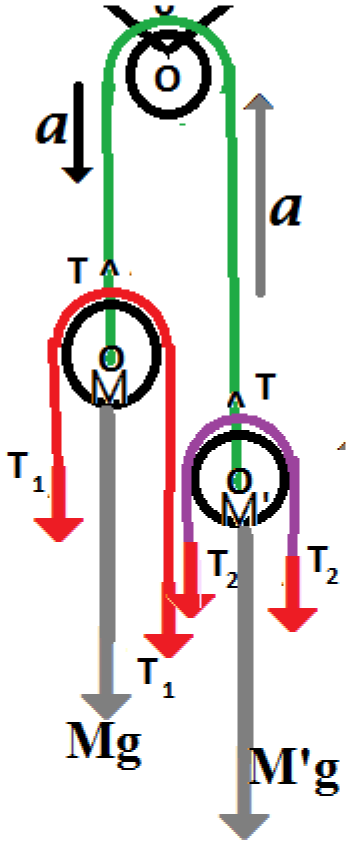
$$m_1 a'_1 = m_1(g-a) - T_1$$

$$m'_1 a'_1 = T_1 - m'_1(g-a)$$

$$a'_1 = \frac{m_1 - m'_1}{m_1 + m'_1} g_1$$

Similarly $$T_2 = \frac{2m_2 m'_2}{m_2 + m'_2}(g+a) = 2\mu_2(g+a) \qquad ...(8)$$

$$a'_2 = \frac{m_2 - m'_2}{m_2 + m'_2} g_2$$

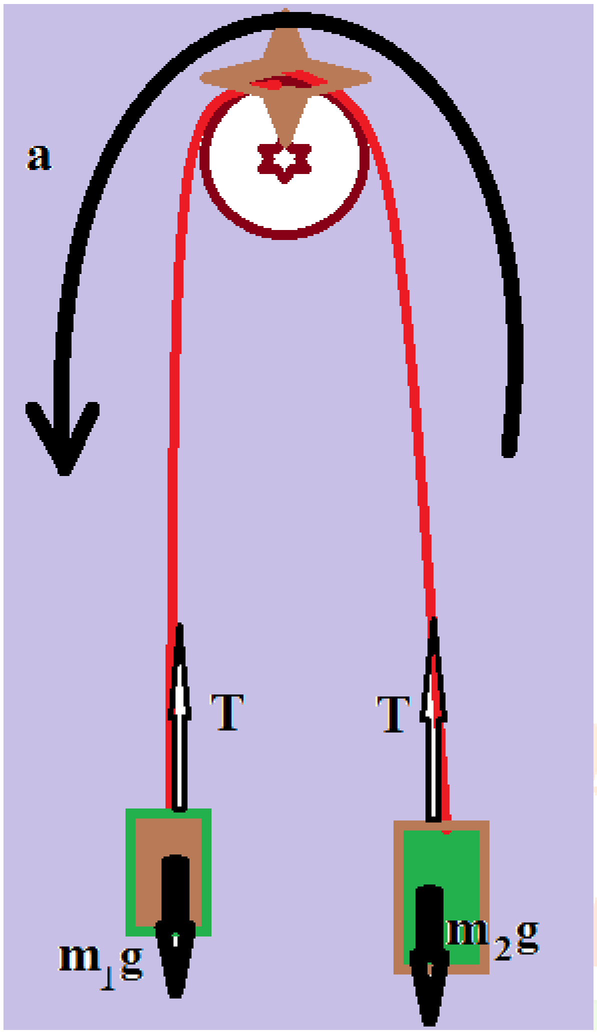


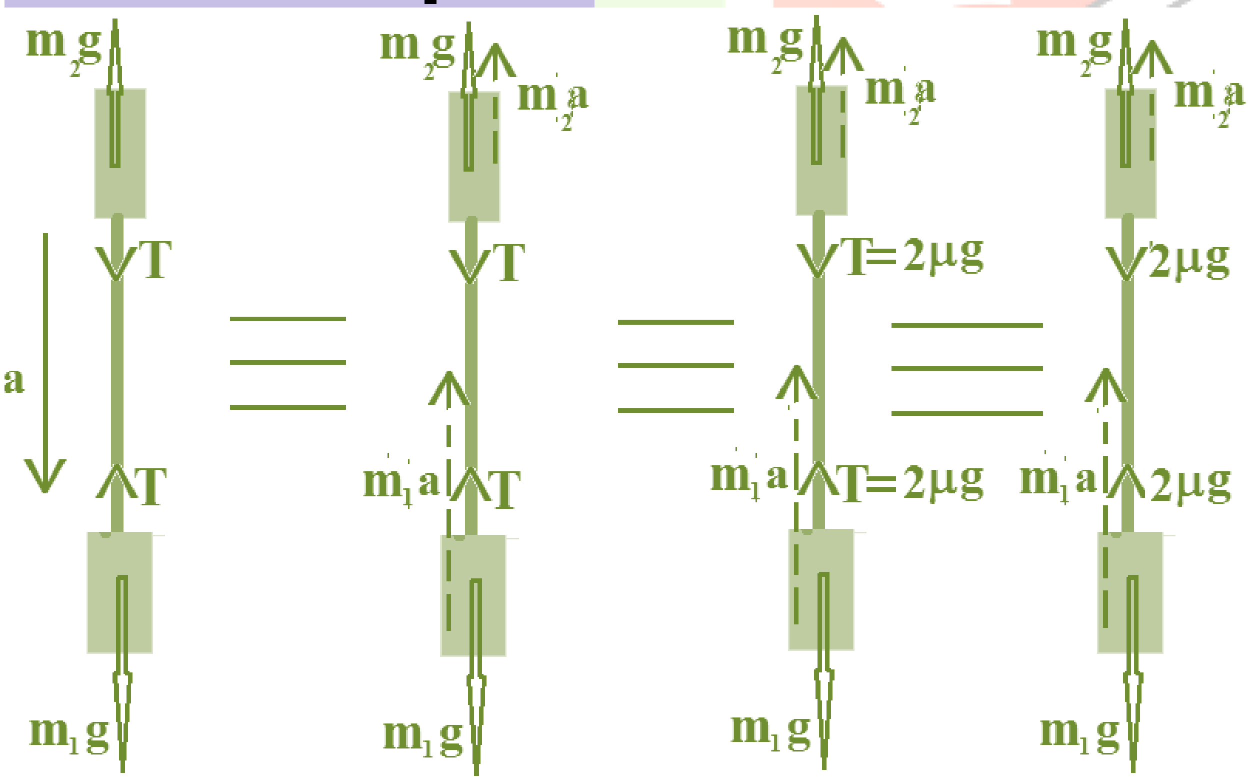
$$Mg + 2T_1 - T + T - 2T_2 - M'g = (M + M')a$$

$$a = \frac{(M - M')g + 2(T_1 - T_2)}{M + M'} \quad \ldots(9)$$

From Eq. (7), (8), and (9),

$$a = \frac{(M - M')g + 2(T_1 - T_2)}{M + M'}$$


a
T
T
m1 g
m2 g


m2 g
T
a
T
m1 g
m2 g
m2 a
T
m1 a
T
m1 g
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m2 a
T=2μg
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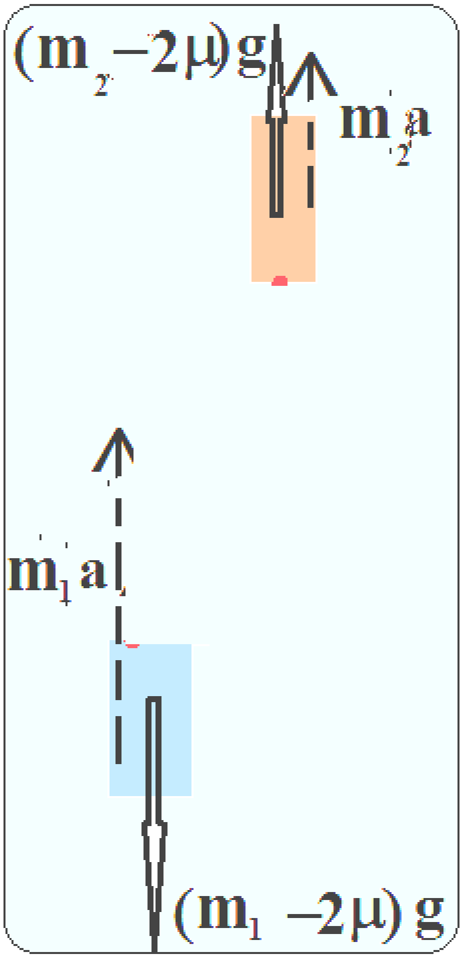
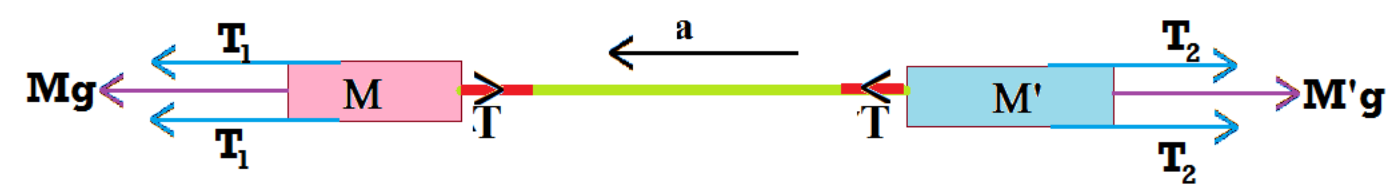
m2 g
m2 a
2μg
m1 a
2μg
m1 g

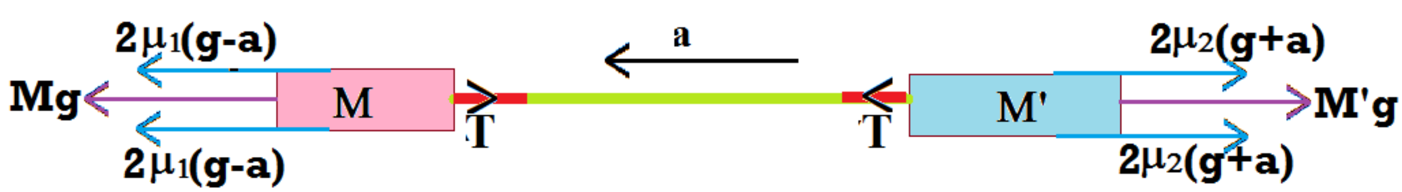


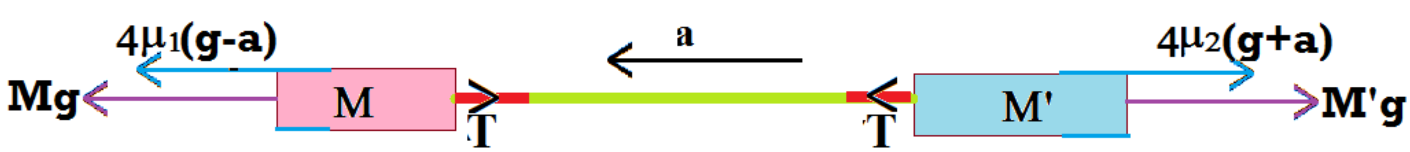
$$(m_1 - 2\mu)g - m_1 a = 0$$

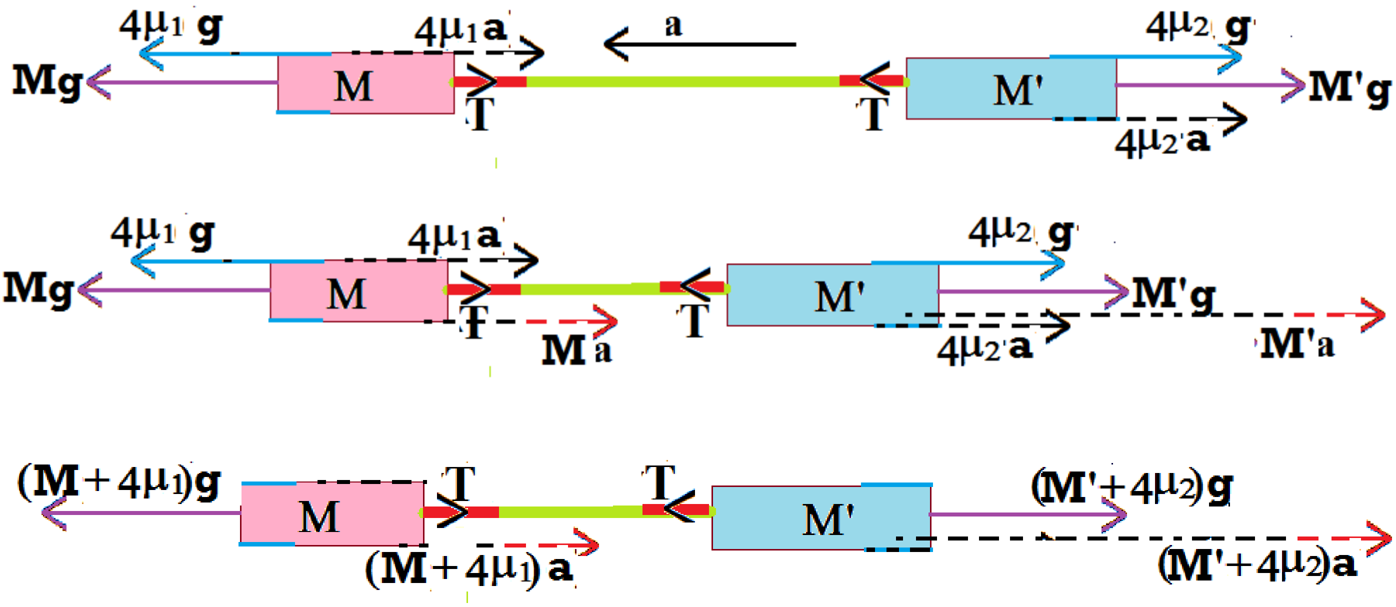
$$(m_2 - 2\mu)g + m_2 a = 0$$

$$\therefore a = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)g; \qquad \mu = \frac{m_1 m_2}{m_1 + m_2}$$









$$a=\left(\frac{(M-M')+4(\mu_1-\mu_2)}{(M-M')+4(\mu_1-\mu_2)}\right)g=\left[\frac{(M+4\mu_1)-(M'+4\mu_2)}{(M+4\mu_1)+(M'+4\mu_2)}\right]g \qquad \ldots(10)$$

$$a=\left[\frac{(M+4\mu_1)-(M'+4\mu_2)}{(M+4\mu_1)+(M'+4\mu_2)}\right]g=\frac{\tilde{M}-\tilde{M}'}{\tilde{M}+\tilde{M}'}g \qquad \ldots(11)$$

$$T=\tilde{M}(g-a)=\tilde{M}'(g+a)$$

$$\Rightarrow 2T=\left(\tilde{M}+\tilde{M}'\right)g-\left(\tilde{M}-\tilde{M}'\right)a$$

$$\Rightarrow 2T=\left(\tilde{M}+\tilde{M}'\right)g-\left(\tilde{M}-\tilde{M}'\right)\left(\frac{\tilde{M}-\tilde{M}'}{\tilde{M}+\tilde{M}'}\right)g$$

$$\Rightarrow 2T=\frac{\left(\tilde{M}+\tilde{M}'\right)^2-\left(\tilde{M}-\tilde{M}'\right)^2}{\left(\tilde{M}+\tilde{M}'\right)}g=\frac{4\tilde{M}\tilde{M}'}{\tilde{M}+\tilde{M}'}g$$

$$T=\frac{2\tilde{M}\tilde{M}'}{\tilde{M}+\tilde{M}'}g \qquad \ldots(12)$$

$$g_1 = g - a = g - \frac{\tilde{M} - \tilde{M}'}{\tilde{M} + \tilde{M}'} g = \frac{2\tilde{M}'}{\tilde{M} + \tilde{M}'} g$$

$$T_1 = 2\mu_1 g_1 = \frac{4\mu_1 \tilde{M}'}{\tilde{M} + \tilde{M}'} g \qquad \text{...(13)}$$

$$g_2 = g + a = g + \frac{\tilde{M} - \tilde{M}'}{\tilde{M} + \tilde{M}'} g = \frac{2\tilde{M}}{\tilde{M} + \tilde{M}'} g$$

$$T_2 = 2\mu_2 g_2 = \frac{4\mu_2 \tilde{M}}{\tilde{M} + \tilde{M}'} g \qquad \text{...(14)}$$

$$a'_1 = \frac{m_1 - m'_1}{m_1 + m'_1} g_1 = \frac{m_1 - m'_1}{m_1 + m'_1} \bullet \frac{2\tilde{M}'}{\tilde{M} + \tilde{M}'} g = \frac{2\tilde{M}'(m_1 - m'_1)}{(\tilde{M} + \tilde{M}')(m_1 + m'_1)} g \qquad \text{...(15)}$$

$$a'_2 = \frac{m_2 - m'_2}{m_2 + m'_2} g_2 = \frac{m_2 - m'_2}{m_2 + m'_2} \bullet \frac{2\tilde{M}}{\tilde{M} + \tilde{M}'} g = \frac{2\tilde{M}(m_2 - m'_2)}{(\tilde{M} + \tilde{M}')(m_2 + m'_2)} g \qquad \text{...(16)}$$

$$m_1 a_1 = m_1 g - T_1$$

$$m_1 a'_1 = m_1 g_1 - T_1 = m_1 (g - a) - T_1$$

$$m_1 (a'_1 + a) = m_1 g - T_1$$

$$a_1 = a'_1 + a = \frac{2\tilde{M}'(m_1 - m'_1)}{(\tilde{M} + \tilde{M}')(m_1 + m'_1)} g + \frac{\tilde{M} - \tilde{M}'}{\tilde{M} + \tilde{M}'} g$$

$$= \frac{g}{\tilde{M} + \tilde{M}'} \left[(\tilde{M} - \tilde{M}') + 2\tilde{M}' \frac{(m_1 - m'_1)}{(m_1 + m'_1)} \right] \qquad \text{...(17)}$$

$$m_2 a_2 = m_2 g - T_2$$

$$m_2 a'_2 = m_2 g_2 - T_2 = m_2 (g + a) - T_2$$

$$m_2 (a'_2 + a) = m_2 g - T_2$$

$$a_2 = a'_2 - a = \frac{2\tilde{M}(m_2 - m'_2)}{(\tilde{M} + \tilde{M}')(m_2 + m'_2)} g - \frac{\tilde{M} - \tilde{M}'}{\tilde{M} + \tilde{M}'} g$$

$$= \frac{g}{\tilde{M} + \tilde{M}'} \left[(\tilde{M}' - \tilde{M}) + 2\tilde{M} \frac{(m_2 - m'_2)}{(m_2 + m'_2)} \right] \qquad \text{...(18)}$$

$$a_1 = a_1' + a = \frac{m_1 - m'_1}{m_1 + m'_1}(g - a) + a = \frac{m_1 - m'_1}{m_1 + m'_1} g + \frac{2m'_1}{m_1 + m'_1} a$$

$$= \left[\frac{m_1 - m'_1}{m_1 + m'_1} + \frac{2m'_1}{m_1 + m'_1} \bullet \frac{\tilde{M} - \tilde{M}'}{\tilde{M} + \tilde{M}'} \right] g \qquad \ldots(19)$$

$$a_2 = a_2' - a = \frac{m_2 - m'_2}{m_2 + m'_2}(g + a) - a = \frac{m_2 - m'_2}{m_2 + m'_2} g - \frac{2m'_2}{m_2 + m'_2} a$$

$$= \left[\frac{m_2 - m'_2}{m_2 + m'_2} + \frac{2m'_2}{m_2 + m'_2} \bullet \frac{\tilde{M} - \tilde{M}'}{\tilde{M} + \tilde{M}'} \right] g \qquad \ldots(20)$$

3. *Discussion*

Using Newton’s laws, D Alembert’s reversed effective force , inertial force we solve the problem. The solution has pedagogic value. Many problems regarding pulleys can be deduced from this problem.

4. *References*

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