Department of Mathematics and Natural Sciences

PHY111 - Principles of Physics-I (Fall 2021)

Assignment-2

Total Marks: 20

Answer all questions.

1. Block 1 of mass $m_1 = 2\ kg$ is placed on block 2 of mass $m_2 = 3\ kg$ which is then placed on a table. A string connecting block 2 to a hanging mass M passes over a pulley attached to one end of the table, as shown in Fig. 1. The mass and friction of the pulley are negligible. The coefficients of friction between block 1 and block 2 are $\mu_{1s} = 0.2$, $\mu_{1k} = 0.1$ and between block 2 and the tabletop are $\mu_{2s} = 0.3$, $\mu_{2k} = 0.15$.

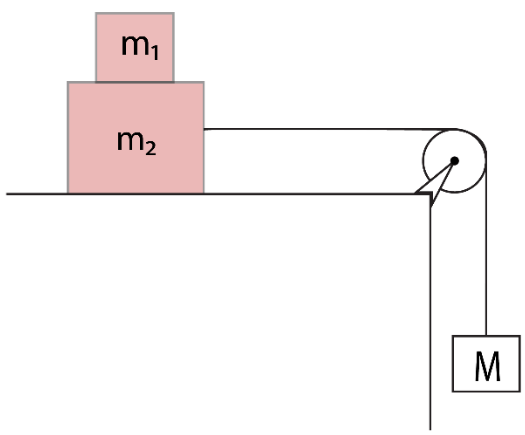


Fig. 1

(a) *(Marks: 3)* Draw the complete free body diagram of the system and determine the largest value of M for which the blocks can remain at rest.

(b) *(Marks: 4)* Now suppose that $M = 2.5\ kg$ which is large enough so that the hanging block descends and block 1 slips on block 2. Draw the complete free body diagram of the system and determine each of the followings.

i. The magnitude a_1 of the acceleration of block 1.

ii. The magnitude a_2 of the acceleration of block 2.

2. Block 1 and block 2, with masses $m_1 = 5\ kg$ and $m_2 = 2\ kg$, are connected by a system of massless, inextensible ropes and massless pulleys as shown in Fig. 2.

(a) *(Marks: 2)* Draw the complete free body force diagram of the system.

(b) *(Marks: 4)* Solve for the accelerations of block 2 and block 1. Assume that downward direction is positive.

(c) *(Marks: 2)* Calculate the tensions in each rope.

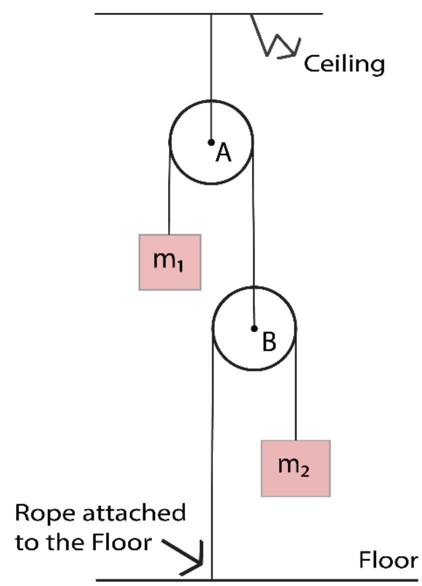


Fig. 2

3. A wet socks clinging to the inside of a washing machine drum which is spinning at a speed of 4.7 m/s. The radius of the drum is 30 cm.

(a) *(Marks: 2)* What is the minimum coefficient of static friction between sock and the drum so that the sock will not slip down?

(b) *(Marks: 1)* At the same rotational speed and coefficient of static friction between sock and the drum, would a sock of twice the mass slide down the wall? Explain your answer.

(c) *(Marks: 2)* As the drum slows down after the washing is done at an angular retardation of 3.25 rad/sec^2. Find the time taken and number of rotations before it stops.

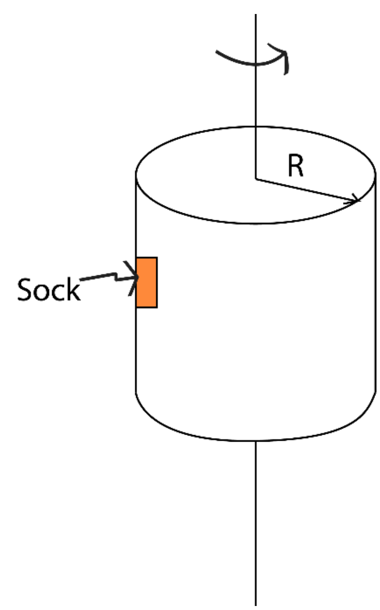
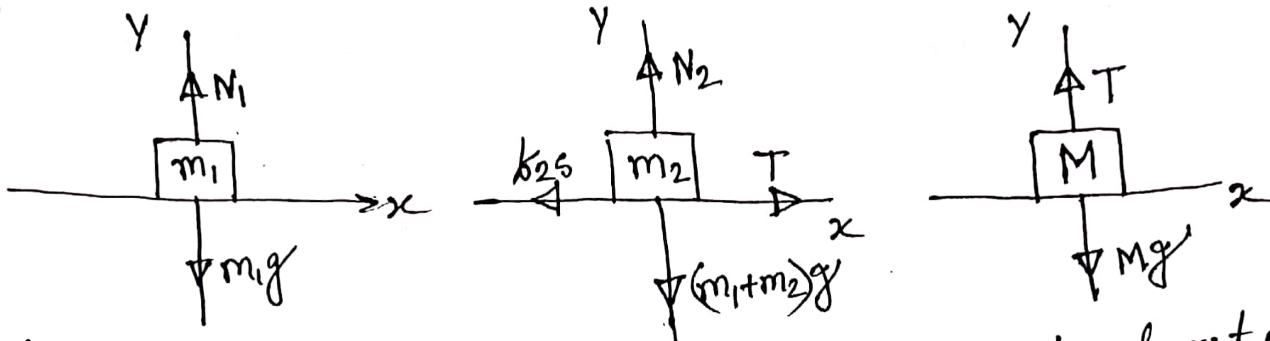


Fig. 3

1. (a)



The largest value of M for which the blocks can remain at rest depends on the maximum frictional force on the blocks on the table.

For m_2 block, According to Newton's 2nd law,

$$x \rightarrow f_{2s,max} = T \quad \text{—— (I)}$$

$$y \rightarrow N_2 = (m_1+m_2)g$$

$$\text{(I)} \rightarrow \mu_{2s} N_2 = \mu_{2s}(m_1+m_2)g = T \quad \text{—— (II)}$$

Here,
$m_1 = 2\,kg$
$m_2 = 3\,kg$
$\mu_{2s} = 0.3$

Again for M block,

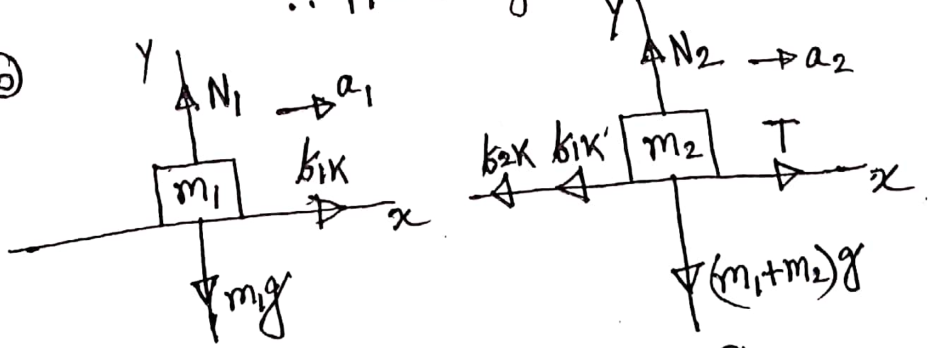
$$\cancel{x}\,y \rightarrow T = Mg$$

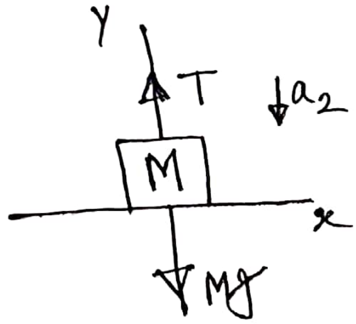
$$\Rightarrow \mu_{2s}(m_1+m_2)g = Mg$$

$$\Rightarrow M = 0.3(2+3)$$

$$\therefore M = 1.5\,kg$$

(b)





(i) For, m_1 block, $x \rightarrow f_{1K} = m_1 a_1$ —— (I)

$$y \rightarrow N_1 = m_1 g \quad \text{—— (II)}$$

$$\text{(I)} \rightarrow f_{1K} = \mu_{1K} N_1 = m_1 a_1$$

$$\Rightarrow a_1 = \frac{\mu_{1K} m_1 g}{m_1}$$

$$\Rightarrow a_1 = 0.1 \times 9.8$$

$$\therefore a_1 = 0.98\,ms^{-2}$$

Here,
$m_1 = 2\,kg$
$m_2 = 3\,kg$
$\mu_{1K} = 0.1$

(ii) For, m_2 block, $x \rightarrow T - f_{1K} - f_{2K} = m_2 a_2$ —— (iii)

$y \rightarrow N_2 = (m_1 + m_2) g$

For, M block, $y \rightarrow Mg - T = M a_2$

$\Rightarrow T = (2.5 \times 9.8) - 2.5 a_2$

$\Rightarrow T = 24.5 - 2.5 a_2$

Here,
$m_1 = 2kg$
$m_2 = 3kg$
$M = 2.5kg$
$\mu_{1K} = 0.1$
$\mu_{2K} = 0.15$

From, equation (iii) $\rightarrow$ $24.5 - 2.5a_2 - \mu_{1K} N_1 - \mu_{2K} N_2 = 3a_2$

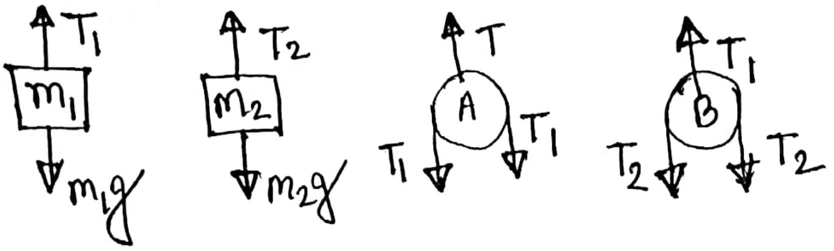
$\Rightarrow 24.5 - \mu_{1K} m_1 g - \mu_{2K} (m_1 + m_2) g = 5.5 a_2$

$\Rightarrow 24.5 - (0.1 \times 2 \times 9.8) - 0.15 (2+3) \times 9.8 = 5.5 a_2$

$\Rightarrow a_2 = \frac{15.19}{5.5}$

$\therefore a_2 = 2.762 \, ms^{-2}$.

(2) (a)



(b) Here, we are considering the downward motion is positive.

For, m_1 block, According to Newton's 2nd law,

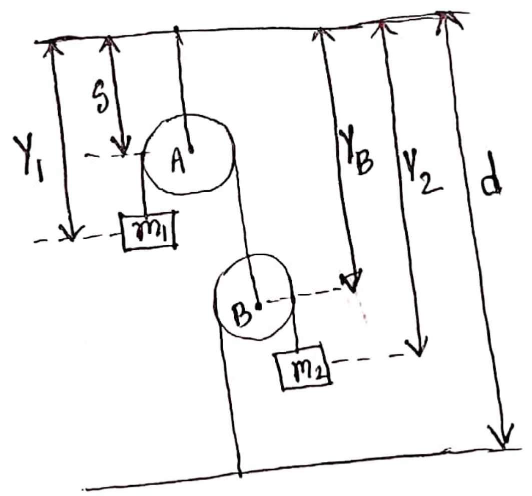
$$m_1 g - T_1 = m_1 a_1 \quad \text{——— (I)}$$

For, m_2 block,

$$m_2 g - T_2 = m_2 a_2 \quad \text{——— (II)}$$

For, pulley A, $T = T_1 + T_1 = 2T_1$ — (III) [Since, massless Pulleys]

For, pulley, B, $T_1 = T_2 + T_2 = 2T_2$ — (IV)



Let, l_1 and l_2 are the length of the ropes attached with m_1 and m_2 block respectively.

Now, $l_1 = Y_1 - S + \pi R + Y_B - S$ and $l_2 = Y_2 - Y_B + \pi R + d - Y_B$

$$\Rightarrow \frac{d^2 l_1}{dt^2} = 0 = a_1 + a_B$$

$$\therefore a_1 = -a_B$$

$$\Rightarrow \frac{d^2 l_2}{dt^2} = a_2 - a_B - a_B$$

$$\Rightarrow 0 = a_2 - 2a_B$$

$$\Rightarrow a_2 = 2a_B$$

$$\therefore \boxed{a_2 = -2a_1} \quad \text{——— (V)}$$

Now, from equation (III), (IV) and (V),

$$m_2 g - \frac{T_1}{2} = -2m_2 a_1$$

$$\Rightarrow T_1 = 2m_2 g + 4m_2 a_1 \quad \text{—— (VI)}$$

Now, from equation (I),

Here,
$m_1 = 5\,kg$
$m_2 = 2\,kg$

$$m_1 g - 2m_2 g - 4m_2 a_1 = m_1 a_1$$

$$\Rightarrow a_1 = \frac{m_1 g - 2m_2 g}{4m_2 + m_1}$$

$$\Rightarrow a_1 = \frac{(5\times9.8) - (2\times2\times9.8)}{(4\times2)+5}$$

$$\therefore a_1 = 0.754\ ms^{-2}\ (\text{downward})$$

From, equation (V), $a_2 = -2\times0.754$

$$\therefore a_2 = -1.508\ ms^{-2}\ (\text{upward})$$

(c) From, equation (VI),

$$T_1 = (2\times2\times9.8) + (4\times2\times0.754)$$

$$\Rightarrow T_1 = 45.232\,N$$

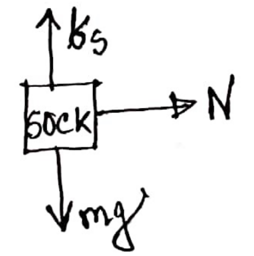
From equation (III), $T = 2T_1 = 2\times45.232$

$$= 90.464\,N$$

From, equation (IV), $T_2 = \frac{T_1}{2} = \frac{45.232}{2}$

$$= 22.616\,N$$

③ ⓐ



Here, $f_s = mg$

and, $N = ma$

$$\Rightarrow \frac{f_s}{\mu_s} = m\frac{v^2}{r}$$

$$\Rightarrow \mu_s = \frac{mgr}{mv^2}$$

$$\Rightarrow \mu_s = \frac{9.8 \times 0.3}{(4.7)^2}$$

$$\therefore \mu_s = 0.133$$

Here,
$m = 80\,gm = 0.08\,kg$
$r = 30\,cm = 0.3\,m$
$v = 4.7\,ms^{-1}$

ⓑ NO,
Here, frictional force is equal to the weight of the sock and proportional to the normal force. Mass of the sock will cancel from the equation for the above condition. So, If we increase the mass at any value it will not slide down the drum surface.

ⓒ We Know, $v = \omega_0 r$

$$\Rightarrow \omega_0 = \frac{v}{r} = \frac{4.7}{0.3}$$

$$\therefore \omega_0 = 15.67\ rad/sec$$

Here,
$\omega = 0$
$\alpha = -3.25\ rad/sec^2$

we Know, $\omega = \omega_0 + \alpha t$

$$\Rightarrow t = \frac{\omega - \omega_0}{\alpha} = \frac{0 - 15.67}{-3.25}$$

$$\therefore t = 4.822\ sec$$

Again, $\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

$$\Rightarrow \Delta\theta = (15.67 \times 4.822) + \frac{1}{2} \times (-3.25) \times (4.822)^2$$

$$\Rightarrow \Delta\theta = 37.777\ rad$$

$$\therefore \text{Number of rotations} = \frac{37.777}{2\pi}$$

$$= 6.012 \approx 6$$