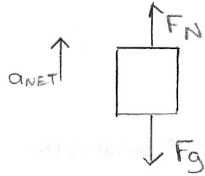


MULTI-BODY FORCES & KINEMATICS

1. On a visit to Taiwan, you seize an opportunity to take your bathroom spring scale with you on a ride to the observation deck of Taipei 101 in the world's fastest elevator. As other passengers board the elevator from the mall level 30 m above the ground, you step on the scale and see that it reads 700 N. The doors close, and for the first 16.0 s, your scale reads 775 N. For the next 5 s, the scale reads 700 N again. During the last 16 s of the ride, the scale reads 625 N.

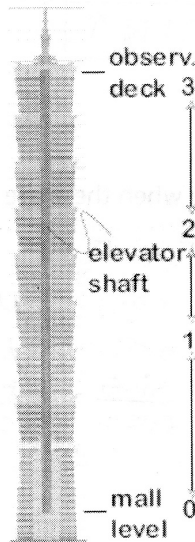


$$F_g = mg$$

$$\frac{F_g}{g} = m$$

$$\frac{700\text{N}}{9.81\text{m/s}^2} = m$$

$$71.4\text{kg} = m$$



$$F_g = 700\text{N}$$

$$F_{N,1} = 775\text{N} \quad t_1 = 16\text{s}$$

$$F_{N,2} = 625\text{N} \quad t_2 = 16\text{s}$$

$$\sum F_y = F_N - F_g$$

$$F_{NET} = F_N - F_g$$

$$a = \frac{F_N - F_g}{m}$$

$$a = \frac{775\text{N} - 700\text{N}}{71.4\text{kg}}$$

$$a_{NET} = 1.05\text{m/s}^2$$

- a. What is the elevator's top speed?

$$v_f = v_i + at$$

$$v_f = 0\text{m/s} + 1.05\text{m/s}^2(16\text{s})$$

$$v_f = 16.8\text{m/s}$$

- b. How high above the ground is the Taipei 101 observation deck?

$$y_i = 30\text{m}$$

$$\Delta y = v_i t + \frac{1}{2} a_y t^2 = \frac{1}{2} (1.05\text{m/s}^2) (16\text{s})^2 = 134.4\text{m}$$

$$\Delta y = v_i t + \frac{1}{2} a_y t^2 = 16.8\text{m/s} (5\text{s}) = 84\text{m}$$

constant velocity

$$\Delta y = v_i t + \frac{1}{2} a_y t^2 = 16.8\text{m/s} (16\text{s}) + \frac{1}{2} (-1.05\text{m/s}^2) (16\text{s})^2 = 134.4\text{m}$$

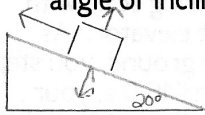
$$h = 30 + 134.4 - 84 + 134.4 = 383\text{m}$$

$$a = \frac{625 - 700}{71.4\text{kg}}$$

$$a_{NET} = -1.05\text{m/s}^2$$

2. The bed of a dump truck is lifted to deposit a cargo of sandbags on the ground. Consider one isolated 45 kg sandbag lying on the floor of the cargo bed.

a. What is the force of friction acting on the box if the sandbag is motionless when the angle of incline is 20° ?



$$\sum F_x = F_{g,x} - F_f$$

$$0 = F_{g,x} - F_f$$

$$F_f = mg \sin \theta$$

$$F_f = 45 \text{ kg} (9.81 \text{ m/s}^2) \sin 20^\circ$$

$$F_f = 151 \text{ N} \uparrow$$

b. If the sandbag first begins to slide when the angle of the incline reaches 40° , what is the value of μ_s ?

$$\sum F_x = F_{g,x} - F_f$$

$$0 = mg \sin \theta - \mu F_N$$

$$0 = mg \sin \theta - \mu mg \cos \theta$$

$$\mu = \frac{\sin \theta}{\cos \theta} = \frac{\sin 40^\circ}{\cos 40^\circ} = \tan 40^\circ = 0.839$$

3. A block of mass m is placed against the vertical front of a cart, and the cart is accelerated forward with an acceleration of magnitude a , as illustrated. The coefficient of static friction between the block and the cart is μ_s , while the coefficient of kinetic friction is μ_k . What is the minimum acceleration magnitude a required to prevent the block from sliding down the front of the cart, in terms of any or all of m , μ_s , μ_k , and physical or mathematical constants?

$$\sum F_x = F_N$$

$$ma_x = F_N$$

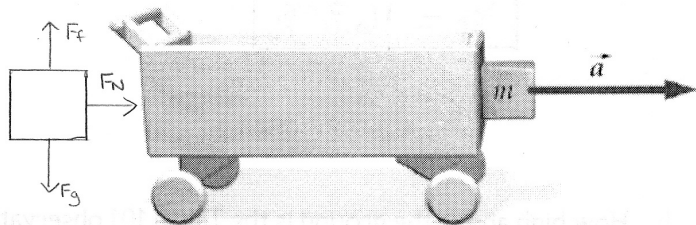
$$\sum F_y = F_{f_s} - F_g$$

$$0 = \mu_s F_N - mg$$

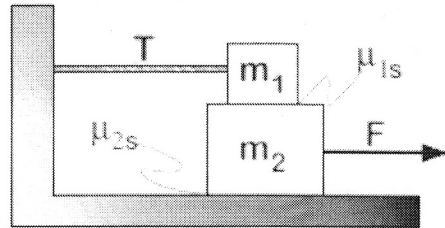
$$0 = \mu_s (ma_x) - mg$$

$$mg = \mu_s ma_x$$

$$\frac{g}{\mu_s} = a_x$$



Force F is gradually increased until the bottom block ($m_2 = 20 \text{ kg}$) begins moving to the right. The top block ($m_1 = 5 \text{ kg}$) is prevented from moving by a light cord (assumed to be massless). The coefficient of static friction between the two blocks is $\mu_{1,s} = 0.15$ and the coefficient of static friction between the bottom block and the floor is $\mu_{2,s} = 0.30$.

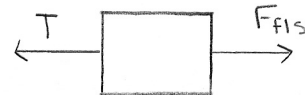


- a. What is the tension in the light cord attached to the top block if it is just about ready to slip relative to the bottom block?

$$\begin{aligned} \sum F_x &= T - F_{f1s} \\ 0 &= T - F_{f1s} \\ 0 &= T - \mu_{1s} F_{N1} \\ T &= \mu_{1s} m_1 g \end{aligned}$$

$$T = 0.15 (5 \text{ kg}) (9.81 \text{ m/s}^2)$$

$$\boxed{T = 7.35 \text{ N}}$$



- b. What is the minimum force F required to move the bottom block?

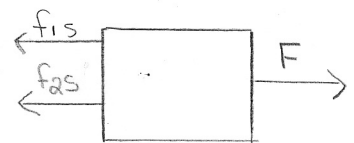
$$\sum F_x = F - F_{f1s} - F_{f2s} = 0$$

$$F = F_{f1s} + F_{f2s}$$

$$F = \mu_{1s} F_{N1} + \mu_{2s} F_{N2}$$

$$F = 0.15 (5 \text{ kg}) (9.81 \text{ m/s}^2) + 0.3 (5 + 20) \text{ kg} (9.81 \text{ m/s}^2)$$

$$\boxed{F = 81 \text{ N}}$$



block and ground are preventing from moving