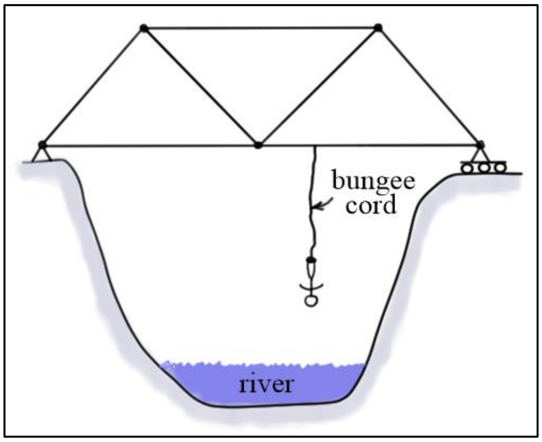
Elementary Dynamics
Exercises #5 – Work/Energy, Conservation of Energy, Newton's Laws for Particle Motion

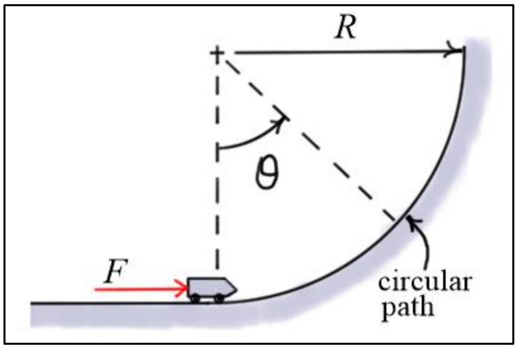
1. A 175 (lb) bungee jumper jumps off a bridge with a bungee cord attached to his legs. The stiffness of the bungee cord is $k = 15\ (\text{lb/ft})$, and its unstretched length $L_u = 60\ (\text{ft})$. Neglecting air resistance and assuming the jumper drops straight down, find: a) v_2 the velocity of the jumper after falling 100 (ft), b) a the acceleration of the jumper when at this point, and c) $x_{\max}$ the maximum distance the jumper falls.



   Answers:

   a) $v_2 \approx 45\ (\text{ft/s})$; b) $a \approx 78.2\ (\text{ft/s}^2)$ upward; c) $x_{\max} \approx 111\ (\text{ft})$

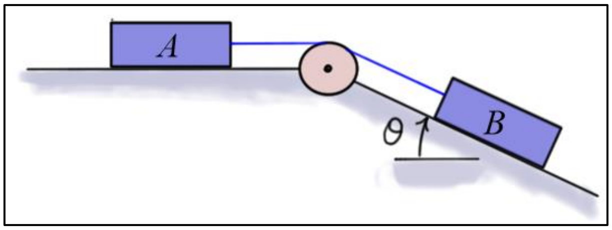
2. The rocket propelled cart is launched on a circular path of radius $R = 15\ (\text{m})$. It starts from rest at the bottom of the path $(\theta = 0)$. The mass of the cart is m = 200 (kg) and the thrust F is assumed to be a constant $4000\ (\text{N})$ and tangent to the path. Neglecting friction and air resistance, at $\theta = 60\ (\text{deg})$ find: a) v the velocity of the cart, b) N the normal force exerted by the path on the cart, and c) a_t the tangential acceleration of the cart.



   Answers:

   a) $v \approx 21.9\ (\text{m/s})$; b) $N \approx 7.4\ (\text{kN})$; c) $a_t \approx 11.5\ (\text{m/s}^2)$

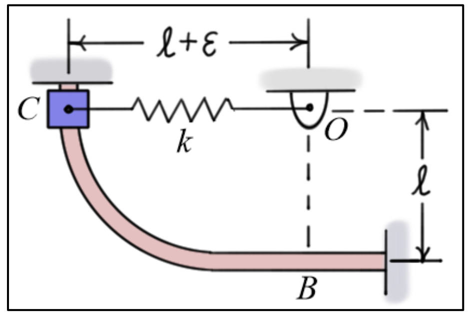
3. The two weights A and B are connected by a ***light*** cable and pulley system. The weights of A and B are $W_A = 100\ (\text{lb})$ and $W_B = 200\ (\text{lb})$, the kinetic coefficient of friction between A and the horizontal plane is $\mu_k = 0.3$, and the angle of the inclined plane is $\theta = 30\ (\text{deg})$. The ***inclined plane*** is ***frictionless***. Given the system ***starts from rest***, find: a) v the velocity of the blocks after they move $5\ (\text{ft})$, and b) T the tension in the cable.



   Answers:

   a) $v \approx 8.67\ (\text{ft/s})$; b) $T \approx 53.3\ (\text{lb})$

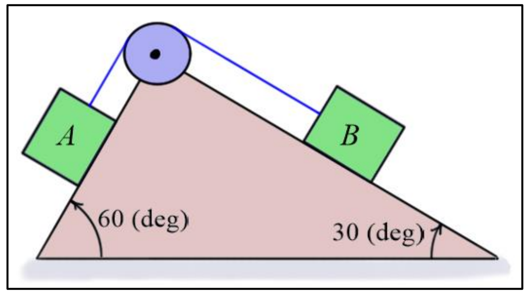
4. The 2 (kg) collar C is ***released from rest*** in the position shown, and it slides along the smooth, curved bar. Length $\ell = 0.1$ (m), and length $\varepsilon = 0.01$ (m). The linear spring has ***unstretched length*** $\ell_u = 0.1$ (m), so the spring is unstretched when the collar is at B. The spring has stiffness $k = 50{,}000$ (N/m). Find v the velocity of the collar when it reaches point B. The motion is in a ***vertical*** plane.



Answer:

$v \approx 2.11$ (ft/s)

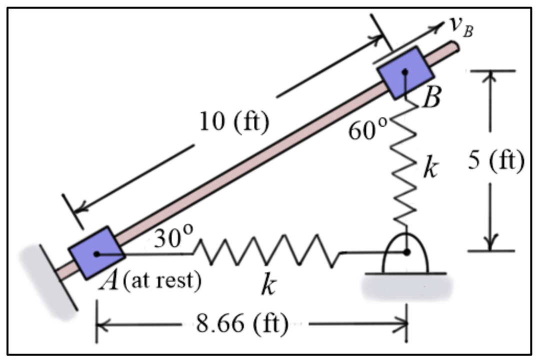
5. The system shown consists of two blocks A and B connected by a ***light*** cable and pulley system. Each block has mass $m = 5$ (kg), and the coefficient of kinetic friction between the blocks and the planes is $\mu_K = 0.1$. Assuming the system is ***released from rest***, find v the velocity of the blocks after they have moved 0.75 (m).



Answer:

$v \approx 1.3$ (m/s)

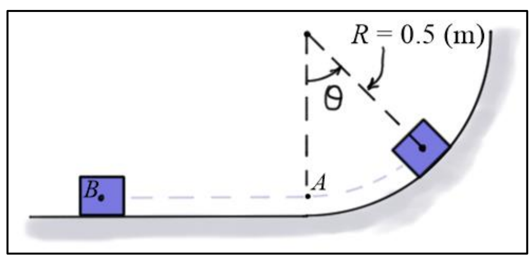
6. The system shown consists of a smooth rod (oriented at 30 (deg) to the horizontal) and a collar. The collar is ***released from rest*** in position A and slides along the bar under the action of the spring and gravity. The collar weighs $W = 5$ (lb), and the spring stiffness is $k = 10$ (lb/ft). The spring has an unstretched length of 4 (ft). Find v_B the velocity of the collar when it reaches position B.



Answer:

$v_B \approx 31.8$ (ft/s)

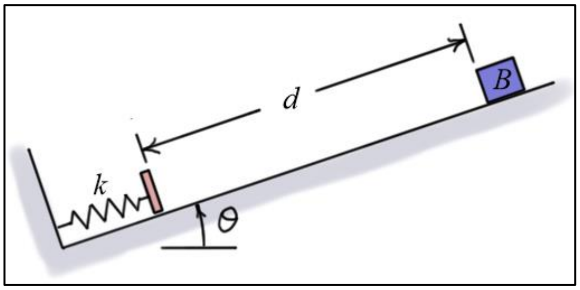
7. Block B has a mass of 2 (kg) and has a velocity $v_A = 2$ (m/s) as it passes point A. Neglecting friction and the size of the block, at $\theta = 30$ (deg) find: a) v the velocity of B, b) $\dot{v}$ the time rate of change of the velocity, and c) F_n the normal force the ground exerts on the block.



Answers:

a) $v \approx 1.64$ (m/s); b) $\dot{v} \approx -4.91$ (m/s^2) (slowing down); c) $F_n \approx 27.7$ (N)

8. Block *B* of mass $4\ (\text{kg})$ is ***released from rest*** in the position shown with $d = 2\ (\text{m})$, slides down the incline, and compresses the spring of stiffness $k = 10,000\ (\text{N/m})$. The plane is inclined at an angle of $\theta = 30\ (\text{deg})$, and the coefficient of kinetic friction between the block and the plane is $\mu_k = 0.2$.

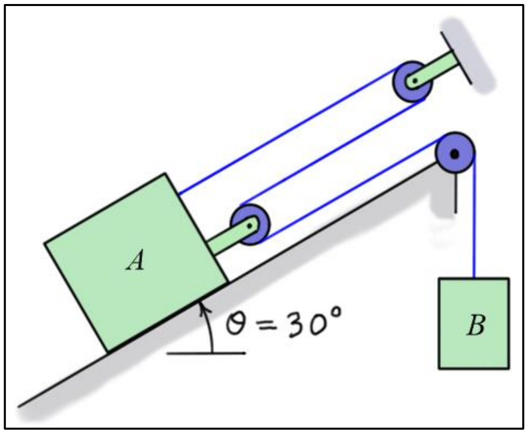


Find: a) v the velocity of the block ***just before*** it hits the spring, and b) $e_{\max}$ the maximum deflection of the spring. Neglect the size of the block and the work done by the weight and friction forces during the compression of the spring.

Answers:

a) $v \approx 3.58\ (\text{m/s})$; b) $e_{\max} \approx 71.6\ (\text{mm})$

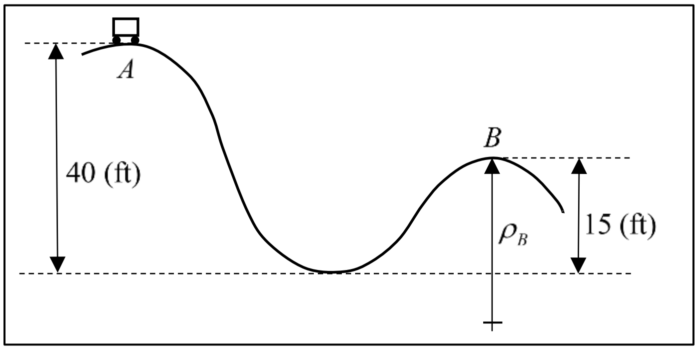
9. The system shown consists of two blocks *A* and *B* connected by a ***light*** cable and pulley system. Block *A* weighs $W_A = 50\ (\text{lb})$, and block *B* weighs $W_B = 20\ (\text{lb})$. The coefficient of friction between block *A* and plane is $\mu_k = 0.2$. When the system is ***released from rest***, block *A* is observed to move ***up the plane***. Find: a) a relationship between the velocities of the two blocks as determined by the pulley system, b) v the velocity of block *A* after it moves 3 feet ***up*** the plane, and c) T the tension in the cable.



Answers:

a) $v_B = 3v_A$; b) $v \approx 4.7\ (\text{ft/s})$; c) $T \approx 13.1\ (\text{lb})$

10. A 2000 (lb.) cart ***coasts*** along the vertical track from *A* to *B*. The cart's velocity at *A* is $v_A = 5\ (\text{ft/s})$. Neglecting friction, find: a) v_B the velocity of the cart when it reaches point *B*, b) N the ***normal force*** the track exerts on the cart at *B* assuming the ***radius of curvature*** of the track at *B* is $\rho_B = 100\ (\text{ft})$, and c) $(\rho_B)_{\min}$ the ***minimum radius of curvature*** of the track at *B* so the cart does not leave the track.



Answers:

a) $v_B \approx 40.4\ (\text{ft/s})$; b) $N \approx 984\ (\text{N})$; c) $(\rho_B)_{\min} \approx 50.8\ (\text{ft})$