Physics 1 Exam 2 Examples

Kinetics

In screeching to a halt, a car leaves skid marks that are 65m long. The coefficient of kinetic friction between the tires and the road is k = 0.71. How fast was the car going before the driver applied the brakes? Show your work and explain your reasoning.

$d = 65m \quad \mu_k = .7 \quad v = 0 m/s$

Steps
1. find deceleration (neg accel)
2. find inital Velocity
   - Utilizing Kinematics

1. $f_k = ma \qquad f_k = \mu_k N = \mu_k mg$

$\frac{\mu_k \cancel{m} g}{m} = \frac{\cancel{m} a}{m}$

$a = \mu_k g = .7 \cdot 9.8 m/s^2 = 6.8 m/s^2$

de acceleration = -acceleration

we need to make it negative

$a = -6.8 m/s^2$

2. $\cancel{v^2}^{0} = v_i^2 + 2ad$

$\sqrt{\frac{-v_i^2}{-1}} = \sqrt{\frac{2ad}{-1}}$

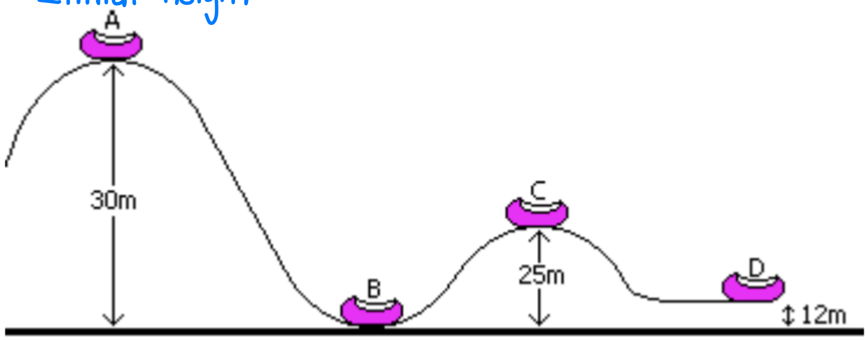
$v_i = \sqrt{-2ad}$

$v_i = \sqrt{-2 \cdot -6.8 m/s^2 \cdot 65m}$

$v_i = 30.076 m/s^2$

Consider the diagram below.

Initial height



$v_0 = 0\ m/s$

a) The roller coaster is pulled up to point A, where it and its screaming occupants are released from rest. Assuming no friction, calculate the speed of the coaster at points B, C, and D. Show your work.

Point B

$PE_A + \cancel{KE_A} = \cancel{PE_B} + KE_B$

$2 \cdot \frac{\cancel{m} g h_a}{\cancel{m}} = \frac{\frac{1}{2}\cancel{m}\boxed{v_b^2}}{\cancel{m}} \cdot 2$

$2 g h_A = v_B^2$

$v_B = \sqrt{2 g h_A}$

$v_B = \sqrt{2 \cdot 9.8 m/s^2 \cdot 30m}$

$v_B = 24.25\ m/s$

Point C

$PE_A + \cancel{KE_A} = PE_C + KE_C$

$mgh_A = mgh_C + \frac{1}{2} m v_C^2$

$-mgh_C \quad -mgh_C$

$\frac{\cancel{m}gh_A - \cancel{m}gh_C}{\cancel{m}} = \frac{\frac{1}{2}\cancel{m}v_C^2}{\cancel{m}}$

$2 \cdot gh_A - gh_C = \frac{1}{2} v^2 \cdot 2$

$2 \cdot g(h_A - h_C) = v^2$

$v = \sqrt{2 \cdot g (h_A - h_C)}$

$v = \sqrt{2 \cdot 9.8 m/s^2 (30m - 25m)} = 9.90\ m/s$

Point D

Same as C Just use h_D instead of h_C

$v = \sqrt{2 \cdot g\ (h_A - h_d)}$

$v = \sqrt{2 \cdot 9.8 m/s^2 (30m - 12m)}$

$v = 18.8\ m/s$

b) Now, suppose the roller coaster passes point A with a speed of 1.70m/s. If the work done by friction is 45,000J, with what speed will it reach B? The mass of the coaster is 1000kg. Show your work.

$v_0 = 1.7\ m/s \quad v_f = ? \quad m = 1000\ kg \quad W_f = 45{,}000 J$

$KE_A + PE_A = KE_B + \cancel{PE_B} + W_B$

$\frac{1}{2} m v_0 + mgh = \frac{1}{2} m v_B^2 + W_B$

$\frac{1}{2} m v_0 + mgh - W_B = \frac{1}{2} m v_B^2$

$\frac{2 \cdot (\frac{1}{2} m v_0 + mgh - W_B)}{m} = v^2$

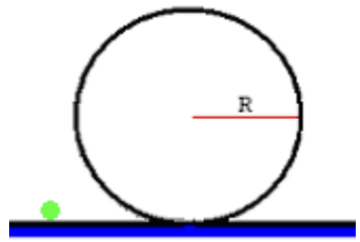
$\sqrt{\frac{2 \cdot (\frac{1}{2} m v_0^2 + mgh - W_B)}{m}} = v$

$v = \sqrt{\frac{2 \cdot (\frac{1}{2} \cdot 1000kg \cdot (1.7 m/s)^2 + 1000kg \cdot 9.8 m/s^2 \cdot 30m - 47{,}000 J}{1000\ kg}} = 22.38\ m/s$

The picture below shows a ball going around a loop. If the initial speed of the ball just before it enters the loop is 4.00m/s, what is the largest value that the radius of the loop, R, can have, if the ball is to remain in contact with the track? You may assume that friction is negligible. Show your work and explain your reasoning.

$v_0 = 4 m/s$

Normal force zeros out at the top



$F_c = \cancel{N}^0 + mg = m\frac{v^2}{R}$

$R \cdot \frac{mg}{m} = \frac{m\frac{v^2}{R}}{m} \cdot R$

$v = \sqrt{gR}$

$h = 2R$

$KE_0 + \cancel{PE_0}^0 = KE_f + PE_0$

$\frac{1}{2}mv_0^2 = \frac{1}{2}mv^2 + mgh$

$\frac{1}{2}mv_0^2 = \frac{1}{2}m(\sqrt{gR})^2 + mg2R$

$\frac{1}{2}mv_0^2 = \frac{1}{2}mgR + mg2R$

$\frac{\frac{1}{2}mv_0^2}{m} = \frac{\frac{5}{2}mgR}{m}$

$\frac{\cancel{2} \cdot \frac{1}{\cancel{2}}v_0^2 = \frac{5}{\cancel{2}}gR \cdot \frac{2}{5}}{g}$

$R = \frac{v_0^2}{5g}$

$R = \frac{(4 m/s)^2}{5 \cdot 9.8 m/s^2}$

$R = .3265 m$

A 500 kg hot air balloon begins at rest and rises. The wind and lift forces combined do 97,000 J of work on the balloon. At what height above the surface of Earth is the speed of the balloon 8.00m/s?

$m = 500 kg$ $v_0 = 0 m/s$ $v = 8.00 m/s$ $W = 97000 J$ $h = ?$ $h = 0$

$\Delta KE = \frac{1}{2}m\Delta v^2$

$\Delta KE = \frac{1}{2} \cdot 500 kg (8 m/s)^2$

$\Delta KE = 16000 J$

$W = \Delta KE + \Delta PE$

$W = \Delta KE + mgh$

$\frac{W - \Delta KE}{mg} = \frac{mgh}{mg}$

$h = \frac{W - \Delta KE}{mg} = \frac{97000 J - 16000 J}{500 kg \cdot 9.8 m/s^2} = 16.5 m$

Energy and momentum

A 9300 kg boxcar traveling at 11.0 m/s strikes a second boxcar at rest. The two stick together and move off with a speed of 4.5 m/s. What is the mass of the second car?

↳ totally inelastic

$m_1 = 9300\,kg \quad v_{o_1} = 11.0\,m/s \quad v_{o_2} = 0\,m/s \quad v_T = 4.5\,m/s \quad m_2 = ?$

$P_b = P_a'$

$P_1 + P_2 = P_T$

$m_1 v_1 + \cancel{m_2 v_2} = (m_1 + m_2) v_T$

$\frac{m_1 v_1}{v_T} = \frac{(m_1 + m_2) v_T}{v_T}$

$\frac{m_1 v_1}{v_2} = m_1 + m_2$

$-m_1 \qquad -m_1$

$m_2 = \frac{m_1 v_1}{v_T} - m_1$

$m_2 = \frac{m_1 v_1}{v_T} - m_1$

$m_2 = \frac{9300\,kg \cdot 11\,m/s}{4.5\,m/s} - 9300\,kg$

$m_2 = 13433\,kg$

A 0.40 kg ball is thrown with a speed of 12 m/s at an angle of 25°. What is its speed at its highest point, and how high does it go? Use conservation of energy and ignore air resistance.

$m = .40\,kg \quad v_o = 12\,m/s \quad \theta = 25°$

$KE_o + \cancel{PE_o} = KE_f + PE_f$

$\frac{\frac{1}{2} m v_o^2}{m} = \frac{\frac{1}{2} m v_f^2 + mgh}{m}$

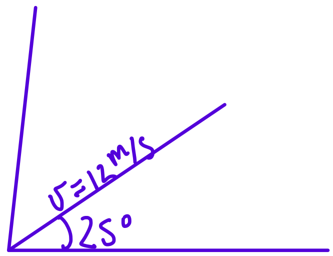
$\frac{1}{2} v_o^2 = \frac{1}{2} v_f^2 + gh$

$-\frac{1}{2} v_f^2 \qquad -\frac{1}{2} v_f^2$

$\frac{\frac{1}{2} v_o^2 - \frac{1}{2} v_f^2}{g} = \frac{gh}{g}$

$h = \frac{v_o^2 - v_f^2}{2g}$

$h = \frac{(12\,m/s)^2 - (12\,m/s \cdot \cos 25°)^2}{2 \cdot 9.8\,m/s^2} = 1.31\,m$



$v_x = 12 \cos 25°$

A 23 g bullet traveling 230 m/s penetrates a 2.0 kg block of wood and emerges cleanly at 170 m/s. If the block is stationary on a frictionless surface when hit, how fast does it move after the bullet emerges?

$m_b = 23g = .023Kg$ $\quad v_B = 230\,m/s$ $\quad m_w = 2kg$ $\quad v_{fB} = 170\,m/s$ $\quad v_w = ?$

$$P_{before} = P_{after}$$

$$P_{Bb} + \cancel{P_{wb}}^{0} = P_{Ba} + P_{wa}$$

$$m_{Bb}v_{Bb} = m_{Ba}v_{Ba} + m_{wa}\underline{v_{wa}}$$

$$m_{Bb}v_{Bb} - m_{Ba}v_{Ba} = m_{wa}v_{wa}$$

$$v_{wa} = \frac{m_{Bb}v_{Bb} - m_{Ba}v_{Ba}}{m_{wa}} = \frac{.023kg \cdot (230\,m/s - 170\,m/s)}{2\,kg} =$$

In the figure below, block 1 of mass m1 slides from rest along a frictionless ramp from height h and then collides with stationary block 2, which has mass m2 = 2m1. The collision is completely inelastic (the blocks stick together). After the collisions, block 2 slides into a region where the coefficient of kinetic friction is μk and comes to a stop in distance d within that region. Derive expressions for a) the speed of block 1 at the bottom of the ramp, b) the speed of the blocks after the collision, and c) the distance d the block travels on the rough surface. Express all your answers as functions of the height h.

$m_1 = ?$ $\quad m_2 = 2m_1$

A) $E_0 = E_f$

$$PE_0 = KE_f$$

$$\sqrt{2\cdot\frac{mgh}{m}} = \sqrt{\frac{\frac{1}{2}mv_1^2}{m}\cdot 2}$$

$$v_1 = \sqrt{2gh}$$

B) $P_0 = P_1 + \cancel{P_2}^{0}$

$$P_0 = m_1v_1$$

$$P_0 = P_f$$

$$m_1v_1 = (m_1+m_2)v_T$$

$$m_1v_1 = m_1 + 2m_1)v_T$$

$$m_1v_1 = 3m_1v_T$$

$$v_1 = 3v_T$$

$$v_T = \frac{v_1}{3}$$

$$v_T = \frac{\sqrt{2gh}}{3}$$

Before

[1] → [2]

After

[1|2]

C) $\Delta K = \cancel{K_f}^{0} - K_i$

$$\Delta K = -\frac{1}{2}m_Tv^2$$

$$W_f = F_f d \qquad F = \mu_k N$$

$$W_f = \mu_k m_T g d = \Delta K$$

$$\mu_k g d = \frac{1}{2}v^2$$

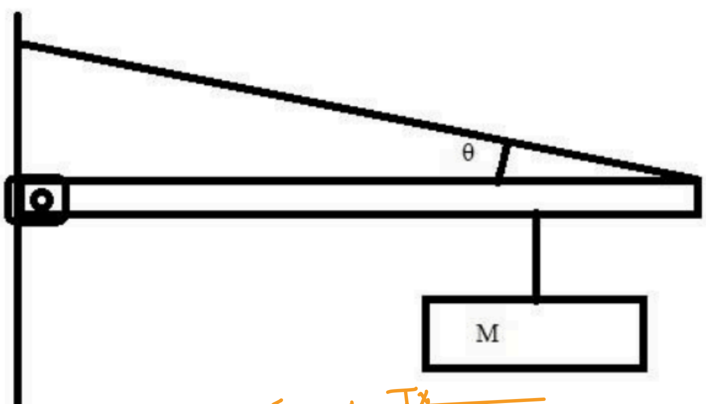
$$d = \frac{v^2}{2\mu_k g}$$

$$d = \frac{\left(\frac{\sqrt{2gh}}{3}\right)^2}{2\mu_k g} = \frac{\frac{\cancel{2}\cancel{g}h}{9}}{\cancel{2}\mu_k \cancel{g}}$$

$$\boxed{d = \frac{h}{9\mu_k}}$$

Statics and torques

In the figure below, a sign is suspended near, but not at the end, of a long horizontal bar. The bar is held in place by a brace and pin at the wall and by a cord attached at the right end of the bar and the wall. The cord is at an angle θ with respect to the horizontal. Draw the free body diagram for the bar and write the 2nd Law equations. Draw the torque diagram and write the torque equation.



Step 2

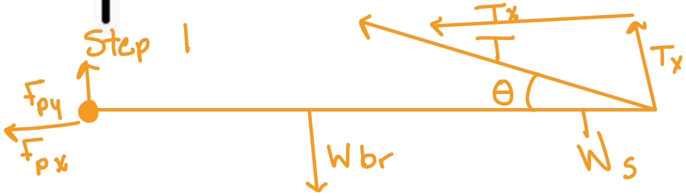
$$\Sigma F_x = f_{px} - T_x = 0$$

$$f_{px} = T_x = T\cos\theta$$

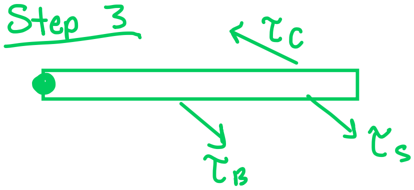
$$\Sigma f_y = f_{py} + T_y - W_b - W_s = 0$$

$$f_{py} + T_y = W_b + W_s$$

$$f_{py} = W_b + W_s + T\sin\theta$$



Step 3



Step 4

$$\Sigma \tau = 0 = \tau_b + \tau_s - \tau_o$$

$$W_B \frac{L}{2} + W_s r_s - F_{py} L = 0$$

For the previous problem, consider the following values. The mass of the bar is 25 kg, the mass M of the sign is 10 kg, θ = 15°, the length of the bar is 2.0 m, and the sign is hung 1.7 m from the left end of the bar. Calculate the torque on the bar due to the cord. To keep things simple, consider the brace and pivot to act exactly on the left end of the bar.

$$0 = W_b \frac{L}{2} + W_s r_s - T(\sin\theta)L$$

$$\frac{-W_b \frac{L}{2} - W_s r_s}{-\sin\theta L} = \frac{-T\sin\theta L}{-\sin\theta L}$$

$$T = \frac{W_b \frac{L}{2} + W_s r_s}{\sin\theta} = 795.2N$$

$$\tau_{cord} = LT(\sin\theta)$$

$$\tau_c = 2m \cdot 795.2N \cdot \sin 25°$$

$$\tau_c = 411.6 m \cdot N$$

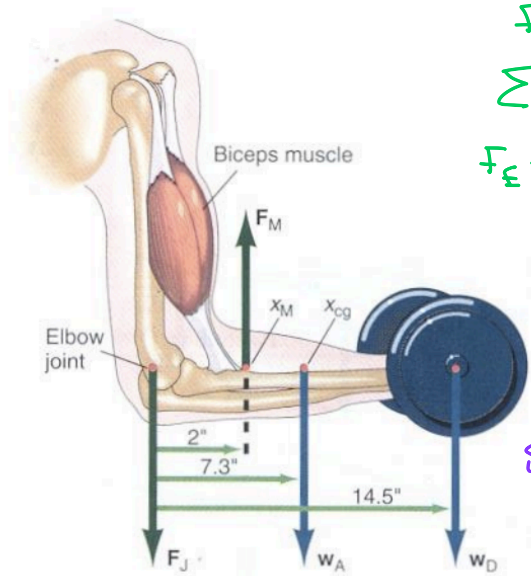
The figure below shows a weightlifter holding a dumbbell in place. The biceps muscle exerts a force on the forearm. The upper arm exerts a force on the elbow joint. Gravity exerts a force at the center of mass of the forearm, and the barbell exerts a force at the hand. Draw the free-body diagram and torque diagram for the situation below.

Step 2

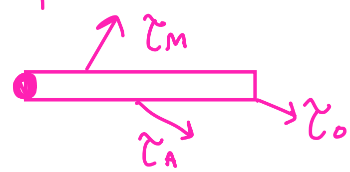
$F_x = 0$

$\Sigma F_y = -F_E + F_M - W_A - W_D = 0$

$F_E = F_M - W_A - W_d$



Step

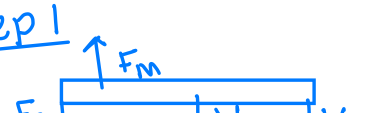


Step 4

$\Sigma \tau = -\tau_m + \tau_A + \tau_D = 0$

$r_M F_M = r_A W_A + r_D W_D$

Step 1



In the above problem, the dumbbell weighs 60 lbs. The forearm weighs 15 lbs. The biceps is attached to the forearm 2.0 in. from the elbow joint; the center of mass of the forearm is 7.30 in. from the elbow joint. (Note: these units are English rather than metric. Pounds are a unit of force in this system, and the unit of torque for this problem is inch-pounds.) Find the force exerted by the biceps to lift the dumbbell. What is the magnitude of the force exerted by the elbow joint? Show your work and explain your reasoning.

$$F_M = \frac{r_A W_A + r_D W_D}{r_M} = \frac{7.3\text{in} \cdot 15\text{lb} + 14.5\text{in} \cdot 60\text{lb}}{2\text{in}} \doteq 48.751\ N$$