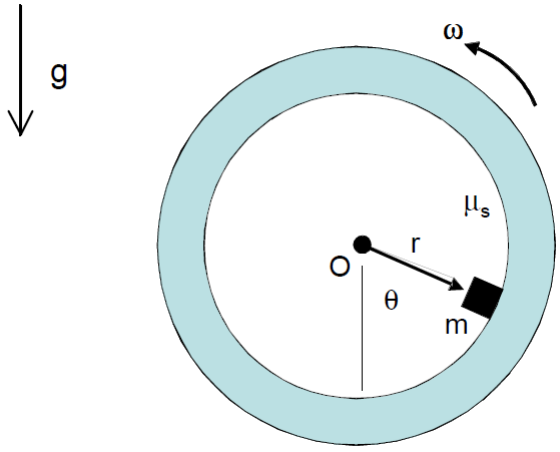
Exam No. 2 - sample exam problems
Problem 1A

Given: The drum of an industrial polisher, shown below, rotates about point O with a constant speed ω. A small cube of aluminum is placed on the inner surface of the drum. It is observed that this piece of metal has no motion relative to the polisher's surface as it passes through $\theta = 0$.

Find: If the cube begins to slip at that angle shown, determine the rotation rate of the drum.



Exam No. 2 - sample exam problems
Problem 1B

Given: Particles A and B (having masses of m and 2m, respectively) slide inside a tube. The particles are connected by an inextensible cable of length R. The tube rotates about the fixed point O with the tube remaining in the same horizontal plane (i.e., gravitational forces do NOT affect the motion of A and B). At the instant shown, the tube is rotating with a <u>*constant*</u> angular speed ω, with particles A and B at distances R and 2R from O and with these particles moving outward within the tube at a rate of $\dot{R}$. (Please note that $\dot{R} \neq 0$.) All surfaces are to be considered smooth.

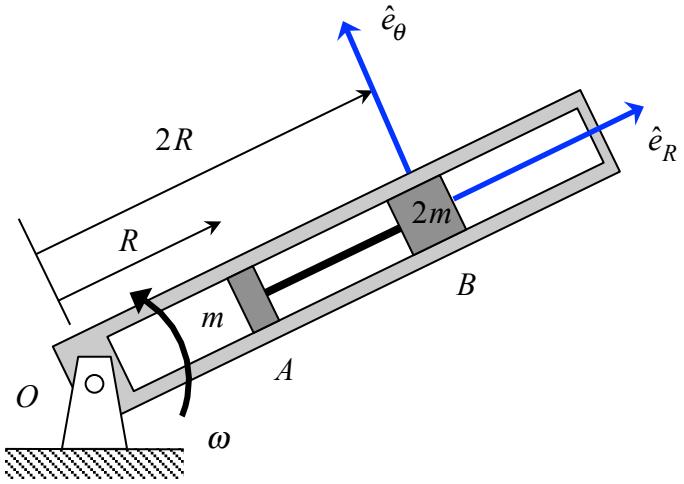
Find: For this problem:

a) Draw individual free body diagrams for particles A and B.

b) Determine the tension in the cable AB.

c) Determine the normal force acting on particle B due to the tube as the system rotates.

HINT: Use the polar coordinate system shown in your analysis.



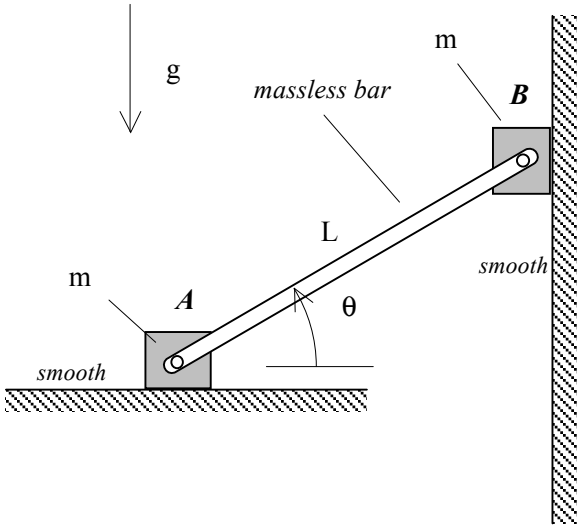
HORIZONTAL PLANE

Exam No. 2 - sample exam problems
Problem 2A

Given: System released from rest with $\theta = 36.87°$. Consider bar AB to have negligible mass.

Find: Determine the *angular velocity* of the bar when $\theta = 0$. Use: $m = 100\ kg$ and $L = 2\ meters$.

Please clearly indicate the four steps in a neat and orderly presentation of your work.



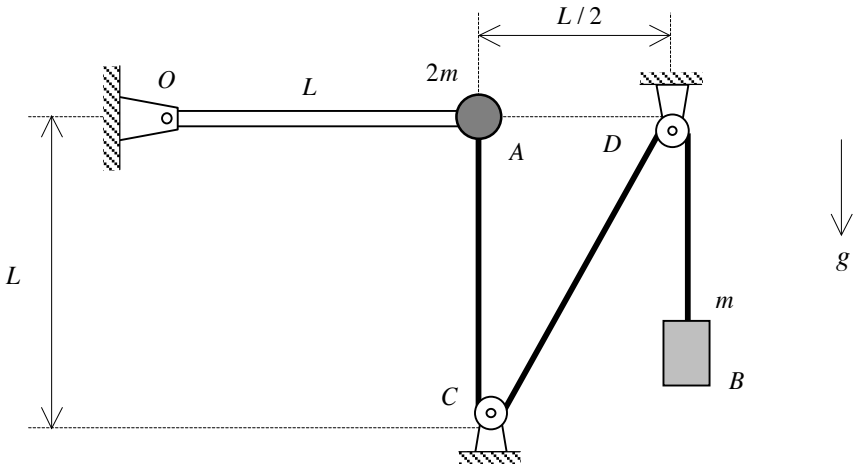
Exam No. 2 - sample exam problems
Problem 2B

Given: Particle A (of mass 2m) is attached to a rigid bar of negligible mass. Particle A is also connected to a cable that is wrapped around two pulleys and connected to particle B on its other end. The system is released from rest with OA being horizontal and with section AC of the cable being vertical. Assume that the radii of the pulleys to negligible.

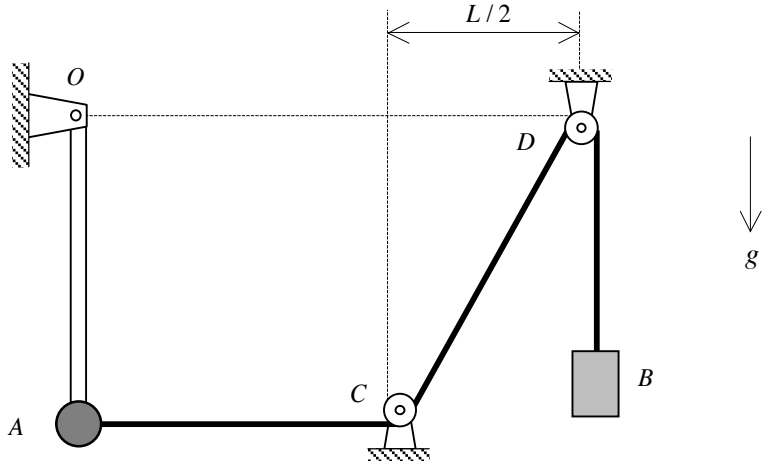
Find: Determine the *angular velocity* of the bar at Position 2 where it has rotated 90° CW to a vertical orientation. (At Position 2, section AC of the cable is horizontal.) Use the following parameter values in your work: $m = 10kg$ and $L = 4\,meters$.

Please clearly indicate the four steps in a neat and orderly presentation of your work.

Position 1



Position 2



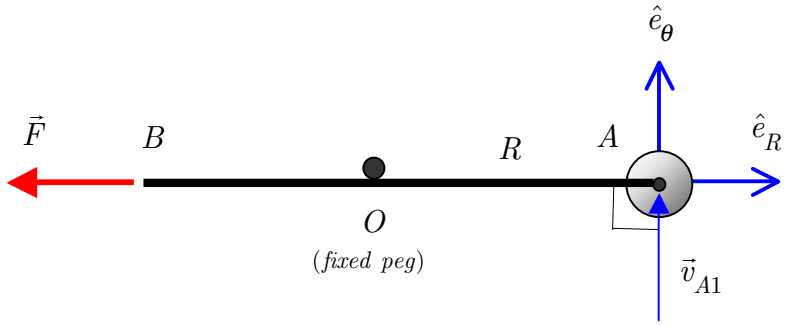
Exam No. 2 - sample exam problems
Problem 2C

Given: Particle A (of mass m) slides upon a *smooth* HORIZONTAL surface. A flexible, inextensible cord is connected to A at one end and has a constant force $\vec{F}$ acting to the left on the other end. Initially, when A is at a radial distance of $R = R_1$ from O, the cord is in contact with a small, smooth peg at O. At this instant, A is moving perpendicular of line OA with a speed of v_{A1}, as shown in the figure.

Find: When A is at a radial distance of $R = R_2$ from O, determine the speeds of ends A and B of the cord. Use the following parameter values in your work: $m = 10kg$, $R_1 = 2\ meters$, $R_2 = 3\ meters$, $\left|\vec{F}\right| = 280\ N$ and $v_{A1} = 15\, m/sec$.

HINT: Draw an FBD of particle A and the cord together as your system. Use both the work/energy equation and the angular impulse/momentum equation for the system in your work. If you use conservation of either energy or angular momentum, justify!

Please clearly indicate the four steps in a neat and orderly presentation of your work.



HORIZONTAL SURFACE

Exam No. 2 - sample exam problems
Problem 2D

Given: A box having a mass of M is constrained to move along a smooth, horizontal surface. Block A (having a mass of m) is able to slide along smooth, horizontal surface inside the box, as shown in the figure below. Block A is pressed against a spring having a stiffness of k. Initially, the system is at rest and the spring is compressed by an amount Δ_1. The coefficient of restitution between A and the box at end B is e.

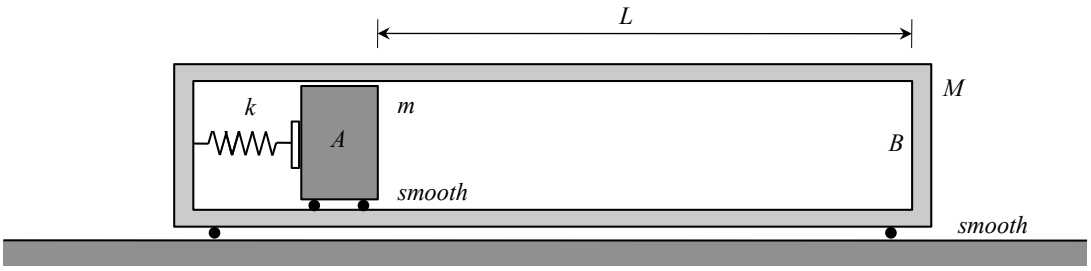
Find: After the spring is released:

a) Determine the speed of the box and the speed of block A immediately BEFORE A impacts the box at B. Write your answers as vectors.

b) Determine the speed of the box and the speed of block A immediately AFTER A impacts the box at B. Write your answers as vectors.

Use the following: $m = 3kg$, $M = 5kg$, $k = 12{,}000N/m$, $e = 0.5$, $\Delta_1 = 0.3m$ and $L = 2m$.

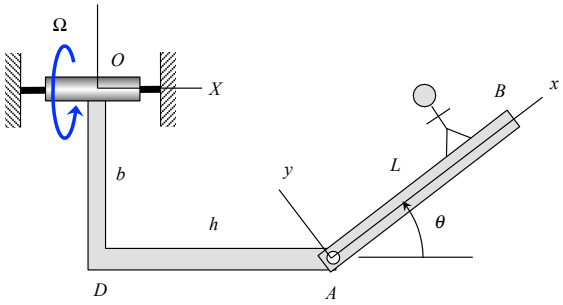
Please clearly indicate the four steps in a neat and orderly presentation of your work.



HORIZONTAL SURFACE

Exam No. 2 - sample exam problems
Problem 3A

The L-shaped member ODA rotates about a fixed axis at end O at a *constant* rate of Ω. Arm AB is pinned to ODA at A. The angle θ between line DA and AB is being increased at a *constant* rate of $\dot{\theta}$. *An observer is placed on arm AB*, along with the *xyz*-axes being attached to AB. It is desired to use the following moving reference frame equation to determine the acceleration of point B:



$$\vec{a}_B = \vec{a}_A + \left(\vec{a}_{B/A}\right)_{rel} + \vec{\alpha}\times\hat{r}_{B/A} + 2\vec{\omega}\times\left(\vec{v}_{B/A}\right)_{rel} + \vec{\omega}\times\left(\vec{\omega}\times\vec{r}_{B/A}\right)$$

Provide expressions for the following terms in the above equation. Write your answers in terms of their *xyz*-components and leave the answers in terms of, *at most*: Ω, θ, $\dot{\theta}$, b, h and L.

2 points – $\vec{\omega} =$

2 points – $\vec{\alpha} =$

2 points – $\left(\vec{v}_{B/A}\right)_{rel} =$

2 points – $\left(\vec{a}_{B/A}\right)_{rel} =$

2 points – $\vec{a}_A =$

Exam No. 2 - sample exam problems
Problem 3B

Given: Trucks A and B (having masses of M_A and M_B, respectively, where $M_A = 2M_B$) experience a low-speed, head-on collision on an icy road. The drivers of these two trucks (each having the same mass m) are both securely constrained by shoulder harnesses (and, fortunately, are not injured in the collision). *Let F_A and F_B represent the magnitudes of the respective forces acting on the drivers by their shoulder harnesses during the collision*. Assume that the collision does not do appreciable damage to either truck and that the trucks behave as rigid bodies during impact.

Find: Circle the answer below that most accurately describes the size of the force F_A as compared to the force F_B:

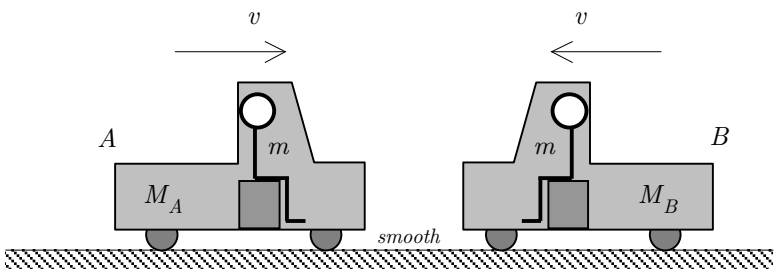
a) $F_A < F_B$

b) $F_A = F_B$

c) $F_A > F_B$

d) More information is needed about the collision to answer this question.

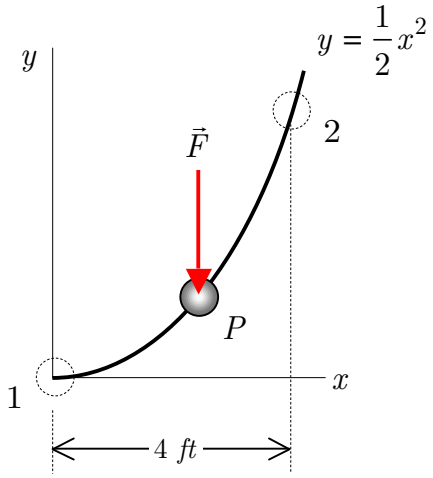
Provide a mathematical justification for your answer.



Exam No. 2 - sample exam problems
Problem 3C

Given: Particle P moves along a curved guide whose shape is given by the Cartesian description of $y = \frac{1}{2}x^2$, where x and y are given in feet. Between positions 1 and 2 shown on the figure below, a downward force $\vec{F}$ having a *constant* magnitude of 100 lbs acts on P.

Find: Determine the work done on P by $\vec{F}$ in going from position 1 to position 2.



Exam No. 2 - sample exam problems
Problem 3D

Given: Particle P (of mass m) is allowed to slide within a smooth slot cut into block B (of mass 2m). Block B is allowed to slide along a smooth horizontal surface. At instant "1", the system of P and B is at rest. At instant "2", particle P has slid to the bottom of the slot.

Find: Circle the response below that most accurately describes the speed of block B at instant "2":

a) $v_{B2} = 0$

b) $v_{B2} = \sqrt{gh\,/\,3}$

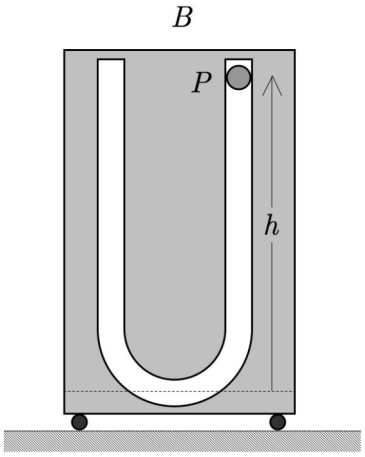
c) $v_{B2} = \sqrt{gh\,/\,2}$

d) $v_{B2} = \sqrt{gh}$

e) $v_{B2} = \sqrt{2gh}$

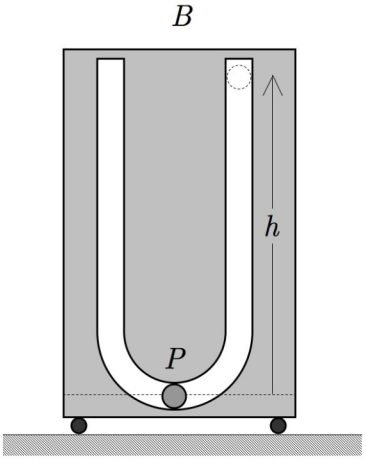
f) $v_{B2} = \sqrt{3gh}$

g) none of the above



instant "1"

Provide a mathematical justification for your response.



instant "2"

Exam No. 2 - sample exam problems
Problem 3E

Particle A, of mass m, is moving to the right with a speed of v_{A1} when it strikes a stationary particle B (having a mass of 2m). For a coefficient of restitution between A and B of $e = 0.2$, circle the answer below that most accurately describes the motion of A after impact:

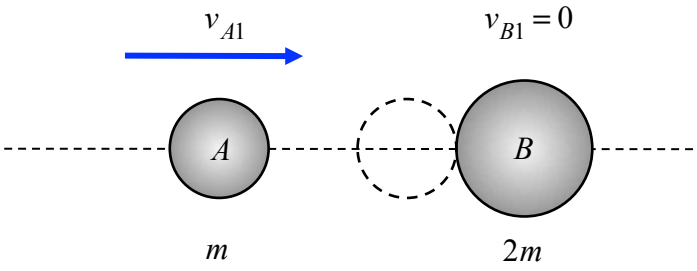
a) A is moving to the right.

b) A is stationary.

c) A is moving to the left.

d) A numerical value for v_{A1} is needed to answer this question.

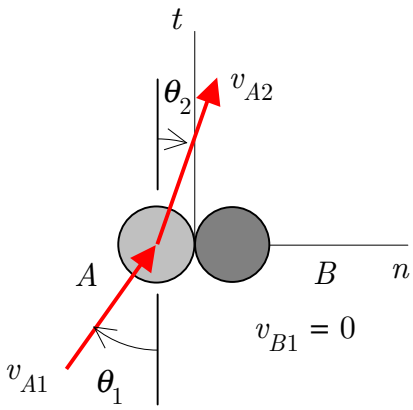
You do NOT need to provide justification for your answer.



Exam No. 2 - sample exam problems
Problem 3F

Given: Particle A (of mass m) is traveling with a speed of v_{A1} in the direction shown below when it strikes a stationary particle B (of mass m). The coefficient of restitution for the impact of A with B is known to be $e = 0$.

Find: If $\theta_1 = 36.87°$, what is the direction of travel of particle A *after* impacting B? Provide a mathematical justification for your answer.



Exam No. 2 - sample exam problems
Problem 3G

Given: Particle P (of mass m) is dropped from rest at a height of h above a stationary, ground surface. The duration of the impact of P with the ground is known to be Δt, and the coefficient of restitution of the impact is e.

Find: Determine the average impact force on P. Use the following parameters in your analysis: $m = 2\ kg$, $h = 0.5\ meters$, $e = 0.5$ and $\Delta t = 0.01\ seconds$.