These sample exam problems are intended to serve as talking points between you and the instructor for the exam review session. Solutions for these problems will not be posted.

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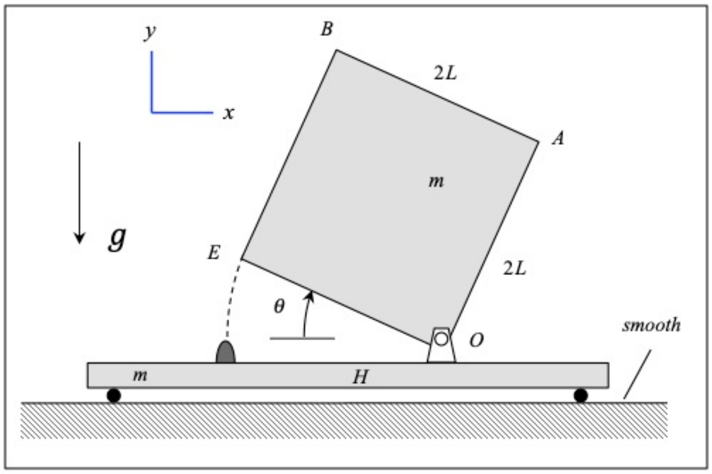
Final Examination (ALTERNATE)

PROBLEM NO. 1 – 20 points



Given: A homogeneous square plate OABE (having a mass of *m*) is pinned to cart H (which has a mass of m). The cart is able to slide along a smooth, horizontal surface. The system is released from rest from a position where corner B is displaced slightly to the left of being directly above O.

Find: It is desired to know the angular velocity of the plate when $\theta = 0$, immediately *before* the plate strikes the bumper at E. Please follow the four steps provided below, and present your work within the appropriate steps.

Solution:

SETP 1: Choose your system and draw an appropriate free body diagram for your system.

STEP 2: Kinetics

STEP 3: Kinematics

STEP 4: Solve for the angular velocity of the plate. Write your answer as a vector. Leave your answer in terms of, at most: m, g, L and θ.

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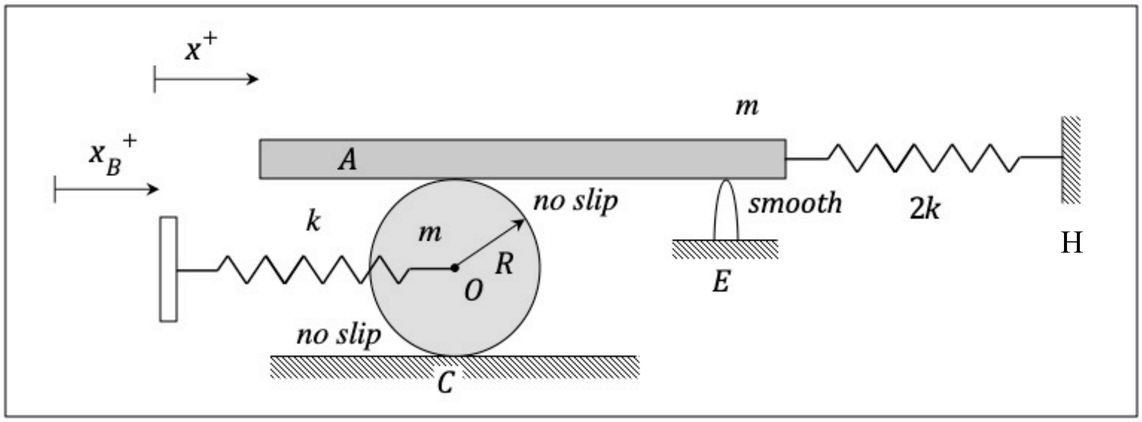
PROBLEM NO. 2 – 20 points

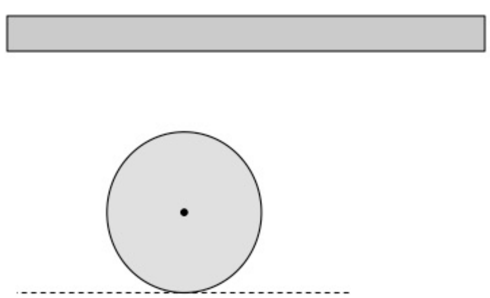


Given: Consider the system above that is made up of a homogeneous disk (with a mass of *m* and outer radius *R*), block A (having a mass of *m*), two springs (of stiffnesses *k* and 2*k*) and a moveable base B. The disk rolls without slipping on a fixed horizontal surface, with block A translating without slipping on the top surface of the disk. Base B moves with a prescribed horizontal motion of $x_B(t) = b\sin\Omega t$. Let the coordinate *x* measure the motion of block A. The springs are unstretched when $x = x_B = 0$.

Find: It is desired to know the differential equation of motion (EOM) for the system in terms of the *x* coordinate, and the particular solution for the EOM. Please follow the steps provided below, and present your work within the appropriate steps.

Solution:

<u>SETP 1</u>: Choose you "system" and draw the appropriate free body diagram(s) for your system.



<u>STEP 2</u>: Kinetics

STEP 3: Kinematics

STEP 4: EOM. Leave your answer as a differential equation in terms of, at most: m, k, R, b, Ω, x and time derivatives of x.

STEP 5: DERIVE the particular solution of the EOM starting with the general form of a linear differential equation with sinusoidal excitation.

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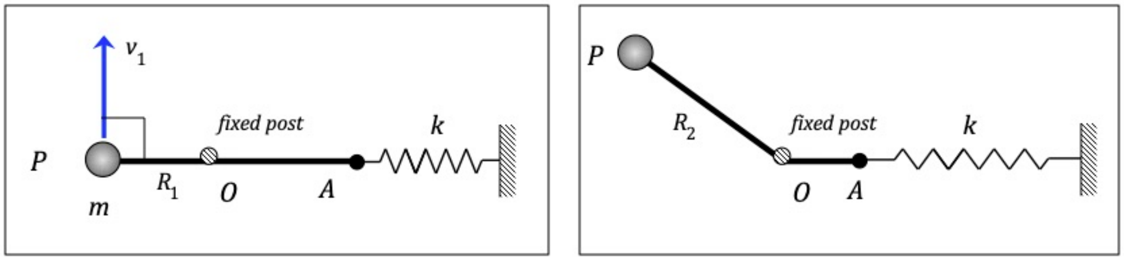
PROBLEM NO. 3 – 20 points



Position 1 Position 2

Given: Particle P (having a mass of *m*) is able to slide on a smooth, HORIZONTAL surface. A cable is attached to P, with the cable being in contact with a smooth, fixed post at O, and with a spring of stiffness k attached to the cable at end A of the cable. At Position 1, P is at a distance of R_1 from post O and is moving with a speed of v_1 in a direction that is perpendicular to OP. The spring is unstretched at Position 1. At Position 2, P has moved outward with the radial distance from O to P being $R_2 = 2R_1$.

Find: It is desired to know the velocity vector of P at Position 2.

Solution:

SETP 1: Draw a free body diagram (FBD) of P. Show the polar unit vectors $\hat{e}_R$ and $\hat{e}_\theta$ in your FBD.

STEP 2: Kinetics

STEP 3: Kinematics: Write down the velocity of P in terms of its polar coordinates and using the polar unit vectors $\hat{e}_R$ and $\hat{e}_\theta$.

STEP 4: Find the velocity of P. Write your answer as a vector, and in terms of, at most: m, R_1, k and v_1.

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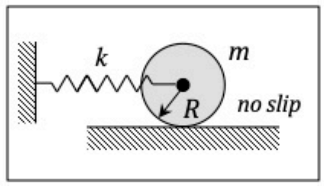
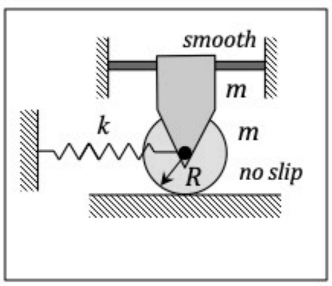
PROBLEM NO. 4 – 20 points TOTAL

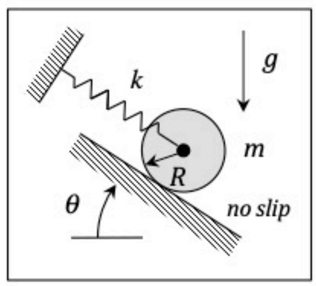
NOTE: You are not required to show your work on Problem 4. There is no partial credit awarded for the different parts of the problem.



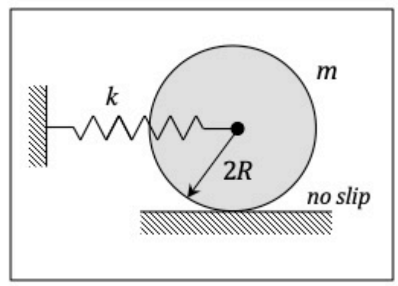
System 0



System 1



System 2



System 3

Let ω_{n0}, ω_{n1}, ω_{n2} and ω_{n3} represent the natural frequencies for Systems 0, 1, 2 and 3 shown above. For all four systems, the disks are homogeneous and have a mass of *m*.

PART A.1 – 2 pts. – choose the correct response

a) $\omega_{n0} > \omega_{n1}$

b) $\omega_{n0} = \omega_{n1}$

c) $\omega_{n0} < \omega_{n1}$

d) More information is needed to answer this question.

PART A.2 – 2 pts. – choose the correct response

a) $\omega_{n0} > \omega_{n2}$

b) $\omega_{n0} = \omega_{n2}$

c) $\omega_{n0} < \omega_{n2}$

d) More information is needed to answer this question.

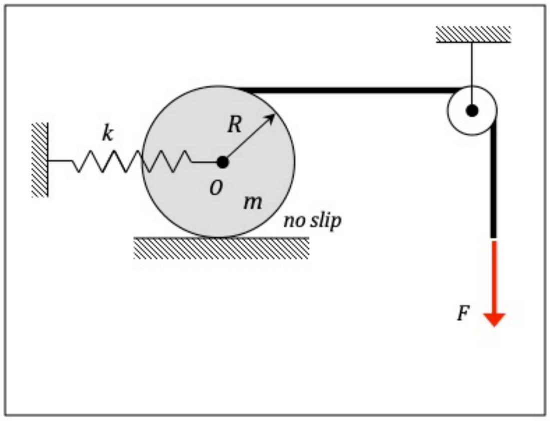
PART A.3 – 2 pts. – choose the correct response

a) $\omega_{n0} > \omega_{n3}$

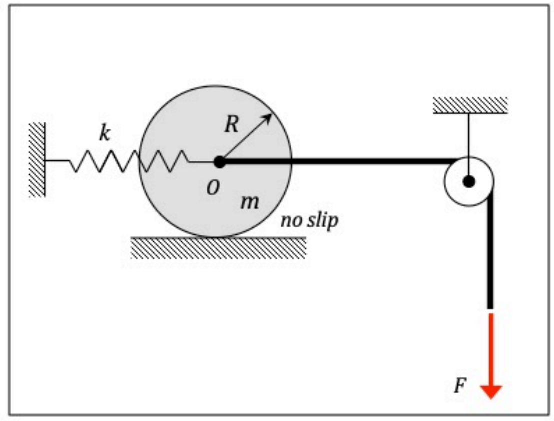
b) $\omega_{n0} = \omega_{n3}$

c) $\omega_{n0} < \omega_{n3}$

d) More information is needed to answer this question.



System I



System II

PART B – 1 pt.

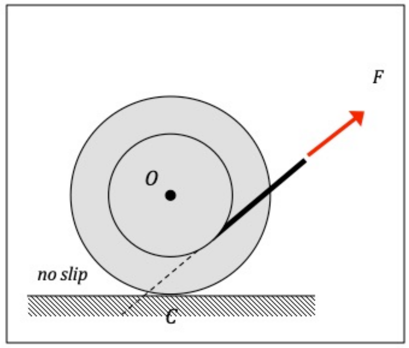
The force F for both Systems I and II pulls the center O of the disk to the right through a distance of d. Let $U_{1\rightarrow 2}^{(I)}$ and $U_{1\rightarrow 2}^{(II)}$ represent the work done for F for Systems I and II, respectively.

a) $U_{1\rightarrow 2}^{(I)} > U_{1\rightarrow 2}^{(II)}$

b) $U_{1\rightarrow 2}^{(I)} = U_{1\rightarrow 2}^{(II)}$

c) $U_{1\rightarrow 2}^{(I)} < U_{1\rightarrow 2}^{(II)}$

d) More information is needed in order to answer this question.

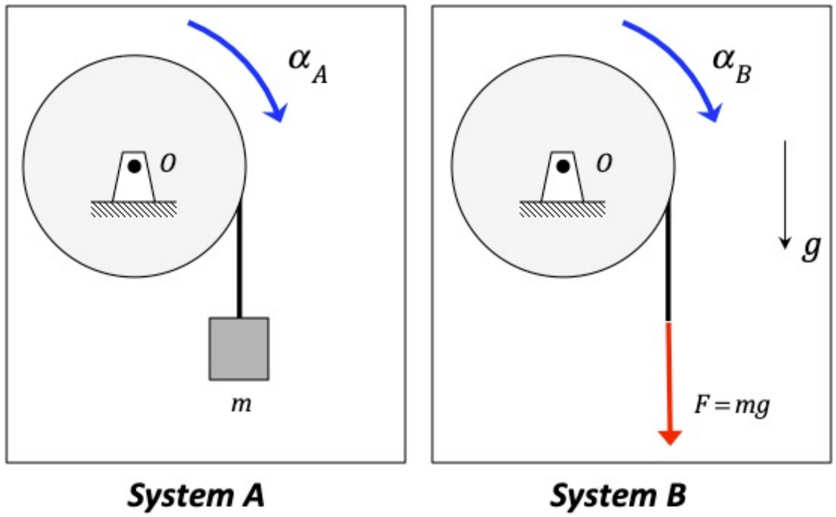


PART C – 1 pt.

As a result of the applied force F, the center of the drum O will:

a) Move to the right.
b) Will not move.
c) Move to the left.
d) More information is needed in order to answer this question.

PROBLEM NO. 4 (continued)



PART D – 1 pt.

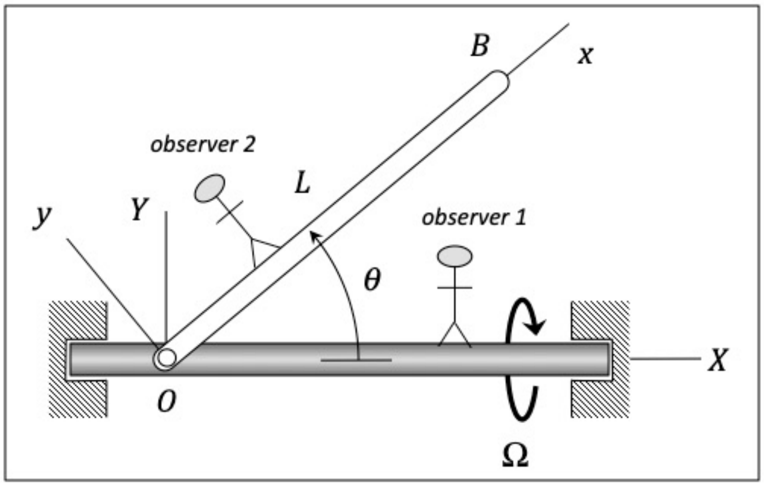
Consider Systems A and B above containing identical disks pinned to ground at center O. In System A, a block of mass *m* is attached to the end of the cable, and in System B a force $F = mg$ is attached to the end of the cable. For both systems, the cables do not slip on the disks. Let α_A and α_B represent the resulting clockwise angular acceleration of the disks in Systems A and B, respectively. Choose the correct response below:

a) $\alpha_A > \alpha_B$

b) $\alpha_A = \alpha_B$

c) $\alpha_A < \alpha_B$

d) More information is needed to answer this question.



PART D

The horizontal shaft above is rotating about a fixed axis with a *constant* rate of Ω. Bar OB is pinned to the horizontal shaft, with the elevation angle θ increasing at a *constant* rate of $\dot{\theta}$. The following moving reference frame kinematics equation is to be used to describe the acceleration of point B for $0<\theta<90°$:

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

D.1 – 2 pts. Using an <u>*observer 2 (attached to OB)*</u>, fill in the following terms below for this equation (*in terms of their xyz-coordinates*):

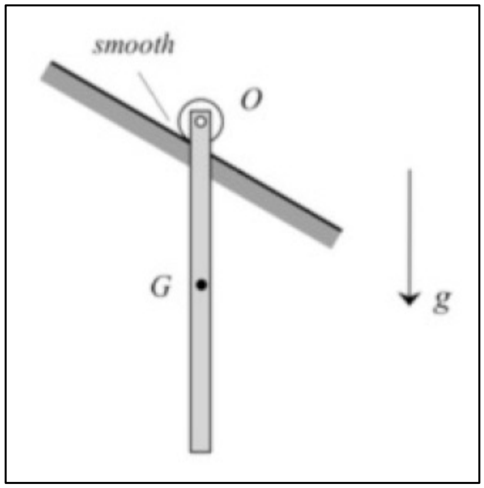
$\vec{\omega} =$

$\vec{\alpha} =$

D.2 – 2 pts. Using an <u>*observer 1 (attached to the horizontal shaft)*</u>, fill in the following terms below for this equation (*in terms of their xyz-coordinates*):

$\left(\vec{v}_{B/O}\right)_{rel} =$

$\left(\vec{a}_{B/O}\right)_{rel} =$



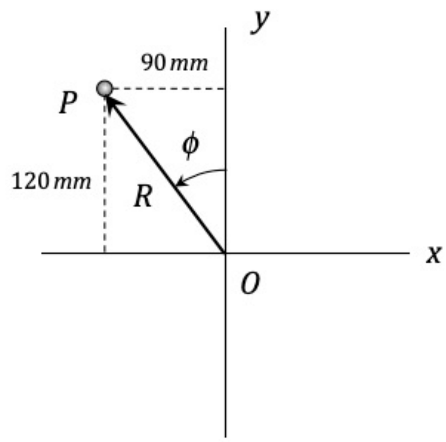
PART E – 1 pt.
A thin, homogeneous bar is attached to a roller at end O. The roller is able to roll along a smooth incline, as shown. The bar is released from rest. On release, the *angular acceleration* of the bar is:

a) clockwise.

b) counterclockwise.

c) zero.

d) More information is needed to answer this question.



PART F

The velocity and acceleration of particle P are known in terms of their Cartesian components:

$$\vec{v} = (400\,\hat{i} + 300\,\hat{j})\,mm/s$$

$$\vec{a} = (-50\,\hat{i} + 20\,\hat{j})\,mm/s^2$$

For this motion, choose the correct responses:

F.1 – 2 pts.

a) $\dot{R} > 0$

b) $\dot{R} = 0$

c) $\dot{R} < 0$

F.2 – 2 pts.

a) $\dot{\phi} > 0$

b) $\dot{\phi} = 0$

c) $\dot{\phi} < 0$

F.3 – 2 pts.

a) $\ddot{\phi} > 0$

b) $\ddot{\phi} = 0$

c) $\ddot{\phi} < 0$