ME 274 – Spring 2025
Sample Problems for Final Exam

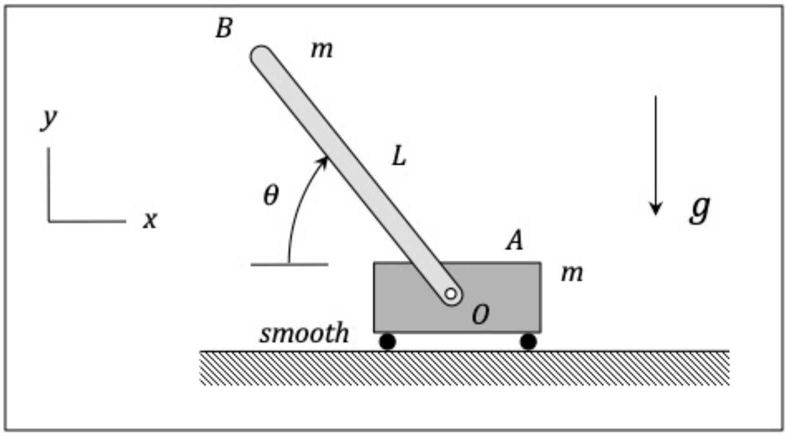
Included here is a set of problems covering topics of the Final Exam. These problems are provided to you for your review in preparing for the exam this semester. Most/all of these problems will likely be covered during the exam review session prior to the exam.

Please note the following.

- Please do not view the problems provided here as being a strict guide for the exact topics that will appear on this semester's exam. Although the topics here are from the official list of exam topics announced, the presence or absence of a particular topic in this set of sample problems do not imply the same presence or absence of that topic on your exam this semester.
- We will not be providing solutions or answers for these problems. Weekly Joys has a large number of sample exam questions from past semesters for which detailed solutions are provided that you can use. Attempt solutions for the sample questions provided here on your own under the more realistic exam conditions of not having the answers. If you get stuck on any problem, attend the exam review session, discuss the problem with your colleagues in the course, and/or ask your instructor/TAs for help. This process will be more helpful to you in your exam preparation than working backwards from known answers to learn how to work problems.

Sample final exam questions **Name** ________________________________

PROBLEM 1A



Given: A thin, homogeneous bar BO (having a mass of m and length L) is pinned to block A (which has a mass of *m*). Block A is able to slide along a smooth, horizontal surface. The system is released from rest with bar BO being at an angle of θ, where $0 < \theta < \pi / 2$.

Find: It is desired to know the angular velocity of bar BO when $\theta = 0$. 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

PROBLEM 1A - continued

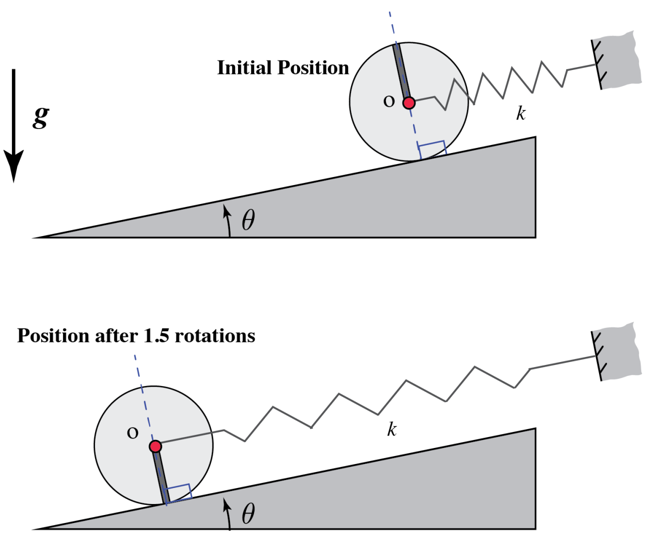
STEP 3: Kinematics

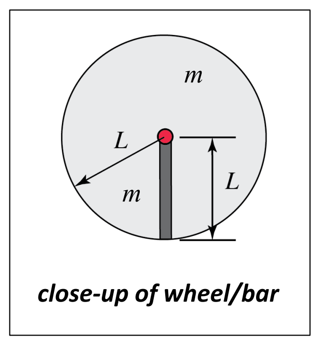
STEP 4: Solve for the angular velocity of bar BO. Write your answer as a vector. Leave your answer in terms of, at most: m, g, L and θ .

Sample final exam questions **Name** ______________________________

PROBLEM 1B

Given: A homogeneous wheel of mass m and radius L has a uniform bar welded to it as shown in the figure below. The bar has mass m and length L. The center O of the wheel is attached to a spring of stiffness k. The wheel is allowed to roll without slip down an inclined surface of angle θ, with the wheel not losing contact with the incline as it rolls. At the initial position shown, the system is at rest, and the spring is initially unstretched. At the final position shown, the wheel has made 1.5 rotations from the initial position. *Note at both the initial and final positions the bar is aligned with a direction that is normal to the incline*.





Find: For this problem:

a) Fill in the table on the next page showing the kinetic and potential energies at the initial and final positions. State your answers in terms of given parameters above. <u>Be sure to indicate the location of your gravitation datum line on the figure above.</u> Use the space below for your work.

PROBLEM 1B - continued

State	Kinetic Energy (T)	Potential (V)
Initial position		
Final position		

b) Find the angular velocity ω of the disk at the final position.

Sample final exam questions

Name ________________________________

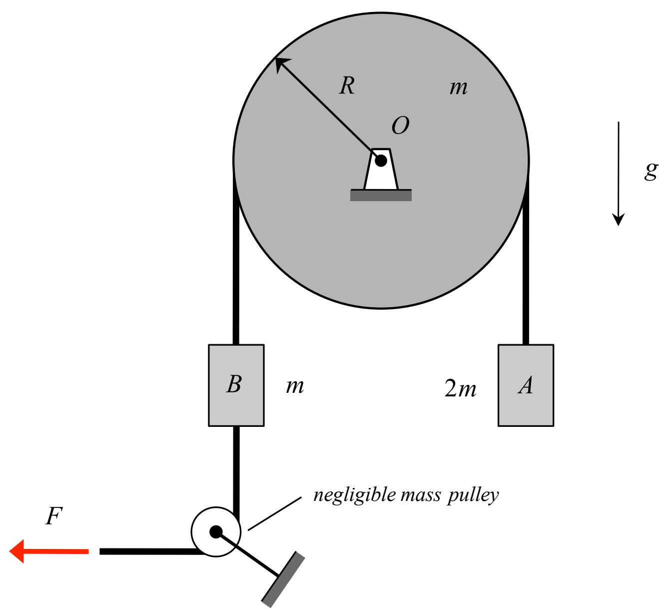
PROBLEM 2A

Given: A homogeneous disk of mass m and outer radius R is attached to a horizontal shaft at the disk's center O. An inextensible cable is wrapped around the outer radius of the disk, as shown. Block A (having a mass of 2m) is attached to one end of the cable, and block B (having a mass of m) is attached to the other end of the cable. A second cable is attached to block B, with a force F applied to the other end of this cable. The system is released from rest. Assume that the cable does not slip on the disk, and that the pulley around which the second cable is wrapped has negligible mass.

Find: For this problem:

a) Draw individual free body diagrams of the disk, block A and block B.

b) Determine the angular acceleration of the disk on release. Write your answer as a vector.



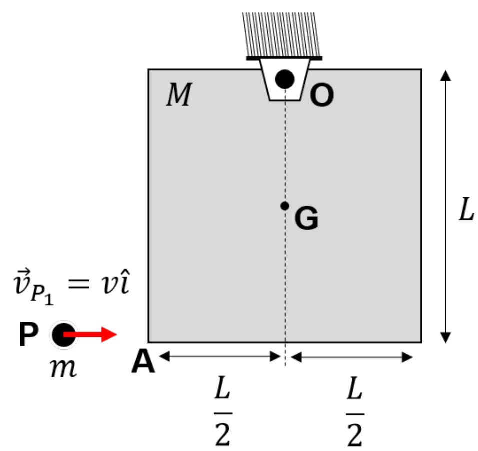
Sample final exam questions

PROBLEM 2B

Given: A particle P of mass m (kg) travels with a horizontal velocity of $\vec{v}_{P1} = v\hat{\imath}$ (m/s) when it impacts the corner A of a homogeneous **square** plate of mass M (kg) as depicted. Immediately after impact the particle P becomes embedded to the plate at point A. The plate is pinned to the ground at O, and has a center of mass G. The sides of the plate are length L (m). All motion occurs in the HORIZONTAL PLANE.

Known variables in this problem are m, M, v, and L.

Find:



(a) Draw the free body diagram of the system made up of particle P and the square plate during impact, clearly indicating the coordinate system.

(b) Why is it beneficial to consider angular momentum about point O instead of G for this system? Justify briefly.

(c) Write the angular momentum expressions for the particle P and the square plate about point O right before impact. Answers should be in terms of, at most, the parameters m, M, L, and v.

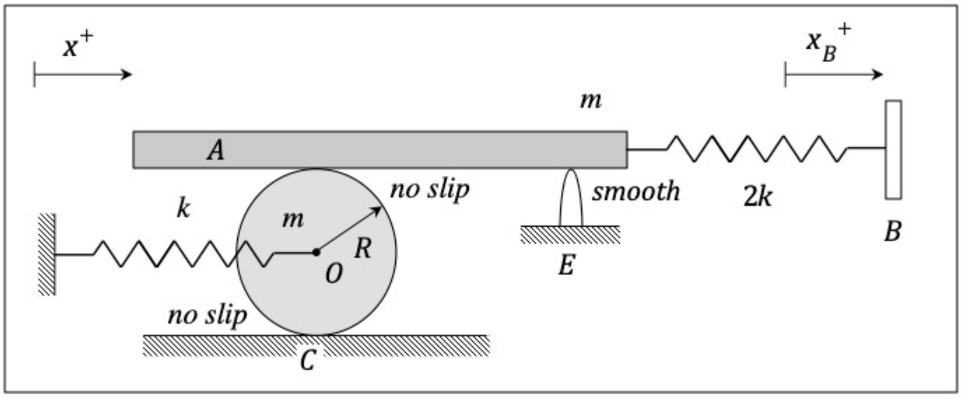
(d) Write the angular momentum expressions for the particle P and the square plate about point O immediately after impact. Answers should be in terms of, at most, the parameters m, M, L, v, and the unknown ω.

(e) Find the angular velocity $\vec{\omega}$ of the square plate immediately after impact. The answer should be in terms of, at most, the parameters m, M, L, and v.

Sample final exam questions

Name ________________________________

PROBLEM 3A

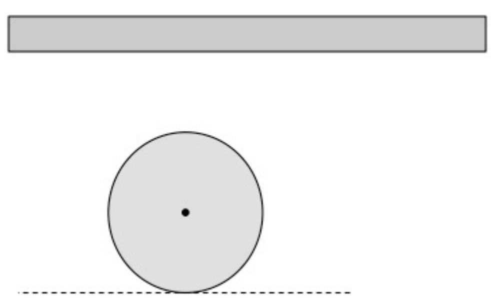


***Given*:** Consider the system above that is made up of a homogeneous disk (with a mass of *m* and outer radius *R*), block A (having a mass of *m*), two springs (of stiffnesses *k* and 2*k*) and a moveable base B. The disk rolls without slipping on a fixed horizontal surface, with block A translating without slipping on the top surface of the disk. Base B moves with a prescribed horizontal surface 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>: Draw individual free body diagrams of the block and the disk.



<u>STEP 2</u>: Kinetics

Sample final exam questions

Name ________________________________

PROBLEM 3A - continued

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.

Sample final exam questions

Name ______________________________

PROBLEM 3B

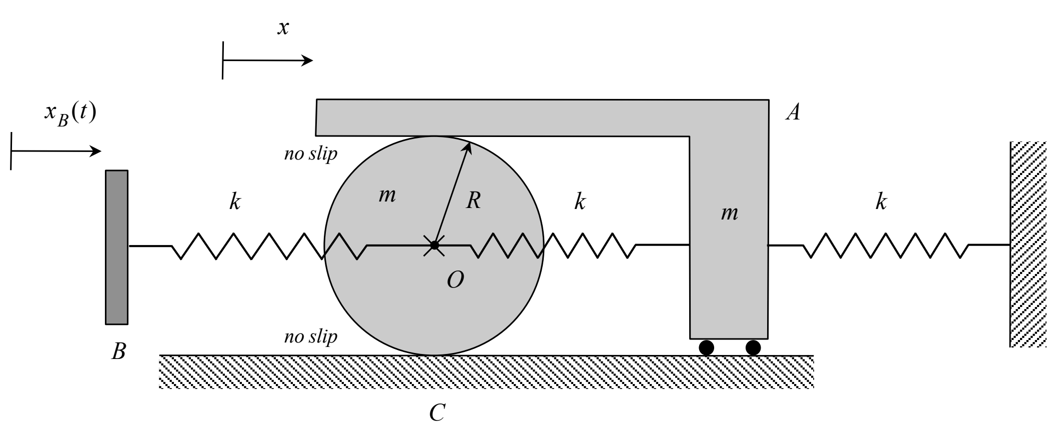
Given: A homogeneous disk (having a mass of m and outer radius R) is able to roll without slipping on a horizontal surface. A spring of stiffness k is attached between the center O of the disk and a moveable base B. A second spring (also of stiffness k) is attached between O and an L-shaped block A, with an arm of block A resting on the top surface of the disk. A third spring (also of stiffness k) is attached between A and a fixed wall on the right. As the system moves, the arm of block A does not slip on the top surface of the disk. Let x represent the motion of block A, and $x_B(t) = b\sin\omega t$ represent the motion of the base B. When $x = x_B = 0$, the springs are unstretched.

Find: For this problem:

a) Draw individual free body diagrams (FBDs) of the disk and of block A.

b) From your FBDs, derive the differential equation of motion (EOM) of the system in terms of the coordinate x.

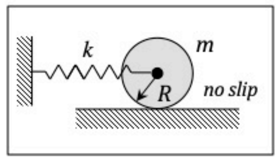
c) Determine the particular solution of the EOM, with this solution describing the steady-state motion of block A. Leave your answer in terms of the parameters of the problem.



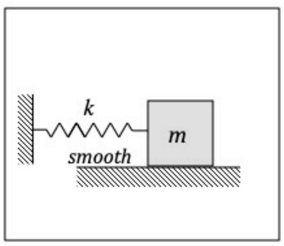
Sample final exam questions ***Name*** ________________________________

PROBLEM NO. 4 – 20 points TOTAL

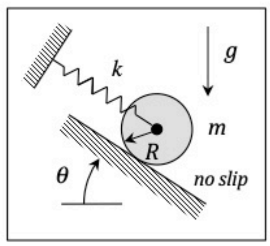
Provide justifications for your choices in the following multiple choice questions.



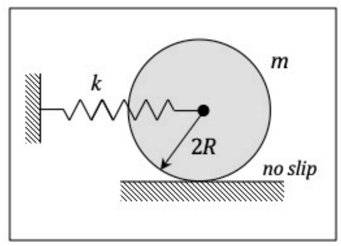
System 0



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, respectively. 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.

PROBLEM NO. 4 (continued)

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

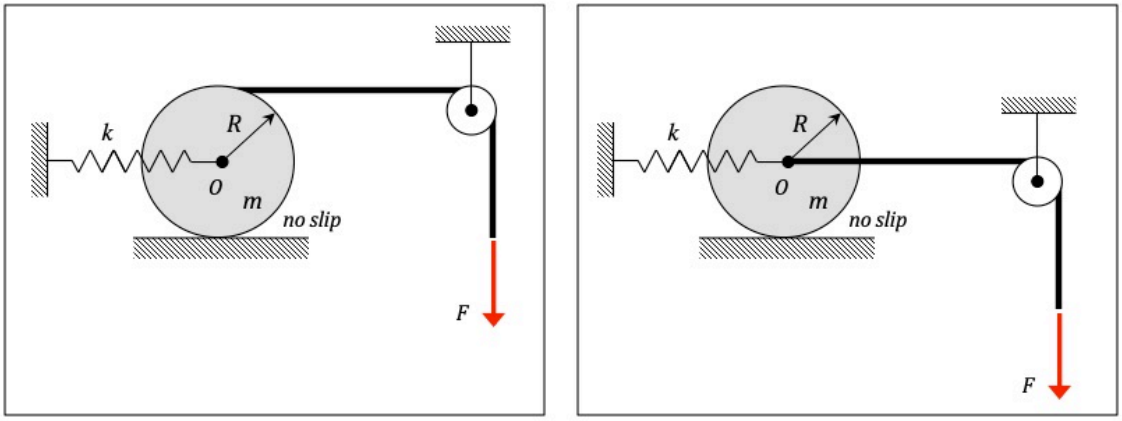
a) $\omega_{n0} > \omega_{n3}$

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

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

d) More information is needed to answer this question.

PROBLEM NO. 4 (continued)



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 $U_{1\to2}^{(I)}$ and $U_{1\to2}^{(II)}$ represent the work done for F for Systems I and II, respectively.

a) $U_{1\to2}^{(I)} > U_{1\to2}^{(II)}$

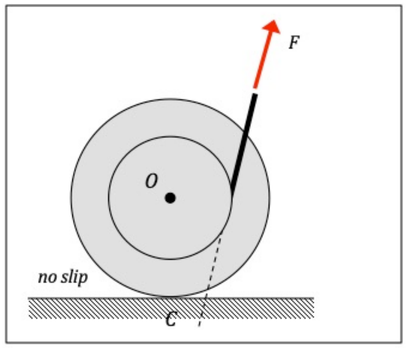
b) $U_{1\to2}^{(I)} = U_{1\to2}^{(II)}$

c) $U_{1\to2}^{(I)} < U_{1\to2}^{(II)}$

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

PROBLEM NO. 4 (continued)

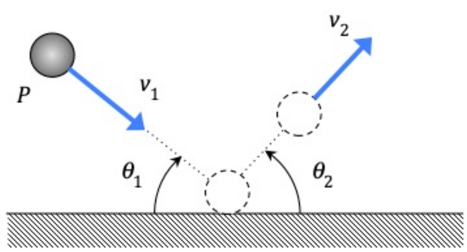
PART C – 1 pt.



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.

PART D – 1 pt.



Particle P strikes a stationary wall with a speed of v_1 and an angle θ_1. For a coefficient of restitution of $0 < e < 1$, the rebound angle θ_2 is such that:

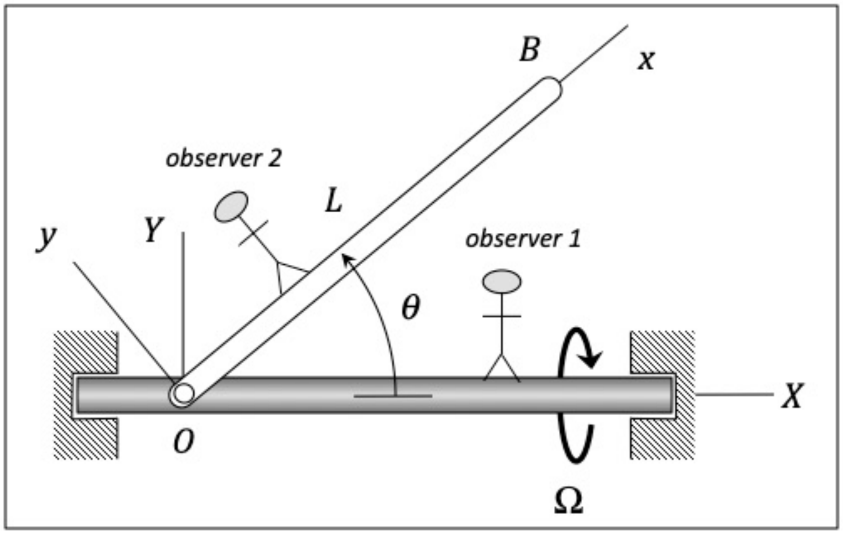
a) $\theta_2 > \theta_1$

b) $\theta_2 = \theta_1$

c) $\theta_2 < \theta_1$

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

PROBLEM NO. 4 (continued)



PART E

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 *observer 1 (attached to the horizontal shaft),* fill in the following terms below for this equation (*in terms of their xyz-coordinates*):

$\vec{\omega}=$

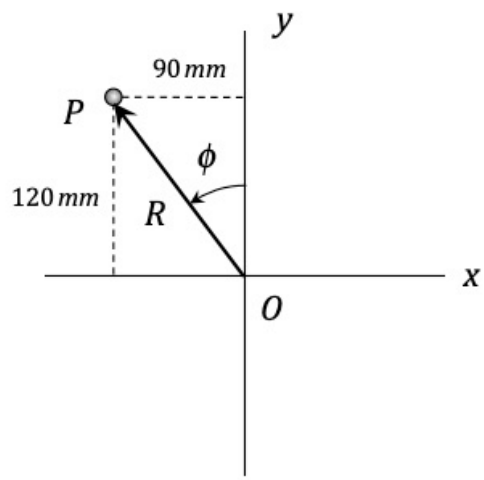
$\vec{\alpha}=$

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

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

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

PROBLEM NO. 4 (continued)



PART F

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

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

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

For this motion:

F.1 – 2 pts.

a) $\dot{R} > 0$

b) $\dot{R} = 0$

c) $\dot{R} < 0$

F.2 – 2 pts.

a) $\ddot{R} > 0$

b) $\ddot{R} = 0$

c) $\ddot{R} < 0$

F.3 – 2 pts.

If v is the speed of P, then:

a) $\dot{v} > 0$

b) $\dot{v} = 0$

c) $\dot{v} < 0$

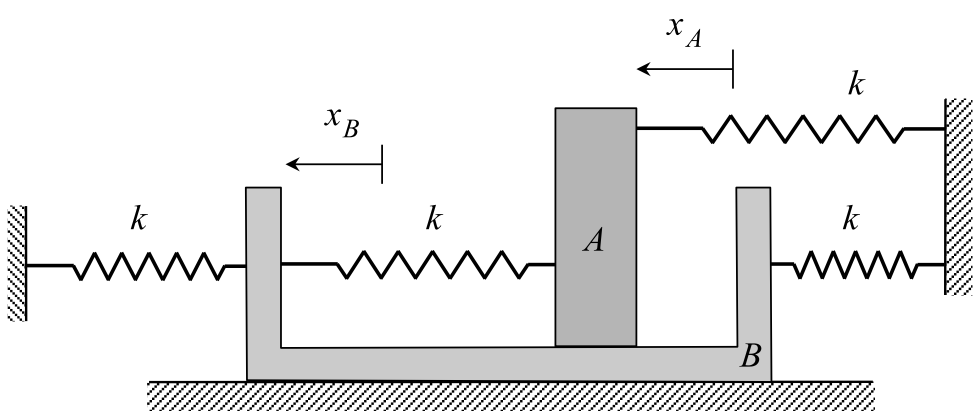
Sample final exam questions

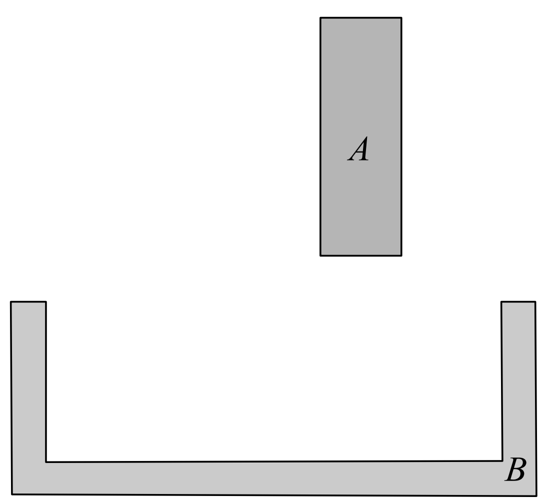
Name ______________________________

PROBLEM 4G

The system shown below moves within a horizontal plane. The displacements of blocks A and B in the system shown below are defined as x_A and x_B, respectively, with the positive senses for these displacements shown in the figure. The springs are unstretched when $x_A = x_B = 0$. Blocks A and B each have a mass of m. Complete the free body diagrams of blocks A and B below. Assume all surfaces to be smooth. Be sure to label the spring forces with in terms of the variables x_A, x_B and k, and clearly indicate the *direction* of these forces.

HORIZONTAL PLANE





Sample final exam questions

Name ________________________________

PROBLEM 4H

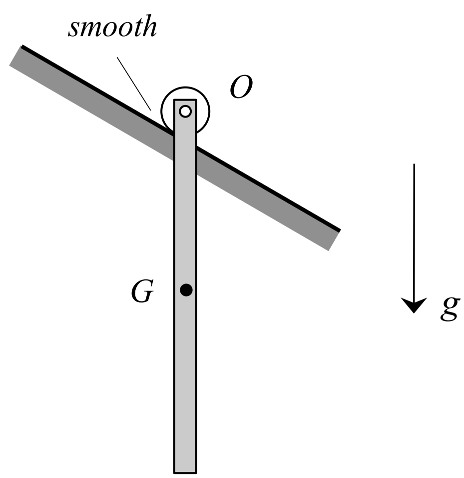
A thin bar is pinned to a small, massless wheel at end O. The wheel is guided by a smooth incline, as shown below. The bar is released from rest. Circle the response below that describes the angular acceleration $\vec{\alpha}$ of the bar:

i) $\vec{\alpha}$ is clockwise

ii) $\vec{\alpha} = \vec{0}$

iii) $\vec{\alpha}$ is counterclockwise

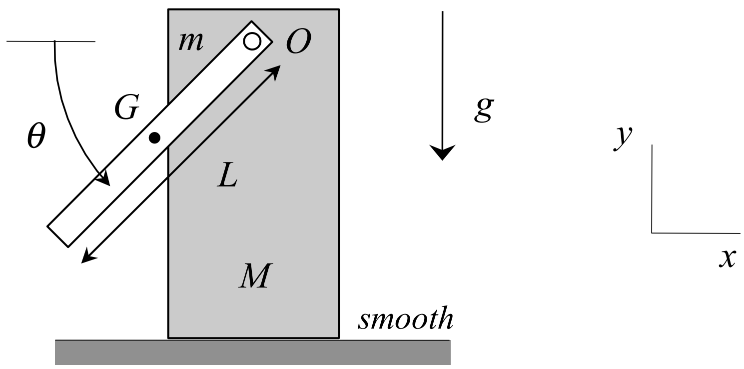
Justify your answer. Include a free body diagram of the bar and wheel in your justification.



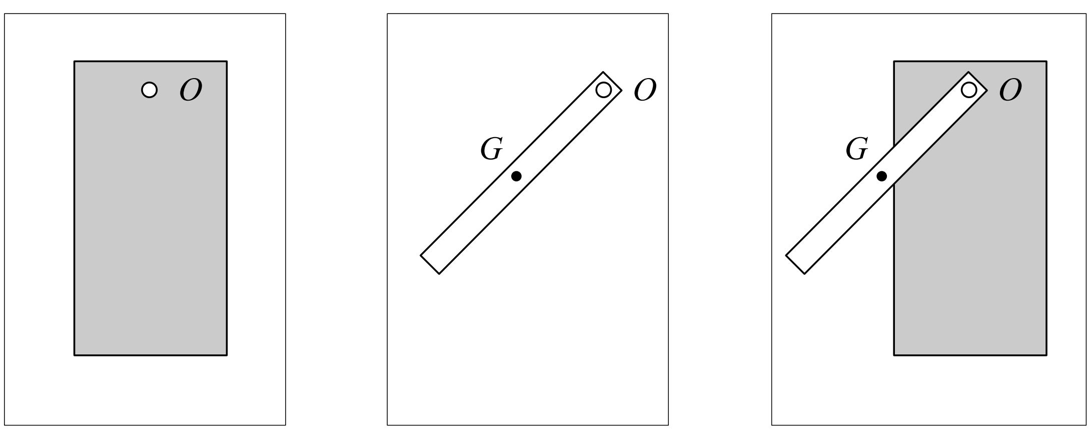
Sample final exam questions

PROBLEM 4I **Name** ________________________________

Consider the block (of mass M) and the thin, homogeneous bar (of length L, mass m and having its center of mass at G) shown below. The bar is pinned to the block at point O, with the block constrained to move along a smooth horizontal surface. The system is released from rest when $\theta = 0$.



Consider also the FBDs for the three systems shown below: System I made up of the block alone, System II made of the bar alone, and System III made up of the bar and block together.



System I *System II* *System III*

PROBLEM 4I - continued **Name** ______________________________

Part D.1: For System I, respond to the following True/False questions concerning motion from $\theta = 0$ to $\theta = 90°$:

i) Energy is conserved: TRUE or FALSE
ii) Linear momentum in the *x*-direction is conserved: TRUE or FALSE

Part D.2: For System II, respond to the following True/False questions concerning motion from $\theta = 0$ to $\theta = 90°$:

i) Energy is conserved: TRUE or FALSE
ii) Linear momentum in the *x*-direction is conserved: TRUE or FALSE

Part D.3: For System III, respond to the following True/False questions concerning motion from $\theta = 0$ to $\theta = 90°$:

i) Energy is conserved: TRUE or FALSE
ii) Linear momentum in the *x*-direction is conserved: TRUE or FALSE