Planning an active learning exercise

Mechanical Engineering
Julie Linsey and Chuck Krousgrill

1. ***Course***
   Sophomore-level mechanics course in dynamics. Course is required for ME majors. Students from other disciplines make up roughly 20% of the enrollment and are from schools for which this course is either required or accepted as a technical elective.

2. ***What do we want them to learn?***
   The course is intended as one in which students develop an understanding of fundamental principles in dynamics. Although the course has often been described as a "problem-solving course", the homework and exam exercises are ones that emphasize conceptual understanding. The active learning exercise proposed here is one in which students are to work in small groups in answering questions related to the application of course concepts to specific problems. The activities need to be designed in such a way that interaction and discussion among members of the groups is encouraged. The Purdue course uses a "lecturebook" written by faculty members in ME's mechanics group. This book serves as both the textbook and lecture notebook for the course. Each chapter in the lecturebook includes a bank of unsolved conceptually-oriented problems.

3. ***What is an activity that can be used to help students gain this skill?***
   At the start of the semester, students in a section of the course are divided into groups of four students. For an active learning exercise, the groups are assigned up to three conceptual questions from one subject, typically taken directly from the course lecturebook. Each group is provided a "huddle board" (small, portable whiteboard, typically 24"x36") and markers. Groups are given 15 minutes to resolve the issue for each question, using the huddle board for recording. At the end, one group for each question is asked to provide a brief oral explanation. Written work on the huddle boards can be recorded after class by the instructor, or a TA, to archive work by the groups. Three sample sets of conceptual questions are included here on the following topics: Newton's second law, conservation of energy and/or momentum, and moving reference frame kinematics.

4. ***What are unique aspects of the course that affects how this activity?***
   Typically the section sizes for the courses are somewhat large, around 120 students. This type of active learning exercise provides learning opportunities generally not possible for large classes not having group exercises. However, the large size limits the opportunity for oral presentations to a small fraction of the students in the class on any given day.

Active learning exercise for VCP-Mechanical

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1. Create 3 conceptual questions for your class. Consider the learning objectives and the difficult concepts that the conceptual questions are related to.

For examples of good conceptual questions see the following:

- Attached examples
- http://cihub.org/
- http://www.me.utexas.edu/~alps/alpContent/studentALPs.php

Active learning problems for NEWTON'S SECOND LAW

The following are three conceptual problems that emphasize evaluation of analytical results to explain physical behavior related to forces and accelerations.

Question CIV.1

Blocks A and B (having masses of m and $2m$, respectively) are connected by a lightweight, rigid rod. In System 1, a force F acts to the left on block A. In System 2, the same force acts to the left on block B. Let F_1 and F_2 represent the magnitude of the load carried by the rod in Systems 1 and 2, respectively. Circle the answer below that most accurately represents the magnitudes of F_1 and F_2:

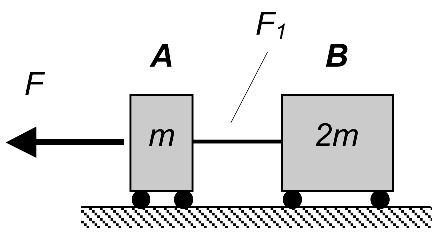
a) $F_1 > F_2$

b) $F_1 = F_2$

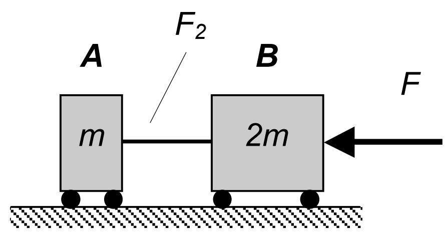
c) $F_1 < F_2$

d) More information is needed to answer this question

Provide a justification for your answer.



System 1



System 2

Question CIV.2

Particle P travels in a vertical plane within a smooth, circular slot, where the radius of the slot is $r = 05$ m. At the position shown below, the speed of P is known to be $v = 3$ m/s. For this position:

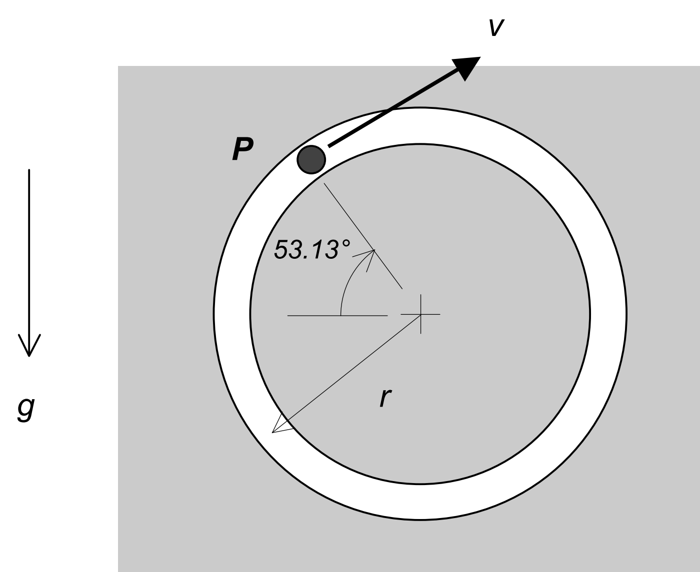
a) P is in contact with the outer surface of the slot.

b) P is in contact with the inner surface of the slot.

c) P is in contact with neither surface of the slot.

d) More information is needed to answer this question

Provide a justification for your answer.



Question CIV.26

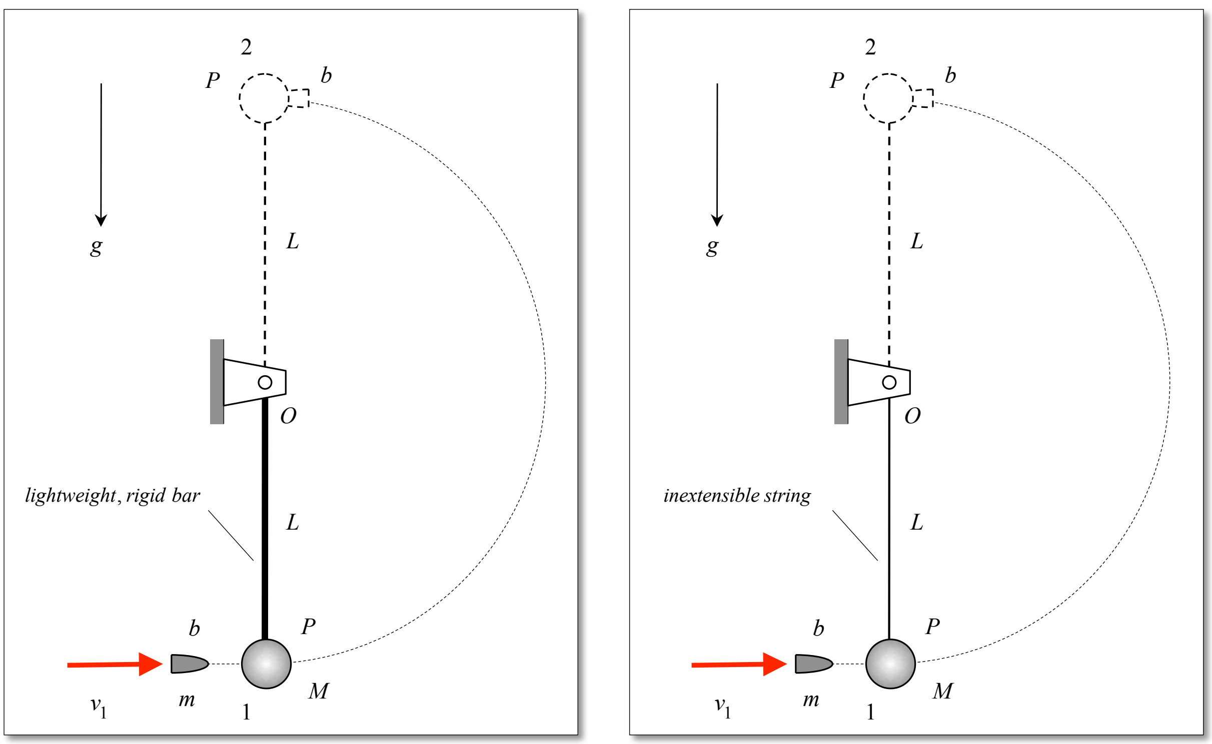
In System A shown below left, particle P connected to a pin joint at O with a lightweight, rigid bar of length L. Bullet b impacts the stationary particle P with a speed of v_1, and after impact the bullet sticks to P. System B is identical to System A except the rigid bar is replaced by an inextensible string of length L. Let $(v_{1,min})_A$ represent the minimum value of v_1 that is required for particle P in System A to reach position 2, a position where P is at a distance of L immediately above O. Let $(v_{1,min})_B$ represent the minimum value of v_1 that is required for P in System B to reach position 2. Circle the response below that most accurately describes the relative magnitudes of $(v_{1,min})_A$ and $(v_{1,min})_B$:

a) $(v_{1,min})_A > (v_{1,min})_B$

b) $(v_{1,min})_A = (v_{1,min})_B$

c) $(v_{1,min})_A < (v_{1,min})_B$

Justify your response with equations and/or words.



System A System B

Active learning problems for ENERGY and MOMENTUM

The following are three conceptual problems that emphasize the decision making thought process in determining which, if any, quantities that are conserved during an event. These decisions are important in setting up solutions to dynamics problems.

Question CIV.9

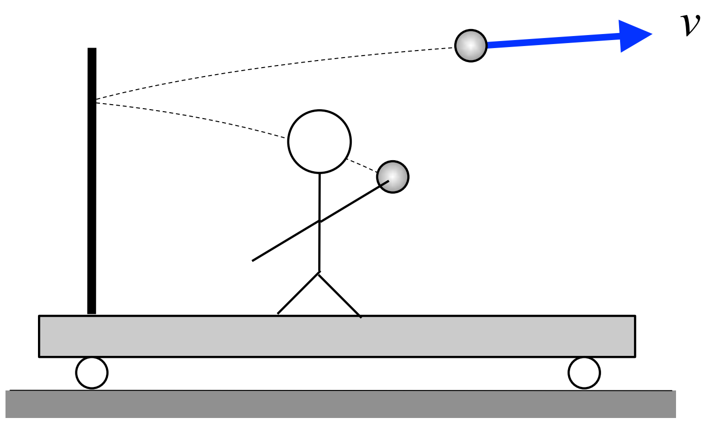
You are on a cart that is initially at rest on a smooth track. You throw a ball at a partition that is rigidly mounted on the cart. If the ball bounces off the partition as shown in the figure, then at the instant shown in the figure:

a) the cart is moving to the right

b) the cart is stationary

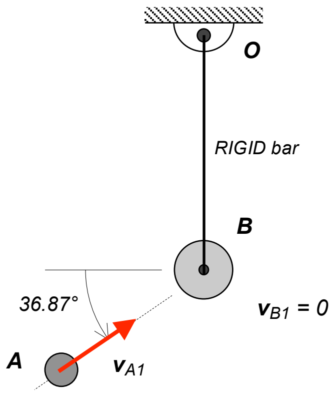
c) the cart is moving to the left

d) more information is needed about the impact of the ball with the partition in order to answer this question



Question CIV.15

Particle B is attached to a rigid bar BO with BO pinned to ground at O. Particle A strikes the stationary particle B with a speed of v_{A1} in the direction shown. The coefficient of restitution for this impact is $e < 1$. Consider all surfaces to be smooth and all motion in a horizontal plane. Respond to the following true/false questions below.



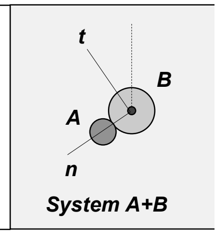
For System A+B

linear momentum in the n-direction is conserved: *TRUE* or *FALSE*

linear momentum in the t-direction is conserved: *TRUE* or *FALSE*

angular momentum about point O is conserved: *TRUE* or *FALSE*

mechanical energy is conserved: *TRUE* or *FALSE*



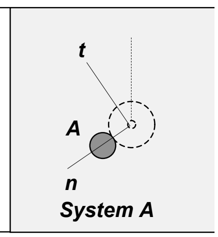
For System A

linear momentum in the n-direction is conserved: *TRUE* or *FALSE*

linear momentum in the t-direction is conserved: *TRUE* or *FALSE*

angular momentum about point O is conserved: *TRUE* or *FALSE*

mechanical energy is conserved: *TRUE* or *FALSE*



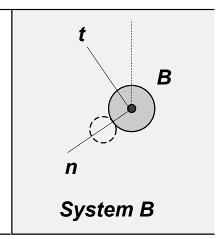
For System B

linear momentum in the n-direction is conserved: *TRUE* or *FALSE*

linear momentum in the t-direction is conserved: *TRUE* or *FALSE*

angular momentum about point O is conserved: *TRUE* or *FALSE*

mechanical energy is conserved: *TRUE* or *FALSE*



Question CIV.20

Consider the system shown below where A, B and E masses of m, $2m$ and $2m$, respectively. The system starts from rest with $\theta = 0$. Consider the motion of the system through a second position when $\theta = 90°$. Answer the following.

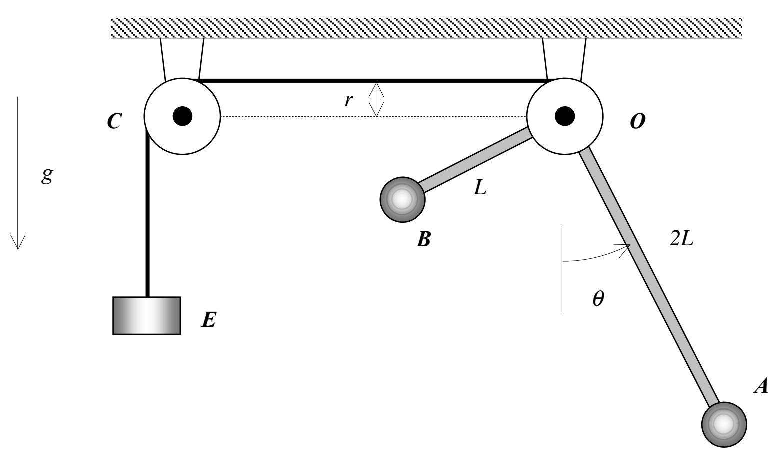
TRUE or FALSE: Energy is conserved for each particle individually.

TRUE or FALSE: Energy is conserved for the total system of A+B+E.

TRUE or FALSE: Linear momentum in the horizontal direction is conserved for the total system of A+B+E.

TRUE or FALSE: Linear momentum in the vertical direction is conserved for the total system of A+B+E.

TRUE or FALSE: Angular momentum about point O is conserved for the system of A+B.



Active learning problems for MOVING REFERENCE FRAME KINEMATICS

The following are three conceptual problems that emphasize the decision making processes in problem solving moving reference frame kinematics problems. These issues are typically related to the choice of observer to be used for the analysis. A photo of a sample huddle board response from a group is also provided.

Question CIII.3

Sprinkler arm OA is pinned to a cart at point O. The cart moves to the right with a speed of v_{cart} with $\dot{v}_{cart} = 2ft/s^2$= constant. Fluid flows through the sprinkler arm at a rate of $\dot{d}$ with $\ddot{d} = -3ft/s^2$ = constant. The sprinkler arm is being raised at a constant rate of $\dot{\theta} = 4$ rad/s. An observer and xyz coordinate system are attached to the sprinkler arm, as shown in the figure below. The following equation is to be used to find the acceleration of a pellet P that flows with the fluid in the arm:

$$\vec{a}_P = \vec{a}_O + \left(\vec{a}_{P/O}\right)_{rel} + \vec{\alpha} \times \vec{r}_{P/O} + 2\vec{\omega} \times \left(\vec{v}_{P/O}\right)_{rel} + \vec{\omega} \times \left[\vec{\omega} \times \vec{r}_{P/O}\right]$$

Provide numerical values for the following terms when: $d = 3$ ft, $v_{cart} = 3$ ft/s, $\dot{d} = 5$ ft/s and $\theta = 90°$.

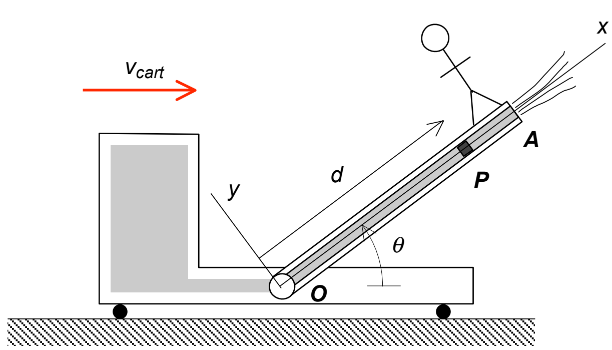
$\vec{a}_O =$

$\vec{\omega} =$

$\vec{\alpha} =$

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

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



Question CIII.5

Arm AB rotates about a fixed vertical axis with a constant rate of ω_1. A ring, with its center at O and of radius r, rotates about arm AB with a constant rate of ω_2. A particle P moves along the ring with $\dot{\theta} = constant$. Let the XYZ axes be fixed, and the xyz axes be attached to the ring. At the position shown, $\theta = 90°$ and the xyz axes are aligned with the XYZ axes. It is desired to use the following equation to determine the acceleration of P for the position shown:

$$\vec{a}_P = \vec{a}_O + \left(\vec{a}_{P/O}\right)_{rel} + \vec{\alpha} \times \vec{r}_{P/O} + 2\vec{\omega} \times \left(\vec{v}_{P/O}\right)_{rel} + \vec{\omega} \times \left[\vec{\omega} \times \vec{r}_{P/O}\right]$$

Provide expressions for the following terms appearing in this equation.

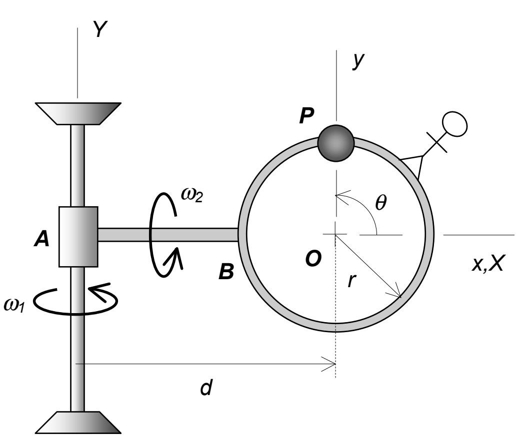
$\vec{a}_O =$

$\vec{\omega} =$

$\vec{\alpha} =$

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

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



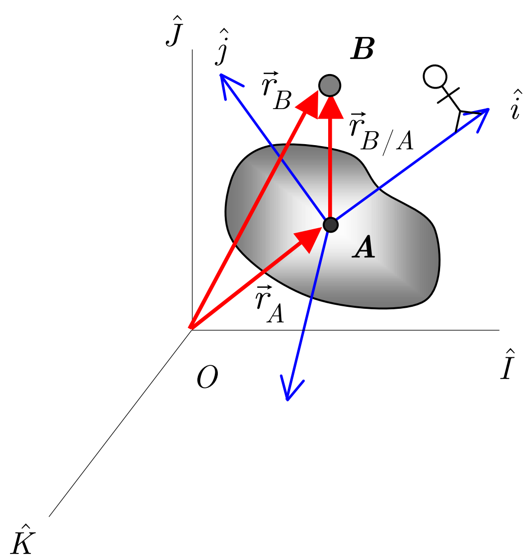
Question CIII.7

Consider an observer who is riding along on a moving (translating and rotating) rigid body. We wish to use the observation of this person in describing the motion of some point B, which is not fixed to the body, in the following moving reference frame acceleration equation.

$$\begin{aligned}\vec{a}_B &= \vec{a}_A + \left(\vec{a}_{B/A}\right)_{rel} + \vec{\alpha} \times \vec{r}_{B/A} + 2\vec{\omega} \times \left(\vec{v}_{B/A}\right)_{rel} + \vec{\omega} \times \left[\vec{\omega} \times \vec{r}_{B/A}\right] \\ &= \vec{a}_A + \vec{a}_{B/A}\end{aligned}$$

Answer the following questions in words:

- What is the meaning of $\vec{\omega}$?
- What is the meaning of $\vec{\alpha}$?
- What is the meaning of $\left(\vec{v}_{B/A}\right)_{rel}$?
- What is the meaning of $\left(\vec{a}_{B/A}\right)_{rel}$?
- What restrictions, if any, are on the choice of point A?
- What is the difference in meaning between $\vec{a}_{B/A}$ and $\left(\vec{a}_{B/A}\right)_{rel}$?



Team LS

$\vec{\omega} = \dot{\theta}\hat{k}$ rad/s

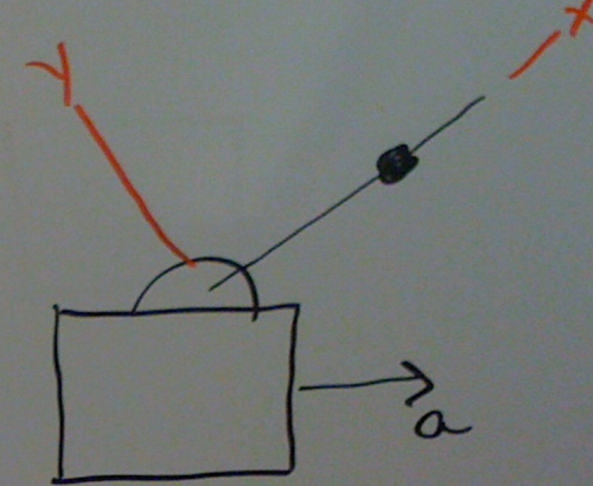
$\vec{\alpha} = \ddot{\theta}\hat{k} = \vec{0}$ rad/s^2

$(\vec{V}_{P/A})_{rel} = \dot{R}\hat{\imath}$ units

$(\vec{a}_{P/A})_{rel} = \vec{0}$ units

$\vec{a}_A = a\hat{\imath}$ units

$\vec{r}_{P/A} = R\hat{\imath}$ units



Find P when
$\theta = \emptyset$