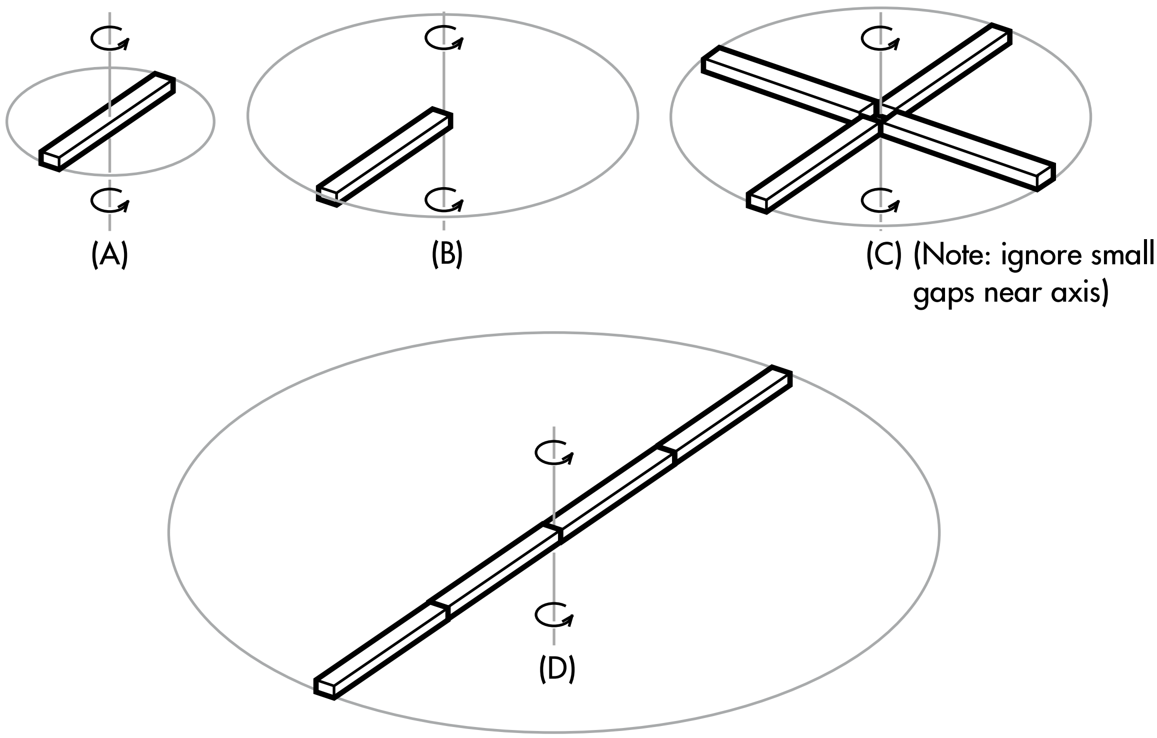
Uniform bars (each with the same mass and length) are mounted to swing around in various configurations.



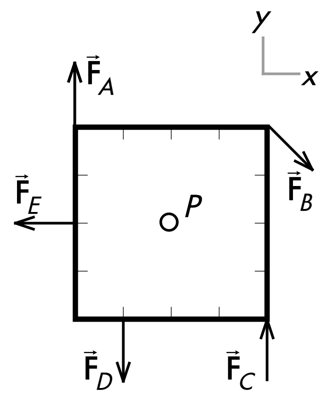
1. Rank the total mass of each configuration, from least to greatest amount. Indicate ties, if any.

________ ________ ________ ________
(least) (greatest)

2. Rank the rotational inertia of each configuration, from least to greatest amount. Indicate ties, if any.

________ ________ ________ ________
(least) (greatest)

Forces with the same magnitude are exerted on a uniform square object that can rotate about a pivot point *P* at its center. (Calculate all torques with respect to the central pivot.)



3. Identify the forces ($\vec{\mathbf{F}}_A$, $\vec{\mathbf{F}}_B$, $\vec{\mathbf{F}}_C$, $\vec{\mathbf{F}}_D$, $\vec{\mathbf{F}}_E$) that exert counterclockwise, clockwise, or zero torques on the square.

Counterclockwise torque force(s):
Clockwise torque force(s):
Zero torque force(s):

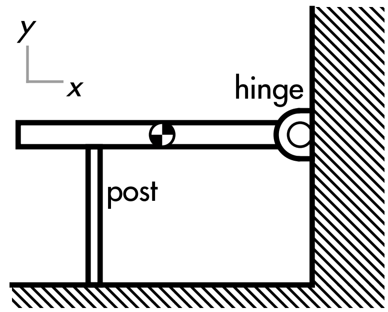
4. Rank the perpendicular lever arms (ℓ_A, ℓ_B, ℓ_C, ℓ_D, ℓ_E) of each force exerted on the square from least to greatest magnitude. Indicate ties, if any.

________ ________ ________ ________ ________
(least) (greatest)

5. Rank the torque exerted by each force on the square (τ_A, τ_B, τ_C, τ_D, τ_E) from least to greatest magnitude (regardless of direction). Indicate ties, if any.

________ ________ ________ ________ ________
(least) (greatest)

A uniform table is supported at two points: a hinge at the right end of the table, and a post located one-quarter of its length in from the left end. (Calculate all torques with respect to the hinge.)



6. Identify the forces ($\vec{\mathbf{F}}_{post}$, $\vec{\mathbf{w}}$, and $\vec{\mathbf{F}}_{hinge}$) that exert counterclockwise, clockwise, or zero torques on the table.

Counterclockwise torque force(s):
Clockwise torque force(s):
Zero torque force(s):

7. Rank the perpendicular lever arms (ℓ_{post}, ℓ_{w}, ℓ_{hinge}) of each force exerted on the table from least to greatest magnitude. Indicate ties, if any.

________ (least) ________ ________ (greatest)

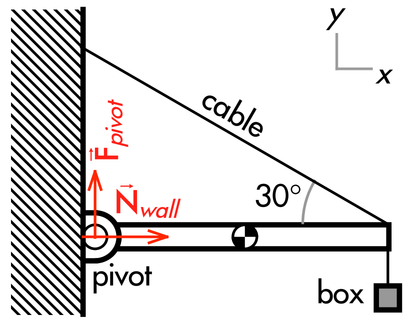
8. Rank the torque exerted by each force on the table (τ_{post}, τ_{w}, τ_{hinge}) from least to greatest magnitude (regardless of direction). Indicate ties, if any.

________ (least) ________ ________ (greatest)

9. Discuss why the force of the post on the table has a smaller magnitude than the weight of the table.

Explanation:

A uniform beam is mounted on a pivot at one end, with a box hanging from the far end, and held horizontal by a 30° cable also attached to the far end. The beam is twice the mass of the box. The pivot supports the left end of the beam with an upwards force, while the wall exerts a normal force on the left end of the beam. (Calculate all torques with respect to the pivot.)



10. Identify the forces ($\vec{\mathbf{F}}_{pivot}$, $\vec{\mathbf{N}}_{wall}$, $\vec{\mathbf{w}}$, $\vec{\mathbf{T}}$, $\vec{\mathbf{F}}_{box}$) that exert counterclockwise, clockwise, or zero torques on the beam.

Counterclockwise torque force(s):
Clockwise torque force(s):
Zero torque force(s):

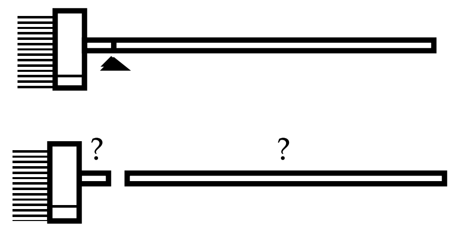
11. Rank the perpendicular lever arms (ℓ_{pivot}, ℓ_N, ℓ_w, ℓ_T, ℓ_{box}) for each force on the beam from least to greatest magnitude. Indicate ties, if any.

________ ________ ________ ________ ________
(least) (greatest)

12. Rank the torque exerted by each force on the beam (τ_{pivot}, τ_N, τ_w, τ_T, τ_{box}) from least to greatest magnitude (regardless of direction). Indicate ties, if any.

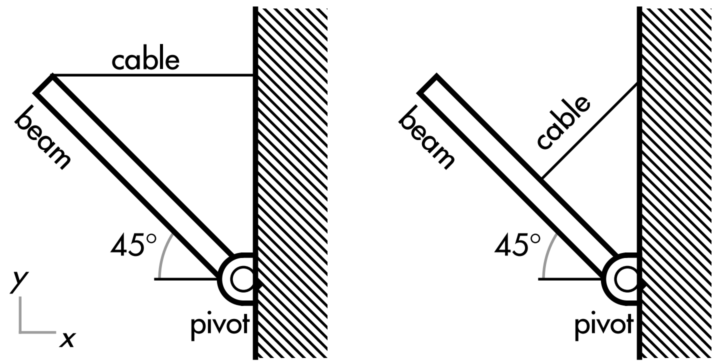
________ ________ ________ ________ ________
(least) (greatest)

13. A broom is carefully balanced, as shown at right. If the broom is cut exactly at that balancing point, the __________ end has more mass.



(A) brush.
(B) stick.
(C) (There is a tie.)
(D) (Unsure/guessing/lost/help!)

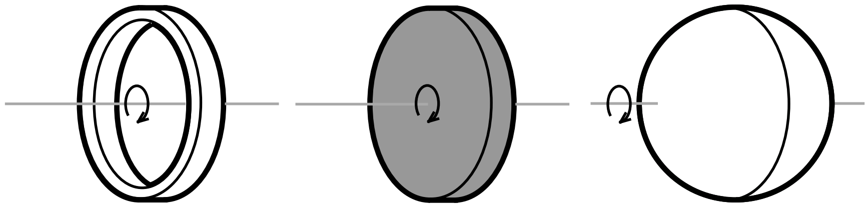
Two identical uniform beams are mounted on a pivot at one end, and are held stationary at an angle of 45° with respect to the horizontal, either by a horizontal cable at the end of the beam, or a cable attached perpendicular to the middle of the beam. (Calculate all torques with respect to the pivot.)



14. The __________ cable exerts a larger magnitude torque on its beam.
(A) horizontal.
(B) diagonal.
(C) (There is a tie.)
(D) (Unsure/guessing/lost/help!)

15. The __________ cable exerts a larger magnitude force on its beam.
(A) horizontal.
(B) diagonal.
(C) (There is a tie.)
(D) (Unsure/guessing/lost/help!)

Objects of the same mass and radius are held at the top of a ramp, and then are each released from rest and roll without slipping down to the bottom of the ramp. Ignore kinetic friction and drag



(A) ring

(B) disk

(C) solid sphere

16. Rank the *decrease* in gravitational potential energy ΔPE_{grav} of each object, from being released to reaching the bottom of the ramp, from least to greatest amount. Indicate ties, if any.

_______ _______ _______
(least) (greatest)

17. Rank the rotational inertia of each object, from least to greatest amount. Indicate ties, if any.

_______ _______ _______
(least) (greatest)

18. Rank the final translational speed v_f of each object as it reaches the bottom of the ramp, from least to greatest magnitude after being released from each spring. Indicate ties, if any.

_______ _______ _______
(least) (greatest)

19. Rank the *increase* in *translational* kinetic energy ΔKE_{tr} of each object, from being released to reaching the bottom of the ramp, from least to greatest amount. Indicate ties, if any.

_______ _______ _______
(least) (greatest)

20. Rank the *increase* in *rotational* kinetic energy ΔKE_{rot} of each object, from being released to reaching the bottom of the ramp, from least to greatest amount. Indicate ties, if any

_______ _______ _______
(least) (greatest)

21. An unopened, well-sealed bag of potato chips is purchased at sea level, and then is brought up on a car trip into the mountains. As a result, the bag "inflates" and becomes rigid. This is because the pressure:
(A) inside the bag increased.
(B) outside the bag decreased.
(C) (Both of the above choices.)
(D) (Unsure/guessing/lost/help!)

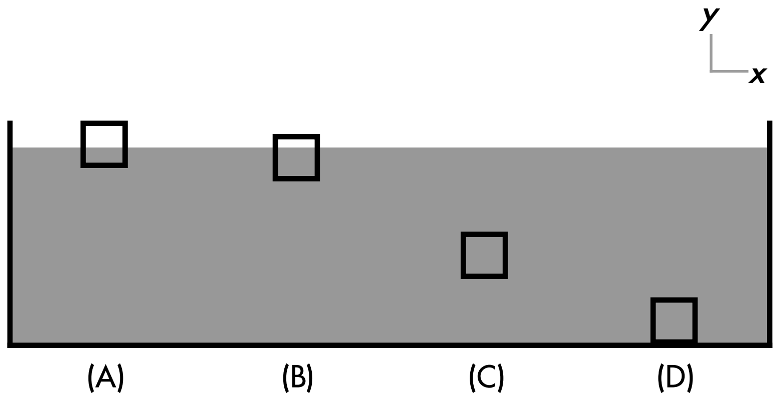
A suction cup is firmly pressed onto a smooth surface, making an airtight seal. This occurs while exposed to the atmosphere, at sea level.

22. When the suction cup is pulled, __________ keeps it stuck to the surface.
(A) vacuum force.
(B) suction.
(C) pressure difference.
(D) friction.
(E) (Unsure/guessing/lost/help!)

23. If this suction cup is exposed to the atmosphere at a much higher altitude, the suction cup will require __________ force to unstick, compared to unsticking while exposed to the atmosphere at sea level.
(A) less.
(B) the same amount of.
(C) more.
(D) (Unsure/guessing/lost/help!)

24. If this suction cup is at the bottom of a bathtub of water at sea level, the suction cup will require __________ force to unstick, compared to unsticking while exposed to the atmosphere at sea level.
(A) less.
(B) the same amount of.
(C) more.
(D) (Unsure/guessing/lost/help!)

Objects (same volumes, but different densities) float (or do not float) in a tank of water.



25. Rank the weight of each object, from least to greatest magnitude. Indicate ties, if any.

________ (least) ________ ________ ________ (greatest)

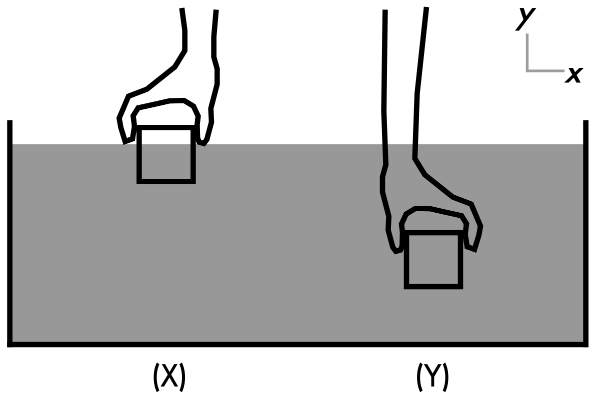
26. Rank the volume displaced by each object, from least to greatest amount. Indicate ties, if any.

________ (least) ________ ________ ________ (greatest)

27. Rank the buoyant force exerted on each object, from least to greatest magnitude. Indicate ties, if any.

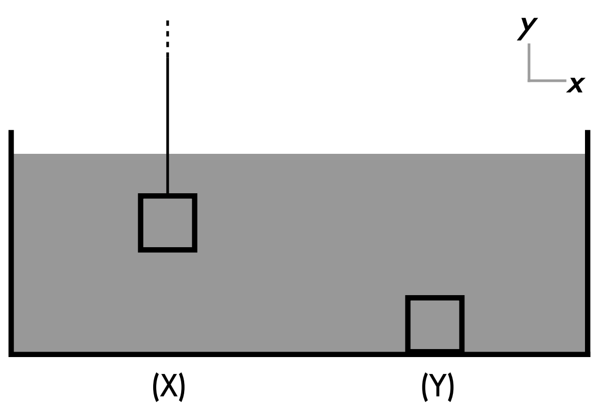
________ (least) ________ ________ ________ (greatest)

Two objects (same volume, same density) are held either half- or fully-submerged in a tank of water[1]. It is not known whether these two objects are both lighter or denser than water.



28. Object __________ has the greater magnitude buoyant force exerted on it.
- (A) X.
- (B) Y.
- (C) (There is a tie.)
- (D) (Not enough information is given.)
- (E) (Unsure/guessing/lost/help!)

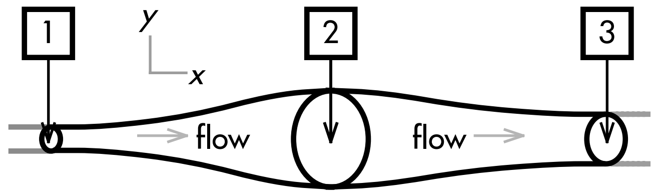
Two objects (same volume, same density) are in a tank of water: one hangs down from a string, while the other rests on the bottom of the tank.



29. The __________ has the greater magnitude.
- (A) tension force on object X.
- (B) normal force on object Y.
- (C) (There is a tie.)
- (D) (Not enough information is given.)
- (E) (Unsure/guessing/lost/help!)

[1] Diagram adapted from Fig. 2.1, p. 11, Eric Mazur, *Peer Instruction: A User's Manual*, Prentice-Hall, Inc., 1997.

Assume ideal fluid flow of water through this section of horizontal pipe.



30. Rank the volume flow rate $\Delta(Vol)/\Delta t$ of water through each section of pipe, from least to greatest magnitude. Indicate ties, if any.

________ (least) ________ ________ (greatest)

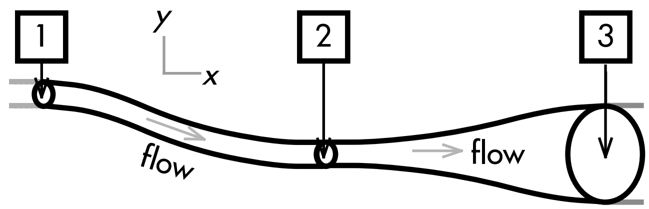
31. Rank the flow speed v of water through each section of pipe, from least to greatest magnitude. Indicate ties, if any.

________ (least) ________ ________ (greatest)

32. Rank the water pressure P in each section of pipe, from least to greatest amount. Indicate ties, if any.

________ (least) ________ ________ (greatest)

Assume ideal fluid flow of water through this section of pipe, which has a constant cross-sectional area from as it descends from [1]→[2], and has a widening cross-sectional area as it moves horizontally from [2]→[3].



33. Rank the volume flow rate $\Delta(Vol)/\Delta t$ of water through each section of pipe, from least to greatest magnitude. Indicate ties, if any.

________ (least) ________ ________ (greatest)

34. Rank the flow speed v of water through each section of pipe, from least to greatest magnitude. Indicate ties, if any.

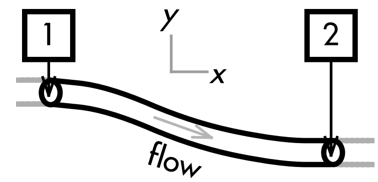
________ (least) ________ ________ (greatest)

35. Rank the water pressure P in each section of pipe, from least to greatest amount. Indicate ties, if any.

________ (least) ________ ________ (greatest)

36. (Assume ideal fluid flow.)

As water flows from [1]→[2], the [volume flow rate / flow speed / pressure]:

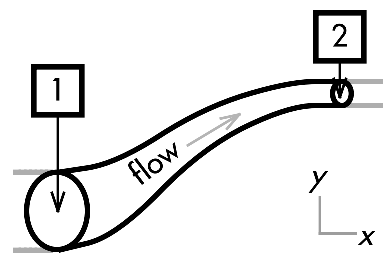


(A) decreases.
(B) increases.
(C) remains constant.
(D) (Unsure/guessing/lost/help!)

---

37. (Assume ideal fluid flow.)

As water flows from [1]→[2], the [volume flow rate / flow speed / pressure]:



(A) decreases.
(B) increases.
(C) remains constant.
(D) (Unsure/guessing/lost/help!)

Equations and constants:

$g = 9.80 \ \frac{\text{m}}{\text{s}^2}$.

$\tau = F\ell$.

$W_{nc} = \Delta KE_{tr} + \Delta KE_{rot} + \Delta PE_{grav} + \Delta PE_{elas}$.

$W = Fs\cos\theta = \tau\theta$.

$\Delta KE_{tr} = \frac{1}{2}m\left(v_f^2 - v_0^2\right)$.

$\Delta KE_{rot} = \frac{1}{2}I\left(\omega_f^2 - \omega_0^2\right)$.

$v_t = r\omega$.

$\Delta PE_{grav} = mg\left(y_f - y_0\right)$.

$\Delta PE_{elas} = \frac{1}{2}k\left(x_f^2 - x_0^2\right)$, where $F_{elas} = -kx$.

$P = \frac{F}{A}$.

$P_{atm} = 1.013 \times 10^5 \text{ Pa}$.

$\rho = \frac{\text{mass}}{\text{Volume}}$.

$\rho_{air} = 1.2 \ \frac{\text{kg}}{\text{m}^3}$; $\rho_{water} = 1.0 \times 10^3 \ \frac{\text{kg}}{\text{m}^3}$.

$F_B = \rho g(\text{Volume})$.

$\frac{\Delta(\text{Volume})}{\Delta t} = A_1v_1 = A_2v_2$; $A_{circle} = \pi r^2$.

$0 = (P_2 - P_1) + \frac{1}{2}\rho\left(v_2^2 - v_1^2\right) + \rho g\left(y_2 - y_1\right)$.