8A SPRING 2000

MOMENTS OF INERTIA

- **Hoop about cylinder axis**
  - \( I = MR^2 \)

- **Annular cylinder (or ring) about cylinder axis**
  - \( I = \frac{M}{2} \left( R_1^2 + R_2^2 \right) \)

- **Solid cylinder (or disk) about cylinder axis**
  - \( I = \frac{MR^2}{2} \)

- **Thin rod about axis through center \( a \) to length**
  - \( I = \frac{ML^2}{12} \)

- **Thin rod about axis through one end \( a \) to length**
  - \( I = \frac{ML^2}{3} \)

- **Solid sphere about any diameter**
  - \( I = \frac{2MR^2}{5} \)

- **Thin spherical shell about any diameter**
  - \( I = \frac{2MR^2}{3} \)

- **Hoop about any diameter**
  - \( I = \frac{MR^4}{2} \)

- **Rectangular plate about \( a \) axis through center**
  - \( I = \frac{ML^4}{12} \)
10. (1) A sinusoidal transverse water wave has a wavelength of 6 meters and a frequency of 0.3 Hz. The wave moves in the (−z) direction and the displacement is along the (±y) axis. The displacement at \( z = 0.9 \text{ m} \) is \((-0.1) \text{ m}\). When the time \( t = 1.2 \text{ sec} \), (a) Calculate the amplitude of the wave; (b) Calculate the velocity of the wave; (c) Show explicitly that your units in part (a) are correct. \([a = 6 \text{ points}, b = c = 2 \text{ each} \]
(10)(2) Suppose that $2 \times 10^{-4}$ m$^3$ of hot water at 368 K is poured into an insulated glass cup (filling it), of mass 0.3 kg, which is initially at 298 K. Assuming that no heat flows into the surroundings, calculate the final equilibrium temperature of (cup + water). Specific heat: glass, 840 J kg$^{-1}$ K$^{-1}$; water, 4186 J kg$^{-1}$ K$^{-1}$. Densities: water, 1000 kg m$^{-3}$; glass, 2000 kg m$^{-3}$. 
15. (3) A "dumb-bell", at rest, is composed of two point masses $m_1$ and $m_2$ attached to the two ends of a massless rod of length $2r$. The dumb-bell lies on a frictionless horizontal surface and can rotate about a fixed axis (normal to the surface) through point 0, as shown.

A third mass $m_3$ moves (normal to the axis of the dumb-bell) on the surface with velocity $v$, hits $m_2$ and sticks to $m_2$. The dumb-bell begins to rotate. Calculate, using the conservation of angular momentum, the angular speed $\omega$ of the rotating dumb-bell just after it is hit by $m_3$. (Your answer will be in terms of $v$, $r$, and the masses.)
(15)(4) A spherical bubble of air rises from the bottom of a lake 10 meters deep. The volume of the bubble is $10^{-6}$ m$^3$ at the lake bottom and increases as the bubble rises. Calculate the volume of the bubble at the surface of the lake. You may assume that the water temperature is constant, and that the air in the bubble behaves as an ideal gas. The atmospheric pressure above the lake is $10^5$ Pa and the mass density of water is $10^3$ kg m$^{-3}$. 
A vertical spring is suspended at one end and a mass of 0.30 kg is attached to the other end. The spring stretches by 0.15 meter when the mass is attached. The spring is then stretched (vertically downward) an additional 0.10 meter and released from rest. (a) Calculate the value of the spring (force) constant $k$; (b) Calculate the angular frequency $\omega$ of oscillation; (c) Calculate the amplitude $A$ of the oscillations; (d) Calculate the period $T$ of the oscillations.

$[a = 4, b = 4, c = 3, d = 4$ points$]$
Two blocks of masses $m_1$ and $m_2$ are arranged as shown. The cord is massless and the pulley is frictionless and massless. However, there is friction between block $m_1$ and the surface of the incline. (Block $m_2$ hangs freely vertically from the cord.) If block $m_1$ is just on the verge of moving up the incline, calculate the coefficient of static friction $\mu_s$ between block $m_1$ and the surface of the incline.
(10) (7) One mole of an ideal gas at a temperature of 300K is compressed isothermally and reversibly from a volume of 1.0 m$^3$ to a volume of 0.2 m$^3$. (a) Calculate the change $\Delta E_{int}$ in the internal energy of the gas; (b) Calculate the amount of heat $Q$ leaving the gas; (c) Calculate the change $\Delta S_{gas}$ in the entropy of the gas; (d) Calculate the change $\Delta S_{sur}$ in the entropy of the surroundings of the gas; (e) Does your answer to part (c) conflict with the Second Law of Thermodynamics? Justify your answer with an explanation. [Each part = 2 pts]
(25)(8) One mole of He (a monatomic gas) is at a temperature of 120 K, with a volume of 0.1 m$^3$ and at a pressure of 10$^4$ N m$^{-2}$. The gas undergoes the following three-step process. Step A is a reversible compression to a volume of 0.05 m$^3$ at a constant pressure of 10$^4$ N m$^{-2}$. Step B is heating the gas at a constant volume of 0.05 m$^3$ to a pressure of 2 x 10$^4$ N m$^{-2}$. Step C is a reversible isothermal expansion to a volume of 0.1 m$^3$. The gas may be assumed to be ideal at all times. (a) Calculate the temperature of the gas at the end of each step of the process; (b) Draw a pV diagram showing each step of the process, indicating on the diagram the temperatures obtained in part (a); (c) Calculate the total work done by the gas in the three-step process [a=10, b=5, c=10 points].
A thin rod of length \( L \) and mass \( m \) stands vertically on a horizontal surface. The rod begins to fall from rest, but its lower end does not slide and acts as a pivot. Calculate the angular speed \( \omega \) of the rod as a function of the angle \( \theta \) the rod makes with the horizontal surface.
(20)(10) Two blocks of masses $m_1$ and $m_2$ slide down an inclined plane which makes an angle $\theta$ with the horizontal. The coefficients of kinetic (sliding) friction of the blocks with the surface of the incline are $\mu_1$ and $\mu_2$, respectively. The blocks remain in contact with each other as they slide. Calculate the accelerations $a_1$ and $a_2$ of the blocks.
(25) (II) A small body of mass \(m\) starts from rest at the top of a hemispherical bowl of radius \(R\), as shown. The body slides down the frictionless inner surface of the bowl, always remaining in contact with the surface. (a) If the position of the body is specified by the angular coordinate \(\theta\) (as shown), calculate the angular acceleration \(\alpha\) (relative to an axis through point \(O\)) as a function of \(\theta\); (b) Make a graph (a neat sketch will do) showing the variation of \(\alpha\) with \(\theta\) for values of \(\theta\) between 0 and \(\pi\) radians; (c) Describe briefly in words the variation of angular acceleration with angular coordinate as the body moves \([a = 10, b = 10, c = 5]\).
(20)(12) Two solid cubes of wood, each of edge \( l \), are glued together. The cubes are of different mass densities and so have masses \( m_1 \) and \( m_2 \), where \( m_1 \) is larger than \( m_2 \). The combination of cubes is held horizontally (the cubes are side by side) in water so that it floats partially submerged. Calculate the magnitude of the net torque exerted (about an axis through the geometric center of the combination) on the combination at the instant the cubes are released.
(a) The wave is moving in the (-x) direction and the displacement is along the (+y) axis, so the wave function is
\[ y(x,t) = A \sin (kx + \omega t). \]

Since the wavelength \( \lambda = 6 \text{ m} \), the wave number \( k = (2\pi / \lambda) = 1.047 \text{ m}^{-1} \). The frequency \( \nu = 0.3 \text{ Hz} \), so the circular frequency \( \omega = 2\pi \nu = 1.885 \text{ Hz} \). We are told that the displacement \( y \) at \( z = 0.9 \text{ m} \), when \( t = 1.2 \text{ sec} \), is \( y = (-0.1) \text{ m} \), so the eqn. above becomes
\[ -0.1 = A \sin [(1.047)(0.9) + (1.885)(1.2)] \]
\[ -0.1 = A \sin (3.204) = A(-0.0626) \]
so
\[ A = 1.596 \text{ m} \]
is the amplitude of the wave.

(b) The velocity \( v \) of the wave is, from \( v = \lambda \nu, \)
\[ v = \lambda \nu = (6)(0.3) = 1.8 \text{ m/sec} \]

(c) Since \( \lambda \) is in meters, \( k \) is in (meters)^{-1}. Since \( z \) is in meters, \((kz)\) is dimensionless. The same is true of \((\omega t)\) since \( \omega \) is in \text{ sec}^{-1} \text{ Hz} and \( t \) is in seconds. The argument \((kz + \omega t)\) of the sine is therefore dimensionless, as it should be. The sine is thus a pure (that is, dimensionless) number, so the amplitude \( A \) has the same units as the displacement \( y \), namely meters, which are the correct units for the amplitude.
2. In this problem, we assume that the amount of heat $Q$ (lost by water) is equal to the amount of heat $Q$ (gained by glass) because the glass cup is insulated. Let $T$ be the final equilibrium temperature of the (cup + water), where $368 K > T > 298 K$. From the definition of specific heat $C_s$,

$$Q = mC_s \Delta T$$

where $m$ is the mass and $Q$ is the amount of heat required to raise the temperature of mass $m$ by $\Delta T$ Kelvin. Then

$$Q_{\text{lost by water}} = Q_{\text{gained by glass}}$$

$$m_w C_w (368 - T) = m_g C_g (T - 298)$$

Putting in the numerical values given for $m_w$, $C_w$, $m_g$, and $C_g$, and using

mass = (mass density)(volume),

we have

$$(10^3)(2 \times 10^4)(4186)(368 - T) = (0.3)(840)(T - 298)$$

$$(837)(368 - T) = (252)(T - 298)$$

$$3.83 \times 10^5 = (1089)T$$

$$T = 352 K$$
(3) The conservation of angular momentum $L$ for this system becomes

$$L \text{ (relative to } O, \text{ before hit)} = L \text{ (relative to } O, \text{ after hit)}$$

and

$$L \text{ (rel. } O, \text{ before hit)} = L \text{ (rel. } O) + L \text{ (dumb-bell, rel. } O)$$

As $m_3$ strikes the dumb-bell, its angular momentum (relative to $O$) is $(m_3 v_r)$; the initial angular momentum of the dumb-bell is zero because the dumb-bell is at rest. Therefore

$$L \text{ (rel. } O, \text{ before hit)} = m_3 v_r + 0 = m_3 v_r$$

After the collision the system rotates about $O$ with angular speed $\omega$, so

$$L \text{ (rel. } O, \text{ after hit)} = I \omega$$

where $I$ is the moment of inertia of the dumb-bell with mass $m_3$ attached to $m_2$. From the definition of $I$,

$$I = m_1 r^2 + (m_2 + m_3) r^2 = (m_1 + m_2 + m_3) r^2$$

Conservation of angular momentum gives

$$m_3 v_r = (m_1 + m_2 + m_3) r^2 \omega$$

$$\omega = \frac{m_3 v_r}{(m_1 + m_2 + m_3) r}$$

for the angular speed $\omega$ of the system after collision.
(4) From Pascal's law,
\[ p(y) = p_0 + pgy \]
is the hydrostatic pressure at a depth \( y \) in a fluid of mass density \( p \) over a free surface at which the pressure is \( p_0 \). Because the bubble is stable, the air pressure inside the bubble equals the fluid pressure outside. At the surface (\( y = 0 \)), the pressure \( p(0) = p_0 \), the atmospheric pressure, where \( p_0 = 10^5 \text{ N/m}^2 \). At a depth \( y = 10 \) meters, the fluid pressure is
\[ p(10) = p_0 + pgy = 10^5 + (10^3)(9.8)(10) = 1.98 \times 10^5 \text{ N/m}^2. \]

Since the gas (air) in the bubble is ideal, we have
\[ pV = nRT; \]
since \( n, R, \) and \( T \) are all constants, \((nRT)\) is constant, so
\[ p(0)V(0) = p(10)V(10) \]
meaning that the product \((pV)\) has the same value at the surface \((y = 0)\) and at the depth \( y = 10 \) meters. We are given that \( V(10) = 10^{-6} \text{ m}^3 \), so the volume \( V(0) \) at the surface is
\[ V(0) = \frac{p(10)V(10)}{p(0)} = \frac{(1.98 \times 10^5)(10^{-6})}{10^5} \]
\[ V(0) = 1.98 \times 10^{-6} \text{ m}^3 \]
is the volume of the bubble at the surface of the lake.
With the spring stretched, the upward restoring force exerted on the mass is equal to the downward gravitational force (weight) on the mass. Then:

\[ kx = mg \]
\[ k = \frac{mg}{x} \]

Since \( m = 0.30 \text{ kg} \), \( g = 9.8 \text{ m/s}^2 \), and \( x = 0.15 \text{ meter} \)

\[ k = 19.6 \text{ N/m} \]

(b) The angular frequency \( \omega \) of oscillation (after the mass is released from rest) is:

\[ \omega = \left( \frac{k}{m} \right)^{\frac{1}{2}} = \left[ \frac{19.6}{0.30} \right]^{\frac{1}{2}} = 8.08 \text{ rad/s} \]

\[ \omega = 8.08 \text{ Hz} \]

(c) Since the spring is stretched by a further 0.1 meter and then the mass is released, the amplitude \( A = 0.1 \text{ meter} \):

\[ A = 0.1 \text{ meter} \]

(d) The period \( T \) of the oscillations is given by:

\[ T = \frac{2\pi}{\omega} = \frac{6.28}{8.08} \]

\[ T = 0.78 \text{ sec} \]
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(6)

\[ T = \text{tension in massless cord}; \quad N = \text{normal force exerted on } m_1; \]
\[ f = \text{frictional force exerted on } m_1; \]
and \( (N = m_1 g \cos \theta) \) because \( m_1 \) has zero acceleration along \( y \).

**Newton's Second Law for } m_1:** \[ -m_1 g \sin \theta + T - f = 0 \quad (m_1 \text{ at rest}) \]

**Newton's Second Law for } m_2:** \[ T - m_2 g = 0 \quad (m_2 \text{ at rest}) \]

Since \( m_1 \) is just about to move: \( f = \mu_s N = \mu_s m_1 g \cos \theta \)

so Second Law equations become

\[ -\sin \theta (m_1 g) + T - \mu_s m_1 g \cos \theta = 0 \]

\[ T = m_2 g \]

and

\[ -\sin \theta (m_1 g) + m_2 g - \mu_s m_1 g \cos \theta = 0 \]

\[ (m_2 - m_1 \sin \theta) = \mu_s m_1 \cos \theta \]

\[ \mu_s = \frac{(m_2 - m_1 \sin \theta)}{(m_1 \cos \theta)} \]

is coefficient of static friction between \( m_1 \) and incline.
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(a) Since the gas is ideal, its internal energy \( E_{\text{int}} \) depends only on the temperature. Since the temperature is constant in an isothermal process, the internal energy is constant in an isothermal process. Therefore \( \Delta E_{\text{int}} = 0 \).

(b) Work is done on the gas when the gas is compressed, so (from our sign convention, \( W \) is negative in this process). From the First Law, \( \Delta E_{\text{int}} = Q - W = 0 \) in this isothermal process. Since \( W \) is negative, \( Q = W \), so \( Q \) is negative also, meaning that heat energy leaves the gas. To calculate \( Q \), we calculate

\[
W = \int p \, dv = \int \frac{RT}{V} \, dV = RT \ln \left( \frac{0.2}{0.1} \right) = (8.31)(300) \ln(0.2) \\
W = -4012 \text{ Joulles} \quad \Rightarrow \quad Q = -4012 \text{ J} \Rightarrow 4012 \text{ J of heat leaves gas}
\]

(c) The compression is reversible, so \( dS = \frac{1}{T} dQ \) and

\[
\Delta S_{\text{gas}} = \int dS = \int \frac{1}{T} dQ = \frac{1}{T} \int dQ = Q/T \quad \text{when } Q<0
\]

\[
\Delta S_{\text{gas}} = (-4012/300) \text{ JK}^{-1} \Rightarrow \Delta S_{\text{gas}} = -13.37 \text{ JK}^{-1}
\]

and the entropy \( S_{\text{gas}} \) decreases by 13.37 JK\(^{-1}\) in the process.

(d) The process is reversible, so \( \Delta S_{\text{gas} + \text{surroundings}} = 0 \), and

\[
\Delta S_{\text{gas}} + \Delta S_{\text{sur}} = 0 \Rightarrow \Delta S_{\text{sur}} = +13.37 \text{ JK}^{-1}
\]

and the entropy of the surroundings increases by 13.37 JK\(^{-1}\).

(e) No. The Second Law says that \( \Delta S \) (system + heat the gas) can be negative as long as \( \Delta S \) (system + surround.) > 0.
(8)(a) Call the starting state of the gas $\dot{1}$, so $p_1 = 10^4 \text{ Nm}^{-2}$, $V_1 = 0.1 \text{ m}^3$, $T_1 = 120 \text{ K}$. Step A takes the gas to state $\dot{2}$, in which $p_2 = 10^4 \text{ Nm}^{-2}$, $V_2 = 0.05 \text{ m}^3$, and we want to find $T_2$. Since the gas is ideal, $pV = RT$; since $p_1 = p_2$, we have

$$\frac{T_1}{V_1} = \frac{T_2}{V_2} \implies \frac{120}{0.1} = \frac{T_2}{0.05} \implies T_2 = 60 \text{ K}$$

is the temperature at the end of Step A. Then Step B takes the gas to state $\dot{3}$, in which $p_3 = 2 \times 10^4 \text{ Nm}^{-2}$, $V_3 = 0.05 \text{ m}^3$, and we want to find $T_3$. Since $V_2 = V_3$, the ideal gas law gives us

$$\frac{T_2}{p_2} = \frac{T_3}{p_3} \implies \frac{60}{10^4} = \frac{T_3}{2 \times 10^4} \implies T_3 = 120 \text{ K}$$

is the temperature at the end of Step B. Then Step C takes the gas to state $\dot{4}$, in which $V_4 = 0.1 \text{ m}^3$, $T_4 = 120 \text{ K}$, and we want to find $p_4$. Step C is isothermal, so $T_3 = T_4$, and we have

$$(p_3V_3) = (p_4V_4) \implies (2 \times 10^4)(0.05) = (p_4)(0.1) \implies p_4 = 10^4 \text{ Nm}^{-2}$$

This result tells us that state $\dot{4}$ is the same as state $\dot{1}$; process is cyclic.

(b) Draw the $pV$ diagram of the cyclic process:

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![Diagram]

(continued ->)
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(b) [Continued] (c) To calculate the work done by the gas we use

\[ W = \int p \, dV \]

where \( W \) is positive when the gas does work on the surroundings and \( W \) is negative when the surroundings do work on the gas.

In Step A, \( p = \text{const.} = 10^4 \text{ N/m}^2 \), so the work \( W_A \) done by the gas is

\[ W_A = \int_1^2 p \, dV = p(V_2 - V_1) = (10^4)(0.05 - 0.10) = -500 \text{ Joules} \]

and since \( W_A < 0 \) because work is done on the gas in the compression in Step A, so the work \( W_A \) done by the gas is negative.

In Step B, the volume is constant, so no work is done by the gas in this step:

\[ W_B = 0 \]

In Step C, the gas expands isothermally (\( T = 120 \text{K} \)) from \( V_3 = 0.05 \text{ m}^3 \) to \( V_1 = 0.10 \text{ m}^3 \), so, since \( pV = RT \),

\[ W_C = \int_3^1 p \, dV = RT \int_3^1 \frac{dV}{V} = RT \ln \left( \frac{0.10}{0.05} \right) = RT \ln 2 \]

\[ W_C = (8.31)(120) \ln 2 = +691 \text{ Joules} \]

In Step C, the expanding gas does 691 J of work on the surroundings. Since the gas does work, \( W > 0 \).

The total work \( W \) done by the gas in the three-step cyclic process is

\[ W = W_A + W_B + W_C = -500 + 0 + 691 = +191 \text{ J}. \]

\[ W = +191 \text{ J}. \]
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9. The easiest solution uses conservation of energy: the sum of kinetic and gravitational potential energy is constant as rod falls.

**Red is vertical (\( \theta = \frac{\pi}{2} \)):** \( U = (1/2)mgL \), \( K = 0 \) (stable at rest)

**Red is falling (\( \theta < \frac{\pi}{2} \)):** \[
\begin{align*}
U &= (1/2)mgL \sin \theta \\
K &= \frac{1}{2} I \omega^2 = \frac{1}{2} \left( \frac{1}{3} mL^2 \right) \omega^2
\end{align*}
\]

Conservation:
\[
\frac{1}{2} mgL = \frac{1}{2} mgL \sin \theta + \frac{1}{2} \left( \frac{1}{3} mL^2 \right) \omega^2
\]
\[
mgL (1 - \sin \theta) = \frac{1}{3} mL^2 \omega^2
\]
\[
(3g/L) (1 - \sin \theta) = \omega^2
\]

\[
\omega = (3g/L)^{1/2} (1 - \sin \theta)^{1/2}
\]
gives angular speed \( \omega \) as function of angle \( \theta \).
(10) The situation is as shown; free diagrams are for $m_1$ and $m_2$.

\[ N_1 = m_1 g \cos \theta \]
\[ F = m_1 m_2 g \cos \theta \]
\[ m_2 g \sin \theta \]
\[ m_2 g \cos \theta \]

**Block $m_1$**

**Block $m_2$**

Force $F$ is force exerted on $m_1$ by $m_2$ (since $m_1$ and $m_2$ are in contact).

Force $F'$ is force exerted on $m_2$ by $m_1$. Let $a_1$ and $a_2$ be magnitudes of accelerations of two masses. Then

**Newton's Second Law for $m_1$:**

\[ F + m_1 g \sin \theta - \mu_1 m_1 g \cos \theta = m_1 a_1 \]

**Newton's Second Law for $m_2$:**

\[ -F' + m_2 g \sin \theta - \mu_2 m_2 g \cos \theta = m_2 a_2 \]

**Newton's Third Law:**

Since blocks remain in contact with each other: $a_1 = a_2$

\[ F = F' \]

Giving four equations in the four unknowns: $a_1, a_2, F, F'$

Solving gives:

\[ (m_1 + m_2) g \sin \theta - (\mu_1 m_1 + \mu_2 m_2) g \cos \theta = (m_1 + m_2) a_1 \]

\[ a_1 = g \sin \theta - g \cos \theta \left( \frac{\mu_1 m_1 + \mu_2 m_2}{m_1 + m_2} \right) \]

so acceleration (down incline) of block $m_1$. Acceleration $a_2$ of block $m_2$ has (since $a_1 = a_2$) same value.
(a) We want to find the angular acceleration \( \alpha \) as a function of the angular coordinate \( \theta \). Since the net torque \( T \) is related to \( \alpha \) by
\[ T = I \alpha \]
we can find \( \alpha \) if we find \( T \). Then
\[ T = \vec{r} \times \vec{F} \]
where \( \vec{r} \) is radial and \( |\vec{r}| = R \) and \( \vec{F} \) is tangential, \( |\vec{F}| = mg \cos \theta \). Since the angle between \( \vec{r} \) and \( \vec{F} \) is 90°,
\[ T = |\vec{r}||\vec{F}| \sin \theta = mgR \cos \theta \]
(The component \( (mg \sin \theta) \) of \( mg \) is equal to the normal force \( N \) (not shown above) in magnitude and opposite in direction.) Since \( T = mR^2 \), we have
\[ (mR^2) \alpha = mgR \cos \theta \Rightarrow \alpha = \frac{g}{R} \cos \theta \]
gives \( \alpha \) as a function of angle \( \theta \).

(b) At the start \( (\theta = 0) \), the angular acceleration \( \alpha = (g/R) \) and is positive, meaning that the angular speed increases with increasing angle \( \theta \). When \( \theta = \frac{\pi}{2} \), \( \alpha = 0 \), and the angular speed is instantaneously constant with \( \theta \). As \( \theta \) increases beyond \( (\pi/2) \), \( \alpha \) becomes negative and the angular speed decreases with increasing \( \theta \) : \( \omega(\theta) = \frac{g}{R} \sin \theta \).
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\[ F_1 = \text{upward buoyant force on block 1} \]
\[ F_2 = \text{upward buoyant force on block 2} \]
\[ m_1g = \text{weight of block 1} \]
\[ m_2g = \text{weight of block 2} \]
\[ p = \text{density of fluid (water)} \]
\[ V_1 = V_2 = V = \text{submerged volume of blocks (initially)} \]

From Archimedes' Principle: \[ F_1 = F_2 = pgV \]

\[ T_1 = \text{torque exerted by forces on 1 about center O of combination} \]
\[ T_2 = \text{torque exerted by forces on 2 about center O of combination} \]

\[ T_1 = (pgV - m_1g)(\frac{L}{2}) \]
\[ T_2 = (pgV - m_2g)(\frac{L}{2}) \]

where (since \( m_1 \neq m_2 \)) torques \( T_1 \) and \( T_2 \) are in opposite directions, so the net torque is

\[ \tau = (T_2 - T_1) = pgV\frac{L}{2} - m_2 g \frac{L}{2} - pgV \frac{L}{2} + m_1 g \frac{L}{2} \]

\[ \tau = (m_1 - m_2) g \frac{L}{2} \]

Since \( T_1 \) moves blocks counterclockwise and \( T_2 \) moves blocks clockwise, and (we are given) \( m_1 \) is larger than \( m_2 \), \( \tau > 0 \), meaning block 1 moves downward (the combination moves counterclockwise) due to net torque \( \tau \).