Physics 211 Exam 3 Spring 2014

Last Name:________________ First Name ________________ ID ________________

Discussion Section:________ Discussion TA Name:_________________________

Instructions—
Please turn off your cell phone and put it away.
Calculators may not be shared. Please keep yours on your own desk.
This is a closed book exam. You have ninety (90) minutes to complete it.

1. Use a #2 pencil. Do not use a mechanical pencil or pen. Darken each circle completely, but stay within the boundary. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner. Be especially careful that your mark covers the center of its circle.

2. Print your **NETWORK ID** in the designated spaces at the right side of the answer sheet, starting in the left most column, then **mark the corresponding circle** below each character. If there is a letter "o" in your NetID, be sure to mark the "o" circle and not the circle for the digit zero. If and only if there is a hyphen "-" in your NetID, mark the hyphen circle at the bottom of the column. When you have finished marking the circles corresponding to your NetID, check particularly that you have not marked two circles in any one of the columns.

3. Print **YOUR LAST NAME** in the designated spaces at the left side of the answer sheet, then mark the corresponding circle below each letter. Do the same for your **FIRST NAME INITIAL**.

4. **You may find the version of this Exam Booklet at the top of the next page.** Mark the version circle in the TEST FORM box at the bottom right on your answer sheet. **DO THIS NOW!**

5. Print your UIN# in the **STUDENT NUMBER** designated spaces and mark the corresponding circles. You need not write in or mark the circles in the SECTION box

6. Sign your name (**DO NOT PRINT**) on the **STUDENT SIGNATURE** line.

7. On the **SECTION** line, print your **DISCUSSION SECTION**. You need not fill in the COURSE or INSTRUCTOR lines.

Before starting work, check to make sure that your test booklet is complete. ***In addition to these instructions, you should have 8 numbered pages (23 questions) plus one (1) Formula Sheet.***

Academic Integrity: **Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including expulsion.**

This Exam Booklet is Version A. Mark the **A** circle in the TEST FORM box at the bottom right on your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is worth a total of **102** points, composed of two types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.

A) If you mark only one answer and it is the correct answer,
you earn **6** points.
B) If you mark two answers, one of which is the correct answer,
you earn **3** points.
C) If you mark three answers, one of which is the correct answer,
you earn **2** points.
D) If you mark no answers, or more than three, you earn 0 points.

MC3: *multiple-choice-three-answer questions, each worth 3 points*.
No partial credit.

A) If you mark only one answer and it is the correct answer,
you earn 3 points.
B) If you mark a wrong answer or no answers, you earn 0 points.

Check to make sure that you bubble in ALL of your answers on the scantron (answer sheet).
Only what is marked on your scantron/answer sheet will count!

The next three questions pertain to the situation described below.

A solid sphere, a hollow sphere, and a solid cylinder have the same mass M and the same radius R. They are positioned at the top of the same ramp at the same height h = 4.3 m. They are released from rest and roll down the ramp without slipping.

1) Which object has the largest velocity when it reaches the bottom of the ramp?

a. The solid sphere.
b. The solid cylinder.
c. The answer cannot be determined with the information provided.
d. All three objects have the same velocity at the bottom of the ramp.
e. The hollow sphere.

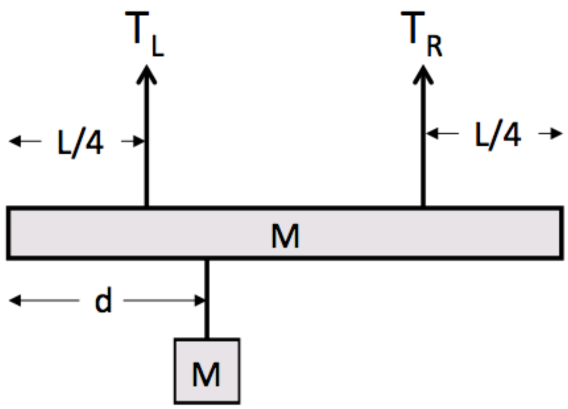
2) What is the velocity of the solid sphere when it reaches the bottom of the ramp, V_s?

a. V_s = 7.11 m/s
b. V_s = 6.49 m/s
c. V_s = 9.19 m/s
d. V_s = 7.76 m/s
e. V_s = 10.27 m/s

3) Suppose the answer to the above problem is V_s. If the radius of the solid sphere was increased, but its mass and the vertical distance it rolls down the ramp was kept the same, how would its new speed at the bottom of the ramp V_{new} compare to V_s. ?

a. $V_{new} = V_s$
b. $V_{new} < V_s$
c. $V_{new} > V_s$

The next three questions pertain to the situation described below.



A beam of mass M=4.3 kg and length L=5.1 m is suspended by two vertical ropes as shown. The rope on the left has tension T_L and is attached a distance $L/4$ from the left end of the beam. The rope on the right has tension T_R and is attached a distance $L/4$ from the right end of the beam. A box that has the same mass M as the beam is suspended by a short rope which it attached a distance d from the left end of the beam.

4) If the box is hung directly under the left rope (i.e. $d = L/4$), how would T_L compare to T_R?

a. $T_L > T_R$
b. $T_L < T_R$
c. $T_L = T_R$

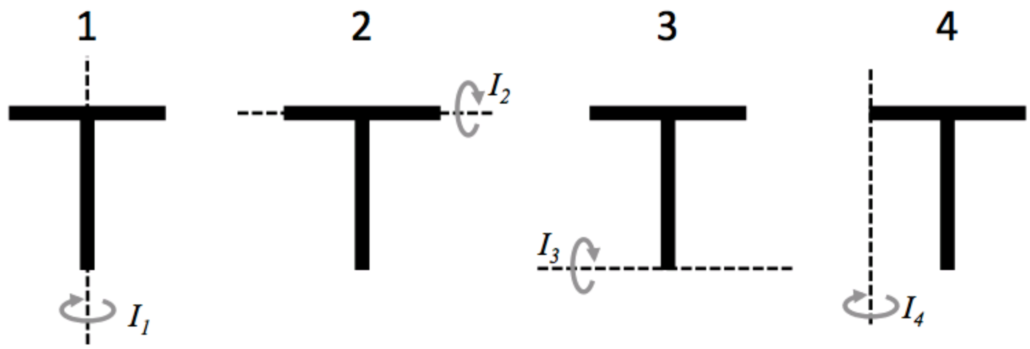
5) What is the value of d for which $T_L = \frac{3}{4} Mg$?

a. d = 1.7 m
b. d = 4.25 m
c. d = 3.19 m
d. d = 5.1 m
e. d = 1.27 m

6) If the box is hung at the right end of the beam (i.e. $d = L$), what is the value of T_R?

a. T_R = 84.37 N
b. T_R = 0 N
c. T_R = 56.24 N
d. T_R = 63.27 N
e. T_R = 42.18 N

The next two questions pertain to the situation described below.

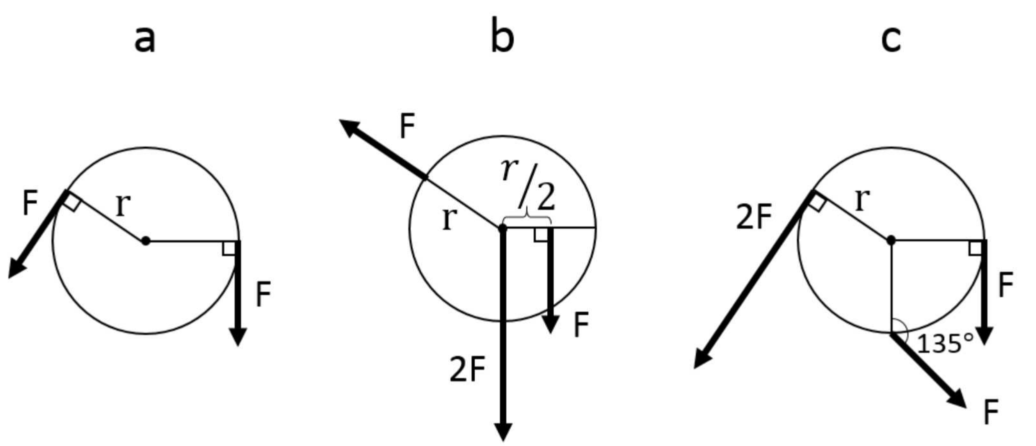


A T shaped object is made by combining two identical, uniform thin rods of equal mass and length. The object can be rotated about the four different axes shown by the dashed lines in the four diagrams.

7) Rank in increasing order the moments of inertia, I_1 to I_4 for rotation about the dashed lines.

a. $I_2 < I_1 < I_4 < I_3$
b. $I_1 < I_2 < I_4 < I_3$
c. $I_1 < I_2 < I_3 < I_4$

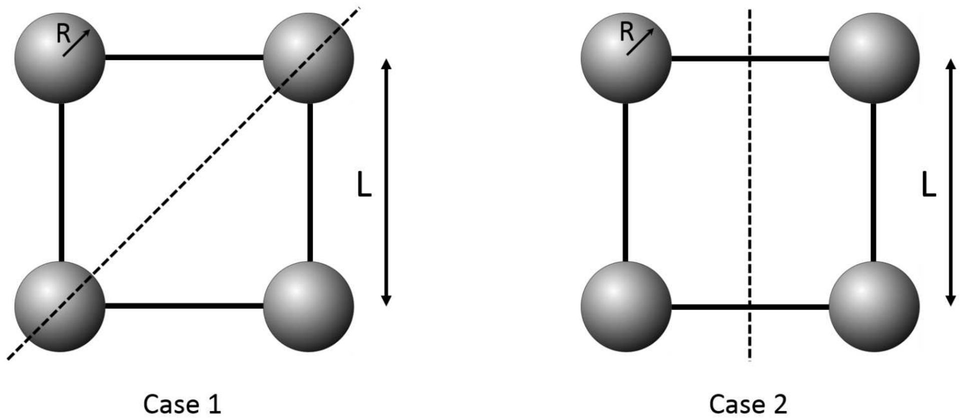
8)



Choose the situation where the magnitude of the torque about the center of mass is largest.

a. Situation C
b. Situation A
c. Situation B

The next two questions pertain to the situation described below.



Four solid spheres with mass M and radius R are connected together with massless rods to form a square of length L. In Case 1, the object is rotated about an axis along the diagonal of the square. In Case 2, the object is rotated about an axis that bisects the sides of the square.

9) Compute the ratio of the moments of inertia, I_1/I_2 for the two cases.

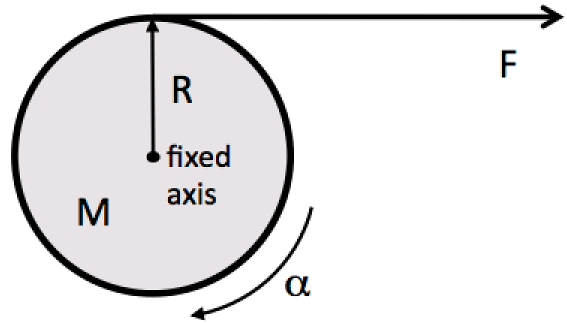
a. $I_1/I_2 = 2$
b. $I_1/I_2 = 1$
c. $I_1/I_2 = 1/2$
d. $I_1/I_2 = 1/\sqrt{2}$
e. $I_1/I_2 = \sqrt{2}$

10) If the solid spheres were replaced with hollow spheres, how would the ratio I_1/I_2 change?

a. The ratio would decrease.
b. The ratio would increase.
c. The ratio would not change.

The next four questions pertain to the situation described below.

A solid cylinder of radius R = 0.5 m starts from rest and can rotate without friction about an axis through its center of mass as shown. A string is wrapped around the circumference of the cylinder and is pulled with a constant force F=4 N. The rotation axis is fixed so that the center of mass of the cylinder does not move as the cylinder rotates. The magnitude of the angular acceleration of the cylinder is α = 13 rad/s^2.



11) Which of the following statements is true?

a. There is a non-zero net force on the cylinder, but the net torque on the cylinder is zero.
b. There is both a non-zero net torque and a non-zero net force on the cylinder.
c. There is a non-zero net torque on the cylinder, but the net force on the cylinder is zero.

12) What is the mass of the cylinder M ?

a. M = 0.31 kg
b. M = 2.46 kg
c. M = 0.15 kg
d. M = 0.62 kg
e. M = 1.23 kg

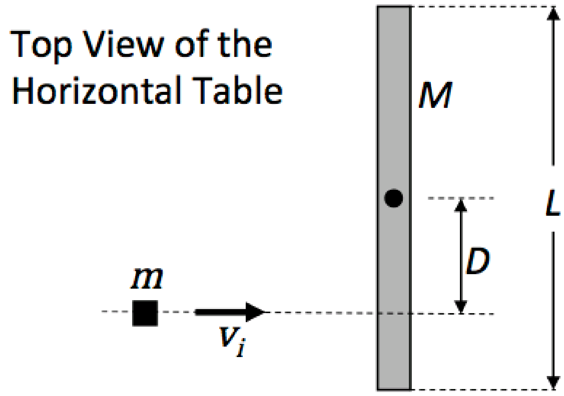
13) What is the angular displacement θ_t of the cylinder after the force has been pulling for time t = 9 seconds?

a. θ_t = 117 rad
b. θ_t = 526.5 rad
c. θ_t = 1053 rad
d. θ_t = 58.5 rad
e. θ_t = 2106 rad

14) Suppose the kinetic energy of the cylinder after 9 seconds of pulling is K_t. How does the kinetic energy after pulling for twice as much time, K_{2t}, compare to K_t?

a. $K_{2t} < 2K_t$
b. $K_{2t} = 2K_t$
c. $K_{2t} > 2K_t$

The next three questions pertain to the situation described below.



A block (which you should treat like a point particle) has mass m = 1.515 kg and slides with initial speed v_i in the +x direction. It collides with a rod of length L = 1.3 m and mass M = 30.3 kg, which is initially at rest and oriented perpendicular to the path of the block. The block hits the rod a distance D = 0.39 from the center of the rod. After the collision, the block is at rest and the rod spins with angular velocity of ω_f = 28 rad/s. Everything is on top of a horizontal frictionless table, and the rod has a fixed frictionless pivot through its center that allows it to rotate freely but keeps its center from moving.

15) Which of the following statements best describes the collision?

a. Neither the angular momentum about the pivot nor the linear momentum are conserved.
b. The angular momentum about the pivot is conserved, but the linear momentum is not conserved.
c. The angular momentum about the pivot and the linear momentum are both conserved.

16) What was the initial speed of the block?

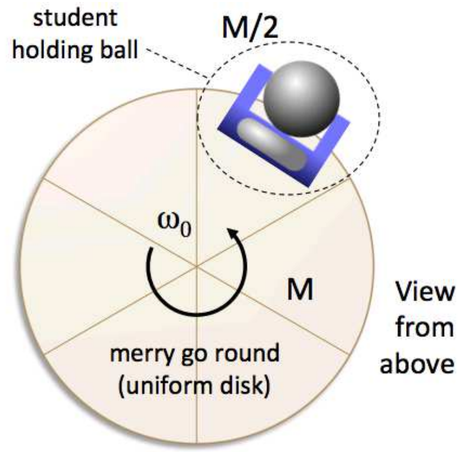
a. v_i = 808.89 m/s
b. v_i = 46.99 m/s
c. v_i = 93.98 m/s
d. v_i = 1213.33 m/s
e. v_i = 202.22 m/s

17) Suppose the experiment is repeated using new block that has the same mass and initial speed as in the original situation, but is made of a different material so that it bounces back and ends up moving in the -x direction after the collision. How would the final angular velocity of the rod in this new case, ω_{new}, compare to the final angular velocity of the rod in the original case ω_f?

a. $\omega_{new} = \omega_f$
b. $\omega_{new} > \omega_f$
c. $\omega_{new} < \omega_f$

The next three questions pertain to the situation described below.

A student holding a heavy ball stands facing outward on the outer edge of a merry go round. As viewed from above, the merry go round rotates counter-clockwise in the horizontal plane around a frictionless vertical axis through its center, and the magnitude of its initial angular velocity is ω_0.



18) Suppose the student throws the ball straight outward, directly away from the center of the merry go round. What happens to the magnitude of the angular velocity of the merry go round?

a. It decreases.
b. It does not change.
c. It increases.

19) Instead of throwing the ball outward, suppose she throws the ball to her right. What happens to the magnitude of the angular velocity of the merry go round?

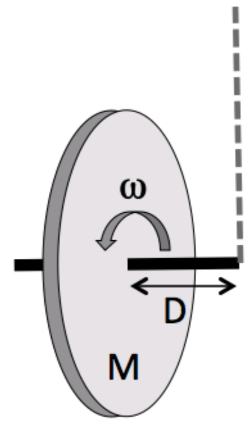
a. It increases.
b. It decreases.
c. It does not change.

20) Suppose instead that the student holds on to the ball and walks from the outer edge of the merry go round to its center. After she reaches the center, what is the magnitude of the new angular velocity of the system ω_{new}? Assume the merry go round is a uniform solid disk of mass M, and treat the combination of the student and the ball as a point particle that has mass $M/2$.

a. $\omega_{new} = \omega_0$
b. $\omega_{new} = 4\omega_0/3$
c. $\omega_{new} = 3\omega_0/2$
d. $\omega_{new} = 2\omega_0$
e. $\omega_{new} = 3\omega_0$

The next three questions pertain to the situation described below.

A gyroscope made from a solid disk of mass M and radius R hangs from a vertical rope attached to the ceiling. The disk spins around a horizontal axle through its center in the direction shown by the arrow, and the rope is attached to one end of this axle at a distance $D = 1.32$ m from the center of mass of the disk.



The moment of inertia of the disk is $I = 2.69$ kg-m^2. The angular momentum of the spinning disk is $L = 74.9$ kg-m^2/s. The time it takes the gyroscope to make one complete revolution in the horizontal plane (its precession period) is 13.2 seconds).

21) What is the magnitude of the angular velocity of the spinning disk?

a. $\omega = 33.4$ rad/s
b. $\omega = 27.8$ rad/s
c. $\omega = 66.7$ rad/s
d. $\omega = 41.7$ rad/s
e. $\omega = 83.4$ rad/s

22) What is the mass of the gyroscope ?

a. $M = 1.38$ kg
b. $M = 3.63$ kg
c. $M = 0.88$ kg
d. $M = 2.75$ kg
e. $M = 76.35$ kg

23) Suppose the same gyroscope is moved to the surface of a new planet where the acceleration of gravity on the surface is bigger than it is on Earth. How does the precession period change?

a. It decreases.
b. It stays the same.
c. It increases.

Phys 211 Formula Sheet

Kinematics
$\mathbf{v} = \mathbf{v}_0 + \mathbf{a}t$
$\mathbf{r} = \mathbf{r}_0 + \mathbf{v}_0 t + at^2/2$
$v^2 = v_0^2 + 2a(x-x_0)$

$g = 9.81\ m/s^2 = 32.2\ ft/s^2$

$\mathbf{v}_{A,B} = \mathbf{v}_{A,C} + \mathbf{v}_{C,B}$

Uniform Circular Motion
$a = v^2/r = \omega^2 r$
$v = \omega r$
$\omega = 2\pi/T = 2\pi f$

Dynamics
$\mathbf{F}_{net} = m\mathbf{a} = d\mathbf{p}/dt$
$\mathbf{F}_{A,B} = -\mathbf{F}_{B,A}$

$F = mg$ (near earth's surface)
$F_{12} = -Gm_1m_2/r^2$ (in general)
(where $G = 6.67\text{x}10^{-11}\ Nm^2/kg^2$)
$\mathbf{F}_{spring} = -k\,\mathbf{\Delta x}$

Friction
$f = \mu_k N$ (kinetic)
$f \leq \mu_S N$ (static)

Work & Kinetic energy
$W = \int \mathbf{F}\cdot\mathbf{dl}$
$W = \mathbf{F}\cdot\mathbf{\Delta r} = F\,\Delta r\,\cos\theta$
(constant force)

$W_{grav} = -mg\Delta y$
$W_{spring} = -k(x_2^2 - x_1^2)/2$

$K = mv^2/2 = p^2/2m$
$W_{NET} = \Delta K$

Potential Energy
$U_{grav} = mgy$ (near earth surface)
$U_{grav} = -GMm/r$ (in general)
$U_{spring} = kx^2/2$
$\Delta E = \Delta K + \Delta U = W_{nc}$

Power
$P = dW/dt$
$P = \mathbf{F}\cdot\mathbf{v}$ (for constant force)

System of Particles
$\mathbf{R}_{CM} = \Sigma m_i\mathbf{r}_i / \Sigma m_i$
$\mathbf{V}_{CM} = \Sigma m_i\mathbf{v}_i / \Sigma m_i$
$\mathbf{A}_{CM} = \Sigma m_i\mathbf{a}_i / \Sigma m_i$
$\mathbf{P} = \Sigma m_i\mathbf{v}_i$
$\Sigma\mathbf{F}_{EXT} = M\mathbf{A}_{CM} = d\mathbf{P}/dt$

Impulse
$\mathbf{I} = \int \mathbf{F}\,dt$
$\Delta\mathbf{P} = \mathbf{F}_{av}\Delta t$

Collisions:
If $\Sigma\mathbf{F}_{EXT} = 0$ in some direction, then
$\mathbf{P}_{before} = \mathbf{P}_{after}$ in this direction:
$\Sigma m_i\mathbf{v}_i$ (before) $= \Sigma m_i\mathbf{v}_i$ (after)

In addition, if the collision is elastic:
* $E_{before} = E_{after}$
* *Rate of approach = Rate of recession*
* *The speed of an object in the Center-of-Mass reference frame is unchanged by an elastic collision.*

Rotational kinematics
$s = R\theta,\ v = R\omega,\ a = R\alpha$
$$\left.\begin{aligned}\theta &= \theta_0 + \omega_0 t + {}^1/_2\alpha t^2\\ \omega &= \omega_0 + \alpha t\\ \omega^2 &= \omega_0^2 + 2\alpha\Delta\theta\end{aligned}\right\}$$

Rotational Dynamics
$I = \Sigma m_i r_i^2$
$I_{parallel} = I_{CM} + MD^2$
$I_{disk} = I_{cylinder} = {}^1/_2 MR^2$
$I_{hoop} = MR^2$
$I_{solid\text{-}sphere} = {}^2/_5 MR^2$
$I_{spherical\ shell} = {}^2/_3 MR^2$
$I_{rod\text{-}cm} = {}^1/_{12} ML^2$
$I_{rod\text{-}end} = {}^1/_3 ML^2$
$\tau = I\alpha$ (rotation about a fixed axis)
$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$, $|\tau| = rF\sin\phi$

Work & Energy
$K_{rotation} = {}^1/_2 I\omega^2$,
$K_{translation} = {}^1/_2 MV_{cm}^2$
$K_{total} = K_{rotation} + K_{translation}$
$W = \tau\theta$

Statics
$\Sigma\mathbf{F} = 0$, $\Sigma\tau = 0$ (about any axis)

Angular Momentum:
$\mathbf{L} = \mathbf{r} \times \mathbf{p}$
$L_z = I\omega_z$
$\mathbf{L}_{tot} = \mathbf{L}_{CM} + \mathbf{L}^*$
$\boldsymbol{\tau}_{ext} = d\mathbf{L}/dt$
$\boldsymbol{\tau}_{cm} = d\mathbf{L}^*/dt$
$\Omega_{precession} = \tau / L$

Simple Harmonic Motion:
$d^2x/dt^2 = -\omega^2 x$
(differential equation for SHM)

$x(t) = A\cos(\omega t + \phi)$
$v(t) = -\omega A\sin(\omega t + \phi)$
$a(t) = -\omega^2 A\cos(\omega t + \phi)$

$\omega^2 = k/m$ (mass on spring)
$\omega^2 = g/L$ (simple pendulum)
$\omega^2 = mgR_{CM}/I$ (physical pendulum)
$\omega^2 = \kappa/I$ (torsion pendulum)

General harmonic transverse waves:
$y(x,t) = A\cos(kx - \omega t)$
$k = 2\pi/\lambda,\quad \omega = 2\pi f = 2\pi/T$
$v = \lambda f = \omega/k$

Waves on a string:
$$v^2 = \frac{F}{\mu} = \frac{(\text{tension})}{(\text{mass per unit length})}$$

$$\bar{P} = \frac{1}{2}\mu v\omega^2 A^2$$
$$\frac{d\bar{E}}{dx} = \frac{1}{2}\mu\omega^2 A^2$$
$$\frac{d^2y}{dx^2} = \frac{1}{v^2}\frac{d^2y}{dt^2} \quad \text{Wave Equation}$$

Fluids:

$$\rho = \frac{m}{V} \qquad p = \frac{F}{A}$$

$$A_1v_1 = A_2v_2$$

$$p_1 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = p_2 + \tfrac{1}{2}\rho v_2^2 + \rho g y_2$$

$$F_B = \rho_{liquid} g V_{liquid}$$

$$F_2 = F_1\frac{A_2}{A_1}$$