Physics 211 Exam 3 Fall 2013

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 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.

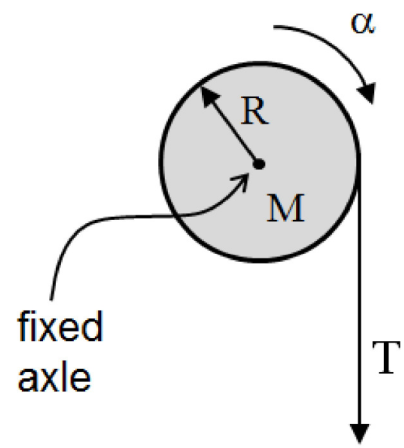
A) If you mark only one answer and it is the correct answer,
you earn **6** points.
B) If you mark two answers, one of which is the correct answer,
you earn **3** points.
C) If you mark three answers, one of which is the correct answer,
you earn **2** points.
D) If you mark no answers, or more than three,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

The next four questions pertain to the situation described below.

A solid disk having a radius of R = 0.31 m is constrained to rotate about a fixed frictionless axle through its center. The moment of inertia of the disk about the rotation axis is I = 1.85 kg-m^2 . A string is wrapped several times around its circumference, and is pulled in a direction perpendicular to the rotation axis as shown. The string does not slip as it unwinds, and the disk is initially at rest. The angular acceleration of the disk is α = 18.2 rad/s and does not change.



1) What is the tension in the string?

a. T = 3.05 N
b. T = 108.61 N
c. T = 58.71 N
d. T = 33.67 N
e. T = 10.44 N

2) What is the mass of the disk ?

a. M = 11.94 kg
b. M = 1.85 kg
c. M = 19.25 kg
d. M = 5.97 kg
e. M = 38.5 kg

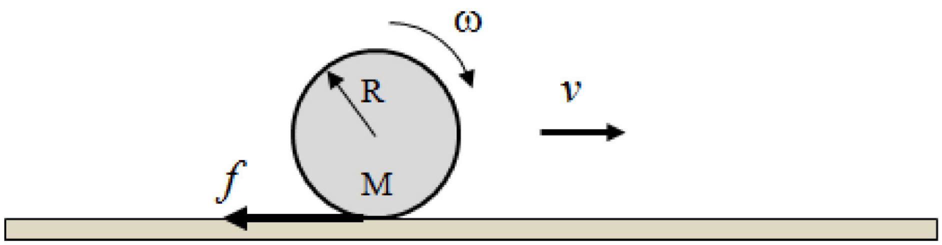
3) A time Δt after the disk starts to turn, it has made N_0 complete revolutions. How many complete revolutions has it made at a time $2\Delta t$ after it starts to turn?

a. $2N_0$
b. $4N_0$
c. $8N_0$

4) A time Δt after the disk starts to turn, the magnitude of its angular velocity is ω_0 . What is the magnitude of its angular velocity at a time $2\Delta t$ after it starts to turn?

a. $4\omega_0$
b. $8\omega_0$
c. $2\omega_0$

The next three questions pertain to the situation described below.



A bowling ball (uniform solid sphere) having a mass M = 4.05 and a radius of R = 0.104 m is thrown down a bowling alley. The initial speed of the center of mass of the ball is v_0 , and the initial angular velocity of the ball around its center of mass is zero. As the ball slides down the bowling alley the force of friction between the ball and the floor is f = 1.85N.

5) While the ball is sliding, what is the magnitude of the angular acceleration of the ball around an axis through its center of mass?

a. α = 4.39 rad/s^2
b. α = 8.78 rad/s^2
c. α = 6.59 rad/s^2
d. α = 13.18 rad/s^2
e. α = 10.98 rad/s^2

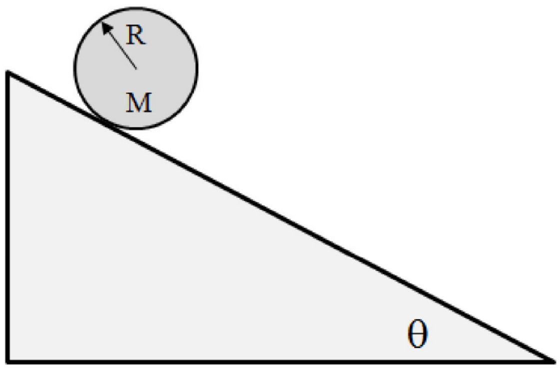
6) While the ball is sliding, which of the following statements best describes the relationship between the magnitude of the velocity of the center of mass V and the magnitude of the angular velocity of ball around an axis through its center of mass ω ?

a. $V = \omega R$
b. $V > \omega R$
c. $V < \omega R$

7) Eventually the ball starts to roll without slipping. Which of the following statements best describes the total kinetic energy of the ball as it rolls?

a. The total kinetic energy of the ball when it is rolling is higher than its initial kinetic energy because it now has translational kinetic energy as well as rotational kinetic energy.
b. The total kinetic energy of the ball when it is rolling is the same as its initial kinetic energy, but is now distributed between translational and rotational kinetic energy.
c. The total kinetic energy of the ball when it is rolling is lower than its initial kinetic energy because friction did negative work on the ball.

The next three questions pertain to the situation described below.



A hollow ball (spherical shell) having a mass M = 2.02 and a radius of R = 0.171 m is released from rest on a rough inclined plane which makes an angle $\theta = 30^{o}$ with the horizontal. The static frictional force causes the ball to roll without slipping as it moves down the incline.

8) What is the magnitude of the acceleration of the center of mass of the ball?

a. $a = 4.9$ m/s^2
b. $a = 1.96$ m/s^2
c. $a = 2.94$ m/s^2
d. $a = 3.5$ m/s^2
e. $a = 3.27$ m/s^2

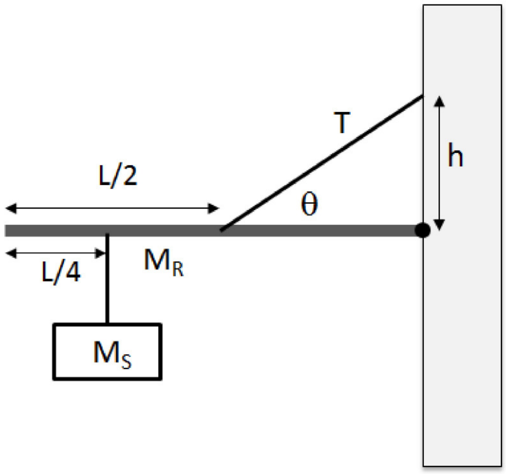
9) Suppose the magnitude of the acceleration of the ball is a . What is the magnitude of the static frictional force that the inclined plane exerts on the ball ?

a. $f < Ma$
b. $f = Ma$
c. $f > Ma$

10) Now suppose that three objects, a solid ball, a solid disk, and a hollow hoop, are simultaneously released from rest at the top of the inclined plane. The objects all roll down the plane without slipping. What is the order in which the objects arrive at the bottom of the incline?

a. The hoop arrives first, then the disk, and finally the ball.
b. The ball arrives first, then the disk, and finally the hoop.
c. The disk arrives first, then the hoop and finally the ball.

The next three questions pertain to the situation described below.



A horizontal rod of length L and mass M_R = 1.8 kg is used to hang a sign on a wall. The right end of the rod is attached to the wall by a hinge. A wire having tension T runs from the center of the rod to a place on the wall a distance h above the hinge as shown. The wire makes an angle $\theta = 25^o$ with the rod. The sign has mass M_S = 0.6 kg and hangs distance L/4 from the end of the rod. The system is in equilibrium.

11) What is the tenstion T in the wire that runs between the wall and the rod?

a. T = 62.67 N
b. T = 29.23 N
c. T = 41.78 N
d. T = 20.89 N
e. T = 9.74 N

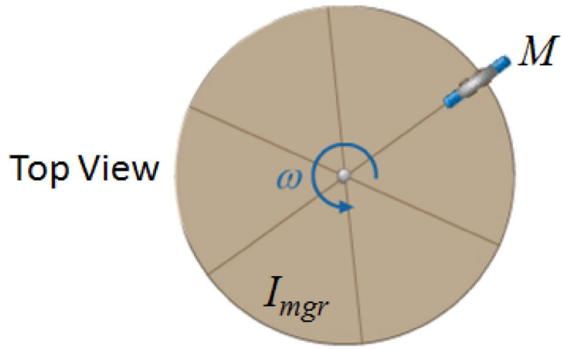
12) What is F_V , the vertical component of the force that the hinge exerts on the right end of the rod? A positive answer indicates an upward force and a negative answer indicates a downward force. Hint: Balance torques about an axis through the center of the rod.

a. F_V = 5.89 N
b. F_V = -4.41 N
c. F_V = -5.89 N
d. F_V = -2.94 N
e. F_V = 2.94 N

13) Suppose the answer to the first question on this page is T . If the wire is replaced by a longer one that runs from the **left end** of the rod to the same point on the wall a height h above the hinge, and if the rod is still horizontal, how would the new tension in the wire, T_{new} , compare to T ?

a. $T_{new} < T$
b. $T_{new} = T$
c. $T_{new} > T$

The next two questions pertain to the situation described below.



A child of mass M = 40 kg is standing next to a merry-go-round having moment of inertia I_{mgr} = 834 kg-m^2 and radius R = 2.3 m. The merry-go-round is initially rotating with angular speed ω_0 = 6 rad/s. The child now jumps onto the outer edge of the merry-go-round and starts to rotate with it. You can treat the child as a point mass.

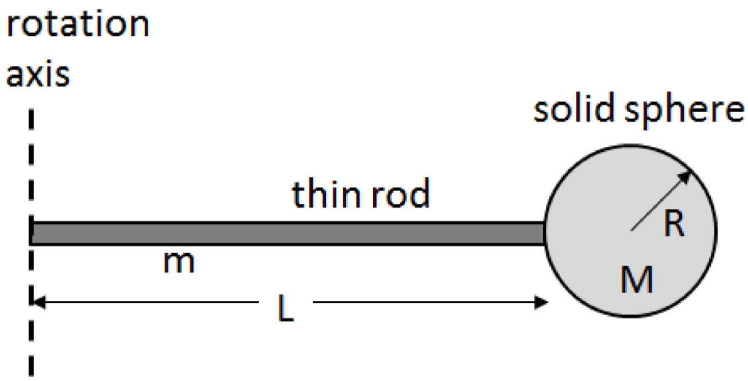
14) What is the angular speed ω of the merry-go-round after the child jumps on?

a. ω = 5.36 rad/s
b. ω = 7.52 rad/s
c. ω = 4.79 rad/s
d. ω = 6 rad/s
e. ω = 6.72 rad/s

15) Suppose the total kinetic energy of the system with the child standing on the edge of the merry go round is K_{edge} . The child now walks inward and stands at the center of the merry-go-round. How does K_{center} , the new kinetic energy of the system when the child is at the center, compare to K_{edge} ?

a. $K_{center} = K_{edge}$
b. $K_{center} < K_{edge}$
c. $K_{center} > K_{edge}$

The next two questions pertain to the situation described below.



A uniform solid sphere having mass M and radius R is attached to the end of a uniform thin rod of length L and mass m . The moments of inertia of a rod and of a sphere are given in your formula sheet.

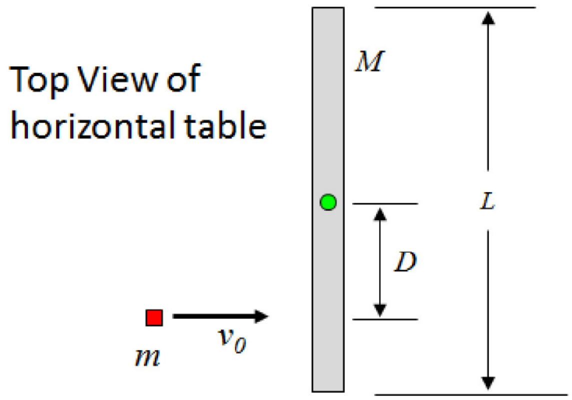
16) Which expression is correct for the moment if inertia I_{end} of the of the sphere-rod object about a perpendicular axis through the left end of the rod, as shown in the picture?

a. $I_{end} = \frac{1}{12}mL^2 + M((L+R)^2 + \frac{2}{5}R^2)$
b. $I_{end} = \frac{1}{3}mL^2 + M[(L^2 + \frac{2}{5}R^2]$
c. $I_{end} = \frac{1}{3}mL^2 + \frac{2}{5}MR^2$
d. $I_{end} = \frac{1}{12}mL^2 + M[(L^2 + \frac{2}{5}R^2]$
e. $I_{end} = \frac{1}{3}mL^2 + M((L+R)^2 + \frac{2}{5}R^2)$

17) Suppose the answer to the above problem is I_{end} . If the orientation of the rotation axis were kept the same but moved to the right so that it passed through the center of mass of the system, how would the new moment of inertia, I_{cm} , compare to I_{end} ?

a. $I_{cm} > I_{end}$
b. $I_{cm} < I_{end}$
c. $I_{cm} = I_{end}$

The next two questions pertain to the situation described below.



A block (which you should treat like a point particle) has mass m = 0.23 kg and slides with initial speed v_0 . It hits and sticks a distance D = 0.18 from the center of a horizontal rod of length L = 1.8 m and mass M = 0.53 kg, which is initially at rest and oriented perpendicular to the path of the block. 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.

18) After the block hits the rod they rotate together with a constant angular velocity of ω = 14.7 rad/sec. What was the initial speed of the block?

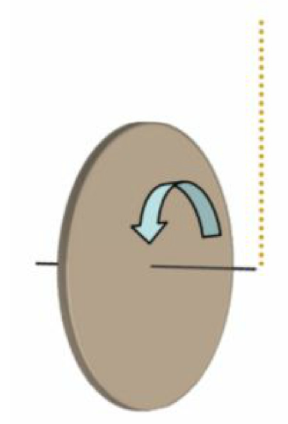
a. v_0 = 11.6 m/s
b. v_0 = 53.46 m/s
c. v_0 = 2.65 m/s
d. v_0 = 11.89 m/s
e. v_0 = 50.81 m/s

19) Which of the following statements best describes the external forces and torques acting on the rod-block system during the collision?

a. The total external torque around the pivot is not zero, but the total external force on the system is zero.
b. Both the total external torque around the pivot and the total external force on the system are zero.
c. The total external torque around the pivot is zero, but the total external force on the system is not zero.

The next four questions pertain to the situation described below.

A gyroscope made from a solid disk of mass M = 5.7 kg and radius R = 0.44 m hangs from a 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 disk. The angular momentum of the disk is L = 74.9 kg-m^2/s.



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

a. ω = 204 rad/s
b. ω = 407 rad/s
c. ω = 326 rad/s
d. ω = 136 rad/s
e. ω = 163 rad/s

21) If viewed by somone looking down on the gyroscope from above, which way does it precess?

a. Clockwise.
b. Counterclockwise.
c. There is not enough information given to determine this.

22) What is the period of the precession of the gyroscope (in other words, the time needed to make one complete revolution in the horizontal plane) ?

a. T = 3.19 s
b. T = 0.99 s
c. T = 19.13 s
d. T = 1.01 s
e. T = 6.38 s

23) Suppose the answer to the above problem is T . If the gyroscope were moved to the surface of a new planet where the acceleration of gravity on the surface was half that on earth, how would the new precession period T_{new} compare to T .?

a. $T_{new} = 2T$
b. $T_{new} = T/2$
c. $T_{new} = T/4$

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)
$f \le \mu_S N$ (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)

<u>In addition, if the collision is elastic:</u>
* $E_{before} = E_{after}$
* *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
$I = \Sigma m_i r_i^2$
$I_{parallel} = I_{CM} + MD^2$
$I_{disk} = I_{cylinder} = {}^1\!/_2MR^2$
$I_{hoop} = MR^2$
$I_{solid\text{-}sphere} = {}^2\!/_5MR^2$
$I_{spherical\ shell} = {}^2\!/_3MR^2$
$I_{rod\text{-}cm} = {}^1\!/_{12}ML^2$
$I_{rod\text{-}end} = {}^1\!/_3\,ML^2$
$\tau = I\alpha$ (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:
$y(x,t) = A\cos(kx - \omega t)$
$k = 2\pi/\lambda$, $\omega = 2\pi f = 2\pi/T$
$v = \lambda f = \omega/k$

Waves on a string:

$$v^2 = \frac{F}{\mu} = \frac{(\text{tension})}{(\text{mass per unit length})}$$

$$\overline{P} = \frac{1}{2}\mu v\omega^2 A^2$$

$$\frac{d\overline{E}}{dx} = \frac{1}{2}\mu\omega^2 A^2$$

$$\frac{d^2y}{dx^2} = \frac{1}{v^2}\frac{d^2y}{dt^2} \quad \text{Wave Equation}$$

Fluids:

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

$$A_1v_1 = A_2v_2$$

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

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

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