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 10 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 **105** points, composed of two types of questions.

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

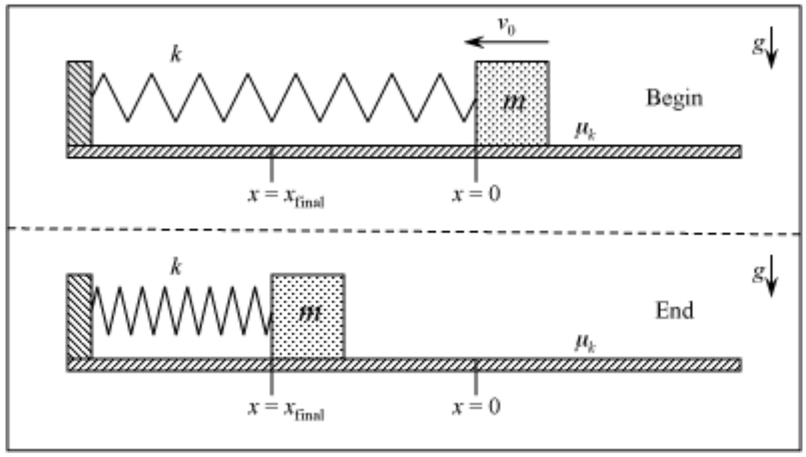
A) If you mark only one answer and it is the correct answer,
you earn **6** points.
B) If you mark two answers, one of which is the correct answer,
you earn **3** points.
C) If you mark three answers, one of which is the correct answer,
you earn **2** points.
D) If you mark no answers, or more than three,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

A mass $m = 8$ kg is attached to a spring with spring constant $k = 4.5$ N/m, as shown in the figure. When the spring is unstretched, its end attached to the mass will be at the position $x = 0$. The coefficient of kinetic friction for the sliding mass is $\mu_k = 0.1$. As the mass passes through $x = 0$, it has velocity $v_0 = 8$ m/s to the left. The mass eventually comes to rest at the position $x = x_{final}$.



1) What is the magnitude of the total work done on the mass (between when it passes through $x = 0$ and when it comes to rest) by the sum of ***all*** the forces which act on it?

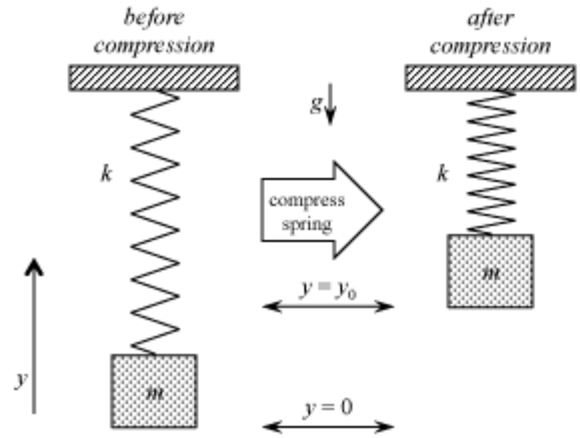
a. 0 J
b. 6.4 J
c. 7.85 J
d. 64 J
e. 256 J

2) Recall that the coefficient of kinetic friction is less than the coefficient of static friction. What is the possible range of values for the magnitude of x_{final}?

a. equal or less than 10.67 m
b. equal or less than 1.74 m
c. equal or less than 6.4 m

The next two questions pertain to the situation described below.

A mass m = 7 kg is supported by a spring with spring constant k = 6.5 N/m. The spring is oriented vertically and is suspended from the ceiling, as shown in the figure. The weight of the mass stretches the spring so that the equilibrium position for the bottom of the mass, when it is supported by the spring, is at $y = 0$. A physics student lifts the mass so that the bottom of the mass is at $y = y_0$ with y_0 = 2.8 m.



3) The student releases the mass. What is the maximum speed reached by the mass as it oscillates up and down?

a. 9.81 m/s
b. 7.89 m/s
c. 7.41 m/s
d. 192.28 m/s
e. 2.7 m/s

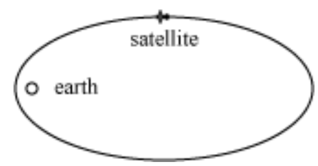
4) What is the lowest y value reached by the mass?

a. -2.8 m
b. -7.84 m
c. -1.67 m

5) You come upon an object that moves under the influence of a mysterious force field which exerts a force $\vec{F}(x) = -be^{-cx}\hat{x}$ ($\hat{x}$ is a unit vector in the x direction.) The values of the constants b and c are b = 4.5 N and c = 0.6 m^{-1}. How much work must ***you*** do to move the object from x_{initial} = 0 to x_{final} = 4 m? Assume the object is initially at rest.

a. -6.82 J
b. 6.82 J
c. 6.13 J
d. 16.37 J
e. -18 J

6) A satellite travels in an elliptical orbit around the earth, as shown in the following figure. Neglecting any interaction the satellite might have with the earth's atmosphere, which ***one*** of the following statements is true?

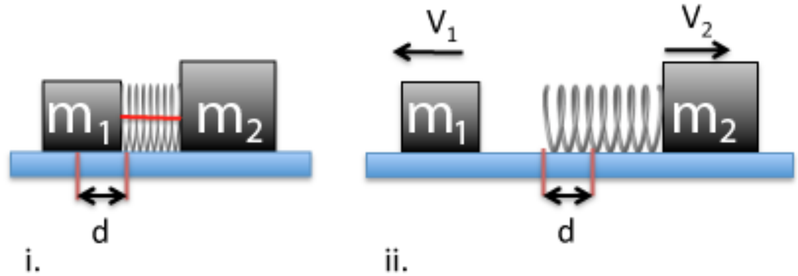


a. Because gravity is a conservative force, the magnitude of the satellite's mechanical energy is constant everywhere in its orbit.
b. Because gravity is a conservative force, the magnitude of the satellite's momentum is constant everywhere in its orbit.
c. Because gravity is a conservative force, the satellite's kinetic energy is constant everywhere in its orbit

7) A satellite is launched into a circular orbit 4.4×10^7 m above ***the center of the earth***. Unfortunately, a meteor smacks into the satellite, stopping it dead in its orbit. The broken satellite falls from rest straight towards the surface of the earth and crashes into the ocean. Recall that the radius and mass of the earth are approximately 6.36×10^6 m and 5.97×10^{24} kg, respectively. Neglecting its interaction with the atmosphere, how fast is the satellite moving when it crashes?

a. 3140 m/s
b. 10350 m/s
c. 27175 m/s
d. 29382 m/s
e. 4254 m/s

The next two questions pertain to the situation described below.



A box of mass m_1=7 kg is tied to a second box of mass m_2 = 3.6 kg. The second box has a massless spring (spring constant k = 2.4 N/m) attached to it and both masses rest on a frictionless surface. The boxes are initially tied together with a piece of rope in such a way so that the spring is compressed a distance d = 0.1 m from its equilibrium position as shown in fig i. The rope is then cut, releasing the boxes as shown in fig ii.

8) Comparing the total mechanical energy and momentum of the system of boxes and spring in figs i and ii (after the rope is cut), which of the following statements is true?

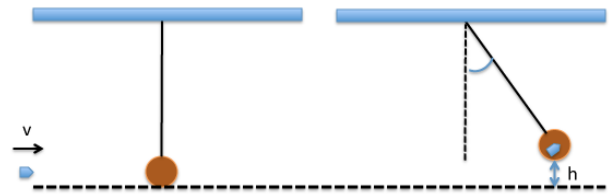
a. Both the system's mechanical energy and momentum are conserved
b. The system's momentum is conserved, but its mechanical energy is not
c. The system's mechanical energy is conserved, but its momentum is not

9) What is the final velocity of the second box V_2 in fig. ii, after the rope is cut and the two boxes are no longer in contact?

a. 0.066 m/s
b. 0.11 m/s
c. 0.034 m/s
d. 0.213 m/s
e. 0.056 m/s

The next three questions pertain to the situation described below.

A bullet of mass m is fired at a wooden ball of mass M hanging from a string of length L. The bullet has initial velocity v and embeds itself in the wooden ball when it hits.



10) Which of the following statements are true?

a. The collision is elastic and mechanical energy and momentum are conserved during the collision
b. The collision is inelastic and momentum is conserved during the collision, but not mechanical energy
c. The collision is inelastic and mechanical energy is conserved during the collision, but not momentum

11) After the bullet is embedded in the ball, which of the following statements best describes the swinging bullet + ball system and its subsequent motion?

a. The system's total momentum is conserved
b. The system's mechanical energy is conserved
c. The system's mechanical energy is the same as before the bullet struck the ball.

12) Which expression describes the maximum height of the ball?

a. $v^2/(2g)$
b. $m^2v^2/(2g(m+M)^2)$
c. $m^2v^2/(2gL(m+M)^2)$
d. $L - v^2/(2g)$
e. $v^2/(2gL)$

The next two questions pertain to the situation described below.

A basketball of mass m=1 kg is initially at rest h = 1.6 m above the ground. It falls to the ground, bounces back, and reaches a maximum post-bounce height that is only 70% of h. A camera measures the time interval in which the ball is in contact with the ground to be 0.1 second.

13) What is the average force exerted on the ball during its bounce, when it is in contact with the ground?

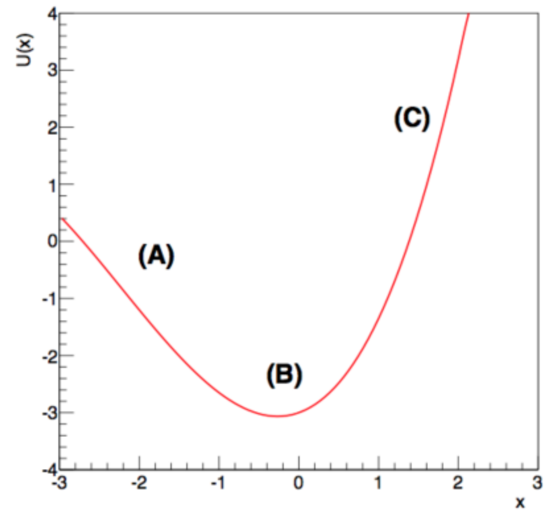
a. 156.96 N
b. 46.88 N
c. 56.03 N
d. 102.91 N
e. 47.09 N

14) Which of the following statements best describes the ball while it is in contact with the ground?

a. The total mechanical energy of the ball is conserved
b. The total momentum of the ball is conserved
c. Neither the total mechanical energy nor the total momentum of the ball is conserved.

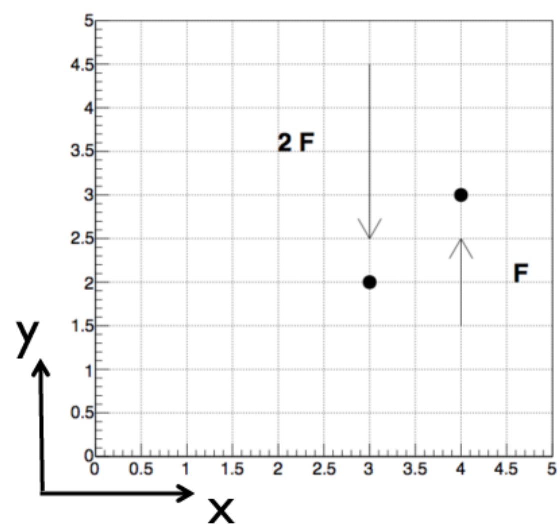
15) The figure shows a plot of the potential energy of a particle U(x) as a function of the particle's x coordinate.

At which of the three positions is the magnitude of the force acting on the particle the largest?



a. point B
b. point C
c. point A

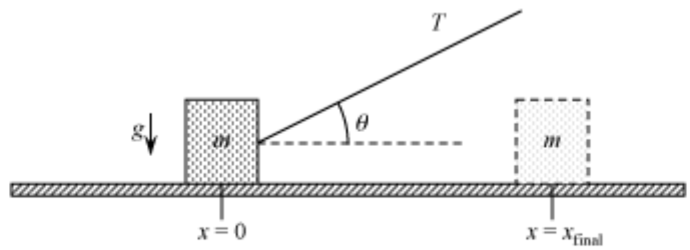
Two masses (each of mass M) are positioned as shown in the above figure. The left mass is acted on by a force of magnitude 2F in the negative y direction and the right mass is acted on by a force of magnitude F in the positive y direction, as shown by the arrows.



16) What is the acceleration of the center of mass of the system?

a. F /m and points along the negative y axis
b. F /2m and points along the negative y axis
c. F /2m and points along the positive y axis
d. 0 m/s
e. 2F /m and points along the negative y axis

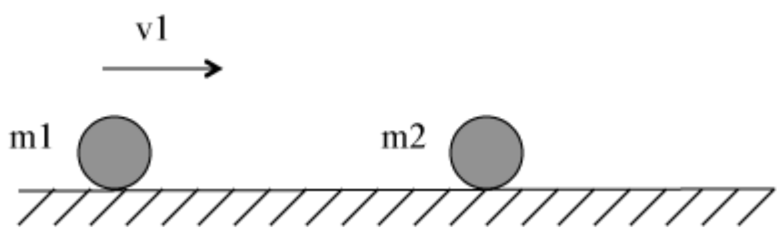
17) A mass m = 35 kg is towed along a frictionless surface by a rope in which a constant tension T = 45 N is maintained. The rope makes an angle θ = 26° to the horizontal, as shown in the figure.The mass is initially at rest at x = 0. As the mass passes the point x_{final} = 10 m, its speed v is



a. 404.46 m/s
b. 4.81 m/s
c. 5.07 m/s

The next two questions pertain to the situation described below.

A mass m1 = 4.5 kg initially moving on a frictionless surface to the right with a velocity of v1=10 m/s elastically collides with a second mass m2= 8 kg that is initially at rest. After the collision, m2 moves to the right. Before and after the collision, the masses move along the same line.



18) What is the velocity of the second mass after collision?

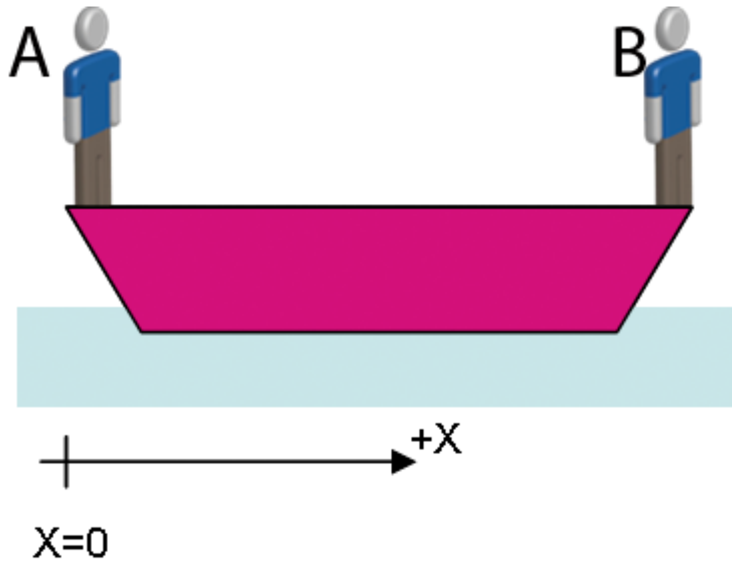
a. 6 m/s
b. 5.62 m/s
c. 10 m/s
d. 7.2 m/s
e. -6.4 m/s

19) In which direction is the first mass moving after the collision?

a. To the right
b. The mass is stationary
c. To the left

The next two questions pertain to the situation described below.

Two people (person A, mass 60 kg; person B, mass 70 kg) are at either end of a 200 kg boat which is L = 16 m long as shown in the figure. The water is still and the left edge of the boat is at x = 0 m



20) What is the x coordinate of the center of mass of the boat and two people system?

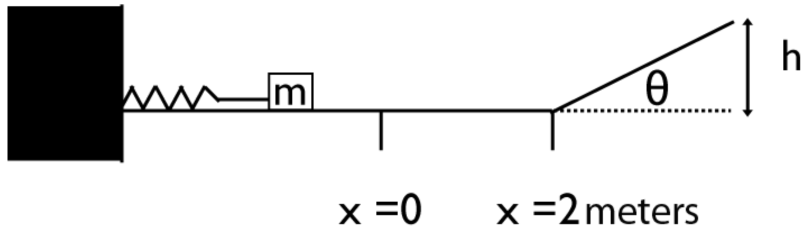
a. 8.24 m
b. 8 m
c. 7.76 m

21) Person A moves to the other end of the boat, to be with person B. By how much does the position of the boat change relative to the above situation?

a. 0.48 m
b. 2.91 m
c. 0 m
d. -2.91 m
e. -7.76 m

The next three questions pertain to the situation described below.

A block of mass m = 1.8 kg is at the end of a spring (k = 22 N/m) compressed by Δx = 0.19 m from its equilibrium position as shown.



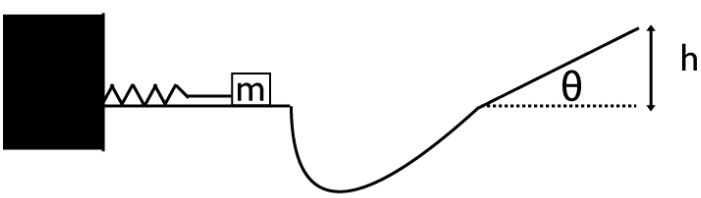
22) The block is on a table where the coefficient of kinetic friction increases for $x > 0$ so that $\mu_k(x) = \beta x/2$. For $x < 0$ the table is frictionless. If $\beta = 0.0025$, what is the maximum height the block reaches after it is released from the spring? Assume that x refers to the location of the right edge of the box. The ramp itself is frictionless.

a. 0.01999 m
b. 0.04248 m
c. 0.02186 m
d. 0.04373 m
e. The block does not reach the ramp

23) Now assume that a perfect lubricant is applied everywhere to the table so that there is no friction at all. The spring is compressed by the same amount, and the block is launched as before. The height on the ramp to which the block rises is now measured to be h_2. After this, the angle of incline is doubled to 2θ; the spring is again compressed by the same amount, the block launched, and the height h_3 to which the block rises measured. How does h_3 compare to h_2?

a. h_3 is more than h_2
b. h_3 is less than h_2
c. $h_3 = h_2$

24) The ramp's angle of incline is returned to θ and the table reshaped as shown. The table remains frictionless. When the block is launched in the same fashion as before, how does the height h to which it rises compare to the height h_2 in the previous problem?



a. h = h_2
b. h is less than h_2
c. h is more than h_2

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 $G = 6.67\times10^{-11}\ Nm^2/kg^2$)
$\mathbf{F}_{spring} = -k\,\mathbf{\Delta x}$

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)

<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

$I = \Sigma m_i r_i^2$
$I_{parallel} = I_{CM} + MD^2$
$I_{disk} = I_{cylinder} = {}^1\!/_2 MR^2$
$I_{hoop} = MR^2$
$I_{solid\text{-}sphere} = {}^2\!/_5 MR^2$
$I_{spherical\ shell} = {}^2\!/_3 MR^2$
$I_{rod\text{-}cm} = {}^1\!/_{12} ML^2$
$I_{rod\text{-}end} = {}^1\!/_3 ML^2$
$\tau = I\alpha$ (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:

$y(x,t) = A\cos(kx - \omega t)$
$k = 2\pi/\lambda$, $\omega = 2\pi f = 2\pi/T$
$v = \lambda f = \omega/k$

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:

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

$$A_1v_1 = A_2v_2$$

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

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

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