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 **108** points, composed of two types of questions.

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

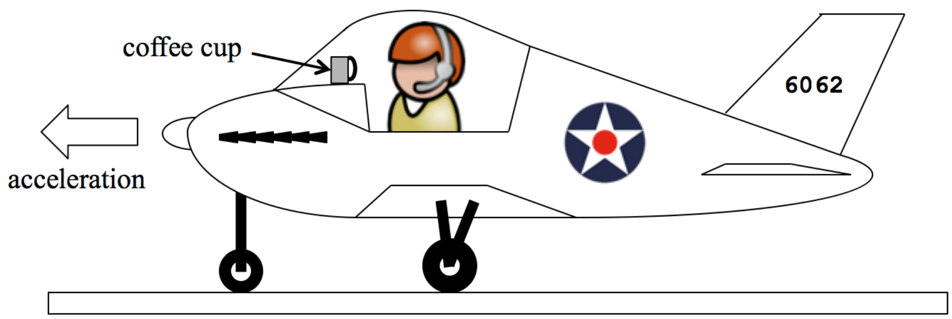
A) If you mark only one answer and it is the correct answer,
you earn **6** points.
B) If you mark two answers, one of which is the correct answer,
you earn **3** points.
C) If you mark three answers, one of which is the correct answer,
you earn **2** points.
D) If you mark no answers, or more than three, 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 careless pilot leaves an empty coffee cup on top of his instrument panel as he accelerates along a horizontal runway. There is friction between the instrument panel and the coffee cup, but it is insufficient to hold the cup in place. The cup slides off the instrument panel and bangs into the pilot as he accelerates down the runway.



1) As it slides along the instrument panel toward the pilot, the work done by friction on the cup is

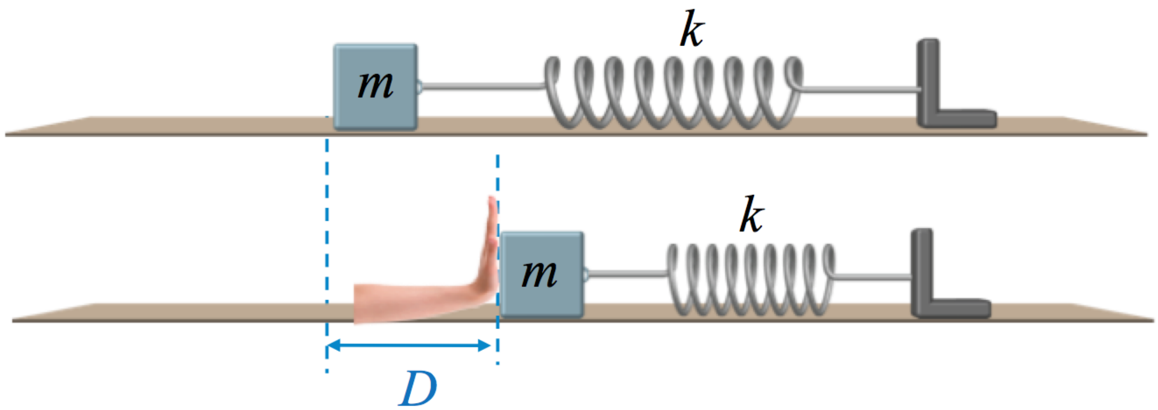
a. zero.
b. negative.
c. positive.

2) The direction of the frictional force acting on the cup is

a. towards the back of the plane.
b. towards the front of the plane.
c. undefined, since friction does no work in this case.

The next three questions pertain to the situation described below.

A box of mass m is initially at rest at $x = 0$ on a horizontal frictionless surface. It is attached to an unstretched spring with spring constant k, aligned with the x axis, whose other end is attached to a wall as shown. A hand applies a force on the box in the positive x direction so that it moves to the right with a constant velocity until it reaches $x = D$, where it stops moving.



3) What is the work done by the hand on the box?

a. $+\int_0^D \frac{1}{2}kx^2\,dx$
b. 0
c. $-\int_0^D kx\,dx$
d. $-\int_0^D \frac{1}{2}kx^2\,dx$
e. $+\int_0^D kx\,dx$

4) Suppose the answer to the above question is W_D. If the hand instead pushed the box twice the distance, the work done by the hand on the box is W_{2D}. How does W_{2D} compare with W_D?

a. $W_{2D} < 2W_D$
b. $W_{2D} > 2W_D$
c. $W_{2D} = 2W_D$

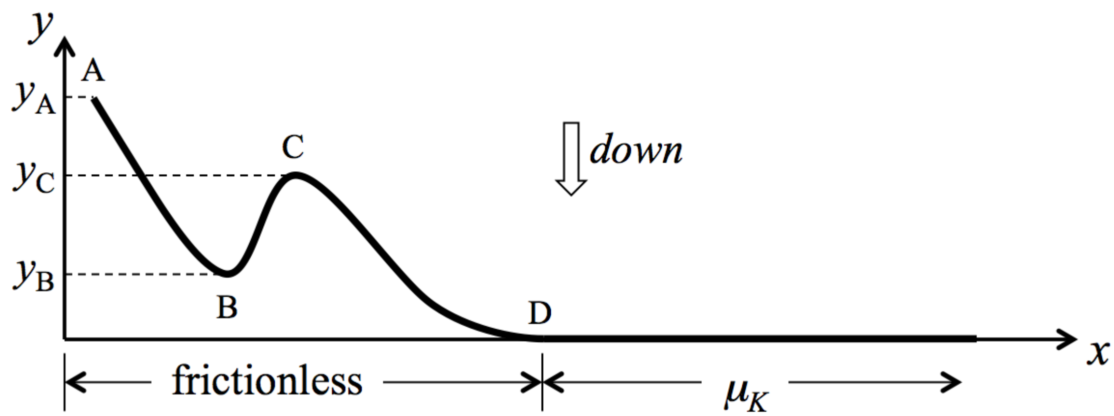
5) The total work done on the box by all forces during this motion is

a. zero.
b. positive.
c. negative.

The next three questions pertain to the situation described below.

A ski slope starts at point A, descends to point B, climbs to point C, then descends to point D. To the right of point D the surface is level and the coefficient of kinetic friction between the ground and the skier is μ_K. There is no friction anywhere to the left of point D. The elevations of points B, C, and D are y_B = 55 m, y_C = 115 m, and y_D = 0 m.

A skier starts from rest at point A and slides down the hill. She is observed to have a speed of 28 m/s at point C.



6) What is the starting elevation of the skier?

a. y_A = 115 m
b. y_A = 95 m
c. y_A = 155 m
d. y_A = 40 m
e. y_A = 210 m

7) If the skier slides a distance 540 m beyond point D before coming to rest, what is μ_K?

a. μ_K = 0.287
b. μ_K = 0.389
c. μ_K = 0.176
d. μ_K = 0.213
e. μ_K = 0.074

8) If y_A and μ_K were kept the same as above, but the elevation of point C were reduced to 40 m, the distance beyond point D that the skier would slide before stopping would be

a. greater than 540 m.
b. equal to 540 m.
c. less than 540 m.

The next three questions pertain to the situation described below.

A spherical planet has radius R_P = 7500 km and mass M_P = 8×10^{24} kg. The planet has a spherical moon of radius R_M = 2 × 10^3 km and mass M_M = 9 ×10^{22} kg. The distance between the center of the planet and the center of the moon is 2.5 × 10^5 km. The universal gravitational constant is $G = 6.67 \times 10^{-11} Nm^2/kg^2$.

9) How far from the center of the planet is the center of mass of the planet-moon system?

a. 2781.2 km
b. 1.25 × 10^5 km
c. 10197.8 km
d. 7438.8 km
e. 2.5 × 10^5 km

10) What is the escape velocity from the surface of the planet (i.e. the minimum initial velocity that an object launched from the surface needs to have in order to get infinitely far away) ? Ignore any effects due to the moon.

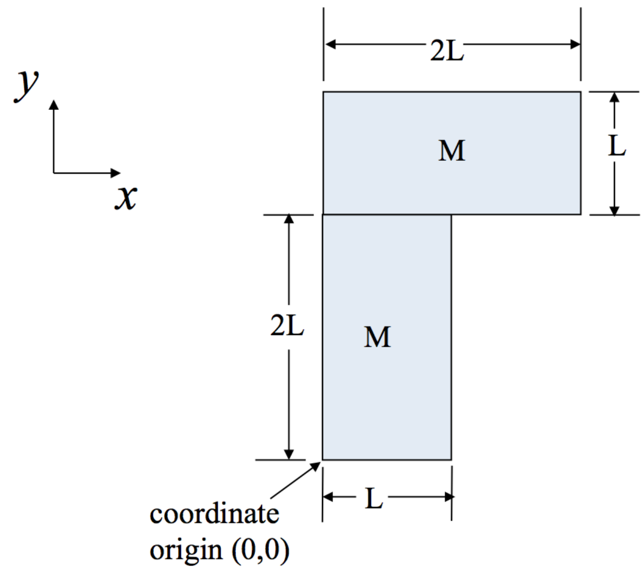
a. V_i = 4.4 m/s
b. V_i = 5964.3 m/s
c. V_i = 11928.7 m/s
d. V_i = 16869.7 m/s
e. V_i = 8434.8 m/s

11) If the planet was compressed so that it had the same mass but one quarter the radius, how would the escape velocity change?

a. It would double.
b. It would quadruple.
c. It would stay the same.

The next two questions pertain to the situation described below.

Two rectangular blocks each have mass M, length 2L, and width L. They are arranged as shown in the figure. In the following questions, use the lower left-hand corner of the system as the origin.



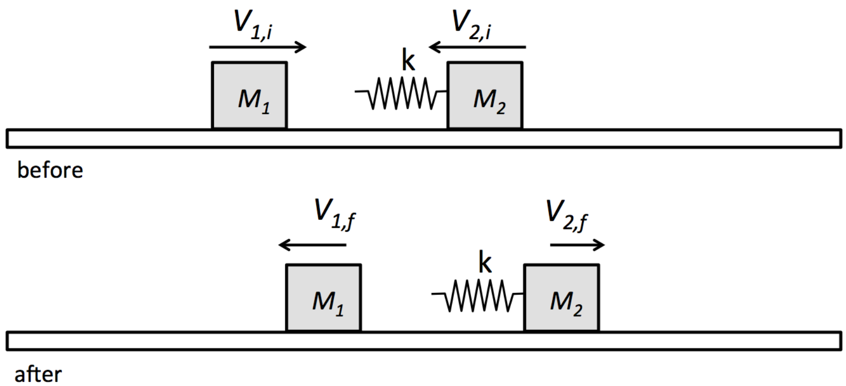
12) What are the (x,y) coordinates of the center of mass of the system?

a. (3L/4, 7L/4)
b. (3L/5, 7L/5)
c. (5L/4, 9L/4)
d. (3L/2, 5L/4)
e. (2L/3, 4L/3)

13) If the mass of the top block were decreased but its size were to remain the same, what would happen to the location of the center of mass of the system?

a. It will move to the left and up.
b. It will move to the left and down.
c. It will move to the right and up.

The next two questions pertain to the situation described below.



Two carts move toward each other on a one-dimensional horizontal frictionless track. Cart 1 has mass M_1 = 2 kg and initial velocity $V_{1,i}$ = 2.596 m/s. Cart 2 has mass M_2 = 3.1 kg and initial velocity $V_{2,i}$ = -0.935 m/s. A spring between them makes the collision between the carts elastic.

14) Before the collision, what is the velocity of cart 1 as viewed by someone in the center of mass reference frame?

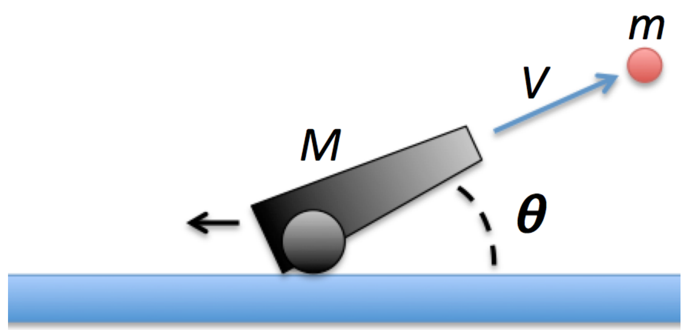
a. $V^*_{1,i}$ = 2.15 m/s
b. $V^*_{1,i}$ = -2.15 m/s
c. $V^*_{1,i}$ = -1.38 m/s
d. $V^*_{1,i}$ = 1.38 m/s
e. $V^*_{1,i}$ = 0.45 m/s

15) After the collision, what is the speed of cart 1 as viewed by someone in the reference frame of cart 2?

a. $V_{1,2}$ = 0.45 m/s
b. $V_{1,2}$ = 1.66 m/s
c. $V_{1,2}$ = 4.52 m/s
d. $V_{1,2}$ = 3.53 m/s
e. $V_{1,2}$ = 2.45 m/s

The next three questions pertain to the situation described below.

A cannon of mass M = 2100 kg is initially at rest on a horizontal frictionless surface of ice. It fires a cannonball of mass m = 55 kg (not included in M). An observer on the ice measures the initial angle of the cannonball as it exits the cannon's barrel to be θ = 35 degrees above horizontal, and its initial speed to be V = 240 m/s. The cannon recoils and slides to the left.



16) Considering the system made up of the cannon and the cannonball, which of the following quantities are the same just before and just after the cannonball is fired?

a. The horizontal component of momentum.
b. Both the horizontal and vertical components of momentum.
c. The vertical component of momentum.

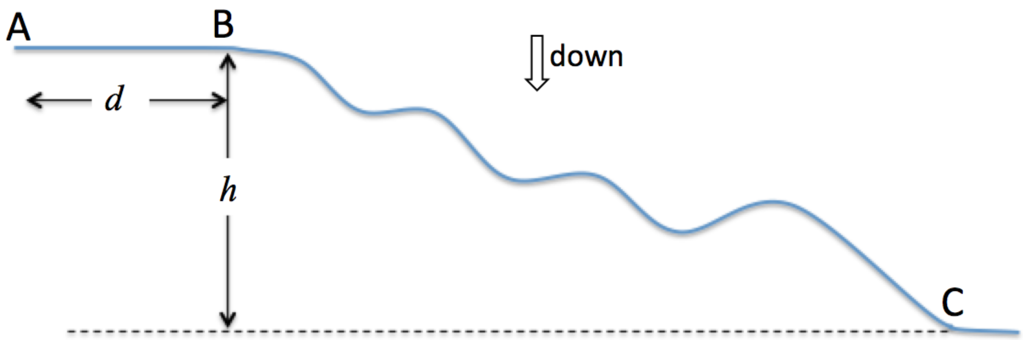
17) In the reference frame of the cannon, the initial angle of the cannonball relative to the surface of the ice is

a. greater than 35 degrees.
b. equal to 35 degrees.
c. less than 35 degrees.

18) At the instant the cannonball hits the ice, how far to the left of its initial position has the cannon moved? (You can neglect the height of the cannon's barrel above the ice in your calculation.)

a. 5517.5 m
b. 144.5 m
c. 101.2 m
d. 206.4 m
e. 72.3 m

The next three questions pertain to the situation described below.



A bobsled having mass M = 210 kg is initially at rest at point A at the top of the track shown in the figure. The distance from point A to point B is d = 25 m and is horizontal. From point B to point C the track twists and turns as it moves down the hill. The vertical distance from point B to point C is h = 95 m. The track is **not** frictionless.

19) Four men, each having the same mass m = 85 kg, start pushing the sled from point A toward point B. Each one pushes with the same force 157.5 N for the whole distance d. When the bobsled reaches point B its speed is 10 m/s. What was the total work done by all forces on the bobsled as it moved from point A to point B?

a. 7×10^3 J
b. 2.1×10^4 J
c. 15750 J
d. 10500 J
e. 31500 J

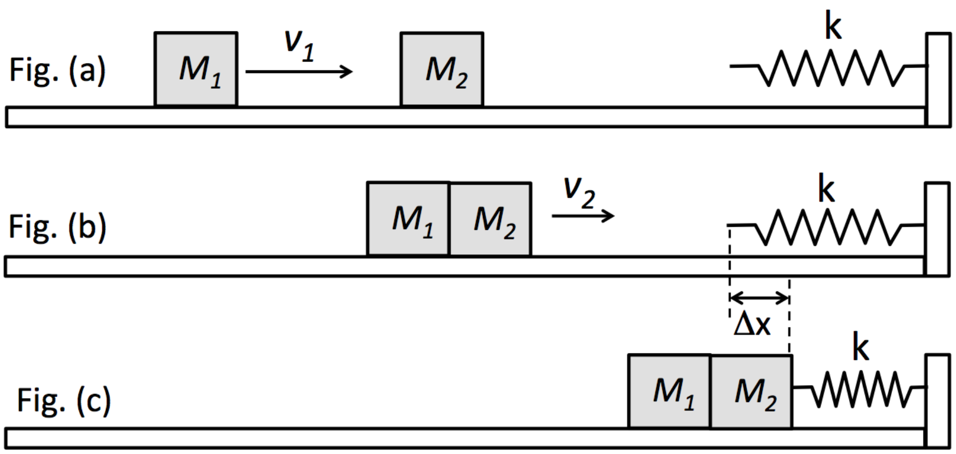
20) The four men jump on the bobsled at Point B and slide down the hill. As they pass point C at the bottom of the hill their speed is 60 m/s. What was the work done on the bobsled and the men by nonconservative forces as they moved from point B to point C?

a. -512572 J
b. 449928 J
c. 512572 J
d. 171790 J
e. 962500 J

21) The total work done on the bobsled by all forces between point A and point C is

a. negative.
b. zero.
c. positive.

The next three questions pertain to the situation described below.



A box of mass M_1 slides on a horizontal frictionless surface with speed V_1, as in Fig. (a). It collides with, and sticks to, an initially stationary box of mass M_2, as in Fig. (b). The speed of the boxes moving together after the collision is V_2.

22) Which of the following is a correct expression for M_1 in terms of other variables?

a. $M_1 = M_2 V_2/(V_1 - V_2)$
b. $M_1 = M_2 V_2/V_1$
c. $M_1 = M_2(V_1 - V_2)/V_2$

23) If $M_1 = 5$ kg and $M_2 = 7$ kg, what is the ratio of the final kinetic energy of the blocks just after the collision, K_F, to the initial kinetic energy of the blocks just before the collision, K_I?

a. $K_F/K_I = 7/5$
b. $K_F/K_I = 2/7$
c. $K_F/K_I = 5/7$
d. $K_F/K_I = 7/12$
e. $K_F/K_I = 5/12$

24) The boxes now slide into the free end of a spring whose other end is fixed as shown in Fig. (c). If the spring constant is k, which of the following is a correct expression for the maximum compression of the spring ΔX in terms of other variables?

a. $\Delta X = V_2\sqrt{(M_1 + M_2)/2k}$
b. $\Delta X = V_2\sqrt{(M_1 + M_2)/k}$
c. $\Delta X = V_1\sqrt{M_1/2k}$

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 $G = 6.67 \times 10^{-11}\ Nm^2/kg^2$)

$\mathbf{F}_{spring} = -k\,\mathbf{\Delta x}$

Friction

$f = \mu_k N$ (kinetic)

$f \leq \mu_S N$ (static)

Work & Kinetic energy

$W = \int \mathbf{F}\cdot d\mathbf{l}$

$W = \mathbf{F}\cdot\mathbf{\Delta r} = F\,\Delta r\,\cos\theta$

(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

$s = R\theta$, $v = R\omega$, $a = R\alpha$

$\left.\begin{array}{l} \theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2 \\ \omega = \omega_0 + \alpha t \\ \omega^2 = \omega_0^2 + 2\alpha\Delta\theta \end{array}\right\}$

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:

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

$$A_1 v_1 = A_2 v_2$$

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

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

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