Last Name: ________________ First Name: ______________________ NetID: __________________

Discussion Section: ______ Discussion TA: ____

Instructions – ***Turn off your cell phone and put it away. Please keep your calculator on your own desk. Calculators may not be shared.***

This is a closed book exam. You have (1.5) hours to complete it.

I. *Fill in ALL the information requested on the lines above and sign the Formula Sheet.*

II. At the end of this exam, you must return this Exam Booklet complete with all pages, including the formula sheet, along with your answer sheet.

III. If you do not turn in a complete Exam Booklet, your Answer Sheet will not be graded, and you will receive the grade AB (Absent) for this exam.

1. Fill in completely (until there is no white space visible) the circle for each intended input – both on the identification side of your answer sheet and on the side on which you mark your answers. 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.
2. Print your last name in the **YOUR LAST NAME** boxes on your answer sheet and print the first letter of your first name in the **FIRST NAME INI** box. Mark (as described above) the corresponding circle below each of these letters.
3. Print your NetID in the **NETWORK ID** boxes, and then mark the corresponding circle below each of the letters or numerals. Note that there are different circles for the letter "I" and the numeral "1" and for the letter "O" and the numeral "0". **Do not** mark the hyphen circle at the bottom of any of these columns.
4. You may find the version of **this Exam Booklet at the top of the page** Mark the **version** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**
5. Stop **now** and double-check that you have bubbled in all the information requested in 2 through 4 above and that your marks meet the criteria in 1 above. Check that you do not have more than one circle marked in any of the columns.
6. 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.
7. On the **SECTION** line, print your **DISCUSSION SECTION**. (You need not fill in the COURSE or INSTRUCTOR lines.)
8. Sign **(DO NOT PRINT)** your name on the **STUDENT SIGNATURE** line.

CHECK NOW THAT YOU HAVE COMPLETED ALL OF THE ABOVE STEPS

Before starting work, check to make sure that your test booklet is complete. Grading policy is explained on page 2.

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 dismissal from the university.

This Exam Booklet is Version A. Mark the **A** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is composed of three types of multiple choice questions in addition to the free response questions on the last page.

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 four answers, one of which is the correct answer, you earn **1.5** points.
(d) If you mark five answers, one of which is the correct answer, you earn **1.2** points

MC3: *multiple-choice-three-answer questions, each worth 3 points.* **Partial credit will be granted as follows.**

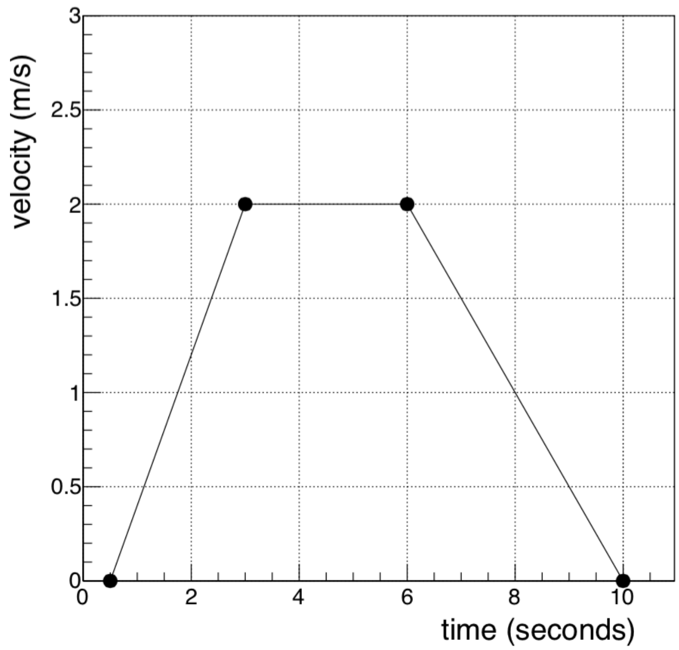
(a) If you mark only one answer and it is the correct answer, you earn **3** points.
(b) If you mark two answers, one of which is the correct answer, you earn **1.5** points.
(c) If you mark three answers, one of which is the correct answer, you earn **1** point.

MC2: *multiple-choice-three-answer questions, each worth 2 points.* **Partial credit will be granted as follows.**

(a) If you mark only one answer and it is the correct answer, you earn **2** points.
(b) If you mark two answers, one of which is the correct answer, you earn **1** point.

The next two questions pertain to the situation described below.

A box of mass $m_1 = 2$ kg moves along the x axis. A plot of its velocity versus time is shown in the figure to the right.



1) Which of the following statements is true?

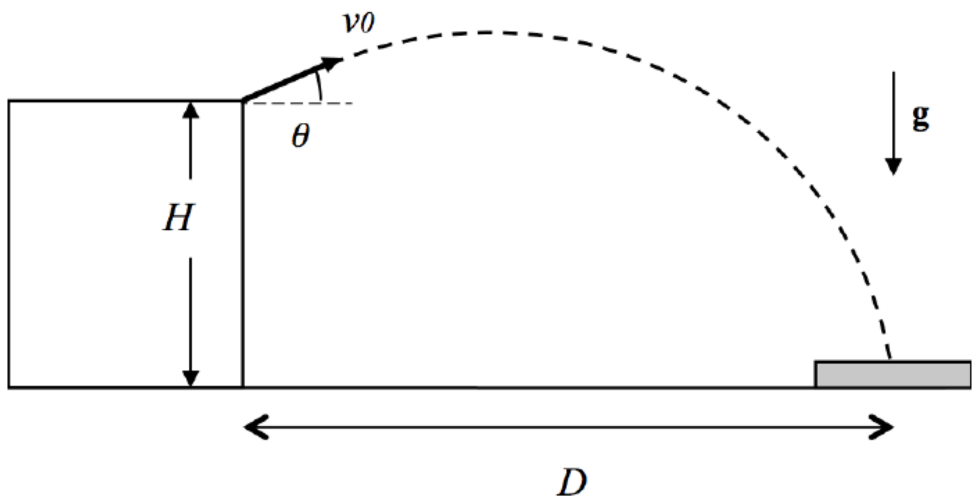
a. The magnitude of the acceleration of the box is larger at t = 2 seconds than at t = 8 seconds.
b. The magnitude of the acceleration of the box is smaller at t = 2 seconds than at t = 8 seconds.
c. The magnitude of the acceleration of the box is the same at t = 2 seconds and at t = 8 seconds.

2) What is the displacement of the box between t = 6 seconds and t = 10 seconds?

a. -8 m
b. 0 m
c. 8 m
d. 4 m
e. -4 m

The next two questions pertain to the situation described below.

A stuntwoman jumps from the rooftop of a building with an initial velocity $v0 = 4$ m/s at an angle $\theta = 26$ degrees with respect to the ground. She lands on a mattress as shown. The height of the building is $H = 6$ m. Ignore air resistance and the thickness of the mattress.



3) At what horizontal distance, D, from the base of the building does she land?

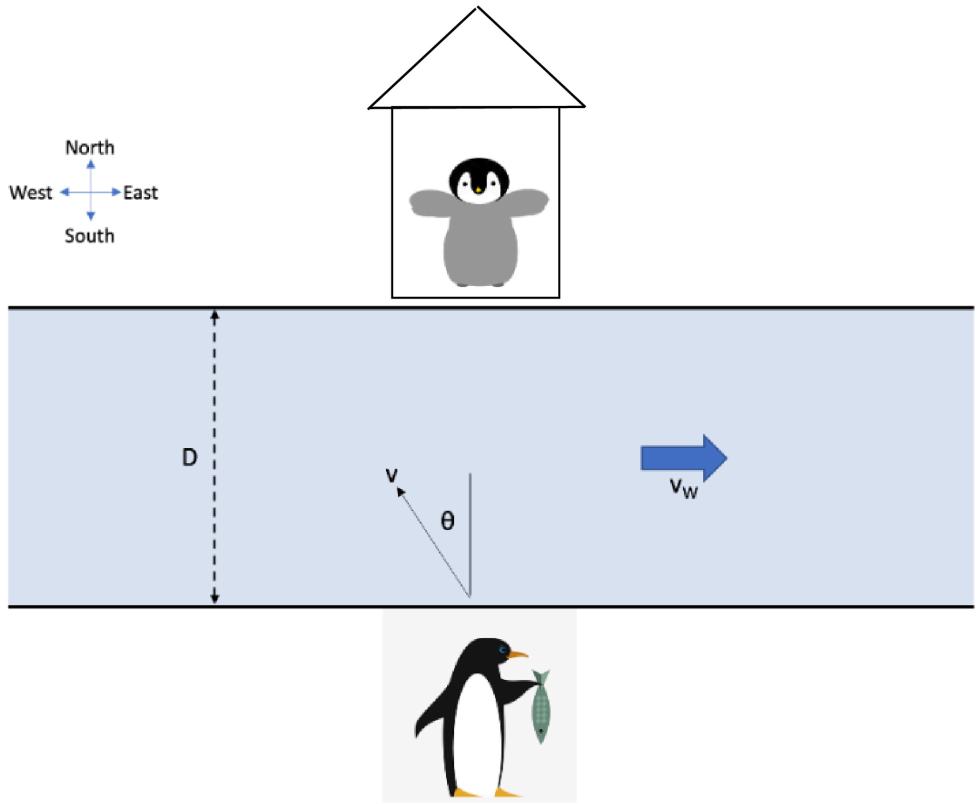
a. 3.98 m
b. 7.16 m
c. 2.69 m
d. 4.67 m
e. 5.7 m

4) The stuntwoman now jumps horizontally ($\theta = 0°$) from the rooftop with the same initial speed. How does her time in the air, $T_{horizontal}$, compare to the answer to the previous problem, call it T_{angle}?

a. $T_{horizontal} > T_{angle}$
b. $T_{horizontal} = T_{angle}$
c. $T_{horizontal} < T_{angle}$

The next two questions pertain to the situation described below.

A penguin on the south shore of a river has a fish dinner to bring home to its baby. The baby is standing on the northern shore of the river, directly north of its parent. Unfortunately, the two are on the opposite sides of the river, separated by a distance of D = 200 m. The water between the two is flowing to the east at a rate of v_W = 4 m/s, parallel to the shores. The penguin parent can swim at a speed of v = 5.5 m/s.



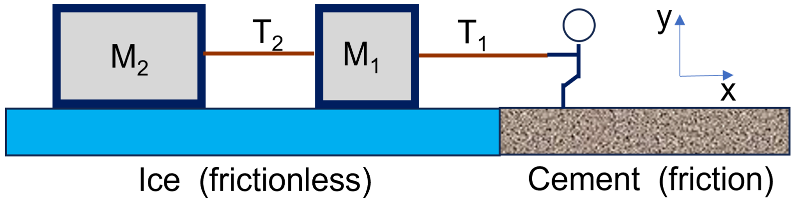
5) What angle θ does the penguin swim to arrive directly across the river?

a. 41.7 degrees
b. 46.7 degrees
c. 43.3 degrees
d. 36 degrees
e. 47.7 degrees

6) How long does it take for the penguin to reach their baby?

a. 36.4 s
b. 138.2 s
c. 53 s

The next three questions pertain to the situation described below.



A student is pulling two boxes connected by a rope. The left box has mass M_2 = 14 kg and the right box has mass M_1 = 18 kg. Both boxes are initially on frictionless ice, the person is standing on cement with coefficient static friction μ_s = 0.8 and coefficient of kinetic friction μ_k = 0.25. The person pulls rope 1 with a constant force T_1 = 125 N

7) What is the *x* component of the acceleration of the blocks?

a. a_x= 3.91 m/s^2
b. a_x= 8.93 m/s^2
c. a_x= 6.94 m/s^2

8) What is the tension in the rope connecting the two blocks?

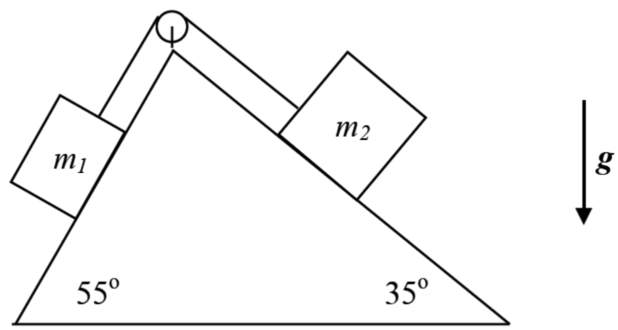
a. T_2= 70.3 N
b. T_2= 97.2 N
c. T_2= 54.7 N

9) The student continues to pull with the constant force. What is the *x* component of the acceleration of the blocks, when block M_1 is on the cement, and block M_2 is on the ice?

a. a_x= 2.83 m/s^2
b. a_x= 2.53 m/s^2
c. a_x= 1.45 m/s^2

The next three questions pertain to the situation described below.

Two masses m_1 and m_2 are attached together with a rope that passes over a massless pulley at the apex of a triangular box as shown. The rope does not stretch and there is no friction between the masses and the box.



10) At an instant when the magnitude of the acceleration of block 1 is observed to be a_1, what is the magnitude of the acceleration of block 2, a_2?

a. a_2 is larger than a_1
b. a_2 is smaller than a_1
c. a_2 is equal to a_1

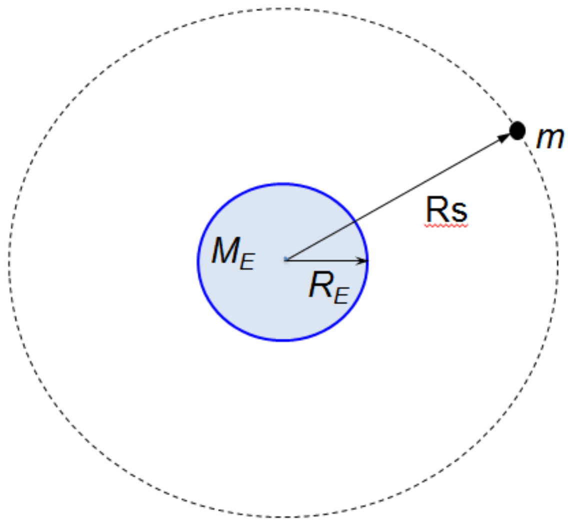
11) If $m_1 = 10$ kg and $m_2 = 20$ kg, what is a_1, the magnitude of the acceleration of m_1?

a. 3.8 m/s^2
b. 0.3 m/s^2
c. 2.7 m/s^2
d. 3.5 m/s^2
e. 1.1 m/s^2

12) If m_1 remains 10 kg, but m_2 is now adjusted so that the acceleration $a_1 =$ 0, what is the tension T in the rope?

a. 56 N
b. 80 N
c. 98 N

The next two questions pertain to the situation described below.



A satellite is put into a circular orbit around the earth. The radius of the satellite's orbit is $R_S = 19 \times 10^6$ m (measured from the center of the earth). The satellite has a mass of $m = 182$ kg. The radius of the Earth is $R_E = 6.37 \times 10^6$ m, the mass of the Earth is $M_E = 5.97 \times 10^{24}$ kg, and the universal gravitational constant is $G = 6.67 \times 10^{-11}\ Nm^2/kg^2$.

13) What is the period of the satellite's orbit?

a. 6.52 hours
b. 5.07 hours
c. 5.79 hours
d. 8.84 hours
e. 7.24 hours

14) Suppose the speed of the satellite as it moves in the above orbit is V_0. If the radius of the circular orbit of the satellite were increased, the speed of the satellite would

a. Be equal to V_0.
b. Be less than V_0.
c. Be greater than V_0.

The next two questions pertain to the situation described below.

In a repeat of a P211 lab experiment, you set an IOLab on its wheels at the base of a ramp made from a flat wooden board. You give the IOLab a quick push up the ramp, so that it rolls freely up to the top of the ramp and then back down. You repeat this process several times, recording the acceleration measured by the wheel sensor. Analyzing the acceleration data, you conclude that the (magnitude of the) acceleration for free rolling up the ramp was 1.03 +/- 0.02 m/s^2, and acceleration down the ramp was 0.85 +/- 0.01 m/s^2.

15) What is the t' value of the upward and downward accelerations?

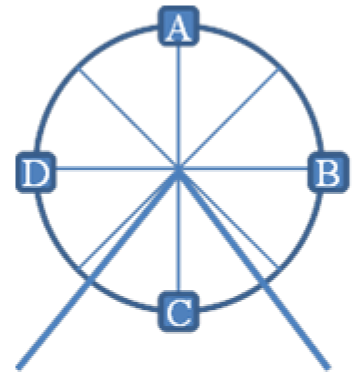
a. 360
b. 8.05
c. 1.04

16) You suspect that the difference between the upward and downward accelerations is due to friction, which you model simply as a frictional force between the IOLab wheels and the board. If the IOLab mass is 0.19 kg, approximately how large would this force have to be to account for the difference in accelerations?

a. 0.034 N
b. 0.068 N
c. 0.017 N

The next two questions pertain to the situation described below.

A Ferris wheel has a radius R and is turning counter-clockwise at a constant angular velocity ω. A student of mass m is sitting in the car labeled A. (Note on this ride, the person is always sitting upright. They do not go upside down)



17) At the instant shown, what is the magnitude of the force that the seat exerts on the student ?

a. $F_{seat,student} = mg$
b. $F_{seat,student} = mg - m\omega^2 R$
c. $F_{seat,student} = m\omega^2 R$
d. $F_{seat,student} = mg + m\omega^2 R$
e. $F_{seat,student} = \sqrt{(mg)^2 + (m\omega^2 R)^2}$

18) At the instant shown, what is the magnitude of the total force on the student ?

a. $F_{total} = mg$
b. $F_{total} = m\omega^2 R$
c. $F_{total} = 0$

This is the last multiple choice question of the exam. Make sure you have completed your bubble sheet, then you can work on the free response page of the exam. Be sure to write your name, netid and section on the free response page.

19) Did you check your answer sheet to ensure you

1. Entered your netid
2. Entered your exam version
3. Marked answers for all 19 questions (including this one)

a. Yes (I did all 3)
b. No (I did not enter my netid)
c. No (I did not enter my exam version)

Name: ____ NetID: _____________ Section: **D__ __**

Physics 211 – Exam 1 Free Response

- Show your work and thinking clearly. Points will not be given if you just give the final answers without showing your work.
- **For this problem, you are only allowed to use the formulas on the formula sheet. If your solution uses other formulas that you may have memorized, points will be deducted.**

Your friend is driving her car along a straight horizontal road. The mass of the car is $M = 1200$ kg and it has an initial velocity of $v_i = 30$ m/s. She slams on the brakes, locking the wheels so they don't spin, and skids to a stop leaving a black rubber skid-mark on the road. The car skids for exactly $t = 7$ seconds as it comes to rest.

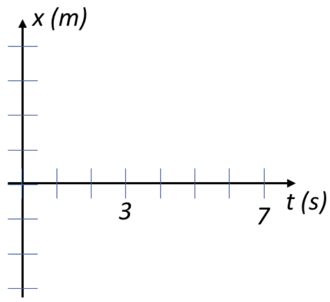
(a) How long is the skid mark on the road? (4 points)

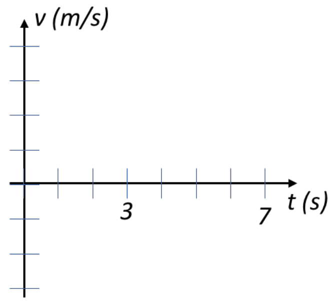
(b) As the car is skidding to a stop, is it the coefficient of **kinetic** or **static** friction that is relevant to the rate at which it slows down? Briefly explain your choice. (2 points)

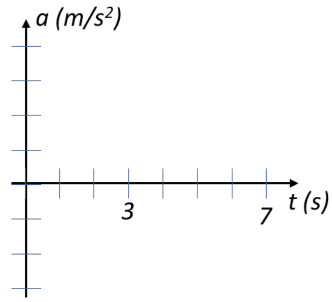
(c) Calculate the coefficient of friction between the tires and the road as the car skids to a stop. (4 points)

More questions on the back side of this sheet

(d) Using the result you obtained above, sketch the plots of $x(t)$, $v(t)$, and $a(t)$. Set $t = 0$ and x=0 to be the instant when your friend first hits the brakes. Be sure to label values for at least two tic marks on the y-axis of each plot (3 points)







(e) Your friend calls a tow truck to tow her car. The truck driver hooks a chain on the car and pulls the car with an acceleration of $a = 2$ m/s^2. Draw the free-body diagram of the car. (3 points)

(f) What is the horizontal force applied by the chain on the car while it accelerates at $a = 2$ m/s^2 ? (4 points)

Kinematics

$\vec{v} = \vec{v}_0 + \vec{a}t$

$\vec{r} = \vec{r}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$

$v^2 = v_0^2 + 2a(x - x_0)$

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

$\vec{V}_{\mathrm{A,B}} = \vec{V}_{\mathrm{A,C}} + \vec{V}_{\mathrm{C,B}}$

Uniform Circular Motion

$a = v^2/r$

$v = \omega r$

$\omega = 2\pi/T = 2\pi f$

Dynamics

$\vec{F}_{\mathrm{net}} = m\vec{a} = d\vec{p}/dt$

$\vec{F}_{\mathrm{A,B}} = -\vec{F}_{\mathrm{B,A}}$

$F = mg$ (near Earth's surface)

$F_{12} = Gm_1m_2/r^2$ (in general)

$F_{\mathrm{spring}} = -k\Delta x$

Friction

$f = \mu_{\mathrm{k}} N$ (kinetic)

$f \le \mu_{\mathrm{s}} N$ (static)

Work & Kinetic Energy

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

$W = \vec{F} \cdot \vec{\Delta r} = F\,\Delta r \cos\theta$ (constant force)

$W_{\mathrm{grav}} = -mg\Delta y$

$W_{\mathrm{spring}} = -k\left(x_2^2 - x_1^2\right)/2$

$K = mv^2/2$

$W_{\mathrm{net}} = \Delta K$

Potential Energy

$U_{\mathrm{grav}} = mgy$ (near Earth's surface)

$U_{\mathrm{grav}} = -GMm/r$ (in general)

$U_{\mathrm{spring}} = kx^2/2$

$\Delta E = \Delta K + \Delta U = W_{\mathrm{nc}}$

Power

$P = dW/dt$

$P = \vec{F} \cdot \vec{v}$

System of Particles

$\vec{R}_{\mathrm{CM}} = \sum m_i \vec{r}_i / \sum m_i$

$\vec{V}_{\mathrm{CM}} = \sum m_i \vec{v}_i / \sum m_i$

$\vec{A}_{\mathrm{CM}} = \sum m_i \vec{a}_i / \sum m_i$

$\vec{P} = \sum m_i \vec{v}_i$

$\sum \vec{F}_{\mathrm{ext}} = M\vec{A}_{\mathrm{CM}} = d\vec{P}/dt$

Impulse

$\vec{I} = \int \vec{F}\,dt$

$\Delta\vec{P} = \vec{F}_{\mathrm{avg}}\Delta t$

Collisions

If $\sum \vec{F}_{\mathrm{ext}} = 0$ in some direction, then $\vec{P}_{\mathrm{before}} = \vec{P}_{\mathrm{after}}$ in this direction:

$\sum m_i \vec{v}_i$ (before) $= \sum m_i \vec{v}_i$ (after)

In addition, if the collision is elastic:

- $E_{\mathrm{before}} = E_{\mathrm{after}}$
- *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

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

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega = \omega_0 + \alpha t$

$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

Rotational Dynamics

$I = \sum m_i r_i^2$

$I_{\mathrm{parallel}} = I_{\mathrm{CM}} + MD^2$

$I_{\mathrm{disk}} = I_{\mathrm{cylinder}} = \frac{1}{2}MR^2$

$I_{\mathrm{hoop}} = MR^2$

$I_{\text{solid-sphere}} = \frac{2}{5}MR^2$

$I_{\text{spherical-shell}} = \frac{2}{3}MR^2$

$I_{\text{rod-cm}} = \frac{1}{12}ML^2$

$I_{\text{rod-end}} = \frac{1}{3}ML^2$

$\tau = I\alpha$ (rotation about a fixed axis)

$\tau = \vec{r} \times \vec{F},\ |\tau| = rF\sin\phi$

Work & Energy

$K_{\mathrm{rotation}} = \frac{1}{2}I\omega^2$

$K_{\mathrm{translation}} = \frac{1}{2}MV_{\mathrm{CM}}^2$

$K_{\mathrm{total}} = K_{\mathrm{rotation}} + K_{\mathrm{translation}}$

$W = \tau\theta$

Statics

$\sum \vec{F} = 0,\ \sum \tau = 0$ (about any axis)

Quadratic Equation

Solution to $ax^2 + bx + c = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Angular Momentum

$\vec{L} = \vec{r} \times \vec{p}$

$L_z = I\omega_z$

$\vec{L}_{\mathrm{total}} = \vec{L}_{\mathrm{CM}} + \vec{L}^*$

$\tau_{\mathrm{ext}} = d\vec{L}/dt$

$\tau_{\mathrm{cm}} = d\vec{L}^*/dt$

$\Omega_{\mathrm{precession}} = \tau/L$

Simple Harmonic Motion

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

$x(t) = A\cos(\omega t + \phi)$

$b(t) = -\omega A\sin(\omega t + \phi)$

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

$\omega^2 = k/m$ (mass on spring)

$\omega^2 = g/L$ (simple pendulum)

$\omega^2 = mgR_{\mathrm{CM}}/I$ (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

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

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

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

$$\frac{d^2y}{dx^2} = \frac{1}{v^2}\frac{d^2y}{dt^2} \text{ (wave equation)}$$

Fluids

$$\rho = \frac{m}{V}$$

$$p = \frac{F}{A}$$

$A_1 v_1 = A_2 v_2$

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

$F_{\mathrm{B}} = \rho_{\mathrm{liquid}} g V_{\mathrm{liquid}}$

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

Uncertainties

$$\delta = \frac{\sigma}{\sqrt{N}}$$

$$t' = \frac{|\mu_{\mathrm{A}} - \mu_{\mathrm{B}}|}{\sqrt{\delta_{\mathrm{A}}^2 + \delta_{\mathrm{B}}^2}}$$