Last Name:________First Name__________Network-ID__________
Discussion Section:_________Discussion TA Name:________________________________

Instructions—
Turn off your cell phone and put it away.
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 a pen. 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 page 2**. Mark the version circle in the **TEST FORM** box at the bottom on the front side of your answer sheet.

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

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

Before starting work, check to make sure that your test booklet is complete. You should have 14 ***numbered pages*** *that include two (2) Formula Sheets.*

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 at the bottom on the front side of your answer sheet.

Exam Grading Policy —
The exam is worth a total of more than 100 points, and will be scaled to 100 points. It is composed of three 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.

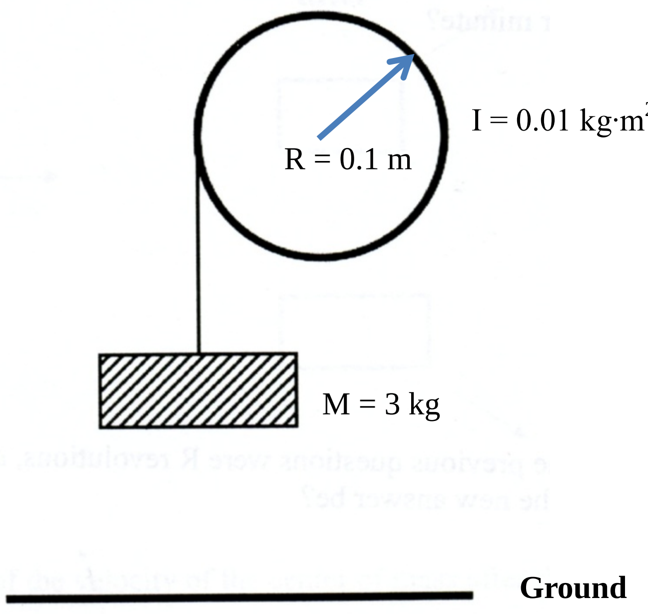
TF: *true-false questions, each worth 2 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer, you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

Unless told otherwise, you should assume that the acceleration of gravity near the surface of the earth is 9.8 m/s^2 *downward and ignore any effects due to air resistance.*

The following three questions concern the same physical situation:

Consider a block attached to a massless rope. The rope is wrapped on a massive fixed pulley as shown.
The mass of the block is M = 3 kg. The radius of the pulley is R = 0.1 m. The moment of inertia of the pulley is I = 0.01 kg·m^2.
The block is released from rest. The rope does not slip. When the block has fallen 2 m the pulley is found to rotate at 8.0 revolutions per second.



1. How fast is the block falling at this point?

   a. 1.0 m/s
   b. 2.0 m/s
   c. 5.0 m/s

2. What is the rotational kinetic energy of the pulley at the same time point?

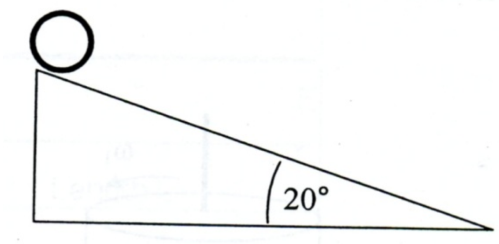
   a. 12.6 J
   b. 13.5 J
   c. 19.8 J

3. The acceleration of the block a is

   a. $a < g$
   b. $a > g$
   c. $a = g$

The following two questions concern the same physical situation:

A hoop (or ring) is released from rest at the top of an inclined plane as shown. The radius of the hoop R = 0.4 m and its mass M = 0.4 kg.
The angle between the plane and the horizontal is 20 degrees. The height of the inclined plane h = 0.8 m. Note: The hoop rolls without slipping.



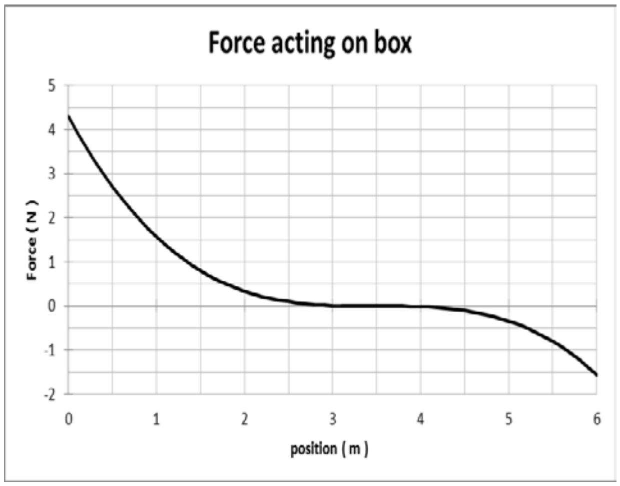
4. What is the translational speed of the hoop when it reaches the bottom of the inclined plane?

   a. 2.8 m/s
   b. 3.6 m/s
   c. 4.2 m/s
   d. 5.7 m/s
   e. 6.6 m/s

5. What is the ratio of the hoop's rotational kinetic energy to its translational kinetic energy, K_{rot}/K_{trans}?

   a. 1/3
   b. 1/2
   c. 1
   d. 3/2
   e. 2

6. A box slides for 6.0 m in the positive direction along a straight line on the floor. During that time a variable force *F* acts on the box in a direction parallel to its motion. From the graph of *F* vs. position shown below, determine which answer most closely matches the work done by *F* as it acted on the box.



a. 2.8 J
b. 5.0 J
c. 6.0 J
d. 25 J
e. 36 J

The following two questions concern the same physical situation:

A hoop and a cylinder of equal mass and radius are rolling down an incline plane without slipping from the same initial height. The hoop has rotational inertia $I_{hoop} = MR^2$ and the cylinder has rotational inertia $I_{cyl} = ½\, MR^2$.

7. When they reach the bottom of the incline, which object has the largest translational kinetic energy?

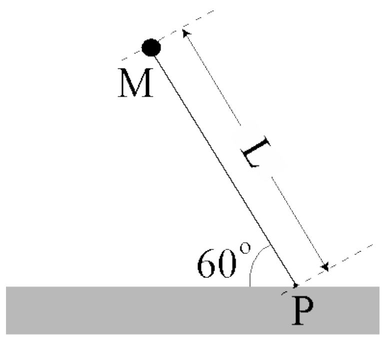
a. the cylinder
b. the hoop
c. the hoop and the cylinder have the same translational kinetic energy

8. In a race down the incline, which of the two will win?

a. the cylinder will win
b. the hoop will win
c. the cylinder and the hoop will reach the bottom of the incline at the same time

The following two questions concern the same physical situation:

A person is holding a bar (of length L = 1.5 m) at an angle of 60 degrees relative to the ground as shown below. An object of mass M = 2 kg is attached to the end of the bar. Because the object is much heavier than the bar, we will ignore the mass of the bar in this problem. When the person lets go of the bar, the bar with the object (of mass M) starts to rotate around P.



9. What is the magnitude of the torque on the bar around point P immediately after the person lets go of the bar?

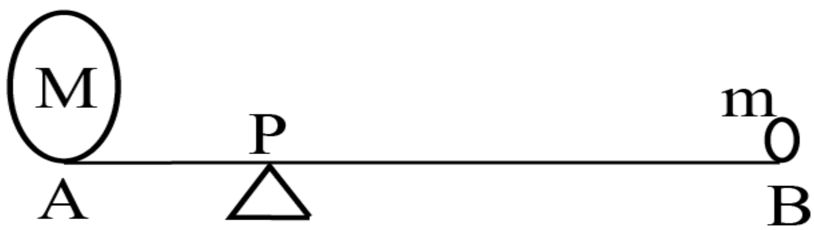
   a. 14.7 N·m
   b. 20.1 N·m
   c. 25.5 N·m
   d. 29.3 N·m
   e. 35.5 N·m

10. The rod continues to rotate around the pivot point P until it hits the ground. What is the direction of angular momentum just before it hits the ground?

    a. to the right
    b. into the page
    c. out of the page

The following two questions concern the same physical situation:

There is a weightless bar of length L = 1 m. At one end A is a mass M = 40 kg and at the other end B is a mass m = 10 kg. The bar is at rest on the pivot P. (Note: Assume + is for counterclockwise rotation.). The drawing below is not to scale.



11. What is the torque around B due to mass M?

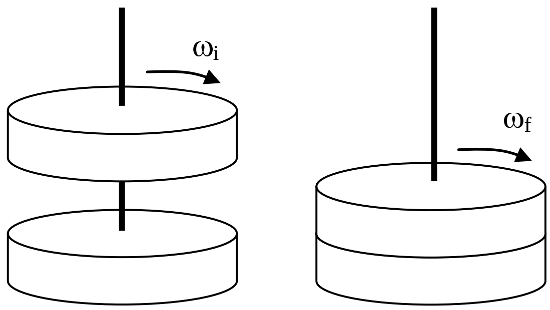
   a. + 392 N·m
   b. + 196 N·m
   c. 0 N·m
   d. –196 N·m
   e. –588 N·m

12. What should be the distance between A and P to keep the system in equilibrium?

   a. 0.1 m
   b. 0.2 m
   c. 0.3 m
   d. 0.4 m
   e. 0.5 m

The following two questions concern the same physical situation:

Two solid disks with equal mass m = 2.5 kg and equal radius R = 0.2 m both slide and rotate without friction on a vertical axis. Initially, the upper disk is rotating with angular velocity ω_i = 46 rad/s and the lower disk is at rest. The upper disk then falls, sticks to the lower disk, after which they are observed rotating together at angular velocity ω_f.



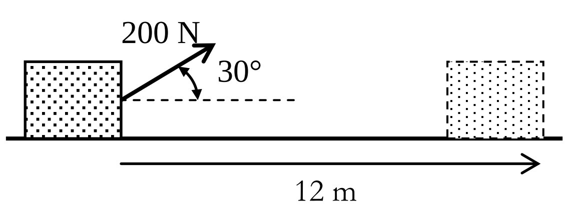
13. What is the final angular velocity ω_f?

    a. 4.71 rad/s
    b. 46.00 rad/s
    c. 23.00 rad/s
    d. 75.35 rad/s
    e. 98.90 rad/s

14. What happens to the total kinetic energy before and after the two disks form a one combined disk?

    a. The total kinetic energy increases.
    b. The total kinetic energy decreases.
    c. The total kinetic energy stays the same.

15. A 200 N force pulls on a box as shown. The box moves a distance of 12.0 m across the floor. The box remains in contact with the floor. How much work was done by the force?



    a. 12.0 J
    b. 173 J
    c. 10.4 J
    d. 2080 J
    e. 2400 J

The following two questions concern the same physical situation:

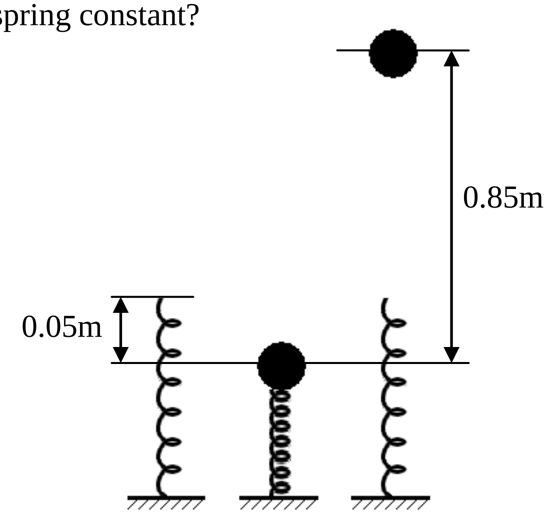
16. A 2.5 kg glider sits on a horizontal air track. Neglect friction of any kind.
A 13.0 N horizontal force begins pushing upon it continuously and causes it to move from x = 0.0 m where it was at rest to x = 0.8 m. How fast is it going when it reaches 0.8 m?

   a. 4.2 m/s
   b. 2.9 m/s
   c. 5.2 m/s
   d. 2.5 m/s
   e. 0.3 m/s

17. If the force acts on the glider for only 2.0 s what is the impulse delivered to the glider? What is the speed of the glider?

   a. impulse = 32.5 kg·m/s speed = 13.0 m/s
   b. impulse = 5.0 kg·m/s speed = 10.4 m/s
   c. impulse = 26.0 kg·m/s speed = 10.4 m/s
   d. impulse = 65.0 kg·m/s speed = 26.0 m/s
   e. impulse = 65.0 kg·m/s speed = 13.0 m/s

18. A 0.50 kg metal ball is placed on top of a spring and pushed down until the spring is compressed by 0.05 m. The ball is released and it flies upward from that release point a total of 0.85 m. At that moment it reaches its maximum height. What is the value of the spring constant?

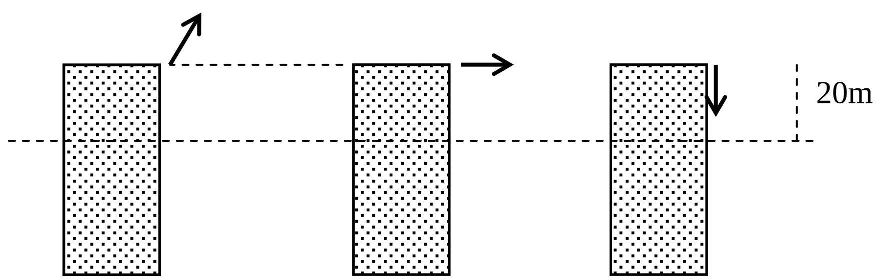


   a. 98.0 N/m
   b. 5.76 N/m
   c. 8.50 N/m
   d. 3332 N/m
   e. 271 N/m

19. A 10 kg box is placed on a 30 degrees incline. It is given a shove down such that it initially gets going at a speed of 10 m/s. The box then slows down and stops after it moves 9.0 m. What is the size of the frictional force?

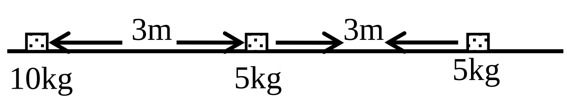
a. 105 N
b. 49.0 N
c. 22.5 N
d. 98.0 N
e. 882 N

20. We stand at the top of a cliff with a machine that launches bowling balls. We now launch three identical balls off the cliff with an initial kinetic energy of 1000 J. The first ball is launched at 45° above the horizontal. The second ball is launched horizontally. The third ball is launched straight downward. Eventually, each one of the balls reaches an altitude of 20 m below the top of the cliff. Neglect air friction. What can we say about their relative speeds at that altitude?



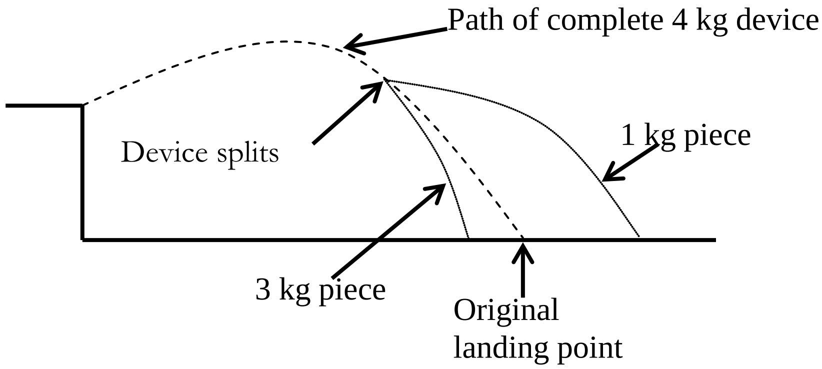
a. $v_{up} > v_{sideways} > v_{down}$
b. $v_{up} < v_{sideways} < v_{down}$
c. $v_{up} = v_{sideways} = v_{down}$
d. $v_{up} < v_{sideways} > v_{down}$
e. $v_{up} > v_{sideways} < v_{down}$

21. Three point masses are spaced out along a line. The middle mass (M_M = 5.0 kg) is 3.0 m to the right of the left mass (M_L = 10 kg). The right mass (M_R = 5.0 kg) is 3.0 m to the right of the middle mass. Where is the center of mass?



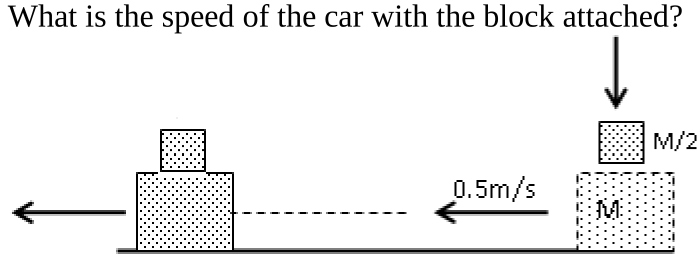
a. It is at the same place as the middle mass.
b. It is 1.5 m to the right of the 10 kg mass.
c. It is 2.25 m to the right of the 10 kg mass.

22. A 4 kg device was tossed off the edge of a cliff and allowed to fall to the ground. Its path is shown below. The process is repeated but during the flight the device splits into two pieces (1 kg and 3 kg) which in turn fall to the ground along different trajectories. Where is the center of mass of the two pieces after they land on the ground?



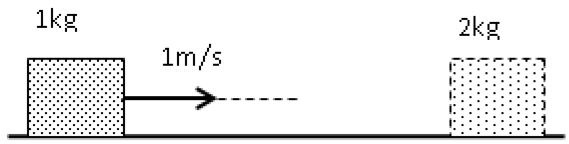
a. To the left of the original landing point.
b. At the original landing point.
c. To the right of the original landing point.

23. A small car of mass M = 1 kg is moving to the left at 0.5 m/s on a level table. We drop a block straight down; its vertical speed is 1.0 m/s when it lands on and sticks to the car. The mass of the block is one half of the mass of the car (M/2 = 0.5kg). What is the speed of the car with the block attached?



a. 0.67 m/s
b. 0.50 m/s
c. 1.50 m/s
d. 0.33 m/s
e. 1.00 m/s

24. Consider a frictionless air-track. A 2 kg glider is at rest on the track. A 1 kg glider moves in the positive direction (to the right) at 1 m/s and hits the 2 kg glider. The collision is a perfectly elastic collision. What is the velocity of the 1 kg glider after the collision?



a. 1 m/s
b. 2 m/s
c. 0.33 m/s
d. -1 m/s
e. -0.33 m/s

Check to make sure you have bubbled in all your answers.
Did you bubble in your name, exam version and network-ID?

Physics 101 Formulas

Kinematics

$\mathbf{v}_{ave} = \Delta\mathbf{x}/\Delta t$ $\mathbf{a}_{ave} = \Delta\mathbf{v}/\Delta t$

$v = v_0 + at$ $x = x_0 + v_0 t + {}^1/_2 at^2$ $v^2 = v_0^2 + 2a\Delta x$

$g = 9.8 m/s^2 = 32.2 ft/s^2$ (near Earth's surface)

Dynamics

$\Sigma\mathbf{F} = m\mathbf{a}$ $F_g = Gm_1m_2 / R^2$ $F_g = mg$ (near Earth's surface)

$f_{s,max} = \mu_s F_N$ Gravitational constant, $G = 6.7 \times 10^{-11}\ N{\cdot}m^2/kg^2$

$f_k = \mu_k F_N$ $a_c = v^2 / R = \omega^2 R$

Work & Energy

$W_F = FS\cos(\theta)$ $K(\text{or } KE) = {}^1/_2 mv^2$ $W_{NET} = \Delta K = K_f - K_i$ $E = K + U$

$W_{nc} = \Delta E = E_f - E_i = (K_f + U_f) - (K_i + U_i)$

$W_{grav} = -mg\Delta y$ U_{grav} (or PE_{grav}) $= mgy$

Impulse & Momentum

Impulse $\mathbf{I} = \mathbf{F}_{ave}\Delta t = \Delta\mathbf{p}$ $\mathbf{F}_{ave}\Delta t = \Delta\mathbf{p} = m\mathbf{v}_f - m\mathbf{v}_i$ $\mathbf{F}_{ave} = \Delta\mathbf{p}/\Delta t$

$\Sigma\mathbf{F}_{ext}\Delta t = \Delta\mathbf{P}_{total} = \mathbf{P}_{total,final} - \mathbf{P}_{total,initial}$ (momentum conserved if $\Sigma\mathbf{F}_{ext} = 0$)

$\mathbf{X}_{cm} = (m_1\mathbf{x}_1 + m_2\mathbf{x}_2)/(m_1 + m_2)$

Rotational Kinematics

$\omega = \omega_0 + \alpha t$ $\theta = \theta_0 + \omega_0 t + {}^1/_2\alpha t^2$ $\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

$\Delta x_T = \Delta\theta R$ $v_T = \omega R$ $a_T = \alpha R$ (rolling without slipping: $\Delta x = \Delta\theta R$ $v = \omega R$ $a = \alpha R$)

Rotational Statics & Dynamics

$\tau = Fr\sin\theta$

$\Sigma\tau = 0$ and $\Sigma F = 0$ (static equilibrium)

$\Sigma\tau = I\alpha$

$I = \Sigma mr^2$ (for a collection of point particles)

$I = {}^1/_2 MR^2$ (solid disk or cylinder) $I = {}^2/_5 MR^2$ (solid sphere) $I = {}^2/_3 MR^2$ (hollow sphere)

$I = MR^2$ (hoop or hollow cylinder) $I = {}^1/_{12} ML^2$ (uniform rod about center)

$W = \tau\theta$ (work done by a torque)

$\mathbf{L} = I\boldsymbol{\omega}$ $\Sigma\boldsymbol{\tau}_{ext}\Delta t = \Delta\mathbf{L}$ (angular momentum conserved if $\Sigma\boldsymbol{\tau}_{ext} = 0$)

$K_{rot} = {}^1/_2 I\omega^2 = L^2/2I$ $K_{total} = K_{trans} + K_{rot} = {}^1/_2 mv^2 + {}^1/_2 I\omega^2$

Simple Harmonic Motion

Hooke's Law: $F_s = -kx$

$W_{spring} = {}^1/_2 kx_i^2 - {}^1/_2 kx_f^2$ $U_{spring} = {}^1/_2 kx^2$

$x(t) = A\cos(\omega t)$ or $x(t) = A\sin(\omega t)$

$v(t) = -A\omega\sin(\omega t)$ or $v(t) = A\omega\cos(\omega t)$

$a(t) = -A\omega^2\cos(\omega t)$ or $a(t) = -A\omega^2\sin(\omega t)$

$\omega^2 = k/m$ $T = 2\pi/\omega = 2\pi\sqrt{m/k}$ $f = 1/T$

$x_{max} = A$ $v_{max} = \omega A$ $a_{max} = \omega^2 A$ $\omega = 2\pi f$

For a simple pendulum $\omega^2 = g/L$, $T = 2\pi\sqrt{L/g}$

Fluids

$P = F/A$, $P(d) = P(0) + \rho gd$ change in pressure with depth d

Buoyant force $F_B = \rho g V_{dis}$ = weight of displaced fluid
Flow rate $Q = v_1A_1 = v_2A_2$ continuity equation (area of circle $A = \pi r^2$)
$P_1 + {}^1/_2\rho v_1^2 + \rho g y_1 = P_2 + {}^1/_2\rho v_2^2 + \rho g y_2$ Bernoulli equation
$\rho_{water} = 1000$ kg/m^3 1m^3 = 1000 liters
$\rho = M/V$ 1 atmos. = 1.01×10^5 Pa 1 Pa = 1 N/m^2

Temperature and Heat

Temperature: Celsius (T_C) to Fahrenheit (T_F) conversion: $T_C = (5/9)(T_F - 32)$
Celsius (T_C) to Kelvin (T_K) conversion: $T_K = T_C + 273$
$\Delta L = \alpha L_0 \Delta T$ $\Delta V = \beta V_0 \Delta T$ thermal expansion
$Q = cM\Delta T$ specific heat capacity
$Q = L_f M$ latent heat of fusion (solid to liquid) $Q = L_v M$ latent heat of vaporization
$Q = kA\Delta T t/L$ conduction
$Q = e\sigma T^4 A t$ radiation ($\sigma = 5.67 \times 10^{-8}$ J/(s·m^2·K^4))
$P_{net} = e\sigma A(T^4 - T_0^4)$ (surface area of a sphere $A = 4\pi r^2$)

Ideal Gas & Kinetic Theory

$N_A = 6.022 \times 10^{23}$ molecules/mole Mass of carbon-12 = 12.000u
$PV = nRT = Nk_BT$ R = 8.31 J/(mol·K) $k_B = R/N_A = 1.38 \times 10^{-23}$ J/K
$KE_{ave} = {}^3/_2 k_BT = {}^1/_2 m v_{rms}^2$ $U = {}^3/_2 Nk_BT$ (internal energy of a monatomic ideal gas)
$v_{rms}^2 = 3k_BT/m = 3RT/M$ (M = molar mass = kg/mole)

Thermodynamics

$\Delta U = Q + W$ (1'st law)

$U = ({}^3/_2)nRT$ (internal energy of a monatomic ideal gas for fixed n)

$C_V = ({}^3/_2)R = 12.5$ J/(mol·K) (specific heat at constant volume for a monatomic ideal gas)

$Q_H = Q_C + W$ (heat engine or refrigerator)
$e = W/Q_H = 1 - Q_C/Q_H$ $e_{max} = 1 - T_C/T_H$ (Carnot engine)
$Q_C/Q_H = T_C/T_H$ at maximum efficiency (2'nd law)
$W = -P\Delta V$ (work done by expanding gas)

Harmonic Waves

$v = \lambda / T = \lambda f$
$v^2 = F/(m/L)$ for wave on a string
$v = c = 3 \times 10^8$ m/s for electromagnetic waves (light, microwaves, etc.)
$I = P/(4\pi r^2)$ (sound intensity)

Sound Waves

Loudness: $\beta = 10 \log_{10}(I/I_0)$ (in dB), where $I_0 = 10^{-12}$ W/m^2

$$f_{observer} = f_{source}\frac{v_{wave} - v_{observer}}{v_{wave} - v_{source}}$$ (Doppler effect)