Physics 101	Hour Exam 2	November 3, 2014

Last Name: ______________ **First Name** ______________ **ID**______________

Discussion Section:__________________ **Discussion TA Name:**__________________

Instructions—Turn off your cell phone and put it away.
Calculators cannot be shared. Please keep yours on your own desk.

This is a closed book exam. You have 90 minutes to complete it.
This is a multiple choice exam. Use the bubble sheet to record your answers.

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 in the bottom right on the front side 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. Write in your course on the **COURSE LINE** and on the **SECTION** *line*, print your **DISCUSSION SECTION**. (You need not fill in the INSTRUCTOR line.)

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

*Before starting work, check to make sure that your test booklet is complete. After these instructions, you should have **9** **numbered pages** plus 2 Formula Sheets.*

On the test booklet:
Write your **NAME**, your **Discussion TA's NAME**, your **DISCUSSION SECTION** and your **NETWORK-ID**. Also, write your **EXAM ROOM** and **SEAT NUMBER**.

When you are finished, you must <u>hand in BOTH the exam booklet AND the answer sheet</u>. Your exam will not be graded unless both are present.

***<u>Academic Integrity</u>*—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 in the bottom right on the front side of your answer sheet. **DO THIS NOW!**

Exam Format & Instructions:

This exam is a combination of
* Three-Answer Multiple Choice (3 points each)
* Five-Answer Multiple Choice (6 points each)

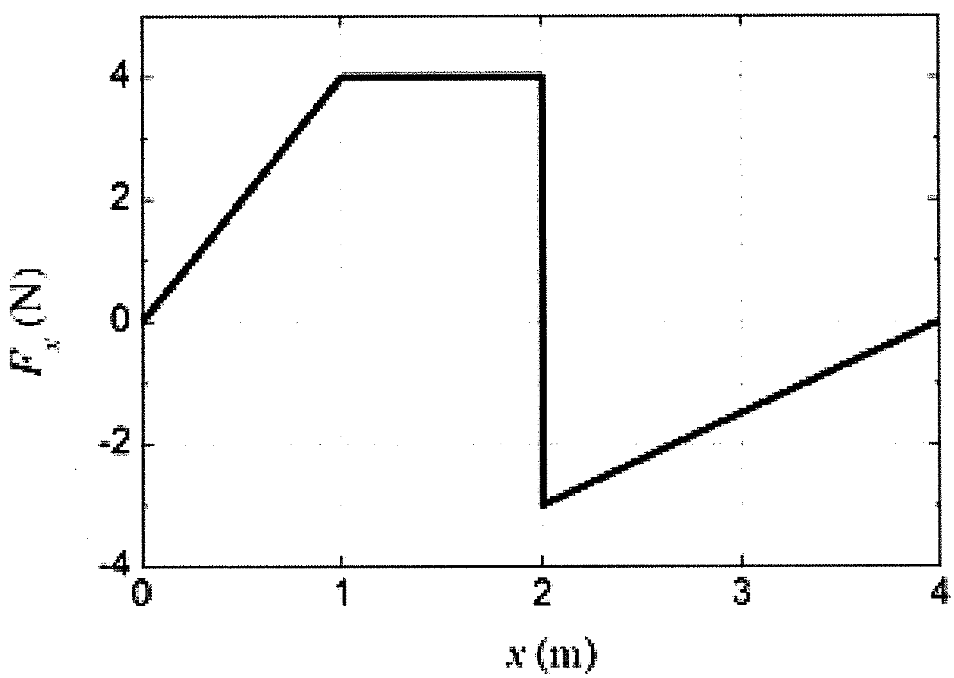
There are 23 problems for a maximum possible raw score of 105points.

Instructions for Three-Answer Multiple Choice Problems:
Indicate on the answer sheet the correct answer to the question (*a, b* or *c*).
Each question is worth 3 points. If you mark the wrong answer, or mark more than one answer, you receive 0 points.

Instructions for Five-Answer Multiple Choice Problems:
Indicate on the answer sheet the correct answer to each question (*a, b, c, d* or *e*).
Credit is awarded in the following way:
- If you mark one answer and it is correct, you will receive 6 points;
- If you mark two answers, and one of them is correct, you will receive 3 points;
- If you mark three answers and one of them is correct, you will receive 2 points.
- If you mark no answer or more than three answers, you will receive 0 points.

1) You push a block of mass 6 kg along a horizontal track over a distance 20 m . What is W , the total work done by the gravity?

a. $W = -1200\ J$
b. $W = 0\ J$
c. $W = 1200\ J$



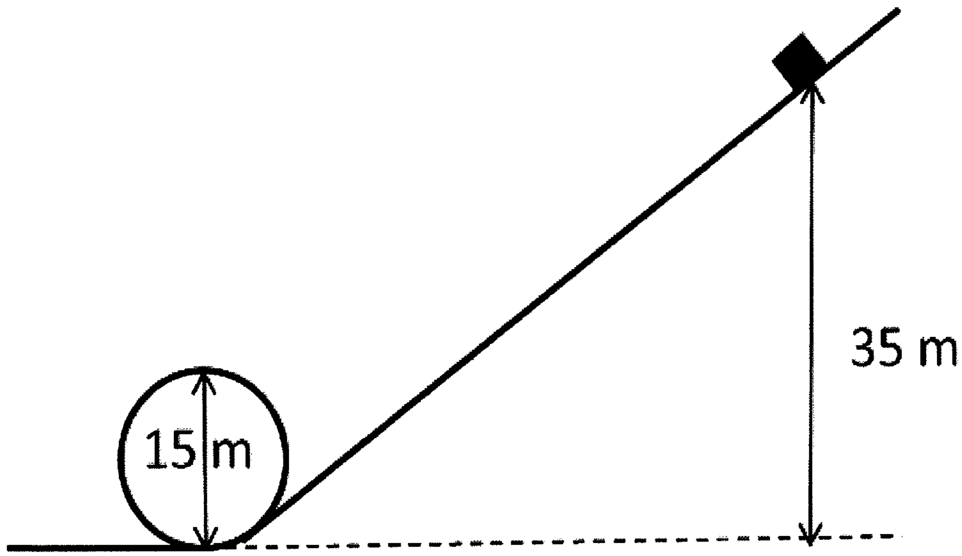
2) A force is exerted on an object along the x-axis as shown above. What is W, the work done by the force on the object during the displacement from 0 to 4 m ?

W = area under curve

$= \frac{1}{2} 1 \times 4 + 1 \times 4 + \frac{1}{2} 2 \times (-3) = 3\ J$

a. $W = 3\ J$
b. $W = 0\ J$
c. $W = 7\ J$

The next two questions pertain to the situation described below.



A block of mass 50 kg is about to roll down a roller coaster track as shown above. Its initial height is 35 m and the diameter of the circular loop is 15 m . Assume that friction and air resistance are negligible.

3) What is v_{top} , the speed of the block at the top of the loop?

a. $v_{top} = 19.8\ m/s$
b. $v_{top} = 14\ m/s$
c. $v_{top} = 31.3\ m/s$

$$\frac{1}{2} m v^2 = mg\,(35\ m - 15\ m)$$

$$v = \sqrt{2g \times 20\ m} = 19.8\ m/s$$

4) What is h_{min} , the minimum initial height such that the block remains on the track at the top of the loop?

a. $h_{min} = 9.4\ m$
b. $h_{min} = 18.8\ m$
c. $h_{min} = 30\ m$
d. $h_{min} = 22.5\ m$
e. $h_{min} = 15\ m$

At top of loop,

$N = 0$

mg

$$mg = ma = m\frac{v^2}{R}$$

$$\Rightarrow v = \sqrt{gR}$$

$$\frac{1}{2} m v^2 = mg\,(h - 15\ m)$$

$$h = 15\ m + \frac{v^2}{2g} = 15\ m + \frac{gR}{2g} = 15\ m + \frac{R}{2}$$

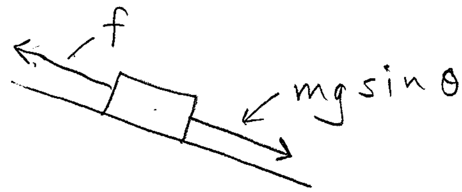
$$= 15\ m + \frac{7.5\ m}{2}$$

$$= 18.75\ m$$

The next three questions pertain to the situation described below.

A 80 *kg* box slides a total of 1 *km* down a slope making an angle of 12^o with respect to the horizontal. The box slides with a constant velocity.

5) What is the frictional force acting on the box?



a. 3.54 N
b. 376 N
c. 163 N
d. 17 N
e. 0 N

$f = mg \sin\theta$
$= 80\ kg \times 9.8\ m/s^2 \times \sin 12^\circ$
$= 163\ N$

6) The total work done on the box over the 1 *km* slide by all forces is:

$W = \Delta KE = 0$

a. *Positive*
b. *Zero*
c. *Negative*

7) Calculate the work done by the frictional force on the box over the full 1 *km* slide.

a. $W_f = 0\ J$
b. $W_f = 3540\ J$
c. $W_f = 1.63 \times 10^5\ J$
d. $W_f = 1.7 \times 10^4\ J$
e. $W_f = 3.76 \times 10^5\ J$

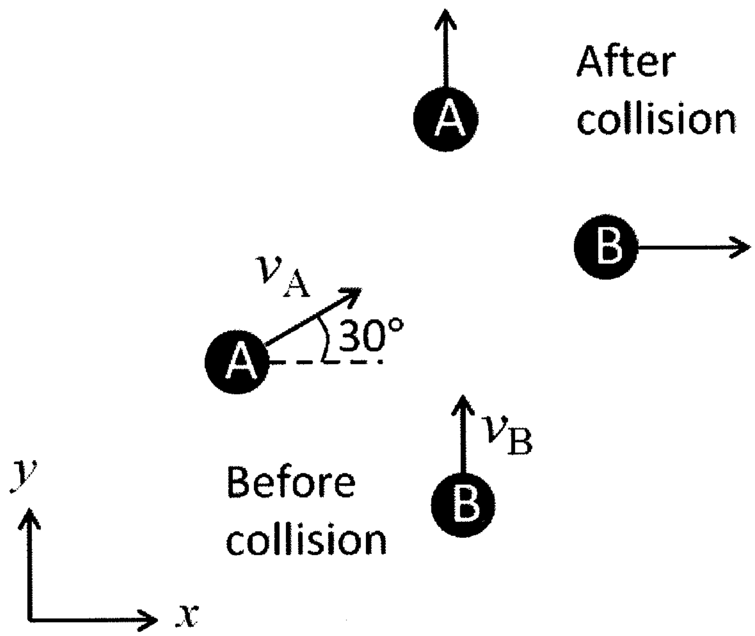
$W = fd$
$= -163\ N \times 1\ Km$
$= -1.63 \times 10^5\ J$

8) A train car of mass 1500 kg moves to the right with a speed of 7 m/s and collides with and couples to an identical stationary train car. What is the final velocity of the two train cars?

$mv = 2mV$

$V = \frac{1}{2}v = 3.5\ m/s$

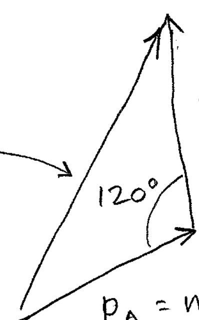
a. 3.5 m/s
b. 1.75 m/s
c. 7 m/s



Two billiard balls, A and B, are moving on a frictionless table as shown above. Their masses are $m_A = 0.8$ kg and $m_B = 0.5\ kg$. Before collision, ball A is moving in the direction 30° off the x-axis with speed $v_A = 6\ m/s$, while ball B is moving along the +y-axis with speed $v_B = 2\ m/s$. After collision, ball A moves along the +y-axis, while ball B moves along the +x-axis. Ignore air resistance.

9) What is P_{after} , the magnitude of the total momentum after collision?

$P_{after} = P_{before}$



$p_B = m_B V_B$
$= 0.5\ kg \times 2\ \frac{m}{s}$
$= 1\ kg\ m/s$

$p_A = m_A V_A$
$= 0.8\ kg \times 6\ m/s$
$= 4.8\ kg\ m/s$

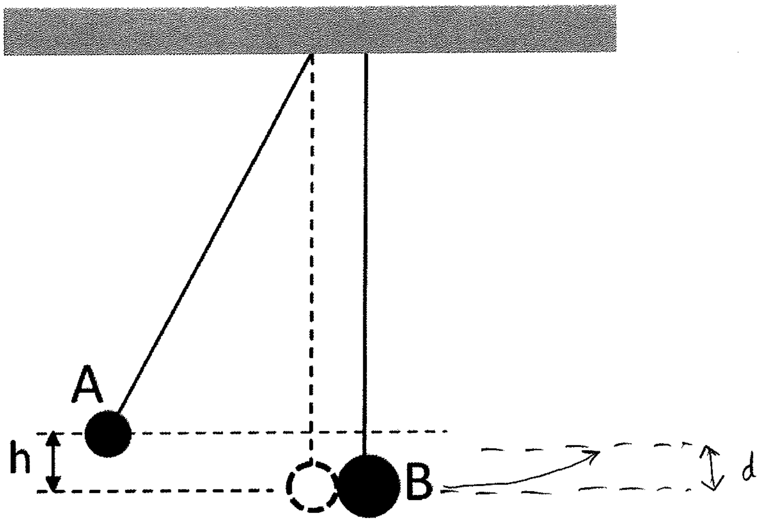
a. $P_{after} = 4.16\ kg \cdot m/s$
b. $P_{after} = 5.37\ kg \cdot m/s$
c. $P_{after} = 2.75\ kg \cdot m/s$
d. $P_{after} = 3.4\ kg \cdot m/s$
e. $P_{after} = 7.56\ kg \cdot m/s$

The next two questions pertain to the situation described below.

Use law of cosines:

$P_{after}^2 = p_A^2 + p_B^2 - 2 p_A p_B \cos 120°$
$= (4.8)^2 + 1 - 2 \times 4.8 \times 1 \times (-0.5) = 28.84$

$P_{after} = 5.37\ kg\ m/s$



Two pendulum bobs made of soft clay hang from a ceiling as shown above. The mass of bob A is $m_A = 1\ kg$ and that of bob B is $m_B = 2\ kg$. Initially, the height of bob A is h and bob B is at rest. They stick together after collision.

10) If bob A is released from a height $h = 0.45\ m$, what is the maximum height attained by the two bobs stuck together after the collision?

a. 0.15 m
b. 0.22 m
c. 0.74 m
d. 0.25 m
e. 0.05 m

$\frac{1}{2} m_A v_A^2 = m_A g h \Rightarrow v_A = \sqrt{2gh}$ before collision

$m_A v_A = (m_A + m_B) V \Rightarrow V = \frac{m_A}{m_A + m_B} v_A$ after collision

$\frac{1}{2}(m_A + m_B) V^2 = (m_A + m_B) g d \Rightarrow d = \frac{V^2}{2g}$

11) How does K_A , the kinetic energy of bob A just before the collision, compare to K_{A+B} , the kinetic energy of the combined bobs just after collision?

a. $K_A = K_{A+B}$
b. $K_A < K_{A+B}$
c. $K_A > K_{A+B}$

Inelastic collision

$= \frac{m_A^2}{(m_A + m_B)^2} \frac{1}{2g} v_A^2$

$= \frac{m_A^2}{(m_A + m_B)^2} \frac{1}{2g} 2gh$

$= \frac{1^2}{(1+2)^2} \times 0.45\ m$

$= 0.05\ m$

12) Two kids are sitting 1 m from the center of a merry-go-round of radius 2 m . They are initially rotating with a constant angular velocity of ω_0 . One of the kids scoots out to the outer rim of the merry-go-round. How does the final angular velocity of the merry-go-round, ω_f , compare to its initial angular velocity?

$$I_o \omega_o = I_f \omega_f$$

$\uparrow$ increase; $\uparrow$ decrease

a. $\omega_f < \omega_0$
b. $\omega_f > \omega_0$
c. $\omega_f = \omega_0$

The next three questions pertain to the situation described below.

A sphere of radius 0.5 m and mass 1 kg rolls without slipping down a plane inclined at 30^o to the horizontal.

13) Compare the velocity of the sphere at the bottom of the inclined plane to a solid cylinder of the same mass and radius. ($I_{sphere} = 2MR^2/5$, $I_{cylinder} = MR^2/2$).

a. $v_{sphere} > v_{cylinder}$
b. $v_{sphere} = v_{cylinder}$
c. $v_{sphere} < v_{cylinder}$

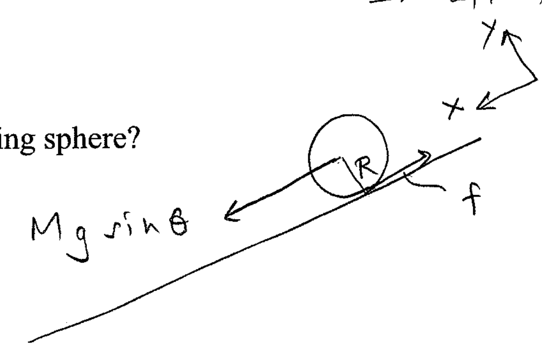
Sphere: smaller I $\Rightarrow$ less rotational KE
$\Rightarrow$ more translational KE

14) Compare the velocity of the rolling sphere to its velocity if it instead slid down the inclined plane without friction.

Sliding $\Rightarrow$ no rotation $\Rightarrow$ no rotational KE
$\Rightarrow$ all translational KE

a. $v_{roll} < v_{slide}$
b. $v_{roll} = v_{slide}$
c. $v_{roll} > v_{slide}$

15) What is the acceleration of the rolling sphere?



a. 5.4 m/s^2
b. 5.7 m/s^2
c. 3.5 m/s^2
d. 7.3 m/s^2
e. 34 m/s^2

$$Mg \sin\theta - f = Ma$$

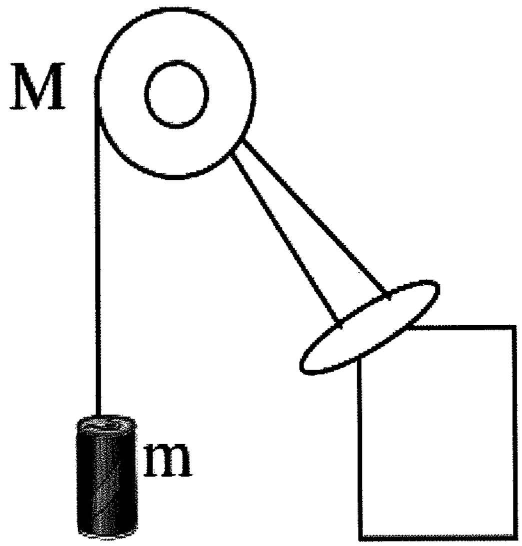
$$Rf = I\alpha = I\frac{a}{R} \Rightarrow f = I\frac{a}{R^2}$$

so $$Mg \sin\theta - I\frac{a}{R^2} = Ma$$

$$\cancel{M}g \sin\theta - \frac{2}{5}\cancel{M}\cancel{R^2}\frac{a}{\cancel{R^2}} = \cancel{M}a$$

$$a\left(1 + \frac{2}{5}\right) = g \sin\theta \Rightarrow a = \frac{5}{7} g \sin\theta = 3.5\ m/s^2$$

The next four questions pertain to the situation described below.



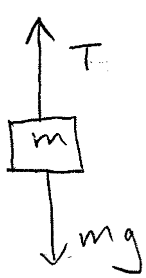
A uniform disk of unknown mass M and radius $R = 10\ cm$ is free to rotate around a fixed horizontal axle supported in frictionless bearing. A light string is wrapped around the rim of the disk and then tied to a mass $m = 60\ g$. The string does not slip as it unwinds on the disk. When released the mass moves down with acceleration $3.27\ m/s^2$. Take $g = 9.8\ m/s^2$. The moment of inertia of a uniform disk is $1/2MR^2$.

16) Determine the angular acceleration of the disk

$a = \alpha R \Rightarrow \alpha = \frac{a}{R} = \frac{3.27\ m/s^2}{0.1\ m} = 32.7\ \frac{rad}{sec^2}$

a. $0\ rad/s^2$
b. $98.1\ rad/s^2$
c. $32.7\ rad/s^2$
d. $0.327\ rad/s^2$
e. $10.9\ rad/s^2$

17) Determine the tension in the string



$T - mg = -ma$

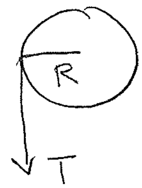
$T = m(g-a)$

$= 0.06\ kg \times (9.8 - 3.27)\ m/s^2$

$= 0.392\ N$

a. $1.96\ N$
b. $5.88\ N$
c. $1.18\ N$
d. $0\ N$
e. $0.392\ N$

18) Determine the mass of the disk



a. 0.12 kg
b. 0.48 kg
c. 0.24 kg
d. 0.36 kg
e. 0.784 kg

$$\tau = I\alpha = I\,a/R$$
$$TR = \frac{1}{2}MR^2\,a/R$$
$$T = \frac{1}{2}Ma \Rightarrow M = \frac{2T}{a} = \frac{2 \times 0.392\ N}{3.27\ m/s^2} = 0.24\ kg$$

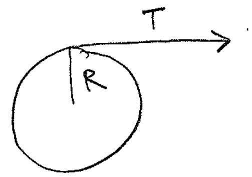
19) If the mass is released from rest, determine kinetic energy of the mass and the wheel combined after it drops a distance $d = 10\ cm$.

a. 0.0588 J
b. 0.1176 J
c. 0.01176 J
d. 0.1764 J
e. 0.0294 J

$$KE = mgh$$
$$= 0.06\ kg \times 9.8\ m/s^2 \times 0.1\ m$$
$$= 0{,}0588\ J$$

The next three questions pertain to the situation described below.

A rope is attached to and wrapped around a disk of radius 2 m and mass 6 kg . The rope is pulled with a force of 6 N such that the force is applied tangentially to the disk. ($I_{disk} = MR^2/2$)



20) What is the torque on the wheel due to the rope?

$\tau = TR = 6\ N \times 2m = 12\ Nm$

a. 3 Nm
b. 12 Nm
c. 6 Nm

21) What is the resulting angular acceleration of the disk?

$\tau = I\alpha \Rightarrow \alpha = \frac{\tau}{I} = \frac{12\ Nm}{\frac{1}{2}MR^2} = \frac{12\ Nm}{\frac{1}{2}6\ kg\ (2m)^2} = 1\ \frac{rad}{s^2}$

a. 0.25 rad/s^2
b. 1 rad/s^2
c. 0.5 rad/s^2

22) What is the work done in rotating the disk through one complete revolution?

$W = \tau\theta = 12\ Nm \times 2\pi\ rad = 75.4\ J$

a. 24 J
b. 38 J
c. 75 J

23) A disk of mass 5 kg and radius 1 m is rotating with an angular velocity of $\omega_0 = 11\ rad/s$. A lump of clay of mass 3 kg is dropped onto the disk at a radius of 0.5 m , sticking to the disk. What is the final angular velocity of the disk? ($I_{disk} = MR^2/2$)

a. 37 rad/s
b. 4.2 rad/s
c. 11 rad/s
d. 14 rad/s
e. 8.5 rad/s

$$I_0 \omega_0 = I_f \omega_f$$

$$\frac{1}{2} MR^2 \omega_0 = \left(\frac{1}{2} MR^2 + m \left(\frac{R}{2}\right)^2\right) \omega_f$$

$$\omega_f = \frac{1}{1 + \frac{1}{2}\frac{m}{M}} \omega_0 = \frac{1}{1 + \frac{1}{2}\frac{3}{5}} 11\ rad/s = 8.46\ \frac{rad}{s}$$

Physics 101 Formulas

Kinematics
$\mathbf{v}_{ave} = \Delta\mathbf{x}/\Delta t$ $\mathbf{a}_{ave} = \Delta\mathbf{v}/\Delta t$
$v = v_0 + at$ $x = x_0 + v_0t + {}^1/_2at^2$ $v^2 = v_0^2 + 2a\Delta x$
$g = 9.8\ m/s^2 = 32.2\ ft/s^2$ (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)
$f_{s,max} = \mu_sF_N$ Gravitational constant, $G = 6.7 \times 10^{-11}\ N{\cdot}m^2/kg^2$
$f_k = \mu_kF_N$ $a_c = v^2 / R = \omega^2R$

Work & Energy
$W_F = FD\cos(\theta)$ $K = {}^1/_2mv^2 = p^2/2m$ $W_{NET} = \Delta K = K_f - K_i$ $E = K + U$
$W_{nc} = \Delta E = E_f - E_i = (K_f + U_f) - (K_i + U_i)$
$U_{grav} = mgy$

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
$\omega = \omega_0 + \alpha t$ $\theta = \theta_0 + \omega_0t + {}^1/_2\alpha t^2$ $\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$
$\Delta x_T = R\Delta\theta$ $v_T = R\omega$ $a_T = R\alpha$ (rolling without slipping: $\Delta x = R\Delta\theta$ $v = R\omega$ $a = R\alpha$)

1 revolution = 2π radians

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)
$I = {}^1/_2MR^2$ (solid disk or cylinder) $I = {}^2/_5MR^2$ (solid ball) $I = {}^2/_3MR^2$ (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)
$\mathbf{L} = I\omega$ $\Sigma\tau_{ext}\Delta t = \Delta\mathbf{L}$ (angular momentum conserved if $\Sigma\tau_{ext} = 0$)
$K_{rot} = {}^1/_2I\omega^2 = L^2/2I$ $K_{total} = K_{trans} + K_{rot} = {}^1/_2mv^2 + {}^1/_2I\omega^2$

Simple Harmonic Motion
Hooke's Law: $F_s = -kx$
$U_{spring} = {}^1/_2kx^2$
$x(t) = A\cos(\omega t)$ 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 $a(t) = -A\omega^2\sin(\omega t)$
$\omega^2 = k/m$ $T = 2\pi/\omega = 2\pi\sqrt{m/k}$ $f = 1/T$
$x_{max} = A$ $v_{max} = \omega A$ $a_{max} = \omega^2A$ $\omega = 2\pi f$
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 $F_B = \rho gV_{dis}$ = weight of displaced fluid
Flow rate $Q = v_1A_1 = v_2A_2$ continuity equation (area of circle $A = \pi r^2$)
$P_1 + {}^1/_2\rho v_1^2 + \rho gy_1 = P_2 + {}^1/_2\rho v_2^2 + \rho gy_2$ 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
$Q = L_fM$ latent heat of fusion (solid to liquid) $Q = L_vM$ latent heat of vaporization
$Q = \kappa A\Delta Tt/L$ conduction
$Q = e\sigma T^4At$ radiation ($\sigma = 5.67 \times 10^{-8}$ J/(s·m²·K⁴))
$P_{net} = e\sigma A(T^4 - T_0^4)$ (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 = 12.000 u
$PV = nRT = Nk_BT$ $R = 8.31$ J/(mol·K) $k_B = R/N_A = 1.38 \times 10^{-23}$ J/K
$KE_{ave} = {}^3/_2k_BT = {}^1/_2mv_{rms}^2$ $U = {}^3/_2Nk_BT$ (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)
$Q_H + Q_C + W = 0$ (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)