Physics 101	Hour Exam 1	October 5, 2015

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)

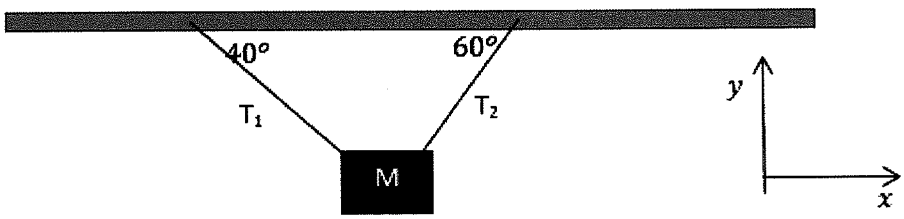
There are 23 problems for a maximum possible raw score of 107points.

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.

The next three questions pertain to the situation described below.

A block of mass M = 5 *kg* hangs in equilibrium from the ceiling as shown in the diagram.



1) Given that the block is in equilibrium, which of the following is necessarily true?

a. The block cannot be moving.
b. The block cannot experience any friction.
(c.) The sum of all the forces acting on the block is zero.

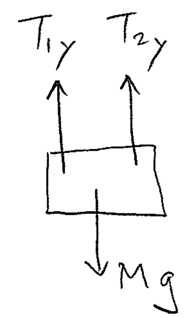
2) The y-components of the two tensions T_1 and T_2 add up to

a. *42 N*
b. *84 N*
c. *31 N*
d. *37 N*
(e.) *49 N*

$T_{1y} + T_{2y} = Mg$

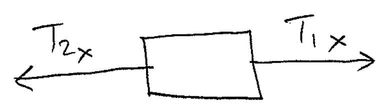
$= 5\ kg \times 9.8\ m/s^2$

$= 49\ N$



3) The ratio T_1/T_2 is equal to (Hint: write out the force equation along the x-direction)

a. *4.41*
(b.) *0.65*
c. *0.5*
d. *6*
e. *0.88*



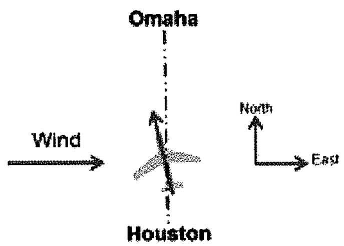
$T_{1x} = T_{2x}$

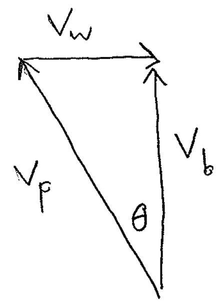
$T_1 \cos 40 = T_2 \cos 60$

$\frac{T_1}{T_2} = \frac{\cos 60}{\cos 40} = 0.65$

The next two questions pertain to the situation described below.

A plane moving at a speed of $v_a = 1150$ km/h relative to the air embarks on a flight from Houston to Omaha separated by a distance of 1290 km directly northward. The pilot finds that there is wind blowing from west to east at a steady speed of 160 km/hour.





4) At what angle west of north should the plane fly?

a. 1.59°
b. 1.99°
c. 2.66°
d. 3.99°
(e.) 8°

$$V_p \sin\theta = V_w$$

$$\sin\theta = \frac{V_w}{V_p} = \frac{160}{1150} = 0.139$$

$$\theta = 8^\circ$$

5) What is the plane's speed relative to the ground v_b?

a. 160 km/h
b. 1310 km/h
(c.) 1138 km/h
d. 1161 km/h
e. 990 km/h

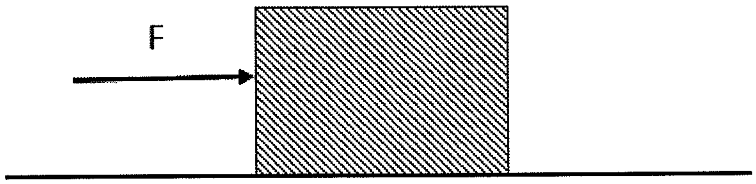
$$V_p^2 = V_w^2 + V_b^2$$

$$\Rightarrow V_b = \sqrt{V_p^2 - V_w^2}$$

$$= \sqrt{(1150)^2 - (160)^2} \text{ km/h}$$

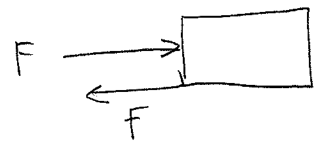
$$= 1138 \text{ km/h}$$

The next two questions pertain to the situation described below.



A block of mass M = 15 kg rests on a table. A force of F = 7 N is applied in the horizontal direction, as shown. The block continues to remain at rest due to friction.

6) The force of friction opposing the motion has a magnitude of



a. 147.15 N
(b.) 7 N
c. The information given is insufficient to answer the question

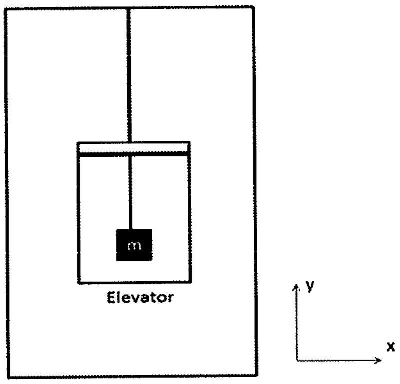
7) Now the applied force is increased to F = 29.4 N and this is the maximum force that can be applied before the block begins to move. The coefficient of static friction μ_s, is equal to

a. 5.01
b. 1.96
c. 19.23
d. 3
(e.) 0.2

$$F = \mu_s N = \mu_s M g$$

$$\mu_s = \frac{F}{Mg} = \frac{29.4\ N}{15\ kg \times 9.8\ m/s^2} = 0.2$$

The next three questions pertain to the situation described below.



A 12 kg mass hangs by a string from the ceiling of an elevator. The elevator is moving down with a constant velocity of 24 m/s.

no acceleration

8) Find the tension, T, in the string:

$T = Mg = 12\ kg \cdot 9.8\ m/s^2 = 117.6\ N$

a. 406 N
(b) 118 N
c. 142 N

9) The elevator begins to slow down at 3 m/s^2. Find the tension during the deceleration.

$T - Mg = Ma$

$T = M(g + a) = 12\ kg \times (9.8 + 3)\ m/s^2 = 153.6\ N$

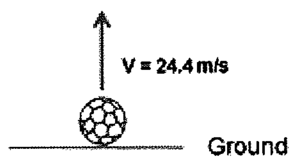
(a.) 154 N
b. 615 N
c. 354 N

10) If the elevator cable was to break and the elevator was to fall freely, the tension in the string holding the mass would become zero

a. False
(b.) True

The next three questions pertain to the situation described below.

A ball is thrown vertically upward from the ground with a speed of 24.4 m/s



11) How long does it take to reach the highest point?

a. 2 s
b. 2.5 s
c. 3 s
d. 1 s
e. 1.6 s

$$V_f = V_0 - gt \Rightarrow t = \frac{V_0}{g} = \frac{24.4\ m/s}{9.8\ m/s^2} = 2.49\ s \quad (V_f = 0)$$

12) How high does the ball rise?

a. 61 m
b. 1.24 m
c. 30.38 m

$$V_f^2 = V_0^2 - 2gh \Rightarrow h = \frac{V_0^2}{2g} = \frac{(24.4\ m/s)^2}{2 \times 9.8\ m/s^2} = 30.38\ m \quad (V_f = 0)$$

13) The ball's height at 2 s is

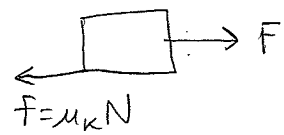
a. 29.2 m
b. 20.1 m
c. 35.6 m

$$Y_f = Y_0 + V_0 t - \frac{1}{2} g t^2 \quad (Y_0 = 0)$$

$$= 0 + 24.4\ m/s \times 2s - \frac{1}{2}\ 9.8\ m/s^2 \times (2s)^2$$

$$= 29.2\ m$$

14) A horse pulls a box of mass M = 55 kg across a rough horizontal surface by applying a horizontal force of 874 N. If the coefficient of kinetic friction between the box and the surface is $\mu_k = 0.5$, what is the acceleration of the box?



a. 6 m/s^2
b. 3 m/s^2
(c.) 11 m/s^2
d. 18 m/s^2
e. 12 m/s^2

$F - \mu_k N = Ma$

$F - \mu_k Mg = Ma$

$a = \frac{F}{M} - \mu_k g = \frac{874\ N}{55\ kg} - 0.5 \times 9.8\ m/s^2 = 11\ m/s^2$

15) An object is dropped from rest at a height h and strikes the ground with velocity v. If the object is instead dropped from rest at a height of 2h, which of the following represents its velocity when it strikes the ground?

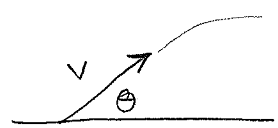
(a.) 1.4 v
b. 4 v
c. v
d. 8 v
e. 2 v

$mgh = \frac{1}{2} m v^2$ so $h \propto v^2$

$\Rightarrow v \propto \sqrt{h}$

$h \to 2h \Rightarrow v \to \sqrt{2h} = \sqrt{2}\, v = 1.4\, v$

16) A projectile is fired with an initial speed of 200 m/s. If it reaches its maximum height after 10 s, at what angle relative to the horizontal was it fired?



a. 90.8°
(b.) 29.3°
c. 60.3°
d. 45.7°
e. 20.4°

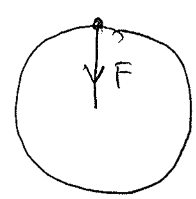
$v_y = v_{y_0} - gt \Rightarrow v_{y_0} = gt$ ($v_y = 0$)

$v \sin\theta = gt$

$\sin\theta = \frac{gt}{v} = \frac{9.8\ m/s^2 \times 10\ s}{200\ m/s} = 0.49$

$\theta = 29.3°$

17) The radius of an object rotating in a circle is quadrupled, while the applied centripetal force remains constant. The speed of the object:

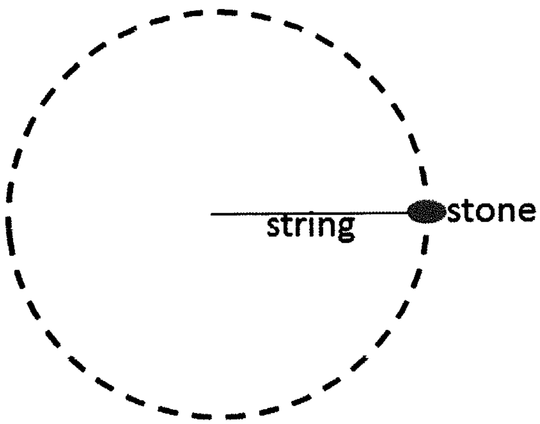


a. decreases by a factor of 2.
b. does not change.
(c) increases by a factor of 2.
d. decreases by a factor of 4.
e. increases by a factor of 4.

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

$\Rightarrow v^2 \propto R \Rightarrow v \propto \sqrt{R}$

$R \to 4R \Rightarrow v \to \sqrt{4R} = 2\sqrt{R} = 2v$



18) A boy uses a string to swing a *2.2 kg* stone around his head. The string is *1.5 m* long, and can bear a maximum tension of *1012 N*. What is the maximum speed at which the boy can swing the stone without breaking the string?

$F = ma \Rightarrow T = m\frac{v^2}{R} \Rightarrow v = \sqrt{\frac{RT}{m}} = \sqrt{\frac{1.5\text{ m} \times 1012\text{ N}}{2.2\text{ kg}}} = 26.3\text{ m/s}$

(a.) $v = 26.3\ m/s$
b. $v = 15.78\ m/s$
c. $v = 42.08\ m/s$

The next two questions pertain to the situation described below.

A bicycle wheel of radius r = 2.5 m is spinning about its own axis. It accelerates uniformly from rest at a rate of $\alpha = 0.25$ rad/s^2 and spins a total of 450 radians.

19) How long does it take to spin 450 radians?

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2 \Rightarrow t = \sqrt{\frac{2\theta}{\alpha}} = \sqrt{\frac{2 \times 450\text{ rad}}{0.25\text{ rad/s}^2}} = 60\text{ s}$ ($\theta_0 = 0$, $\omega_0 = 0$)

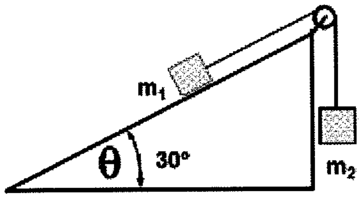
a. 10 s
b. 45 s
(c.) 60 s

20) What is the wheel's final angular velocity?

$\omega = \omega_0 + \alpha t = 0.25\text{ rad/s}^2 \times 60\text{ s} = 15\text{ rad/s}$ ($\omega_0 = 0$)

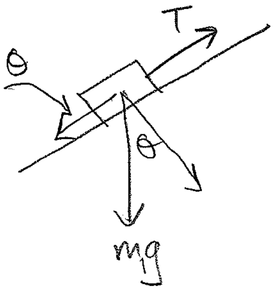
a. 7.5 rad/s
(b.) 15 rad/s
c. 3.75 rad/s

The next two questions pertain to the situation described below.



A block of mass $m_1 = 5$ kg on a frictionless inclined plane of angle 30° is connected by a cord over a small frictionless pulley to a second block of mass $m_2 = 3.3$ kg hanging vertically. We find that the tension in the string is T = 29.3 N.

21) What is the acceleration of mass m_1?



a. 32.37 m/s^2
b. 9.81 m/s^2
(c.) 0.95 m/s^2
d. 2.01 m/s^2
e. 0 m/s^2

$T - mg\sin\theta = m_1 a$

$a = \frac{T}{m_1} - g\sin\theta$

$= \frac{29.3\ N}{5\ Kg} - 9.8\ m/s^2 \sin 30 = 0.96\ m/s^2$

22) The cord now breaks. The acceleration of m_1

a. stays in the same direction
b. Goes to zero
(c.) reverses direction

23) Mass (M) can be measured in kilograms (kg) and velocity (v) can be measured in meters per second (m/s). Kinetic energy is given by $E = \frac{1}{2} Mv^2$. Which of the following is a unit of kinetic energy?

$Mv^2 = kg\ m^2/s^2$

a. $kg\ m^2/s^2$
b. $m\ s^2/kg$
c. kg s /m

24) Which of the following is necessarily NOT in equilibrium?

a. A parachuter descending at constant velocity
b. A car accelerating along a road
c. A pendulum at rest
d. A train moving along a straight track at constant speed
e. A crate resting on the floor

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)

$\Sigma\tau = I\alpha$

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

$\mathbf{L} = I\boldsymbol{\omega}$ $\Sigma\boldsymbol{\tau}_{ext}\Delta t = \Delta\mathbf{L}$

(angular momentum conserved if $\Delta\boldsymbol{\tau}_{ext} = 0$)

$K_{rot} = {}^1/_2I\omega^2 = L^2/2I$ $K_{total} = K_{trans} + K_{rot} = {}^1/_2mv^2 + {}^1/_2I\omega^2$

Moments of Inertia (I)

$I = \Sigma mr^2$ (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)

Fluids

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

$\rho = M/V$ (density)

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

$\rho_{water} = 1000\ kg/m^3$

$1 m^3 = 1000$ liters

$1\ atm = 1.01 \times 10^5\ Pa$

$1\ Pa = 1\ N/m^2$

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

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

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

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

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)

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

$Q = \kappa A \Delta T t/L$ conduction

$Q = e\sigma T^4 At$ 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 = 12.000 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)

$\Delta S = Q/T$ (entropy)