WID: Name:

Please read:

Make your work clear to the grader. Follow these procedures.

- For MC or TF questions, choose the best answer.
- Show formulas you will use, before inserting numbers.
- Show all the essential steps, do the algebra before inserting numbers.
- Give results with **correct SI units** and correct **significant figures**.
- Partial credit is available if your work is clear.
- Unless otherwise requested, **give results in SI units**.
- Using a prefix like n, μ, m, k, M, etc. to express answers if convenient.

Start when you are given the instruction to do so. Good Luck.

1. (4) If a car is moving along a winding road at constant speed, which one of these quantities is zero?

a. its displacement. b. its velocity. c. its acceleration.
d. its change in kinetic energy. e. none of the other choices.

2. (4) If a car is travelling along some x-axis and is slowing down, its acceleration is along

a. $-x$. b. $+x$. c. $-y$. $+y$. e. some other axis not listed.

3. (4) Which of the following controls can be used to make a car accelerate?

a. the steering wheel. b. the gas pedal. c. the brake pedal.
d. all of the choices a,b & c. e. none of the other choices.

4. (4) When a mass travels in a circle at constant speed, its acceleration

a. is zero because the speed is constant. b. points along the arc of the circle.
c. points away from the circle's center. d. points towards the circle's center.

5. (5) Fred takes a walk, first going 5.0 blocks due east, then 7.0 blocks due south, and then finally 9.0 blocks due west. How far along a straight line is he from his starting point, in blocks?

6. (5) A 1680-kg car with initial speed of 24 km/h accelerates uniformly at 3.2 m/s^2 on a straight road. How long will it take for the car to reach a speed of 96 km/h?

7. (5) A 1680-kg car accelerates from rest to 136 km/h (37.8 m/s) on a level road in 11.2 s. What is the average power required, in kW?

. . . .

8. (4) You throw a baseball straight up in the air and it comes back to the launch point in 2.5 seconds. Which quantity would have to be doubled to make it stay in the air for twice as long?

a. the ball's initial speed. b. the ball's initial kinetic energy.
c. the ball's initial potential energy. d. the ball's mass.

. . . .

9. (4) You throw a baseball straight up in the air and it reaches a peak height of 15 m above the launch point. Which quantity would have to be doubled to make it rise twice as high above the launch point?

a. the ball's initial speed. b. the ball's initial kinetic energy.
c. the ball's initial potential energy. d. the ball's mass.

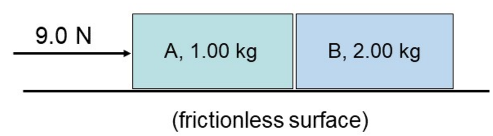
. . . .

10. (4) When a projectile's launch speed is doubled, its range over level ground (for any launch angle) will be changed by a factor of: a. 1 (unchanged). b. $\sqrt{2}$ c. 2 d. 4 e. other.

. . . .

11. (4) Block A of 1.00 kg is being pushed into block B of 2.00 kg by an applied force of 9.0 N and they accelerate together as shown. What can you say about the net forces on them?

a. The net force on A is equal to the net force on B.
b. The net force on A is twice the net force on B.
c. The net force on A is half the net force on B.
d. The net force on A is 1/3 of the net force on B.



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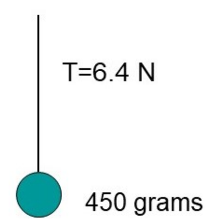
12. (4) A 450-gram ball is suspended on a string. At some instant, the tension in the string is 6.4 N. What is true about the ball's motion?

a. Its acceleration and velocity are both up.
b. Its acceleration and velocity are both down.
c. Its acceleration is up and its velocity is down.
d. Its acceleration is down but its velocity could be up or down.
e. Its acceleration is up but its velocity could be up or down.



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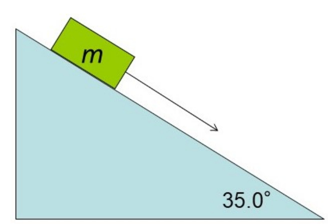
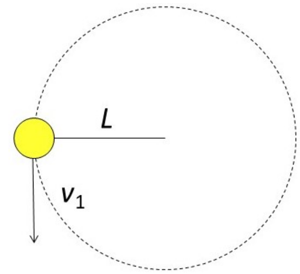
13. (5) A 2.00-kg block slides down along an incline with an acceleration of $0.42g$. This is less than $g \sin\theta$, so there must be friction acting. How large is that friction force?



14. (5) A 1200-kg car is accelerating northward at 4.5 m/s^2. Give the magnitude and direction of the friction force its tires exert on the level road.

15. (10) A 64-kg mass connected to a cord of length $L = 2.00$ m swings around a full circle. When the cord is horizontal, the speed of the mass is $v_1 = 8.0$ m/s.



a) (5) How fast will the mass be moving when it passes the lowest point?

b) (5) How large is the tension in the cord when the mass passes the lowest point?

16. (5) A basketball is approximated as a hollow sphere with rotational inertia $I = (2/3)MR^2$. Suppose it rolls without slipping, with v being the speed of its center. In terms of M and v, write a formula for the total kinetic energy of a rolling basketball.

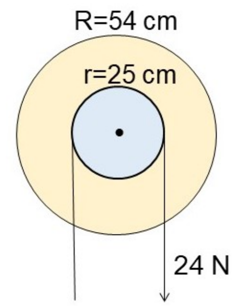
3. ______ / 20

17. (5) A 98 kg football player catches a horizontally moving 0.42 kg football, stopping it in 0.25 s. The average horizontal force of the ball on the player's hands was 45 N. What was the initial speed of the football?

. . . .

18. (10) A wheel in some machinery has a belt that pulls with a 24-N force tangentially at a 25 cm radius. The force is applied for 12.0 s, bringing the wheel to a rotational speed of 3200 rpm, starting from rest.

a) (5) At 3200 rpm, what is the linear speed of the edge at $R = 54$ cm?



b) (5) How large is the rotational inertia of the wheel?

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19. (5) The uppermost floor of a building is 40.0 m above the point where the water main enters the building. To ensure a gauge pressure of 1.00 atm at the uppermost floor, what gauge pressure is needed in the water main?

4. ______ / 20

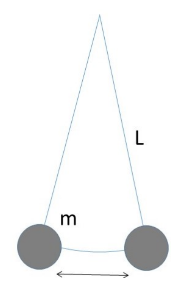
20. (4) Inside a house the pressure is 1.00 atm. If a strong gust of wind blows parallel to a window, the pressure on the outer surface of the window will be

a. less than 1.00 atm. b. 1.00 atm. c. more than 1.00 atm. d. no way to know.

21. (5) A 4.3-kg material sample weighs 12.2 N fully submerged under water. Calculate its density in kg/m^3.

22. (5) Cold water (0.0°C) with a viscosity of 1.8 mPa·s passes through the 1.00-cm radius water main into a house at a speed of 5.00 m/s. What is the flow rate in L/s?

23. (5) A pendulum made from a 25.0 kg mass suspended on a cord is oscillating with a period of 12.0 s. How long is the cord?



24. (4) When a mass connected to a spring is oscillating between points $x = -12.0$ cm and $x = +12.0$ cm, at which point(s) will the speed be maximum?

a. $x = 0$. b. $x = \pm 7.2$ cm. c. $x = \pm 12.0$ cm d. some other value(s).

5. ______ / 23

25. (5) A 42.0 cm long string on a cello is vibrating at 882 Hz in a standing wave with two loops. What is the speed of the waves on the string?

26. (2) **T F** Sound waves in air travel faster when the temperature is higher.

27. (2) **T F** Sound waves in air travel faster if their frequency is higher.

28. (4) You are given two organ pipes: Pipe A is 1.0 m long, open at both ends. Pipe B is 0.5 m long, open at one end and closed at the other. Which has the higher fundamental resonance frequency?

a. pipe A. b. pipe B. c. it's a tie. d. not enough information is given to decide this.

29. (4) A piano string vibrates and produces sound in the air. What property of the waves in air is the same for the waves on the piano string?

a. wavelength. b. frequency. c. intensity. d. speed. e. none of the other choices.

30. (4) Air at STP contains a mixture of O_2, N_2, H_2O, CO_2, etc. What property is the same for them all?

a. molecular speeds. b. molecular rms speeds. c. instantaneous KE_{trans}. d. average KE_{trans}.

31. (15) A container holds 8.00 grams of helium (ideal) gas at 1.00 atm and 295 K.

a) (5) How many moles of helium are present?

b) (5) What is the volume of the container, in liters?

c) (5) How much internal energy is present in the gas, in joules?

32. (10) A 1.00 kg piece of metal initially at 100°C in thrown into an insulated container holding 4.00 L water initially at 0°C. After a short time, the final temperature of both is 12.0°C.

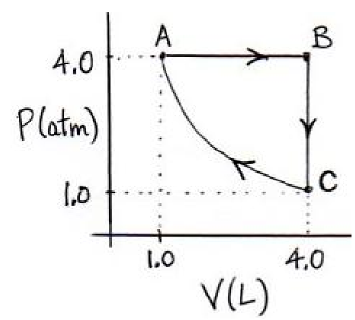
a) (5) Find the heat absorbed by the water.

b) (5) Find the specific heat of the metal.

33. (4) How can a system increase its internal energy. Choose all the ways that correspond to increases.

a. The system gives heat to a colder object.
b. The system absorbs heat from a hotter object.
c. The system does work on its surroundings.
d. The surroundings do work on the system.
e. none of the other choices.

34. (16) The PV diagram indicates a sequence of processes (AB, BC, CA) applied to an ideal gas in an engine, with pressure in atmospheres and volume in liters (1 L = 10^{-3} m^3).



a) (3) Which process could be an isothermal compression?

a. AB b. BC c. CA d. there isn't one.

b) (3) Which process is an isobaric compression?

a. AB b. BC c. CA d. there isn't one.

c) (5) If the gas temperature is 280 K at point A, what is its temperature at point B?

d) (5) Find the work done by the gas in process AB.

35. (12) 1.40 moles of ideal gas expands adiabatically, doing 4200 J of work on its surroundings.

a) (4) The heat transfered to the gas is a. -4200 J b. 0 J c. 4200 J. d. other.

b) (4) The internal energy change of the gas is a. negative b. zero c. positive.

c) (4) The temperature change of the gas is a. negative b. zero c. positive.

. . . .

36. (15) Per cycle, a large heat engine draws 5600 J of thermal energy from a high temperature reservoir at 950 K, while generating 2500 J of work, and exhausting waste heat into the surroundings at 320 K.

a) (5) How large is the efficiency of the engine?

b) (5) Per cycle, what is the entropy change of the surroundings?

c) (5) Using the same high-temperature and low-temperature reservoirs, what is the maximum theoretical efficiency possible?

Prefixes

a=10^{-18}, f=10^{-15}, p=10^{-12}, n=10^{-9}, $\mu = 10^{-6}$, m=10^{-3}, c=10^{-2}, k=10^{3}, M=10^{6}, G=10^{9}, T=10^{12}, P=10^{15}.
atto, femto, pico, nano, micro, milli, centi, kilo, mega, giga, tera, peta.

Physical Constants

$g = 9.80$ m/s^2 (gravitational acceleration)
$M_E = 5.98 \times 10^{24}$ kg (mass of Earth)
$m_e = 9.11 \times 10^{-31}$ kg (electron mass)
$c = 299792458$ m/s (exact speed of light)
$u = 1.6605 \times 10^{-27}$ kg (atomic mass unit)
$R = 8.314$ J/mol·K (gas constant)

$G = 6.67 \times 10^{-11}$ N·m^2/kg^2 (Gravitational constant)
$R_E = 6380$ km (mean radius of Earth)
$m_p = 1.67 \times 10^{-27}$ kg (proton mass)
$\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4 (Stefan-Boltzmann constant)
$N_A = 6.022 \times 10^{23}$/mol (Avogadro's number)
$k = 1.38 \times 10^{-23}$ J/K (Boltzmann's constant)

Units and Conversions

1 inch = 1 in = 2.54 cm
1 mile = 5280 ft =1760 yards
1 m/s = 3.6 km/hour
1 acre = (1 mile)^2/640 = 43 560 ft^2
1 lb = 4.45 N

1 foot = 1 ft = 12 in = 0.3048 m
1 mile = 1609.344 m = 1.609344 km
88 ft/s = 60 mile/hour
1 hectare = (100 m)^2 = 10^4 m^2
1 N = 0.225 lb

1 m^3 = 1000 L
1 cal = 4.186 J
1 J = 1 joule = 1 N·m

symbol	element	atomic number	mass number
H	hydrogen	1	1.00794
He	helium	2	4.00260
C	carbon	6	12.0107
N	nitrogen	7	14.0067
O	oxygen	8	15.9994
Ne	neon	10	20.180
Ar	argon	18	39.948
Fe	iron	26	55.845
Ni	nickel	28	58.693
Cu	copper	29	63.546
Au	gold	79	196.97
U	uranium	92	238.03

Mass numbers are atomic masses in units of "u" where 1 u = 1.6605×10^{-27} kg, or, molar masses for the element (1 mole = 6.02×10^{23} atoms), measured in grams/mole. ($N_A \times 1$ u = 1 gram)

Algebra, Geometry, Trigonometry

Quadratic equations: $ax^2 + bx + c = 0$, solved by $x = \left(-b \pm \sqrt{b^2 - 4ac}\right)/(2a)$.
Triangles: $A = \frac{1}{2}bh$, Circles; $C = 2\pi r$, $A = \pi r^2$, arc $= s = r\theta$. Spheres: $A = 4\pi r^2$, $V = \frac{4\pi}{3}r^3$.
$\sin\theta = (\text{opp})/(\text{hyp})$, $\cos\theta = (\text{adj})/(\text{hyp})$, $\tan\theta = (\text{opp})/(\text{adj})$, $(\text{opp})^2 + (\text{adj})^2 = (\text{hyp})^2$.
$\sin\theta = \sin(180^\circ - \theta)$, $\cos\theta = \cos(-\theta)$, $\tan\theta = \tan(180^\circ + \theta)$, $\sin^2\theta + \cos^2\theta = 1$.

OpenStax Ch 1: Units, measurements, errors or uncertainties

Unit conversions: value = # (old units), (old units) $\times \left(\frac{\text{new units}}{\text{old units}}\right)$ = (new units).
Percent error: measurement = value ± error, percent error = (error / value)×100%.

OpenStax Ch 2: 1D Kinematics - Straight-line motion

Velocity:	$\bar{v} = \Delta x/\Delta t$	$\Delta x = x - x_0$	$v(t)$ = slope of $x(t)$
Acceleration:	$\bar{a} = \Delta v/\Delta t$	$\Delta v = v - v_0$	$a(t)$ = slope of $v(t)$
Constant acceleration:	$v = v_0 + at$,	$\bar{v} = \frac{1}{2}(v_0 + v)$,	$\Delta x = \bar{v}\Delta t$.
	$x = x_0 + v_0 t + \frac{1}{2}at^2$,	$x = x_0 + v_{\text{avg}}t$,	$v^2 = v_0^2 + 2a\Delta x$.
Free fall (+y-axis is up):	$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$,	$v_y = v_{0y} - gt$,	$v_y^2 = v_{0y}^2 - 2g\Delta y$.

OpenStax Ch 3: Vectors & 2D & 3D Motion

Vector $\mathbf{V} = \vec{V} = (V_x, V_y)$, magnitude=$V = \sqrt{V_x^2 + V_y^2}$, direction=$\theta = \tan^{-1}(V_y/V_x)$.
θ = angle from x-axis to $\mathbf{V}$, $V_x = V\cos\theta$, $V_y = V\sin\theta$.
Addition: $\mathbf{A} + \mathbf{B}$, head to tail, Subtraction: $\mathbf{A} - \mathbf{B}$ is $\mathbf{A} + (-\mathbf{B})$, $-\mathbf{B}$ is $\mathbf{B}$ reversed.

Projectiles:	$a_x = 0$,	$v_x = v_{0x}$,	$x = x_0 + v_{0x}t$,	(horizontal x-axis),	$R = (v_0^2/g)\sin 2\theta_0$.
	$a_y = -g$,	$v_y = v_{0y} - gt$,	$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$,	(upward y-axis).	

Relative Motion: $\mathbf{V}_{\mathrm{BS}} = \mathbf{V}_{\mathrm{BW}} + \mathbf{V}_{\mathrm{WS}}$, **B**oat, **S**hore, **W**ater. BS = "boat relative to shore", etc.

OpenStax Ch 4: Newton's Laws

Newton's 1st Law:	$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} = 0$ unless $\vec{F}_{\text{net}} \neq 0$,	$\vec{F}_{\text{net}} = \sum \vec{F}_i$ = sum of all forces on a mass.
Newton's 2nd Law:	$\vec{F}_{\text{net}} = m\vec{a}$,	$F_{\text{net},x} = ma_x,\ F_{\text{net},y} = ma_y,\ F_{\text{net},z} = ma_z$.
Newton's 3rd Law:	$\vec{F}_{AB} = -\vec{F}_{BA}$,	Forces exist in action-reaction pairs.
Gravitational force near Earth:	$F_G = mg$, downward.	Apparent weight is force measured by a scales.
Gravity components on inclines:	$F_\parallel = mg\sin\theta,\ F_\perp = mg\cos\theta$,	← for incline at angle θ to horizontal.
Spring force:	$F_s = -kx$,	x is the displacement from equilibrium.

OpenStax Ch 5: Friction

Normal force:	N or F_N,	acts perpendicular to a surface, acts on the object.
Static friction (object is stuck):	$f_s \leq \mu_s N$,	Can balance other forces in any direction.
Kinetic friction (object sliding):	$f_k = \mu_k N$,	Acts **against** the relative motion of surfaces.

OpenStax Ch 6: Circular Motion

Centripetal Acceleration:	$a_c = v^2/r = \omega^2 r$,	towards the center of the circle,	Use ω in rad/sec!
Circular motion:	speed $v = 2\pi r/T$,	frequency $f = 1/T$,	T = period of one revolution.
	speed $v = \omega r$,	angular speed $\omega = 2\pi f = 2\pi/T$,	ω is in rad/sec.
Gravitation:	$F = Gm_1m_2/r^2$,	free fall $g = GM/r^2$,	$G = 6.67 \times 10^{-11}$ Nm^2/kg^2.
Orbits:	$v^2/r = g = GM/r^2$;	speed $v = \sqrt{GM/r}$,	centripetal a_c = free fall g.

OpenStax Ch 7: Work & Energy

Forces:	F_x,	$F_{\text{gravity},y} = -mg$,	$F_{\text{spring}} = -kx$.
Work:	$W = F_x \Delta x \cos\theta$,	$W_{\text{gravity},y} = -mg\Delta y$,	$W_{\text{spring}} = -\frac{1}{2}k(x_f^2 - x_i^2)$.
PE:	$\Delta\text{PE} = -W_{\text{force}}$,	$\text{PE}_{\text{gravity}} = mgy$,	$\text{PE}_{\text{spring}} = \frac{1}{2}kx^2$.
KE:	$\text{KE} = \frac{1}{2}mv^2$,	$\Delta\text{KE} = W_{\text{net}}$,	W_{net} = work of all forces.
Conservation of Energy:	$\Delta\text{KE} + \Delta\text{PE} = W_{\text{NC}}$,	NC = non-conservative forces.	
Power:	$P_{\text{ave}} = W/t$,	or use P_{ave} = energy/time.	

OpenStax Ch 8: Momentum

Linear momentum:	$\vec{p} = m\vec{v}$,	impulse $\Delta\vec{p} = m\Delta\vec{v} = \vec{F}_{\text{ave}}\,\Delta t$.
Conservation of Momentum:	$m_A\vec{v}_A + m_B\vec{v}_B = m_A\vec{v}_A^{\,'} + m_B\vec{v}_B^{\,'}$,	(2-body collisions, $\vec{F}_{\text{net}} = 0$).
1D elastic collision:	$\frac{1}{2}m_Av_A^2 + \frac{1}{2}m_Bv_B^2 = \frac{1}{2}m_Av_A^{'2} + \frac{1}{2}m_Bv_B^{'2}$,	or $v_A - v_B = -(v_A' - v_B')$.

OpenStax Ch 9: Rotational Motion

Coordinates:	1 rev = 2π rad,	1 rev = 360°,	$\omega = 2\pi f$,	$f = \frac{1}{T}$.
Averages:	$\bar{\omega} = \frac{\Delta\theta}{\Delta t}$,	$\Delta\theta = \bar{\omega}\Delta t$,	$\bar{\alpha} = \frac{\Delta\omega}{\Delta t}$,	$\Delta\omega = \bar{\alpha}\Delta t$.
Linear vs. angular:	$l = \theta r$,	$v = \omega r$,	$a_{\tan} = \alpha r$,	$a_c = \omega^2 r$, use radians!
Constant acceleration:	$\omega = \omega_0 + \alpha t$,	$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$,	$\bar{\omega} = \frac{1}{2}(\omega_0 + \omega)$,	$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$.
Torque, Dynamics:	$\tau = rF\sin\theta$,	$I = \Sigma mr^2$,	$\tau_{\text{net}} = I\alpha$.	
Rotational Inertias:	$I = MR^2$,	$I = \frac{1}{2}MR^2$,	$I = \frac{2}{5}MR^2$,	$I = \frac{1}{12}ML^2$.
(about centers)	(hoop)	(solid cylinder)	(sphere)	(thin rod)
KE, A. Momentum:	$\text{KE}_{\text{rot}} = \frac{1}{2}I\omega^2$,	$L = I\omega$,	$\Delta L = \tau_{\text{net}}\Delta t$.	
Work, power:	$W = \bar{\tau}\Delta\theta$,	$P = \tau\omega$.		

OpenStax Ch 10: Static Equilibrium

$\Sigma F_x = \Sigma F_y = \Sigma F_z = 0$, $\Sigma\tau = 0$, $\tau = rF\sin\theta = r_\perp F = rF_\perp$, τ=torque around a chosen axis.

OpenStax Ch 11: Static Fluids

1 atmosphere = 1 atm = 101.3 kPa = 1.013 bar = 760 torr = 760 mm Hg = 14.7 lb/in^2.

Units:	1 Pa = 1 N/m^2,	1 bar = 10^5 Pa,	1 mm Hg = 133.3 Pa.
Density:	$\rho = m/V$,	$\rho_{H_2O} = 10^3$ kg/m^3 (4°C),	10^3 kg/m^3 = 1 g/cm^3.
Pressure:	$P = F/A$,	$P_2 = P_1 + \rho g d$,	$P_{abs} = P_{atm} + P_{gauge}$.
Archimedes:	$F_B = \rho_{fluid} g V_s$,	F_B = weight of displaced fluid.	

OpenStax Ch 12: Fluid Dynamics

Moving fluid:	$Q = Av$ = constant,	Bernouli Eqn: $P + \frac{1}{2}\rho v^2 + \rho g y$ = constant.
Viscosity:	Definition: $F = \eta A v/\ell$,	Poiseuille Eqn: $Q = \pi r^4 (P_2 - P_1)/(8\eta L)$.

OpenStax Ch 16: Oscillations and Waves

Oscillators:	$F = -kx = ma$,	$f = 1/T$,	$\omega = 2\pi f = 2\pi/T$,	$\omega = \sqrt{k/m}$,	$\omega = \sqrt{g/L}$.
Energy, speed:	$E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$,	$E = \frac{1}{2}kA^2 = \frac{1}{2}mv^2_{max}$,	$v_{max} = \omega A$.		
Waves:	$\lambda = vT$,	$v = f\lambda$,	$I = P/A$,	$I = P/4\pi r^2$.	

Wave speed:	$v = \sqrt{F_T/(m/L)}$ (strings),	$v = (331 \text{ m/s})\sqrt{T/(273 \text{ K})}$ (sound in air).
Standing waves:	node to node = $\lambda/2$,	sketch displacement of string or molecules.
	nodes at both ends of strings.	nodes (antinodes) at closed (open) ends of pipes.

OpenStax Ch 17: Sound

Sound in air:	$v = (331 \text{ m/s})\sqrt{T/273 \text{ K}}$,	$v = 343$ m/s at 20°C,	$d = vt$,	$I = P/A$.
Sound level:	$\beta = (10 \text{ dB})\log(I/I_0)$,	$I = I_0\ 10^{\beta/(10 \text{ dB})}$,	$I_0 = 10^{-12}$ W/m^2.	

OpenStax Ch 13: Ideal Gases & Kinetic Theory

Moles:	$n = N/N_A$,	$n = M/M_A$,	M=sample mass.
Avogadro number:	$N_A = 6.022 \times 10^{23}$/mol,	1 u = (1 gram)/N_A ,	1 u = 1.6605×10^{-27} kg.
Temperature scales:	T(°C) = $\frac{5}{9}$[T(°F)-32],	T(°F)=$\frac{9}{5}$ T(°C)+32,	T(K)=T(°C)+273.15.
Thermal expansion:	$\Delta L = \alpha L_0 \Delta T$,	$\Delta V = \beta V_0 \Delta T$.	
Ideal Gas Law:	$PV = nRT = Nk_BT$,	$R = 8.314$ J/mol·K,	$k_B = R/N_A = 1.38 \times 10^{-23}$ J/K.
Kinetic Theory:	$\overline{KE} = \frac{1}{2}mv^2_{rms} = \frac{3}{2}k_BT$,	$v_{rms} = \sqrt{\frac{3k_BT}{m}} = \sqrt{\frac{3RT}{M_A}}$,	$m = M_A/N_A$ = atom or molecule.

OpenStax Ch 14: Heat Transfer

Heat units:	1.00 cal = 4.186 J,	1.00 Cal = 1.00 kcal = 4186 J.
Internal Energy:	$U = \frac{3}{2}NkT = \frac{3}{2}nRT$,	←(ideal monatomic gases).
Heats absorbed:	$Q = mc\Delta T$ (c =specific heat),	$Q = mL$ (L_F =fusion, L_V =vaporization).
For water:	$c_{liq} = 1.00$ cal/(g·C°) = 4.186 kJ/(kg ·C°),	$c_{ice} = 0.50$ cal/(g·C°) = 2.1 kJ/(kg ·C°).
	$L_F = 79.7$ kcal/kg = 333 kJ/kg,	$L_V = 539$ kcal/kg = 2260 kJ/kg.
Heat transfer:	Conduction: $P = \frac{\Delta Q}{\Delta t} = kA\frac{\Delta T}{l}$,	Radiation: $P_{net} = \frac{\Delta Q}{\Delta t} = e\sigma A(T_1^4 - T_2^4)$.
Solar Energy:	$P = \frac{\Delta Q}{\Delta t} \approx (1000 \text{ W/m}^2)\ eA\cos\theta$,	$\sigma = 5.67 \times 10^{-8}$ W/m^2· K^4.

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Process (const):	isobaric (P).	isothermal (T).	isochoric (V).	adiabatic ($Q = 0$).
1st Law:	$\Delta U = Q - W$	W = area under $P(V)$.	$W = P\Delta V$ for isobaric.	
Heat Engines:	$W = Q_H - Q_L$,	$e = \frac{W}{Q_H} = 1 - \frac{Q_L}{Q_H}$,	$\frac{Q_L}{Q_H} = \frac{T_L}{T_H}$ for Carnot cycle.	
AC, Heat Pumps:	$W = Q_H - Q_L$,	AC: COP = $\frac{Q_L}{W}$,	heat pumps: COP = $\frac{Q_H}{W}$.	
Power:	$P_{ave} = W/t$,	or use $P_{ave} = \frac{\text{energy}}{\text{time}}$.		
2nd Law, Entropy:	$\Delta S_{total} \geq 0$,	$\Delta S_{reversible} = 0$,	$\Delta S_{system} = Q/T_{ave}$.	