Name= **Studio Day/Time=**

Eng. Phys. I **Final Exam - Mechanics & Thermodynamics** **May 12, 2022**

Write **neat** & **clear** work. Show **formulas** used, essential steps, results with correct **units** and **significant figures**. Points shown in parenthesis. For TF and MC, choose the *best* answer. Use $g = 9.80$ m/s^2. Ignore air resistance unless it is mentioned in a question. You are allowed to use only a calculator and the attached equation sheet.

1. (2) **T F** If a length measurement is recorded as $x = 2.5$ m, the uncertainty is at least $\delta x \approx 0.5$ m.

2. (2) **T F** When you calculate (9.80 m/s^2)×(40 s), the result with correct precision and units is 392 m/s.

3. (3) A block of wood rests on a level table. In which direction is the normal force of the table on the block?

a. Horizontal to the right. b. Vertically up.
c. Horizontal to the left. d. Vertically down.

4. (3) Gravity acts on a block of wood resting on a level table. Which force is the "reaction" force to the gravitational force on the wood, as stated in Newton's 3rd Law?

a. The normal force of the table on the block. b. Static friction on the block.
c. The normal force of the block on the table. d. The gravitational force of the block on the Earth.

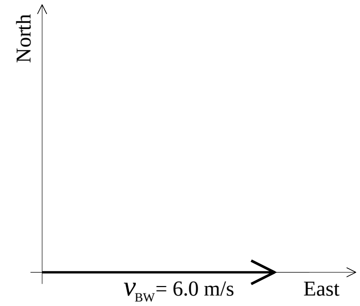
5. (12) A 1.50-kg point particle moves along an x-axis to the right with position as a function of time given by $x(t) = -18t^2 + 9.0t + 32$, where x is in meters and t is in seconds.

a) (4) Find a formula for the velocity as a function of time t.

b) (4) Find a formula for the acceleration as a function of time t.

c) (4) At what time will the particle's velocity reverse direction?

6. (10) Jim is sailing his boat on the Atlantic ocean, pointing the bow due east and moving at $v_{\mathrm{BW}} = 6.0$ m/s relative to the water. However, the ocean has a current flowing at 4.0 m/s in a direction of 30.0° west of north. Relative to the shore, how fast is the boat moving, and at what angle relative to East?



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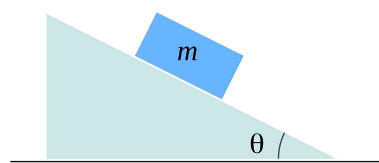
7. (10) A 54.0-kg crate is stuck on a 30.0° slope due to friction, as shown. When the angle is increased to 39.0°, the crate starts sliding downhill. How large is the coefficient of static friction between crate and slope?



8. (21) Match the physics principle on the left with its equation on the right by writing a letter in each space.

1. _____ Newton's 2nd Law.	A. $\Delta K + \Delta U = 0$.
2. _____ Newton's 3rd Law.	B. $\Delta E_{\text{int}} = Q - W$.
3. _____ Archimedes' Principle.	C. $T^2 = 4\pi^2 r^3/(GM)$.
4. _____ Kepler's 3rd Law.	D. $\mathbf{F}_{\text{net}} = m\mathbf{a}$.
5. _____ Conservation of energy.	E. $F_B = \rho_{\text{fluid}} V_s g$.
6. _____ 1st Law of Thermodynamics.	F. $\Delta S_{\text{total}} \geq 0$
7. _____ 2nd Law of Thermodynamics.	G. $\mathbf{F}_{AB} = -\mathbf{F}_{BA}$.

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9. (8) A 52-kg gymnast jumps on a trampoline, which pushes upward on her with an instantaneous force of 720 N. At that instant, what are the magnitude and direction of her instantaneous acceleration?

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10. (8) A baseball player throws a ball with an initial speed of 42 m/s, at an angle of 45° above horizontal. What maximum height above the launch point will it reach? (Ignore air resistance.)

11. (2) **T F** The kinetic energy of a spinning disk doubles when its rotational speed doubles.

12. (2) **T F** The angular momentum of a spinning disk doubles when its rotational speed doubles.

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13. (8) The coefficients of static and kinetic friction for tires on a dry level road are $\mu_s = 0.90$ and $\mu_k = 0.70$. What maximum acceleration from rest can a 1740-kg four-wheel-drive vehicle achieve on this road?

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14. (12) Each of the four wheels of a monster truck has a mass of 165 kg, radius of 1.10 m, and rotational inertia of 125 kg·m^2. The truck accelerates from rest on a level road for 12.0 s at 4.40 m/s^2 and then moves at constant speed.

a) (6) If the wheels aren't slipping, how large is their final angular speed in rad/s?

b) (6) What average mechanical power was used just to get the four wheels rolling without slipping?

15. (12) A rocket is launched straight up with initial speed $v_0 = \sqrt{\frac{8}{9}}\, v_e$ where $v_e = \sqrt{\frac{2GM_E}{R_E}}$ is Earth's escape velocity ($M_E = 5.97 \times 10^{24}$ kg, $R_E = 6380$ km). The rocket coasts with the engine off immediately after launch. Find the maximum altitude reached by the rocket, in units of Earth's radius R_E.

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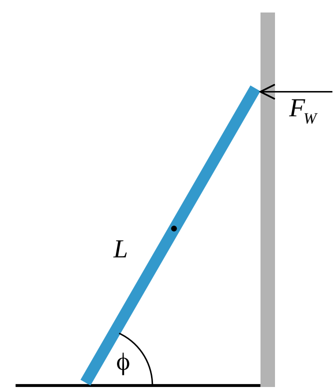
16. (12) A ladder of length $L = 7.50$ m, mass $M = 15.0$ kg, is leaning against a wall at an angle $\phi = 62.0°$ relative to horizontal, stabilized by static friction from the floor. F_W is the force of the wall acting on the ladder (no friction at that point).

a) (4) In terms of the given symbols write an algebraic expression for the torque caused only by F_W relative to the point where the ladder touches the floor.



b) (8) A worker of mass $m = 85.0$ kg stands on a point 80.0% of the way up the ladder. If the ladder doesn't slip, how large is F_W in newtons?

17. (3) Which of the following temperatures is the coldest?

a. 212 K. b. 5° C. c. 22° F. d. -45° C.

18. (3) An energy transfer due to a temperature difference between two objects is known as

a. mechanical work. b. internal energy. c. adiabatic energy. d. heat exchange. e. entropy.

19. (3) The sum of molecular kinetic and potential energies in a substance is known as

a. mechanical work. b. internal energy. c. adiabatic energy. d. heat exchange. e. entropy.

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20. (6) Air is a mixture of various atoms or molecules, including O_2 (oxygen), N_2 (nitrogen), CO_2 (carbon dioxide) and Ar (argon) (see Eq. sheet for masses). Consider a temperature high enough so that all behave as ideal gases.

(a) (3) Which has the highest rms (root-mean-square) speed?

a. O_2. b. N_2. c. CO_2. d. Ar. e. all tie.

(b) (3) Which has the highest translational kinetic energy per atom or molecule?

a. O_2. b. N_2. c. CO_2. d. Ar. e. all tie.

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21. (12) 100.0 grams of a metal at initial temperature 100.0 °C is dropped into a calorimeter containing 100.0 grams of water at initial temperature 0.0 °C. Eventually the system reaches a final temperature of 17.7 °C. The specific heat of water is 1.00 cal/(g °C).

a) (6) What quantity of heat flowed into the water, in calories?

b) (6) How large is the specific heat of the metal, in cal/(g °C)?

22. (4) In which of these processes is work done on a gas? Check all that apply.

a. gas absorbs heat isochorically. b. gas loses heat isochorically. c. gas expands isobarically.
d. gas is compressed isobarically. e. gas is compressed isothermally. f. gas is compressed adiabatically.

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23. (4) In which of these processes does a gas increase its entropy? Check all that apply.

a. gas absorbs heat isochorically. b. gas loses heat isochorically. c. gas expands isobarically.
d. gas is compressed isobarically. e. gas is compressed isothermally. f. gas is compressed adiabatically.

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24. (4) A gas undergoes an isothermal expansion. Which of the listed quantities is zero? Check all that apply.

a. ΔT. b. ΔE_{int}. c. Q. d. W. e. ΔS.

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25. (4) A gas undergoes an adiabatic expansion. Which of the listed quantities is zero? Check all that apply.

a. ΔT. b. ΔE_{int}. c. Q. d. W. e. ΔS.

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26. (4) Which of the following would violate the 2nd Law of Thermodynamics? Check all that apply.

a. 140° F coffee is heated up to 150° F in a microwave oven.
b. 140° F coffee is heated up to 150° F by very vigorous stirring.
c. 140° F coffee is heated up to 150° F when placed in a 40° F refrigerator.
d. 140° F coffee cools down to 110° F when placed in a 40° F refrigerator.
e. 140° F coffee cools down to 110° F when placed in a 450° F oven.

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27. (4) Which of the folllowing are statements of the 2nd Law of Thermodynamics? Check all that apply.

a. Heat never flows spontaneously from a colder object to a hotter object.
b. The entropy of a system and its environment never decreases.
c. A perfect engine is impossible.
d. Entropy is a measure of the disorder in a system.
e. Internal energy depends only on the temperature of a system.

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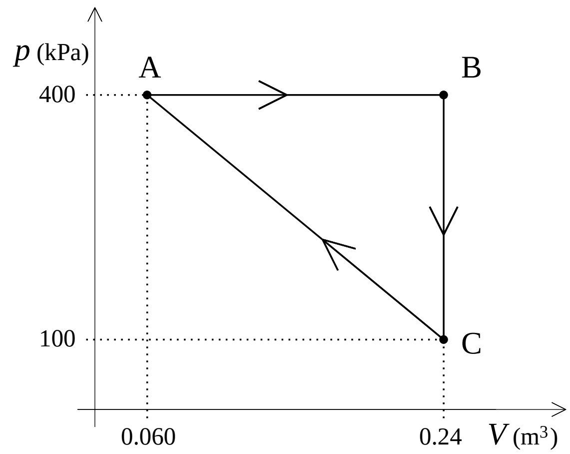
28. (12) A sealed room contains 125 m^3 of O_2 gas at a pressure of 1.00 atm and a temperature of 25° C.

a) (6) How many moles of oxygen molecules are within the room?

b) (6) Calculate the internal energy contained in the oxygen gas in this room, in joules.

29. (15) A heat engine takes 8.0 moles of diatomic ideal gas through the three processes shown in a pV diagram. Note the temperatures, $T_A = T_C = 360$ K.



a) (3) Which process involves all of the heat input from the hot reservoir?

a. A→B. b. B→C. c. C→A.

b) (6) Calculate the heat input Q_H per cycle, in joules.

c) (6) Find the work done by the engine, per cyle, in joules.

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30. (8) An ideal (Carnot) refrigerator is used to cool food to 5.0° C while exhausting heat to the surroundings at 30.0° C. What is the ratio of heat removed from the cold food (Q_L) to the work input (W)?

Prefixes

z=10^{-21}, zepto, a=10^{-18}, atto, f=10^{-15}, femto, p=10^{-12}, pico, n=10^{-9}, nano, $\mu = 10^{-6}$, micro, m=10^{-3}, milli, c=10^{-2}, centi, k=10^{3}, kilo, M=10^{6}, mega, G=10^{9}, giga, T=10^{12}, tera, P=10^{15}, peta, E=10^{18}, exa, Z=10^{21} zeta.

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)
$c = 299\ 792\ 458$ m/s (speed of light)
u $= 1.6605402 \times 10^{-27}$ kg (atomic mass unit)
$k_{\rm B} = 1.3806 \times 10^{-23}$ J/K (Boltzmann's 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)
$N_A = 6.02214 \times 10^{23}$/mol (Avogadro's number)
$R = k_B N_A = 8.31446 \frac{\rm J}{\rm mol\cdot K} = 0.082057 \frac{\rm L\cdot atm}{\rm mol\cdot K}$ (gas constant)

Units & Conversions

1 inch = 1 in = 2.54 cm
1 foot = 1 ft = 12 in = 0.3048 m
1 mile = 5280 ft =1760 yards
1 mile = 1609.344 m = 1.609344 km
1 m/s = 3.6 km/hour
88 ft/s = 60 mile/hour
1 m^3 = 1000 L
1 acre = (1 mile)^2/640 = 43 560 ft^2
1 hectare = (100 m)^2 = 10^4 m^2
1 cal = 4.186 J
1 lb = 4.45 N
1 N = 0.225 lb
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 = 1.6605×10^{-27} kg, or, molar masses for the element (1 mole = 6.022×10^{23} atoms), measured in grams. ($N_A \times 1$ 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: $A = 4\pi r^2$, $V = \frac{4\pi}{3}r^3$

$\sin\theta = ({\rm opp})/({\rm hyp})$, $\cos\theta = ({\rm adj})/({\rm hyp})$, $\tan\theta = ({\rm opp})/({\rm adj})$, $({\rm opp})^2 + ({\rm adj})^2 = ({\rm hyp})^2$.

$\sin^2\theta + \cos^2\theta = 1$, $a^2 + b^2 - 2ab\cos\gamma = c^2$, $\frac{\sin\alpha}{a} = \frac{\sin\beta}{b} = \frac{\sin\gamma}{c}$, $\alpha + \beta + \gamma = 180° = \pi$ rad.

Chapter 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%.

Chapter 2 - Vectors - Magnitude & Direction

2D Vectors:	$\vec{\mathbf{a}} = a_x\hat{\mathbf{i}} + a_y\hat{\mathbf{j}}$,	magnitude = $a = \sqrt{a_x^2 + a_y^2}$,	direction $\to \tan\theta = a_y/a_x$.
Components:	$a_x = a\cos\theta$,	$a_y = a\sin\theta$,	θ=angle to $+x$-axis.
Addition:	$\vec{\mathbf{a}} + \vec{\mathbf{b}}$, head to tail.	Subtraction: $\vec{\mathbf{a}} - \vec{\mathbf{b}}$ is $\vec{\mathbf{a}} + (-\vec{\mathbf{b}})$,	$-\vec{\mathbf{b}}$ is $\vec{\mathbf{b}}$ reversed.
Scalar product:	$\vec{\mathbf{a}} \cdot \vec{\mathbf{b}} = ab\cos\phi$,	$\vec{\mathbf{a}} \cdot \vec{\mathbf{b}} = a_xb_x + a_yb_y + a_zb_z$,	$\hat{\mathbf{i}} \cdot \hat{\mathbf{i}} = 1$, $\hat{\mathbf{i}} \cdot \hat{\mathbf{j}} = 0$, etc.
Cross product:	$\lvert\vec{\mathbf{a}} \times \vec{\mathbf{b}}\rvert = ab\sin\phi$,	$\hat{\mathbf{i}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}}$, etc.	$\hat{\mathbf{i}} \times \hat{\mathbf{i}} = \hat{\mathbf{j}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}} \times \hat{\mathbf{k}} = 0$.

Chapter 3 - 1D Kinematics - Straight-line motion

Velocity:	$v_{\rm avg} = \Delta x/\Delta t$	$\Delta x = x - x_0$	$v(t) = \frac{dx}{dt}$= slope of $x(t)$
Acceleration:	$a_{\rm avg} = \Delta v/\Delta t$	$\Delta v = v - v_0$	$a(t) = \frac{dv}{dt}$= slope of $v(t)$
Integrals = areas:	$x(t) = x_0 + \int_0^t v(t')dt'$,	$v(t) = v_0 + \int_0^t a(t')dt'$.	
Constant acceleration:	$v = v_0 + at$,	$v_{\rm avg} = \frac{1}{2}(v_0 + v)$,	$\Delta x = v_{\rm avg}\Delta t$.
	$x = x_0 + v_0t + \frac{1}{2}at^2$,	$x = x_0 + v_{\rm avg}t$,	$v^2 = v_0^2 + 2a\Delta x$.
Free fall ($+y$-axis is up):	$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$,	$v_y = v_{0y} - gt$,	$v_y^2 = v_{0y}^2 - 2g\Delta y$.

Chapter 4 - 2D and 3D Motion - Vector displacement, velocity, acceleration

Position:	$\vec{\mathbf{r}} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}} + z\hat{\mathbf{k}}$	$\vec{\mathbf{r}} = (x, y, z)$	$\Delta\vec{\mathbf{r}} = (\Delta x, \Delta y, \Delta z)$
Velocity:	$\vec{\mathbf{v}}_{\text{avg}} = \Delta\vec{\mathbf{r}}/\Delta t$	$\vec{\mathbf{v}} = d\vec{\mathbf{r}}/dt$	$\Delta\vec{\mathbf{r}} = \vec{\mathbf{r}} - \vec{\mathbf{r}}_0$
Acceleration:	$\vec{\mathbf{a}}_{\text{avg}} = \Delta\vec{\mathbf{v}}/\Delta t$	$\vec{\mathbf{a}} = d\vec{\mathbf{v}}/dt$	$\Delta\vec{\mathbf{v}} = \vec{\mathbf{v}} - \vec{\mathbf{v}}_0$
Projectiles:	$a_x = 0$	$v_x = v_{0x}$	$x = x_0 + v_{0x}t$
(+y-axis is up)	$a_y = -g$	$v_y = v_{0y} - gt$	$y = y_0 + v_{0y}t - \frac{1}{2}gt^2$
Relative Motion:	$\vec{\mathbf{v}}_{\text{BS}} = \vec{\mathbf{v}}_{\text{BW}} + \vec{\mathbf{v}}_{\text{WS}}$	**B**oat, **S**hore, **W**ater.	BS is "boat relative to shore", etc.
Circular motion:	$a_c = v^2/r = \omega^2 r$	$v = 2\pi r/T = \omega r$	$\omega = 2\pi/T$, T=period of 1 rev.

Chapter 5 - Newton's laws and forces

Newton's 1st Law:	$\vec{a} = \frac{d\vec{v}}{dt} = 0$ 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:	$F_{\parallel} = mg\sin\theta,\ F_{\perp} = mg\cos\theta$,	$\leftarrow$ for incline at angle θ to horizontal.
Spring force:	$F_s = -kx$,	x is the displacement from equilibrium.

Chapter 6 - Friction, circular motion

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.
Centripetal acceleration:	$a_c = v^2/r$,	Points towards the center of the circle.
Rates of circular motion:	speed $v = 2\pi r/T = 2\pi r f$,	frequency $f = \frac{1}{T}$, T=period of one revolution.

Chapter 7 - Work and kinetic energy

Work done by a force:	$dW = \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}} = F\ dr\ \cos\theta$	$W_{AB} = \int_A^B \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}}$ (along the path $A \to B$)
Examples:	$W = \vec{\mathbf{F}} \cdot \Delta\vec{\mathbf{r}}$ (constant $\mathbf{F}$),	$W_s = -\frac{1}{2}k(x_B^2 - x_A^2)$ (spring $F = -kx$).
Work-KE theorem, power:	$\Delta\text{KE} = W_{\text{net}}$ = all works on m.	$\text{KE} = \frac{1}{2}mv^2$, $P = \frac{dW}{dt}$, $P_{\text{ave}} = \frac{\Delta W}{\Delta t}$.

Chapter 8 - Potential energy and Conservation of energy

PE for gravity:	$\Delta U = mg\Delta y$,	$U(y) = mgy+$ constant,	$\leftarrow$(near Earth' surface).
PE for springs:	$\Delta U = \frac{1}{2}k(x_B^2 - x_A^2)$,	$U(x) = \frac{1}{2}kx^2$ + constant.	
Any arbitrary system:	$\Delta E_{\text{mec}} = W_{\text{nc}}$	$E_{\text{tot}} = E_{\text{mec}} + E_{\text{thermal}} + E_{\text{other}}$,	$\Delta E_{\text{tot}} = 0$.

Chapter 9 - Linear momentum and collisions

Linear Momentum:	$\vec{\mathbf{p}} = m\vec{\mathbf{v}}$,	Impulse Theorem:	$\Delta\vec{\mathbf{p}} = \vec{\mathbf{J}} = \int \vec{\mathbf{F}}(t)\,dt = \vec{\mathbf{F}}_{\text{ave}}\Delta t$.
Instantaneous force:	$\vec{\mathbf{F}} = \frac{d\vec{\mathbf{p}}}{dt}$,	Average force:	$\vec{\mathbf{F}}_{\text{ave}} = \frac{\Delta\vec{\mathbf{p}}}{\Delta t}$.
Conservation (@ $\vec{\mathbf{F}}_{\text{net}} = 0$):	$\Delta\vec{\mathbf{p}}_{\text{total}} = 0$,	$\vec{\mathbf{p}}_{1\text{i}} + \vec{\mathbf{p}}_{2\text{i}} = \vec{\mathbf{p}}_{1\text{f}} + \vec{\mathbf{p}}_{2\text{f}}$,	i=initial, f=final.

Center of mass:	$\vec{\mathbf{r}}_{\text{com}} = \frac{m_1\vec{\mathbf{r}}_1 + m_2\vec{\mathbf{r}}_2 + \ldots}{m_1 + m_2 + \ldots}$,	$\vec{\mathbf{v}}_{\text{com}} = \frac{m_1\vec{\mathbf{v}}_1 + m_2\vec{\mathbf{v}}_2 + \ldots}{m_1 + m_2 + \ldots}$	
1D elastic collisions:	$v_{1\text{f}} = 2v_{\text{com}} - v_{1\text{i}}$	$v_{2\text{f}} = 2v_{\text{com}} - v_{2\text{i}}$,	Equal masses swap velocities.
Other collisions:	$\vec{P}_{\text{total}} = M\vec{\mathbf{v}}_{\text{com}}$ = const.	$\vec{P}_{\text{total}} = m_1\vec{\mathbf{v}}_1 + m_2\vec{\mathbf{v}}_2$ = const.	

Chapters 10 - Rotational motion

Coordinates:	1 rev = 2π rad	1 rev = $360°$,	$\omega = 2\pi f$,	$f = \frac{1}{T}$.
Averages:	$\omega_{\text{ave}} = \frac{\Delta\theta}{\Delta t}$,	$\Delta\theta = \omega_{\text{ave}}\Delta t$,	$\alpha_{\text{ave}} = \frac{\Delta\omega}{\Delta t}$,	$\Delta\omega = \alpha_{\text{ave}}\Delta t$.
Radius factors:	$l = \theta r$,	$v = \omega r$,	$a_{\tan} = \alpha r$,	$a_c = \omega^2 r$.
Const. acceleration:	$\omega = \omega_0 + \alpha t$,	$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$,	$\omega_{\text{ave}} = \frac{1}{2}(\omega_0 + \omega)$,	$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$.

Torque:	$\vec{\tau} = \vec{\mathbf{r}} \times \vec{\mathbf{F}}$,	$\tau = rF\sin\theta$,	$\tau = r_\perp F = rF_\perp$,	$\hat{\mathbf{i}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}}$, etc.	
Dynamics, inertia:	$I = \Sigma\, m\, r^2$,	$I = \int dm\, r^2$,	$\tau_{\text{net}} = I\alpha$,	$K_{\text{rot}} = \frac{1}{2}I\omega^2$.	
Rotational inertias:	$I_0 = MR^2$,	$I_0 = \frac{1}{2}MR^2$,	$I_0 = \frac{2}{5}MR^2$,	$I_0 = \frac{1}{12}ML^2$,	$I = I_0 + md^2$.
(about centers)	thin hoop,	solid cylinder,	solid sphere,	thin rod,	$\uparrow$ about parallel axis.
Work, power:	$dW = \tau\, d\theta$,	$W = \int \tau\, d\theta$,	$W = \tau_{\text{ave}}\Delta\theta$,	$P = \tau\omega$.	

Chapter 11 - Angular momentum

Angular momentum:	$\vec{\mathbf{l}} = \vec{\mathbf{r}} \times \vec{\mathbf{p}}$,	$l = rp\sin\theta$,	$l = r_\perp p = rp_\perp$,	$\vec{\mathbf{L}} = \int \vec{\mathbf{r}} \times \vec{\mathbf{v}}\, dm$,	$L = I\omega$.
Dynamics:	$\frac{d}{dt}\vec{\mathbf{L}} = \vec{\tau}_{\text{net}}$,	$\Delta\vec{\mathbf{L}} = \vec{\tau}_{\text{ave}}\Delta t$,	conservation$\rightarrow$	$\vec{\mathbf{L}}_{\text{total}}$ =const.	$\leftarrow$(@ $\vec{\tau}_{\text{net}} = 0$).

Chapter 12 - Static equilibrium

Statics requirements:	$\sum F_x = \sum F_y = \sum F_z = 0$,	$\sum \tau = 0$,	$\tau = rF\sin\theta$.
Stress & strain:	stress $= F_\perp/A$,	strain $= \Delta L/L_0$,	stress $= Y\times$ strain.
Shear forces:	stress $= F_\parallel/A$,	strain $= \Delta x/L_0$,	stress $= S\times$ strain.
Bulk modulus B:	b-stress $= \Delta p$,	b-strain $= \Delta V/V_0$,	b-stress $= B\times$ b-strain.
Units:	stress in Pa=N/m^2,	strain = % or no units,	Y, S, B in Pa=N/m^2.

Chapter 13 - Gravitation

Gravitational force:	$F = Gm_1m_2/r^2$,	$F = mg$,	$g = GM/r^2$,	$v_{\text{escape}} = \sqrt{2GM/r}$.
Gravitational PE:	$U = -Gm_1m_2/r$,	$\Delta U + \Delta K = 0$,	$\Delta K = -\Delta U$,	$\Delta K = \frac{1}{2}m(v_f^2 - v_i^2)$.
Orbits:	$F = mv^2/r$,	$v = 2\pi r/T$,	$v_{\text{orb}} = \sqrt{GM/r}$,	Kepler: $T^2 = \frac{4\pi^2}{GM}\bar{r}^3$.

Chapter 14 - 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:	$p = F/A$,	$p_2 = p_1 + \rho g d$,	$p_{\text{abs}} = p_{\text{atm}} + p_{\text{gauge}}$.
Archimedes:	$F_B = \rho_{\text{fluid}} g V_s$,	Bernoulli energy conserv.→	$p + \rho g y + \frac{1}{2}\rho v^2 =$ const.
Flow rates:	$Q = Av$,	$Q_m = \rho A v$,	$Q = (p_2 - p_1)\pi r^4/(8\eta L)$.
Viscosity:	$F = \eta v A/L$,	$N_R = 2\rho v r/\eta$,	$N_R < 2000$ laminar, $N_R > 3000$ turbulent.

V2 - Chapter 1 - Temperature & Heat transfer

Moles:	$n = N/N_A$,	$n = M/M_A$,	$N_A = 6.022\times 10^{23}$/mol,	1 u $\times N_A$ = 1 gram.
Temperatures:	$T_C = \frac{5}{9}(T_F - 32)$,	$T_F = \frac{9}{5}T_C + 32$,	$T_K = T_C + 273.15$,	$T = \frac{p}{p_{TP}}T_{TP}$.
Expansion:	$\Delta L = \alpha L_0 \Delta T$,	$\Delta A = 2\alpha A_0 \Delta T$,	$\Delta V = \beta V_0 \Delta T$,	$\beta = 3\alpha$ (solids).
Heat transfers:	$Q = mc\Delta T$,	$Q = mL_F$,	$Q = mL_V$,	1 cal = 4.186 J.
Heat flow rates:	$P_{\text{cond}} = kA\Delta T/d$,	$P_{\text{rad}} = \sigma e A(T_2^4 - T_1^4)$,	$P_{\text{solar}} \approx (1\ \frac{\text{kW}}{\text{m}}^2)eA\cos\theta$.	

V2 - Chapter 2 - Kinetic theory & Ideal gases

Ideal gases:	$pV = nRT$,	$pV = Nk_BT$,	$R = 8.314\ \frac{\text{J}}{\text{mol}\cdot\text{K}}$,	$k_B = R/N_A$.
Kinetic theory:	$\overline{\text{KE}}_{\text{trans}} = \frac{m}{2}v_{\text{rms}}^2 = \frac{3}{2}k_BT$,	$v_{\text{rms}} = \sqrt{\frac{3k_BT}{m}} = \sqrt{\frac{3RT}{M_A}}$,	$m = M_A/N_A$,	m =molecule.
Internal energy:	$E_{\text{int}} = nC_VT$,	$E_{\text{int}} = n\frac{d}{2}RT$,	$E_{\text{int}} = N\frac{d}{2}k_BT$,	$d = 3, 5, 6$
Molecules:	monatomic, $d = 3$,	diatomic, $d = 5$,	polyatomic, $d = 6$,	← room temp.
Specific heats:	$Q = nC\Delta T$,	$C_V = \frac{d}{2}R$,	$C_P = C_V + R$,	$\gamma \equiv C_P/C_V$.

V2 - Chapters 3,4 - 1$^{\text{st}}$ and 2$^{\text{nd}}$ Laws of Thermodynamics

Process (constant):	isobaric (p)	isothermal (T)	isochoric (V)	adiabatic (pV^γ with $Q = 0$)
1$^{\text{st}}$ Law:	$\Delta E_{\text{int}} = Q - W$,	$W = \int_i^f p\ dV$,	$W_{\text{isobaric}} = p\ \Delta V$,	$W_{\text{isothermal}} = nRT\ln(V_f/V_i)$.
2$^{\text{nd}}$ Law:	$\Delta S_{\text{total}} \geq 0$,	$\Delta S \equiv \int_i^f dQ/T$,	$\Delta S = mc\ln(T_f/T_i)$,	$\Delta S = mL/T$.
Heat engines:	$W = Q_H - Q_L$,	$\varepsilon = W/Q_H$,	Carnot: $\frac{Q_L}{Q_H} = \frac{T_L}{T_H}$,	$P_{\text{mech}} = W/t$.
AC, heat pumps:	$K_{\text{AC}} = Q_L/W$,	$P_{\text{cool}} = Q_L/t$,	$K_{\text{HP}} = Q_H/W$,	$P_{\text{heat}} = Q_H/t$.