

# Equation Sheet For Quizzes and Tests

You must have memorized the unit prefix values and the formulas related to circles, spheres, and rectangles.

## Chapter 1:

$$\text{density} = \frac{\text{mass}}{\text{volume}} \quad \rho = \frac{m}{V}$$

Aluminum	2.70	g/cm <sup>3</sup>	Lead	11.34	g/cm <sup>3</sup>	Mercury	13.6	g/cm <sup>3</sup>
Copper	8.96	g/cm <sup>3</sup>	Water	1.00	g/cm <sup>3</sup>	Gasoline	0.680	g/cm <sup>3</sup>
Iron	7.87	g/cm <sup>3</sup>	Seawater	1.03	g/cm <sup>3</sup>			

## Chapter 2:

$$\text{velocity} = \text{speed and direction} \quad \text{average velocity} = \frac{\text{change in position}}{\text{change in time}} \quad \bar{v} = \frac{\Delta x}{\Delta t} \quad (\text{unit: } \text{m/s} = \frac{\text{m}}{\text{s}})$$

$$\text{average acceleration} = \frac{\text{change of velocity}}{\text{time}} \quad \bar{a} = \frac{\Delta v}{\Delta t} \quad \text{acceleration has direction} \quad (\text{unit: } \text{m/s}^2 = \frac{\text{m}}{\text{s}^2})$$

Assuming no acceleration, constant velocity, and initial position=0:

$$\text{distance} = (\text{velocity}) \cdot (\text{time}) \quad d = v t$$

Assuming constant acceleration, initial velocity=0 and initial position= 0:

$$\text{velocity} = (\text{acceleration}) \cdot (\text{time}) \quad v = a t \quad \text{distance} = \frac{1}{2} (\text{acceleration}) \cdot (\text{time})^2 \quad d = \frac{1}{2} a t^2$$

$$\text{net force} = (\text{mass}) \cdot (\text{acceleration}) \quad F_{\text{net}} = m a \quad \text{force has direction} \quad \text{unit: newton, } \text{N} = \frac{\text{kg} \cdot \text{m}}{\text{s}^2}$$

Weight is the downward force caused by gravity:

$$\text{weight} = (\text{mass}) \cdot (\text{acceleration due to gravity}) \quad w = m g \quad g = 9.80 \text{ m/s}^2 \quad \text{at earth surface}$$

$$\text{force on object A due to object B} = -\text{force on object B due to object A} \quad F_{\text{A due to B}} = -F_{\text{B due to A}}$$

Momentum:

$$\text{momentum} = (\text{mass}) \cdot (\text{velocity}) \quad p = m v \quad \text{momentum has direction}$$

$$\text{change of momentum} = (\text{average force}) \cdot (\text{time of interaction}) \quad \Delta p = \bar{F} \Delta t$$

$$\text{conservation of total momentum in an isolated system: } p_{\text{total, before}} = p_{\text{total, after}}$$

Circular motion:

$$\text{centripetal acceleration} = \frac{(\text{velocity})^2}{\text{radius of circle}} \quad a_c = \frac{v^2}{r} \quad \text{centripetal force} = \frac{(\text{mass}) \cdot (\text{velocity})^2}{\text{radius of circle}} \quad F_c = \frac{m v^2}{r}$$

Gravitational force in general:

$$\text{gravitational force} = (\text{constant}) \cdot \frac{(\text{one mass}) \cdot (\text{another mass})}{(\text{distance})^2} \quad F = G \frac{m_1 m_2}{d^2} \quad G = 6.67 \times 10^{-11} \frac{\text{N} \cdot \text{m}^2}{\text{kg}^2}$$

$$\text{gravitational acceleration} = \frac{(\text{constant}) \cdot (\text{mass})}{\text{distance}^2} \quad g = G \frac{m}{d^2}$$

### Chapter 3:

Assuming constant force:

$$\text{work done by force} = (\text{force}) \cdot (\text{distance moved in direction of force}) \quad W = Fd \quad \text{unit: joule, } J = \text{N} \cdot \text{m} = \frac{\text{kg} \cdot \text{m}^2}{\text{s}^2}$$

$$\text{power} = \frac{\text{work}}{\text{time}} \quad P = \frac{W}{t} \quad \text{unit: watt, } W = J/s = \frac{J}{s}$$

$$\text{change in gravitational potential energy} = \text{work} = (\text{weight}) \cdot (\text{change in height}) \quad PE = W = Fd = (mg) \cdot h = mgh$$

$$\text{kinetic energy} = \frac{1}{2} (\text{mass}) \cdot (\text{velocity})^2 \quad KE = \frac{1}{2} m v^2$$

If friction can be ignored, total energy is unchanged during free fall from height  $h$ :

$$\text{change in KE} = \text{change in PE} \quad \frac{1}{2} m v^2 = mgh \quad \text{so } v = \sqrt{(2gh)}$$

### Chapter 4:

$$T_F = \frac{9}{5} T_C + 32^\circ\text{F} \quad T_C = \frac{5}{9} (T_F - 32^\circ\text{F}) \quad T_K = T_C + 273^\circ\text{C} = T_C + 273 \text{ K}$$

$$\text{change in heat energy of } H_2O = (\text{mass}) \cdot (\text{specific heat}) \cdot (\text{change in temperature}) \quad Q = m c \Delta T$$

$$c_{ice} = 0.50 \frac{\text{cal}}{\text{g} \cdot ^\circ\text{C}} \quad c_{water} = 1.00 \frac{\text{cal}}{\text{g} \cdot ^\circ\text{C}} \quad c_{steam} = 0.48 \frac{\text{cal}}{\text{g} \cdot ^\circ\text{C}}$$

$$H_2O \text{ fusion heat energy absorbed or released} = (\text{mass}) \cdot (\text{latent heat of } H_2O \text{ fusion})$$

$$Q = m L_f \quad L_f = 80 \frac{\text{cal}}{\text{g}}$$

$$H_2O \text{ vaporization heat energy absorbed or released} = (\text{mass}) \cdot (\text{latent heat of } H_2O \text{ vaporization})$$

$$Q = m L_v \quad L_v = 540 \frac{\text{cal}}{\text{g}}$$

Heat and mechanical energy conversion:

$$1 \text{ food calorie} = 1000 \text{ cal} \quad 1 \text{ cal} = 4.186 \text{ J}$$

### Chapter 5:

$$\text{period} = \frac{1}{\text{frequency}} \quad T = \frac{1}{f} \quad \text{velocity} = (\text{wavelength}) \cdot (\text{frequency}) \quad v = \lambda f$$

$$\text{velocity of sound } v \text{ at temperature } T_C = 331 \text{ m/s} + (0.600 \frac{\text{m}}{\text{s} \cdot ^\circ\text{C}}) \cdot T_C$$

$$\text{speed of light in vacuum} = c = 299792458 \text{ m/s} \quad (\text{Using } 3.00 \times 10^8 \text{ m/s} \text{ is nearly always OK.})$$

$$\text{beat frequency} = \text{one frequency} - \text{other frequency} \quad f_{\text{beat}} = f_2 - f_1$$

$$\text{sound intensity} = \frac{\text{sound power}}{\text{area}} \quad I = \frac{P}{A}$$

$$\text{resonant frequency of a string or an open pipe} = \frac{(\text{an integer}) \cdot (\text{velocity of wave})}{2 \cdot (\text{length})} \quad f_n = \frac{n v}{2 L} \quad n = 1, 2, 3, \dots$$

$$\text{resonant frequency of pipe with closed end} = \frac{(\text{an integer}) \cdot (\text{velocity of wave})}{2 \cdot (\text{length})} \quad f_n = \frac{n v}{4 L} \quad n = 1, 2, 3, \dots$$

## Chapter 6:

quantity of charge = (number of electrons) · (electron charge)  $q = ne = n \cdot (-1.60 \times 10^{-19} \text{ C})$  unit: coulomb, C

Coulomb's Law:

$$\text{electrical force} = (\text{constant}) \left( \frac{(\text{charge on object 1}) \cdot (\text{charge on object 2})}{(\text{distance between objects})^2} \right) \quad F = k \frac{q_1 q_2}{d^2} \quad k = 9.00 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}$$

$$\text{electric potential difference} = \frac{\text{work to create potential difference}}{\text{charge moved}} \quad V = \frac{W}{q} \quad \text{unit: volt, } V = \frac{\text{N}}{\text{C}}$$

$$\text{electric current} = \frac{\text{quantity of charge moved}}{\text{time for the movement}} \quad I = \frac{q}{t} \quad \text{unit: ampere, } A = \frac{\text{C}}{\text{s}}$$

$$\text{resistance} = \frac{\text{electric potential}}{\text{electric current}} \quad R = \frac{V}{I} \quad \text{unit: ohm, } \Omega = \frac{V}{A}$$

$$\text{electric power consumed} = (\text{electric current}) \cdot (\text{electric potential}) \quad P = IV \quad \text{unit: watt, } W = \text{J/s} = \frac{\text{J}}{\text{s}}$$

$$\text{electric cost} = \frac{(\text{electric power in W}) \cdot (\text{time in h}) \cdot (\text{rate in } \$/\text{kW-h})}{1000 \text{ W/kW}}$$

$$\frac{(\text{primary voltage})}{(\text{primary loops})} = \frac{(\text{secondary voltage})}{(\text{secondary loops})} \quad \frac{V_p}{N_p} = \frac{V_s}{N_s} \quad (\text{power in}) = (\text{power out}) \quad P_{\text{in}} = P_{\text{out}}$$

$$(\text{primary voltage}) \cdot (\text{primary current}) = (\text{secondary voltage}) \cdot (\text{secondary current}) \quad V_p I_p = V_s I_s$$

$$R_{\text{total}} = R_1 + R_2 + R_3 + \dots \quad \text{Resistances in series} \quad \frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots \quad \text{Resistances in parallel}$$

## Chapter 7:

$$\text{period} = \frac{1}{\text{frequency}} \quad T = \frac{1}{f} \quad \text{velocity} = (\text{wavelength}) \cdot (\text{frequency})$$

$$\text{speed of light in vacuum} = (\text{wavelength}) \cdot (\text{frequency}) \quad c = \lambda f$$

speed of light in vacuum =  $c = 299792458 \text{ m/s} \approx 3.00 \times 10^8 \text{ m/s}$  (Using  $3.00 \times 10^8 \text{ m/s}$  is nearly always OK.)

$$\text{angle of incidence} = \text{angle of reflection} \quad \theta_i = \theta_r \quad \text{index of refraction} = \frac{\text{speed of light in vacuum}}{\text{speed of light in material}} \quad n = \frac{c}{v}$$

$$\text{energy of photon} = (\text{Planck's constant}) \cdot (\text{photon frequency}) \quad E_{\text{photon}} = hf_{\text{photon}} = (6.63 \times 10^{-34} \text{ J} \cdot \text{s}) f_{\text{photon}}$$

$$\text{Planck's constant} = h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s} \quad \text{momentum of a photon} = \frac{\text{photon energy}}{\text{speed of light}} \quad p_{\text{photon}} = \frac{E_{\text{photon}}}{c} = \frac{h}{\lambda_{\text{photon}}}$$

## Chapter 8:

$$\frac{1}{\text{wavelength}} = (\text{constant}) \left( \frac{1}{2^2} - \frac{1}{(\text{number})^2} \right) \quad \frac{1}{\lambda} = R \left( \frac{1}{2^2} - \frac{1}{n^2} \right) = (1.097 \times 10^7 \frac{1}{\text{m}}) \cdot \left( \frac{1}{2^2} - \frac{1}{n^2} \right)$$

Common energy unit used in atomic and nuclear physics:  $1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$

$$\text{energy of } n^{\text{th}} \text{ orbit state} = \frac{\text{energy of innermost orbit state}}{\text{number squared}} \quad E_n = \frac{E_1}{n^2} = -\frac{13.6 \text{ eV}}{n^2} = -\frac{2.18 \times 10^{-18} \text{ J}}{n^2} \quad n=1, 2, 3, \dots$$

$$\text{wavelength of massive particle} = \frac{\text{Planck's constant}}{\text{particle momentum}} = \frac{\text{Planck's constant}}{(\text{mass}) \cdot (\text{velocity})} \quad \lambda = \frac{h}{mv}$$

## Chapter 9: (no equations)

## Chapter 10:

atomic weight of element = Periodic Table value with units of g/mol

formula mass of compound = sum of atomic masses of atoms in the compound with units of g/mol

$$\text{moles of an element} = \frac{\text{mass in g}}{\text{atomic mass in g/mol}} \quad \text{moles of compound} = \frac{\text{mass in g}}{\text{formula mass in g/mol}}$$

Avogadro's number =  $6.02 \times 10^{23}$  atoms or molecules per mol

$$\frac{\text{atomic mass of element}}{\text{formula mass of compound}} \cdot (\text{number of atoms of element}) \times 100 = \% \text{ of element in compound}$$

## Chapter 11:

$$\text{Concentration by volume: } \% \text{ solute} = \frac{V_{\text{solute}}}{V_{\text{solvent}}} \times 100 \quad \text{By mass: } \% \text{ solute} = \frac{m_{\text{solute}}}{m_{\text{solvent}}} \times 100$$

$$\text{molarity } M = \frac{\text{number of moles}}{1 \text{ L of water}} \quad \text{unit: } M, \text{ mol/L} = \frac{\text{mol}}{\text{L}} \quad \text{pH} = -\log_{10}[\text{H}_3\text{O}^+] \quad [\text{H}_3\text{O}^+] = 10^{-\text{pH}}$$

## Chapter 12: (no equations)

## Chapter 13:

$$\text{energy} = (\text{mass}) \cdot (\text{speed of light})^2 \quad E = mc^2$$

# Symbols and Units

## English letters symbols (Usually shown italicized):

<i>x, y, and z</i>	mainly used for position
<i>r</i>	used for radial distance
<i>d</i>	used for linear distance
<i>l</i>	used for length
<i>w</i>	used for width and for weight
<i>h</i>	used for height
<i>s</i>	used for speed
<i>c</i>	used for the speed of light = 299792458 m/s exactly, approximate value $3.00 \times 10^8$ m/s
<i>c</i>	specific heat in $\text{J/kg} \cdot \text{K} = \text{J/kg} \cdot ^\circ\text{C}$
<i>v</i>	used for velocity = speed with direction
$\bar{v}$	average velocity
<i>a</i>	used for acceleration
$\bar{a}$	average acceleration
<i>g</i>	used for gravitational acceleration (at the earth surface $g = 9.8 \text{ m/s}^2$ )
<i>G</i>	used for the universal gravitation constant = $6.674 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2$
<i>A</i>	used for area
<i>V</i>	used for volume and used for electrical potential (voltage)
<i>I</i>	used for electric current and for intensity (power per unit area) of sound or light
<i>R</i>	used for electrical resistance, the universal gas constant = $8.31 \text{ J/mol} \cdot \text{K}$ and the Rydberg constant = $1.097 \times 10^7 \text{ m}^{-1}$
<i>k<sub>B</sub></i>	used for Boltzmann's constant = gas constant / $N_A = R/N_A = 1.38 \times 10^{-23} \text{ J/K}$
<i>k</i>	coefficient in Coulomb's law = $9.00 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$
<i>F</i>	used for force
<i>N</i>	used for normal (perpendicular) force
<i>N<sub>p</sub>, N<sub>s</sub></i>	used for primary and secondary turn count in a transformer
<i>V<sub>p</sub>, V<sub>s</sub></i>	used for primary and secondary voltages in a transformer
<i>n</i>	used for number of electrons and for the index of refraction of an optical medium
<i>m</i>	used for mass
<i>W</i>	used for work
<i>E</i>	used for energy and also for electric field
<i>KE</i>	kinetic energy
<i>PE</i>	potential energy
<i>U</i>	internal energy
<i>Q</i>	used for heat energy, usually measured in calories (cal)
<i>J</i>	conversion factor for calories to joules = $4.186 \text{ J/cal}$ (used in text, but can be confusing)
<i>P</i>	used for power (energy per unit time)
<i>p</i>	used for pressure (force per unit area)
<i>B</i>	used for magnetic field
<i>T</i>	used for temperature and period of cyclic motion
<i>h</i>	used for Planck's constant = $6.63 \times 10^{-34} \text{ J} \cdot \text{s}$
<i>f</i>	used for frequency
<i>q</i>	used for electric charge
<i>C</i>	used for electrical capacitance
<i>L</i>	used for electrical inductance
<i>L<sub>f</sub>, L<sub>v</sub></i>	used for heat of fusion (melting), and heat of vaporization (condensing)
<i>N<sub>A</sub></i>	used for Avogadro's constant = $6.02 \times 10^{23}$ number of atoms/mol or molecules/mol
<i>e</i>	used for the magnitude of electron charge = $1.60 \times 10^{-19} \text{ C}$ and base of natural logarithms = 2.71827...

Units (NOT italicized, these are easily confused with some of the quantity symbols given above):

<u>Unit</u>	<u>Symbol</u>	<u>Quantity</u>
meters	m	distance
gram	g	mass
second	s	time
newton	$N=kg\cdot m/s^2$	force
joule	$J=N\cdot m=kg\cdot m^2/s^2$	energy, work
watt	$W=J/s$	power, energy per unit time
coulomb	C	electric charge
celsius	$^{\circ}C$	temperature measured from freezing point of water
kelvin	K	temperature measured from absolute zero
ampere	$A=C/s$	electric current, charge per unit time
volt	$V=J/C$	electric voltage
farad	$F=C/V$	electrical capacitance
henry	H	electrical inductance
ohm	$\Omega=V/A$	electrical resistance
tesla	T	magnetic field
hertz	$Hz=1/s$	frequency, cycles per second
radian	rad	angular measure, full circle has $2\pi$ radians
pascal	$Pa=N/m^2$	pressure
mole	mol	$N_A$ atoms or molecules

Greek letter symbols:

pi $\pi$	3.14159265...= circumference of a circle divided by its diameter
rho $\rho$	used for density and resistivity
alpha $\alpha$ , beta $\beta$ , theta $\theta$ , and phi $\phi$	mainly used for angles
alpha $\alpha$ , beta $\beta$ , and gamma $\gamma$	used for different kinds of radioactivity
sigma $\sigma$	used for standard deviation, uncertainty
capital sigma $\Sigma$	used to show summation
omega $\omega$	used for angular frequency
capital omega $\Omega$	used for the unit of electrical resistance
epsilon $\epsilon$ and delta $\delta$	used for small changes
capital delta $\Delta$	used for large changes
mu $\mu$	used for coefficient of friction, prefix for micro ( $10^{-6}$ )
mu naught $\mu_0$	permeability of free space= $4\pi\times 10^{-7}$ H/m
epsilon naught $\epsilon_0$	permittivity of free space= $8.854\times 10^{-12}$ F/m
lambda $\lambda$	used for wavelength