PHYSICS 121 Exam Cover

Physics 121 ID number ____________

Class Section 1 2 3

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Chapter 2 Outline — Motion in One Dimension

Position

Coordinates: origin, + direction

$x(t) \stackrel{\text{def}}{=} x$ at time t.

Average Speed

$$\textit{average speed} \stackrel{\text{def}}{=} \frac{\textit{total distance}}{\textit{total time}}.$$

Displacement

$$\Delta x \stackrel{\text{def}}{=} x_{final} - x_{initial}.$$

Average Velocity

$$\bar{v} \stackrel{\text{def}}{=} \frac{\textit{displacement}}{\textit{time interval}} \stackrel{\text{def}}{=} \frac{\Delta x}{\Delta t}$$

= slope of line between points on x vs. t curve.

Velocity

$$v \stackrel{\text{def}}{=} \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} \stackrel{\text{def}}{=} \frac{dx}{dt} = \text{slope of } x \text{ vs. } t \text{ curve} \iff \Delta x = x_f - x_i = \int_i^f v\,dt.$$

Acceleration

$$a \stackrel{\text{def}}{=} \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} \stackrel{\text{def}}{=} \frac{dv}{dt} = \text{slope of } v \text{ vs. } t \text{ curve} \iff \Delta v = v_f - v_i = \int_i^f a\,dt.$$

Constant Acceleration

If (and only if) acceleration is constant:

$$v = v_0 + at \qquad x - x_0 = v_0 t + \tfrac{1}{2}at^2$$

$$x - x_0 = \tfrac{1}{2}(v + v_0)t \qquad v^2 = v_0^2 + 2a(x - x_0)$$

Free Fall

For free fall with no aerodynamic forces, $a \stackrel{\text{law}}{=} -g$ for all objects, presuming that *up* is the *positive* direction.

$$g = 9.80\,\text{m/s}^2 \approx 32\,\text{ft/s}^2.$$

Chapter 4 Outline — Motion in Two Dimensions

Definitions:

Position: $\vec{r} \stackrel{\text{def}}{=} x\hat{\imath} + y\hat{\jmath} + z\hat{k}$

Displacement: $\Delta\vec{r} \stackrel{\text{def}}{=} \Delta x\hat{\imath} + \Delta y\hat{\jmath} + \Delta z\hat{k}$

Velocity: $\vec{v} \stackrel{\text{def}}{=} \frac{d\vec{r}}{dt} = \frac{dx}{dt}\hat{\imath} + \frac{dy}{dt}\hat{\jmath} + \frac{dz}{dt}\hat{k} = v_x\hat{\imath} + v_y\hat{\jmath} + v_z\hat{k}$

Acceleration: $\vec{a} \stackrel{\text{def}}{=} \frac{d\vec{v}}{dt} = \frac{dv_x}{dt}\hat{\imath} + \frac{dv_y}{dt}\hat{\jmath} + \frac{dv_z}{dt}\hat{k} = a_x\hat{\imath} + a_y\hat{\jmath} + a_z\hat{k}$

For constant acceleration (vector form): $\vec{v} = \vec{v}_0 + \vec{a}t$ and $\vec{r} - \vec{r}_0 = \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$

For free fall with $\vec{a} \stackrel{\text{law}}{=}$ *a constant* $= -\hat{\jmath}g$,

$$v_{x0} = v_0\cos\theta_0 \qquad a_x = 0 \qquad v_x = v_{x0} \qquad x - x_0 = v_{x0}t$$

$$v_{y0} = v_0\sin\theta_0 \qquad a_y = -g \qquad v_y = v_{y0} - gt \qquad y - y_0 = v_{y0}t - \frac{1}{2}gt^2$$

Derived Free-fall results: (Be very careful! — These are for very specific situations.)

The trajectory: $y = (\tan\theta_0)x - \left(\frac{g}{2v_0^2\cos^2\theta_0}\right)x^2$, (a parabola)

The horizontal range and maximum height: $R = \frac{v_0^2}{g}\sin 2\theta_0$, $h = \frac{v_0^2\sin^2\theta_0}{2g}$.

Speed v as a function of time: $v^2 = v_x^2 + v_y^2 = v_{x0}^2 + (v_{y0} - gt)^2$

Speed v as a function of y and x: $v^2 = v_0^2 - 2g(y - y_0)$

Acceleration in Uniform Circular Motion:

$a_r = \frac{v^2}{r}$, directed toward the center of the circle.

Tangential and Radial Acceleration:

$\vec{a} = \vec{a}_r + \vec{a}_t$, with

$a_r = \frac{v^2}{r}$, directed toward the center of the circle.

$a_t = \frac{dv}{dt}$, directed toward the direction of motion.

Relative Motion:

Relative velocity: $\vec{v}_{BA} = \vec{v}_{BC} + \vec{v}_{CA}$

Relative acceleration $\vec{a}_{BA} = \vec{a}_{BC}$ if $\vec{a}_{CA} = 0$

Vector Differentiation

Rectangular form: $\frac{d\vec{V}}{dt} = \frac{dV_x}{dt}\hat{\imath} + \frac{dV_y}{dt}\hat{\jmath} + \frac{dV_z}{dt}\hat{k}$.

Polar form: with $\vec{V} = (V, \theta)$, $\frac{d\vec{V}}{dt} = \frac{dV}{dt}\hat{u}_{\parallel} + V\frac{d\theta}{dt}\hat{u}_{\perp}$.

Chapters 5 and 6 Outline — The Laws of Motion

I. Newton's First Law — The First Law of Motion

A free object moves with $\bar{a} \overset{\text{law}}{=} 0$ ($\bar{v} \overset{\text{law}}{=}$ constant).

If at rest, it remains at rest

If moving, it continues to move in a straight line with constant speed.

The first law is a statement specifying an inertial reference frame.

II. Some Definitions

Acceleration: $\bar{a} \overset{\text{def}}{=} \dfrac{d\bar{v}}{dt}$

Force ($\bar{F}$)

- Push or pull
- Whatever can cause acceleration
- Measured in newtons (N) or pounds (lb)
- A *vector* quantity
- For the same object, $\bar{F}_u \overset{\text{def}}{=} \dfrac{\bar{a}_u}{a_s} F_s$.

(Defines an unknown force in terms of a standard force)

Inertial Mass (m)

- A measure of how an object accelerates in response to force.
- Measured in kilograms (kg) or slugs
- A *scalar* quantity
- For the same force acting, $m_u \overset{\text{def}}{=} \dfrac{a_s}{a_u} m_s$.

(Defines the mass of an unknown object in terms of a standard mass.)

III. Newton's Second Law — The Second Law of Motion

In an *inertial* reference frame:

1. Accelerations are caused by forces.
2. $\bar{a} = \bar{F}/m$, or $\bar{F} = m\bar{a}$ (for consistent units)
3. $\bar{a}$ is in the same direction as $\bar{F}$.
4. The $\bar{F}$ in (2) is the vector sum $\Sigma\bar{F}$ of all the forces acting on the object; the second law in its full glory is

In an inertial frame, $\bar{a} \overset{\text{law}}{=} \dfrac{\Sigma\bar{F}}{m}$ or $\Sigma\bar{F} \overset{\text{law}}{=} m\bar{a}$.

IV. Newton's Third Law — The Third Law of Motion

(A law describing *forces*)

1. All forces result from interactions betweeen pairs of objects.
2. In every interaction there are two forces, ONE ON EACH OBJECT.
3. $\bar{F}_{12} \overset{\text{law}}{=} -\bar{F}_{21}$.

(The two forces have equal strength and act in opposite directions.)

V. Finding Forces

1. Long-range interactions
   gravity, electromagnetic.
   ($\bar{w} \overset{\text{def}}{=} m\bar{g} = -mg\hat{j}$ near Earth's surface.)
2. Contact interactions
   electromagnetic, nuclear
   (tension, friction, 'normal' forces, springs, <u>all other forces</u>.)
   - For a "Hooke's law" spring, $F_{spring} \overset{\text{law}}{=} -kx$.
   - For friction, $f_s \overset{\text{law}}{\leq} \mu_s n$ and $f_k \overset{\text{law}}{=} \mu_k n$.
   - The bouyant force: $\bar{B} = m_f(\bar{a}_f - \bar{g})$
   - For viscous drag at low speed: $\bar{R} \overset{\text{law}}{=} -b\bar{v}$; at higher speeds: $\bar{R} \overset{\text{law}}{=} \frac{1}{2}D\rho Av^2(-\hat{u}_v)$.

In most cases tension T and the 'normal' component n of a contact force can be found only by using the 2nd law of motion. The same is true of static friction unless you know that $f_s = \mu_s n$.

Chapter 7 Outline— Work and Energy

The work-kinetic energy theorem:

For any object,

$$\Delta K \overset{\text{law}}{=} \Sigma W \overset{\text{def}}{=} W_{net}$$

<u>Definitions:</u>

$$\Delta K \overset{\text{def}}{=} K_{final} - K_{initial} \overset{\text{def}}{=} \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2$$

$$W \overset{\text{def}}{=} \int_{initial}^{final} F_s\, ds \overset{\text{def}}{=} \int_i^f \bar{F}\cdot d\bar{s} \overset{\text{def}}{=} \lim_{\Delta s \to 0} \sum \bar{F}\cdot\Delta\bar{s}$$

<u>Special Cases:</u>

1. F = *constant*: $W = \bar{F}\cdot\bar{d} = \bar{F}\cdot\Delta\bar{r}$

e.g.: $W_g = -mg(y_f - y_i)$ for $\bar{F}_g = -mg\hat{j}$

2. 1-dimensional motion:

$$W = \lim_{\Delta x \to 0} \sum F_x \Delta x \overset{\text{def}}{=} \int_i^f F_x\, dx$$

e.g.: $W_H = -\frac{1}{2}k(x_f^2 - x_i^2)$ for $\bar{F}_H = -kx\hat{i}$. (Hooke's law spring)

3. $W = 0$ if $\bar{F} \perp \delta\bar{s}$

<u>The Scalar Product:</u>

$$\bar{A}\cdot\bar{B} \overset{\text{def}}{=} A_x B_x + A_y B_y + A_z B_z = AB\cos\theta = AB_{\parallel} = A_{\parallel}B.$$

$$A^2 = \bar{A}\cdot\bar{A} = A_x A_x + A_y A_y + A_z A_z.$$

<u>Power:</u>

$$P \overset{\text{def}}{=} \lim_{\Delta t \to 0} \frac{\delta W}{\Delta t} = \bar{F}\cdot\bar{v}$$

Chapter 9 Outline — Momentum

<u>Conservation of Momentum:</u>

for an isolated system. ($\bar{F}_{ext} = 0$)

$$\bar{P}_f \overset{\text{law}}{=} \bar{P}_i \text{ or } \Delta\bar{P} \overset{\text{law}}{=} 0 \text{ or } \frac{d\bar{P}}{dt} \overset{\text{law}}{=} 0$$

<u>Definition of momentum:</u>

for a particle $\bar{p} \overset{\text{def}}{=} m\bar{v} \iff K \overset{\text{def}}{=} \dfrac{p^2}{2m}$.

For a system $\bar{P} \overset{\text{def}}{=} \displaystyle\sum_{k=1}^{N} \bar{p}_k \overset{\text{def}}{=} \bar{p}_{tot} \overset{\text{def}}{=} M\bar{v}_{cm}$.

(*Warning:* K_{total} is *not* always equal to $\dfrac{P^2}{2M}$.)

<u>2nd Law of Motion and the Impulse-Momentum Theorem:</u>

particle: $\dfrac{d\bar{p}}{dt} \overset{\text{law}}{=} \Sigma\bar{F} \iff \Delta\bar{p} \overset{\text{law}}{=} \Sigma\displaystyle\int \bar{F}\, dt \overset{\text{def}}{=} \Sigma\bar{I}$

system: $\dfrac{d\bar{P}}{dt} = M\bar{a}_{cm} \overset{\text{law}}{=} \Sigma\bar{F}_{ext} \iff \Delta\bar{P} \overset{\text{law}}{=} \Sigma\displaystyle\int \bar{F}_{ext}\, dt \overset{\text{def}}{=} \Sigma\bar{I}_{ext}$

The integral forms of these equations are the *impulse-momentum* theorems.

<u>Center of mass:</u>

$M\bar{r}_{cm} \overset{\text{def}}{=} \displaystyle\sum_{k=1}^{N} m_k \bar{r}_k$ for discrete particles.

$M\bar{r}_{cm} \overset{\text{def}}{=} \displaystyle\int \bar{r}\, dm$ for continuous systems

Chapter 8 Outline — Conservation of Energy

If a Physical Quantity X is *conserved* for an isolated system

$$\Delta X \overset{\text{law}}{=} 0 \text{ or } X_{final} \overset{\text{law}}{=} X_{initial} \text{ or } X \overset{\text{law}}{=} constant \text{ or } \frac{dX}{dt} \overset{\text{law}}{=} 0$$

<u>Conservation of Energy:</u>

For an isolated system,

$$\Delta E \overset{\text{law}}{=} 0 \text{ or } E_{final} \overset{\text{law}}{=} E_{initial} \text{ or } \frac{dE}{dt} \overset{\text{law}}{=} 0.$$

<u>Definitions:</u>

$E \overset{\text{def}}{=} \Sigma K + \Sigma U + \Sigma U_{int} \overset{\text{def}}{=}$ *kinetic energy + potential energy + internal energy*

$K \overset{\text{def}}{=} \frac{1}{2}mv^2 = \frac{1}{2}m\,\bar{v}\cdot\bar{v}$

$U_{int} \overset{\text{law}}{=} mc^2 =$ A function of temperature, physical state, chemical state and nuclear structure.

Conservative Force: One which does not change internal energy. A force is conservative if the work it does on a particle depends *only* on the initial and final points of the motion, or, equivalently, if the work it does through every closed path is zero.

<u>Potential Energy:</u>

$U_g \overset{\text{def}}{=} mgy$	for $\bar{F} = -mg\hat{j}$.	(near-Earth gravity)
$U_H \overset{\text{def}}{=} \frac{1}{2}kx^2$	for $\bar{F}_H = -kx\hat{i}$	(Hooke's-law spring)
$U \overset{\text{def}}{=} -\frac{k}{r}$	for $\bar{F} = -\frac{k}{r^2}\hat{r}$	(long-range attractive gravity and electrostatic forces)

General definition of U for a conservative force:

$$\Delta U \overset{\text{def}}{=} U_f - U_i \overset{\text{def}}{=} -W_{c,i\to f} \overset{\text{def}}{=} -\int_i^f F_{c,s}\, ds$$

Force from potential energy:

$$F_s = -\frac{\partial U}{\partial s}.$$

<u>Change in Internal Energy</u>

$$\Delta U_{int} \overset{\text{def}}{=} U_{int,f} - U_{int,i} \overset{\text{def}}{=} -W_{nc,i\to f} \overset{\text{def}}{=} -\int_i^f F_{nc,s}\, ds$$

Chapter 10 Outline — Rigid-body, Fixed-axis Rotation

Dynamics:

Equation of Motion: $\tau_{net} \stackrel{def}{=} \Sigma\tau \stackrel{law}{=} I\alpha$ with $\tau \stackrel{def}{=} rF\sin\theta = Fd = Fr_\perp = rF_\perp$

Kinetic Energy: $K = \frac{1}{2}I\omega^2$ for a rotating rigid body.

$= \frac{1}{2}I\omega^2 + \frac{1}{2}Mv^2_{center}$ for a body rolling without slipping.

Kinematics:

The angular variables:

angular position $\theta \stackrel{def}{=} \frac{s}{r}$ radians, angular displacement $\Delta\theta$, angular velocity $\omega \stackrel{def}{=} \frac{d\theta}{dt}$,

and angular acceleration $\alpha \stackrel{def}{=} \frac{d\omega}{dt}$

These are mathematically analogous to the corresponding linear variables for one-dimensional motion Δx, $v \stackrel{def}{=} dx/dt$ and $a \stackrel{def}{=} dv/dt$.

Relations between linear and angular variables for angles in radians:
(r is the radius of a particle's circular motion):

$\Delta s = r\Delta\theta$, $v = r\omega$, $a_{tan} = r\alpha$, $a_{radial} = \frac{v^2}{r} = r\omega^2 = v\omega$.

Relations between angular units:

1 rev = 2π rad = 360°.

For constant angular velocity,

$f = \frac{1}{T} = \frac{\omega}{2\pi}$. f in rev/s, T in s, ω in rad/s.

For rolling without slipping:

$v_{center} = R\omega$.

Rotational Inertia:

General Definition: $I \stackrel{def}{=} \Sigma\delta m\, r_\perp^2 \stackrel{def}{=} \int r_\perp^2\, dm$.

The Parallel-axis theorem: $I = I_{cm} + Md^2$.

Specific uniform bodies:

Solid sphere about a diameter: $I = \frac{2}{5}MR^2$

Spherical shell about a diameter: $I = \frac{2}{3}MR^2$

Thin rod, centered perpendicular axis: $I = \frac{1}{12}ML^2$

with axis through one end: $I = \frac{1}{3}ML^2$

Rectangular plate with perpendicular axis through its center: $I = \frac{1}{12}M(a^2+b^2)$

Solid cylinder about symmetry axis: $I = \frac{1}{2}MR^2$

Solid cylinder about centered diameter: $I = \frac{1}{4}MR^2 + \frac{1}{12}ML^2$

Thin cylindrical shell about symmetry axis: $I = MR^2$

Hollow cylinder about symmetry axis: $I = \frac{1}{2}M(R_1^2 + R_2^2)$

Chapter 12 Outline — Static Equilibrium; Elasticity

The two equilibrium conditions:

Vector forms: $\Sigma\bar{F}_{ext} = 0$ (1), $\Sigma\bar{\tau}_{ext} = 0$ (2)

For coplanar forces: $\Sigma F_{x,ext} = 0$ (1a), $\Sigma F_{y,ext} = 0$ (1b), $\Sigma\tau_{z,ext} = 0$ (2a).

If (1) and (2) are true for one inertial reference point, they are true for all reference points.

Center of gravity:

The center of gravity is located at the center of mass if the object is in a uniform gravitational field.

Chapter 13 Outline — Oscillatory Motion

Kinematics:

$s(t) \stackrel{def}{=} A\cos(\Omega t + \phi)$ represents simple harmonic motion.

In words,

(s at time t) = (amplitude) cos[(angular frequency)t + (phase constant)]

$v(t) = ds/dt = -A\Omega\sin(\Omega t + \phi)$

$a(t) = dv/dt = d^2s/dt^2 = -A\Omega^2\cos(\Omega t + \phi) = -\Omega^2 s$

$\Omega^2 s^2 + v^2 = \Omega^2 A^2$

$\Omega = 2\pi f = 2\pi/T$. f is the *frequency*, T is the *period*.

Equation of Motion:

Any equation of either of the forms

$a = -\Omega^2 s$ or $\Omega^2 s^2 + v^2 = \Omega^2 A^2$,

with $v = ds/dt$ and $a = dv/dt$,

leads to SHM with

$\Omega^2 = (positive\ constant) = (angular\ frequency)^2$.

Spring-block Oscillator:

If $F_x = -kx$, the motion is simple harmonic with

$\Omega = \sqrt{\frac{k}{m}}$, $T = 2\pi\sqrt{\frac{m}{k}}$ and $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$.

The total energy is $E = \frac{1}{2}kA^2$.

The potential energy is $U = \frac{1}{2}kx^2 = \frac{1}{2}kA^2\cos^2(\Omega t + \phi)$

The kinetic energy is $K = \frac{1}{2}mv^2 = \frac{1}{2}kA^2\sin^2(\Omega t + \phi)$

The generality of SHM

Almost all *small* departures from stable equilibrium exhibit SHM.

Chapter 11 — Angular Momentum; Rolling

Conservation of angular momentum:

$\bar{L}_f \stackrel{law}{=} \bar{L}_i$ or $\Delta\bar{L} \stackrel{law}{=} 0$ or $\frac{d\bar{L}}{dt} \stackrel{law}{=} 0$

for an isolated system. ($\bar{\tau}_{ext} = 0$)

For any component z,

$L_{zf} \stackrel{law}{=} L_{zi}$ if $\tau_z = 0$.

2nd law of motion:

With $\bar{\tau} \stackrel{def}{=} \bar{r}\times\bar{F}$,

particle: $\frac{d\bar{L}}{dt} \stackrel{law}{=} \Sigma\bar{\tau}$ or $\Delta\bar{L} \stackrel{law}{=} \Sigma\int\bar{\tau}\, dt$

system: $\frac{d\bar{L}}{dt} \stackrel{law}{=} \Sigma\bar{\tau}_{ext}$ or $\Delta\bar{L} \stackrel{law}{=} \Sigma\int\bar{\tau}_{ext}\, dt$

The integral forms of these equations are the *angular impulse-momentum* theorems.

Definition of angular momentum:

$\bar{L} \stackrel{def}{=} \bar{r}\times\bar{p} \stackrel{def}{=} \bar{r}\times m\bar{v}$ for a particle

$\bar{L} \stackrel{def}{=} \Sigma\bar{L}_k = (\bar{R}\times\bar{P}) + \bar{L}_{cm} = (\bar{R}\times M\bar{V}) + \bar{L}_{cm}$ for a system

$\bar{L} = I\bar{\omega}$ for a rigid body rotating about a principal axis.

Rolling:

For a symmetric object rolling without slipping:

$v_{center} = R\omega$ and $K = \frac{1}{2}I_{cm}\omega^2 + \frac{1}{2}Mv^2_{cm}$.

The vector product $\bar{A}\times\bar{B}$:

If $\bar{A}\times\bar{B} = \bar{C}$, $C \stackrel{def}{=} |\bar{C}| \stackrel{def}{=} AB\sin\theta = AB_\perp = A_\perp B$

$\bar{C}$ is perpendicular to $\bar{A}$ and $\bar{B}$

in the direction given by the *right-hand rule*.

In rectangular components,

$$\bar{A}\times\bar{B} \stackrel{def}{=} \begin{matrix}(A_yB_z - A_zB_y)\hat{\imath} \\ +(A_zB_x - A_xB_z)\hat{\jmath} \\ +(A_xB_y - A_yB_x)\hat{k}\end{matrix} = \begin{vmatrix}\hat{\imath} & \hat{\jmath} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z\end{vmatrix}$$

$= -\bar{B}\times\bar{A}$

Chapter 14 Outline — The Law of Gravity

A. The Law of Universal Gravitation

$\bar{F}_{21} \stackrel{law}{=} \left(G\frac{m_1m_2}{r^2}\right)(-\hat{r}_{12})$, $G = 6.672\times10^{-11}\,\frac{\text{N}\cdot\text{m}^2}{\text{kg}^2} \approx \frac{2}{3}\times10^{-10}\,\frac{\text{N}\cdot\text{m}^2}{\text{kg}^2}$

Valid for points and uniform external spheres.

3rd Law :== TRUE

Always attractive

Gravitational forces are vectors.

Superposition

B. Geophysical Consequences

g of the earth

motion of planets and satellites (Kepler's laws)

rotational motion of double star systems

structure of the large-scale universe.

C. Gravitational Potential Energy

$U_g \stackrel{law}{=} -\frac{Gm_1m_2}{r}$

Examples: Free fall, Escape from the earth, Planets and satellites

Superposition

D. The Gravitational Field

$\bar{g} \stackrel{def}{=} \frac{\bar{F}_g}{m}$.

E. The Principle of Equivalence

$m_{gravitational} = m_{inertial}$; 1 part in 10^{11}.

Conversion Factors

Mass

$1\ \text{kg} = 1000\ \text{g}$

$1\ \text{u} = 1.66 \times 10^{-27}\ \text{kg}$

Length

$1\ \text{m} = 100\ \text{cm} = 3.28\ \text{ft}$

$1\ \text{mi} = 1.61\ \text{km} = 5280\ \text{ft}$

Time

$1\ \text{day} = 86{,}400\ \text{s}$

$1\ \text{year} = 3.16 \times 10^{7}\ \text{s}$

Speed

$60\ \text{mi/h} = 88\ \text{ft/s} \approx 26.8\ \text{m/s}$

$100\ \text{km/h} = 27.7\overline{7}\ \text{m/s} \approx 62.1\ \text{mi/h}$

Angle

$1\ \text{rev} = 360° = 2\pi\ \text{rad}$

Force

$1\ \text{N} = 0.225\ \text{pound}$

$1\ \text{pound} = 4.45\ \text{N}$

Energy

$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$

$1\ \text{kcal} = 10^{3}\ \text{cal} = 4.19\ \text{kJ}$

$1\ \text{kW·h} = 3.6 \times 10^{6}\ \text{J} = 3.6\ \text{MJ}$

Physical Constants

speed of light	c	$3.00 \times 10^{8}\ \text{m/s}$
gravitational constant	G	$\frac{2}{3} \times 10^{-10}\ \text{N·m}^2/\text{kg}^2$
For Earth:		
free-fall acceleration	g	$9.80\ \text{m/s}^2$
mass	M_E	$5.98 \times 10^{24}\ \text{kg}$
mean radius	R_E	$6370\ \text{km}$

Metric Prefixes

prefix	*symbol*	*factor*
tera-	T	10^{12}
giga-	G	10^{9}
mega-	M	10^{6}
kilo-	k	10^{3}
milli-	m	10^{-3}
micro-	μ	10^{-6}
nano-	n	10^{-9}
pico-	p	10^{-12}