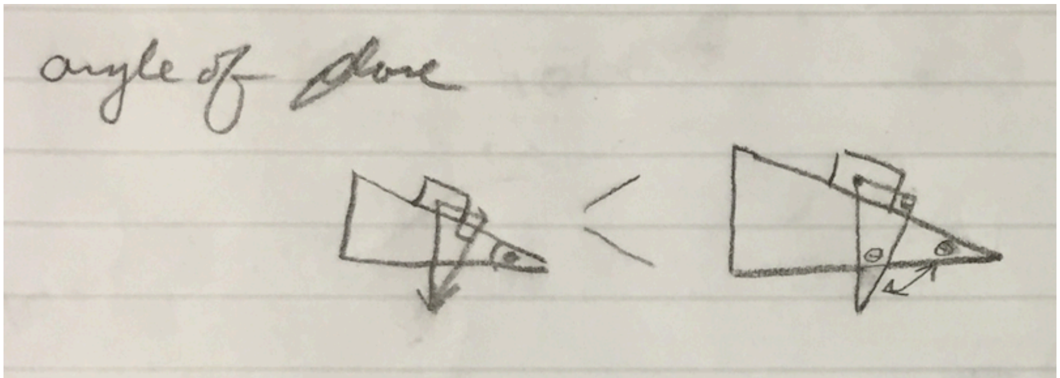
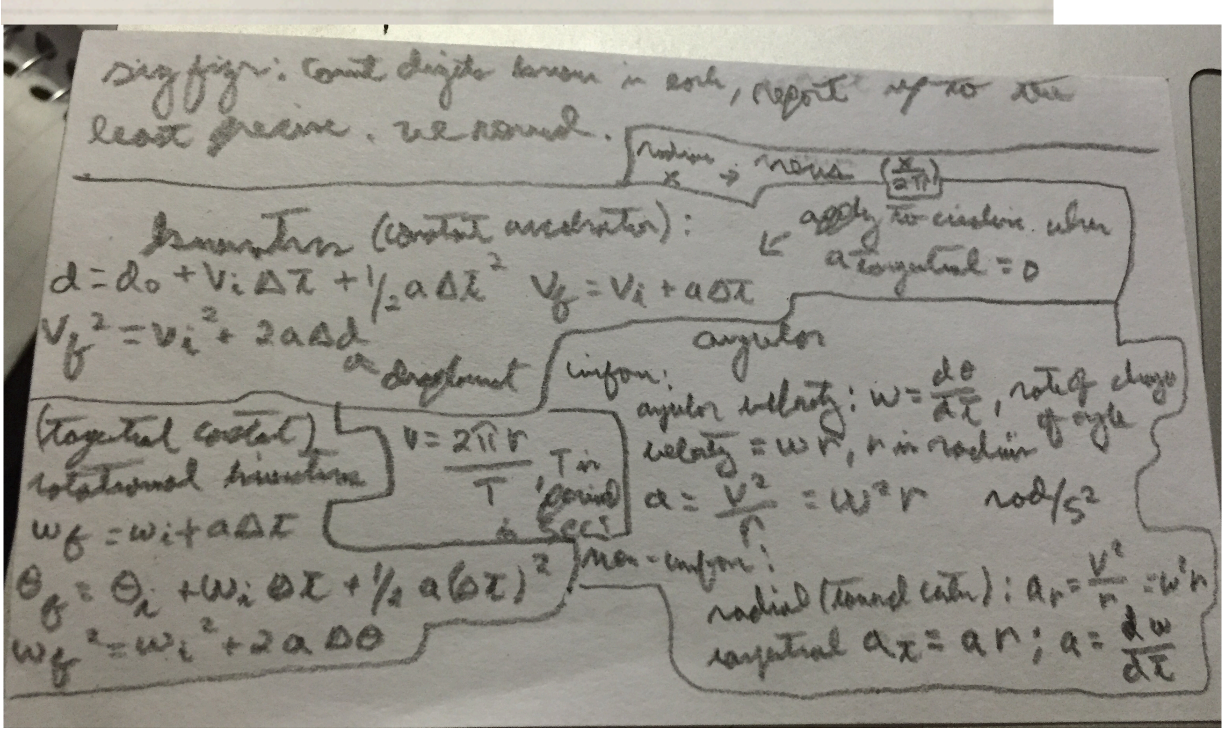
First Test:

Sig figs, round to least precise.

Kinematics:





sig figs: count digits known in each, report up to the least precise. we round.

radians x → revs $\left(\frac{x}{2\pi}\right)$

kinematics (constant acceleration):

$d = d_0 + v_i \Delta t + \frac{1}{2} a \Delta t^2$ $\quad v_f = v_i + a \Delta t$

$v_f^2 = v_i^2 + 2a\Delta d$

Δd displacement

apply to circular when $a_{tangential} = 0$

angular

uniform:

angular velocity: $\omega = \frac{d\theta}{dt}$, rate of change of angle

velocity $= \omega r$, r in radius

$a = \frac{v^2}{r} = \omega^2 r$ $\quad$ rad/s^2

$v = \frac{2\pi r}{T}$, T in period in secs

(tangential constant) rotational kinematics

$\omega_f = \omega_i + a\Delta t$

$\theta_f = \theta_i + \omega_i \Delta t + \frac{1}{2} a (\Delta t)^2$

$\omega_f^2 = \omega_i^2 + 2a\Delta\theta$

non-uniform:

radial (toward center): $a_r = \frac{v^2}{r} = \omega^2 r$

tangential $a_t = ar$; $a = \frac{d\omega}{dt}$

Second test:

quadratic

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

[redacted]

N 1st law: objects remain at rest / in motion unless acted on by other force. (direction)

N 2nd: $F = ma$

N 3rd: every action has an equal and opposite reaction

WORK = F • displacement

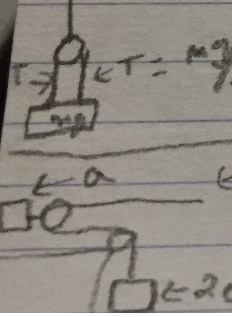
Joules

for an object, net work on object = ΔKE of object

for an object, net work on object = $-\Delta PE$ of object ← only for gravity or spring, otherwise applies for nonconstant force

$F = -kx$

$PE = \frac{1}{2}kx^2$



impulse: $\Delta P = F \cdot \tau$

other usages:

$F = \frac{\Delta P}{\Delta \tau}$ $\quad I = \Delta P = \int f \cdot \tau$

$P = mv$ $\quad F \cdot \Delta \tau = \Delta mv$

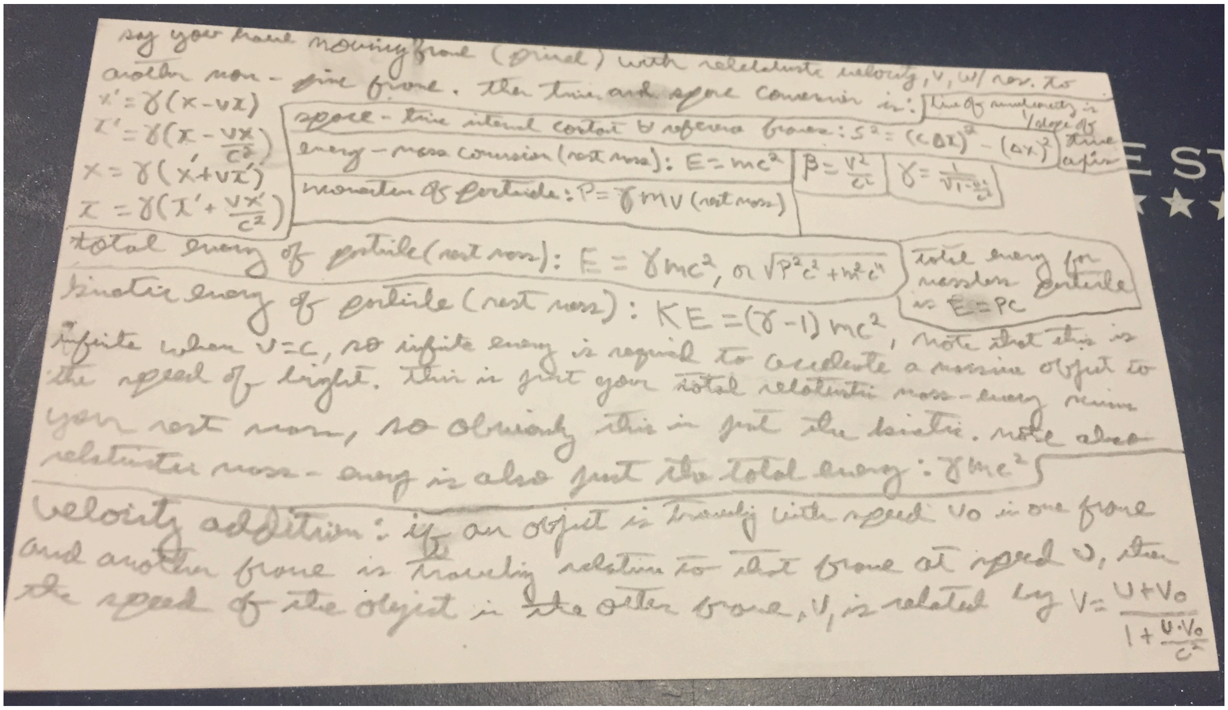
Collisions: KE is not conserved in inelastic. momentum is conserved in both

Relativity:

length contraction: if you're standing still, and you measure the length of a train, and then measure that train again when moving at half the speed of light, the train appears shorter. the rest/proper length, l_0, contracts to L by $L = l_0\sqrt{1 - v^2/c^2}$.

time dilation: time slows down for object traveling close to light speed. both feel like time is moving at same pace, but if they each have a stopwatch and measure a time interval, if the person moving measures τ_0, then the person still will measure $\tau = \frac{\tau_0}{\sqrt{1 - v^2/c^2}}$, similarly $\tau = \gamma \tau_0$. from the person moving, the person still will appear to experience time more slowly. and from the person still, the person moving will appear to experience time more slowly.

absence of simultaneity: if you're observing two flashes of light that are coming at an object between the flashes and will hit the object at the same time (in the ref. frame of the object), and you're moving rel. to the object, then you will see emission of lights as not simultaneous.



say you have moving frame (primed) with relativistic velocity, v, w/ resp. to another non-prime frame. The time and space conversion is:

$x' = \gamma(x - vt)$

$t' = \gamma(t - \frac{vx}{c^2})$

$x = \gamma(x' + vt')$

$t = \gamma(t' + \frac{vx'}{c^2})$

line of simultaneity is 1/slope of time axis

space-time interval constant b/ reference frames: $s^2 = (c\Delta t)^2 - (\Delta x)^2$

energy-mass conversion (rest mass): $E = mc^2$ | $\beta = \frac{v^2}{c^2}$ | $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

momentum of particle: $P = \gamma mv$ (rest mass)

total energy of particle (rest mass): $E = \gamma mc^2$, or $\sqrt{p^2c^2 + m^2c^4}$

total energy for massless particle is $E = pc$

kinetic energy of particle (rest mass): $KE = (\gamma - 1)mc^2$, note that this is infinite when $v = c$, so infinite energy is required to accelerate a massive object to the speed of light. This is just your total relativistic mass-energy minus your rest mass, so obviously this is just the kinetic. note also relativistic mass-energy is also just the total energy: γmc^2

velocity addition: if an object is traveling with speed v_0 in one frame and another frame is traveling relative to that frame at speed v, then the speed of the object in the other frame, V, is related by $V = \frac{v + v_0}{1 + \frac{v \cdot v_0}{c^2}}$

Everything since relativity:

Torque = I * a. Where I is moment of inertia and a is angular acceleration. This is equivalent to f=ma.

Torque = F*r*sin(theta). Direction of torque is given by right hand rule.

Angular frequency: how many full rotations occur per time. Period is the inverse. Should know the formula f=omega/2pi.

Instantaneous linear velocity: omega*r.

Energy pure rotation: **Pure rotation** $E = \frac{1}{2}I\omega^2$

Rolling energy: **Rolling** $E = \frac{1}{2}I\omega^2 + \frac{1}{2}Mv_{cm}^2$

Angular momentum is conserved if $\vec{\tau}_{net} = \vec{0}$.

Angular momentum, L, is $\vec{L} = I\vec{\omega}$ where omega is angular velocity about the axis.

Period of oscillation for rod+ball system swinging under gravity: T = 2*pi*sqrt(I/mg*L_cm)

Direction of angular velocity is given by right hand rule. Curl fingers along direction of spin.

For a door rotating on its hinges, the I_about hinge = m*L^3 / 3

Moments of Inertia:

- Hollow cylinder:
  - 1/2 M (m_o^2 + m_i^2).
- Uniform sphere:
  - 2/5 M R^2
- Uniform ring:
  - MR^2
- Uniform disk/cylinder:
  - 1/2MR^2
- Uniform Rod about center:
  - 1/12 ML^2
- Uniform Rod about end:
  - 1/3 ML^2

The **moment of inertia**

$$I = \sum_i m_i r_i^2 = \int r^2\, dm$$

is the rotational equivalent of mass. The moment of inertia depends on how the mass is distributed around the axis. If I_{cm} is known, the I about a parallel axis distance d away is given by the **parallel-axis theorem:** $I = I_{cm} + Md^2$.

$$F_{M\text{ on }m} = F_{m\text{ on }M} = \frac{GMm}{r^2}$$

where the **gravitational constant** is $G = 6.67 \times 10^{-11}\ \mathrm{Nm^2/kg^2}$.

Circular orbit of r around mass M, $v = \sqrt{\frac{GM}{r}}$

For a planet of mass M and radius R,

- The free-fall acceleration on the surface is $g_{surface} = \frac{GM}{R^2}$
- The escape speed is $v_{escape} = \sqrt{\frac{2GM}{R}}$

Spring constant k, angular frequency (how many crests per second in radians):

Period: $\omega = \sqrt{\frac{k}{m}} \qquad T = 2\pi\sqrt{\frac{m}{k}}$

Convert to Hz with; $f = \frac{\omega}{2\pi}$

Simple harmonic motion:

Frequency $f = \frac{1}{T}$

Angular frequency

$$\omega = 2\pi f = \frac{2\pi}{T}$$

Position $x(t) = A\cos(\omega t + \phi_0)$

$$= A\cos\left(\frac{2\pi t}{T} + \phi_0\right)$$

Velocity $v_x(t) = -v_{max}\sin(\omega t + \phi_0)$ with maximum speed $v_{max} = \omega A$

Acceleration $a_x = -\omega^2 x$

Sinusoidal waves are periodic in both time (period T) and space (wavelength λ):

$$D(x, t) = A\sin[2\pi(x/\lambda - t/T) + \phi_0]$$
$$= A\sin(kx - \omega t + \phi_0)$$

where A is the **amplitude**, $k = 2\pi/\lambda$ is the **wave number**, $\omega = 2\pi f = 2\pi/T$ is the **angular frequency**, and ϕ_0 is the **phase constant** that describes initial conditions.

The fundamental relationship for any sinusoidal wave is $v = \lambda f$.

Damping

If there is a drag force $\vec{D} = -b\vec{v}$, where b is the damping constant, then (for lightly damped systems)

$$x(t) = Ae^{-bt/2m}\cos(\omega t + \phi_0)$$

The time constant for energy loss is $\tau = m/b$.

Speed of wave on string: v=sqrt(Ftension/(total mass/total length))

Destructive interference: Happens when one is positive amplitude and one is negative. the waves actually aren't destroyed, they will continue along exactly as they did before they met.

Constructive interference: Happens when both are in the same direction. They will momentarily add together and then continue to pass through each other.

Standing waves: if you are oscillating at a multiple of one half the wavelength of the wave, then you'll have a standing wave. Distance between nodes and antinodes is wavelength/2.

v of wave = wavelength * frequency.

Doppler shift: frequency = f_0 (c+v_r / c+v_s). Where v_r positive when moving towards source. v_s positive when moving away from receiver.