Phys 111 Exam 2 Review Notes

The following hand-written notes include concept summaries and some example problem types that should be practiced to be ready for what concepts to apply on Exam 2 for section 1 of Phys 111 at the University of Idaho for the Fall 2019 semester.

Exam 2 will cover material from chapter 6-9 from Cutnell & Johnson and will focus on material from homework week 7-10. The exam is 12 problems: 5 multiple choice, 3 free-response, and 3 multi-part. See the appropriate announcement on Bblearn for more details per problem.

Please take note of which chapters are covered on which pages using the top right page number on said page. The fast rule is to add two to each page number since this page is now page 1:

Chapter	Pages	Physics
9	1,5	Rotational Dynamics
8	1-5	Rotational Kinematics
7	11-19	Linear Momentum
6	6-10, 12-13	Energy & Work

A very brief concept summary for each chapter can be found on the next page, but the following is true for all of them.

- Sketch an appropriate, useful diagram that is labeled.
- Write down what you know and what you are supposed to find.
- Review w.t.f (what to find) as often as necessary.
- State the physical law/principle that is the reason for any math you do.
- Write down the "starting" math equation for your application of physics.
- Plug in zeros early after you write down which equation you're going to use.
- Double-check units and $\pm$ signs early and often so you can catch mistakes.
- If you notice a mistake too late to fix it, state why your answer is wrong for partial credit.

Ch. 9 Rotational Dynamics

- Torque (τ) causes rotational acceleration (α). Constant speed means both $\sum \tau = 0$ and $\alpha = 0$.
- There is a law of motion equation for torque, rotational inertia, and acceleration. $\sum \tau = I\alpha$
- Objects with rotational velocity have angular momentum and rotational kinetic energy.
- Angular Momentum , $L = I\omega$. Rotational Kinetic Energy, $RKE = \frac{1}{2}I\omega^2$
- If an object rolls without slipping, then the math is easier for relating linear and rotational motion.

Ch. 8 Rotational Kinematics

- We have a whole new set of variables θ, ω, α that have the same relationships as s, v, a did from before.
- You can always calculate an average, but
- You can only use the equations in the equation sheet if acceleration is constant.
- Circular motion has nice equations to relate linear and rotational quantities.

Ch. 7 Linear Momentum

- Conservation Law: $\vec{p}_o + \vec{J}_{ext} = \vec{p}_f$
- Momentum depends on mass and velocity: $\vec{p} = m\vec{v}$
- Two general types of interactions: collisions and explosions.
- Impulse or change in momentum is caused by a force: $\vec{J} = \Delta\vec{p} = \vec{F}\Delta t$

Ch. 6 Energy & Work

- Conservation Law: $E_o + W_{nc} = E_f$
- Two types of energy: PE and KE. We focus on gravitational PE $= PE_g$.
- Forces cause changes in velocity over a net displacement. $W_{net} = \Delta KE$
- $Work = (Force) \times (displacement\ distance) \times (alignment\ fraction)$
- $W = (Fcos\theta)s$. Not always $cos\theta$ because θ is a specific angle between the force and the displacement direction.
- $\pm$ signs have to do with gaining or losing energy for the system of interest.

Ch. 10 Rot. Dynamics Big Picture

Objects can have I & ω similar to m & v. They then have $L = I\omega$ and $RKE = \frac{1}{2}I\omega^2$.

τ causes $\alpha = \frac{\Delta\omega}{\Delta t}$

Look @ Lect. 17, 18 & HW #10

Ch. 9 Rot. Kinematics

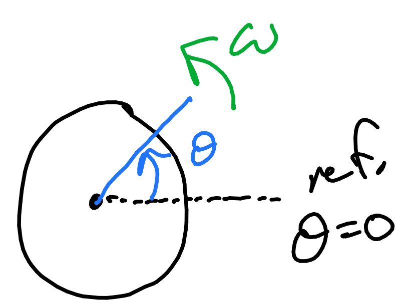
<Quantities>

<Simple Visual>

angle/pos. : θ

speed/vel. : $\omega = \frac{\Delta\theta}{\Delta t}$

accelaration : $\alpha = \frac{\Delta\omega}{\Delta t}$



<averages>

$$\omega_{ave} = \frac{\theta_f - \theta_0}{t_f - t_0}$$

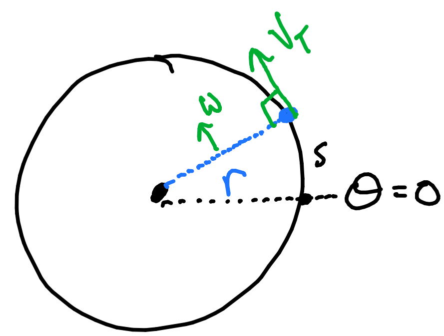
$$\alpha_{ave} = \frac{\omega_f - \omega_0}{t_f - t_0}$$

<Circular Motion>

$s = r\theta$ $\qquad a_c = \frac{v_T^2}{r}$

$v_T = \frac{\Delta s}{\Delta t}$ $\qquad v_T = r\omega$

$v_T = \frac{r\Delta\theta}{\Delta t}$ $\qquad a_T = r\alpha$



HW#9 Prob.2 FOC 8.7

set $v_0 = 0$, $\omega_0 = 0$ for a const. accel. α.

If @ $t_1 = 7.0\,s$, $\omega_1 = 16\,\frac{rad}{s}$, find ω_2 @ $t_2 = 14.0\,s$. If const. α

use math: $\alpha = \frac{\omega_f - \omega_0}{t_f - t_0} \rightarrow \omega_f = \omega_0 + \alpha t$

$$\alpha = \frac{16 - 0}{7.0 - 0} \frac{\frac{rad}{s}}{s} = \frac{16}{7} \frac{rad}{s^2}$$

Then $\omega = \omega_0 + \alpha t$ can be used to get ω_2.

$$\omega_2 = \omega_0 + \alpha t_2 = 0 + \left(\frac{16}{7}\right)(14.0)\,\frac{rad}{s}$$

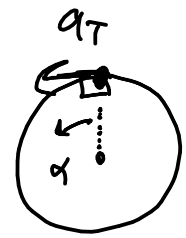
$$\boxed{\omega_2 = 32.0\ rad/s}$$

HW9 Prob. 9 8.34

Given: Know α, consider when $a_T = g$.

Goal: Find r if this is happening on a circular path.

Given $\alpha = +12.0 \frac{rad}{s^2}$



Using: $a_T = r\alpha$

rewrite to $r = \frac{a_T}{\alpha}$

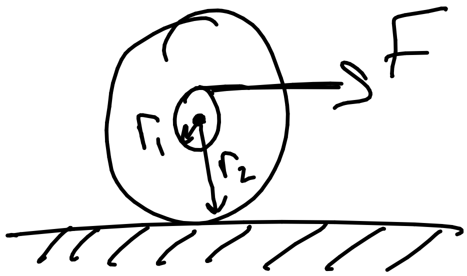
$r = \frac{g}{\alpha}$ given $a_T = g$

(Plugging in #'s) $r = \left(\frac{9.8}{12}\right)\frac{\frac{m}{s^2}}{\frac{rad}{s^2}} \approx \frac{10}{12}\, m$

$$\boxed{r = 0.83\, m}$$

HW 9
Prob. 10 8.42 (similar)

Consider



$\vec{F}$ causes $a_T = 3.0 \frac{rad}{s^2}$

such that wheel rolling without slipping.

inner radius $= r_1$
outer " " $= r_2$

given: $a_T = r_1 \alpha$
use $\alpha = \frac{a_T}{r}$

or

given: $V_1 = r_1 \omega$
use $\omega = \frac{V_1}{r_1}$

Physics ω is const. for all r, V pairs b/c the inner & outer circle rotate together.

Goal: $V_2 = r_2 \omega$

given: $V_1 = 3.00 \frac{m}{s}$
$r_1 = 0.4\,m$
$r_2 = 0.6\,m$

$\rightarrow \omega = \frac{V_1}{r_1} = 7.5 \frac{rad}{s}$

$$\boxed{V_2 = r_2 \omega = 4.5 \frac{m}{s}}$$

5/19

Ch. 9 Hot Topics

- rolling w/o slipping
- $v = r\omega$ & $a = r\alpha$
- (rot.) kinematic equations

$\omega = \omega_0 + \alpha t \longleftrightarrow \alpha = \frac{\omega - \omega_0}{t}$

$$\omega^2 = \omega_0^2 + 2\alpha\theta$$
$$\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$

Energy Ch. 6 — Hot Topics — 6/19

HW#7

- conservation Law: $E_0 + W_{nc} = E_f$

- Work $= (\text{Force})(\text{Displacement})\left(\begin{matrix}\text{alignment}\\\text{fraction}\end{matrix}\right)$

in book $W = (F\cos\theta)\,s$ * not always $\cos\theta$ used *

$s =$ distance over which the force acts on an object

- $W_{net} = \Delta KE = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_0^2$

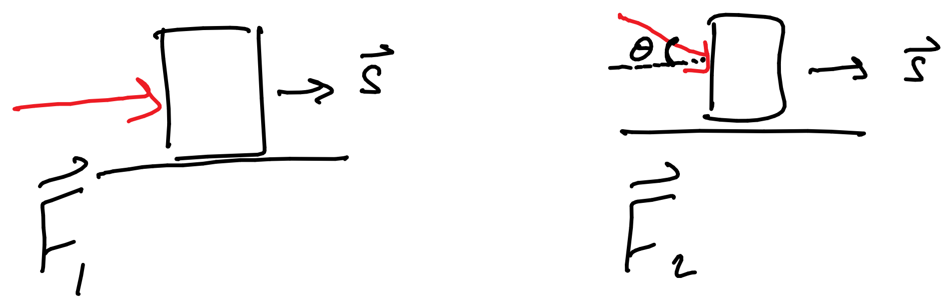
  - Const. speed = no work $\leftrightarrow$ $W=0$
    $W=0 \longleftrightarrow \Sigma\vec{F}=0$

3 Types of Energy we've worked with

1. $KE = \frac{1}{2}mv^2$
2. $PE_g = mgh$ (h = height)
3. $RKE = \frac{1}{2}I\omega^2$

HW#7 Prob 2 6.9 (Modified)

Two people push differently, but do the same work on a cart.



Given $W_1 = W_2$

$s = 5.0\,m$ $W_2 = 60.0\,J$

Goal

what's F_1?

Using def.: $W_1 = F_1 s\,(1)$ b/c $\cos 0 = 1$

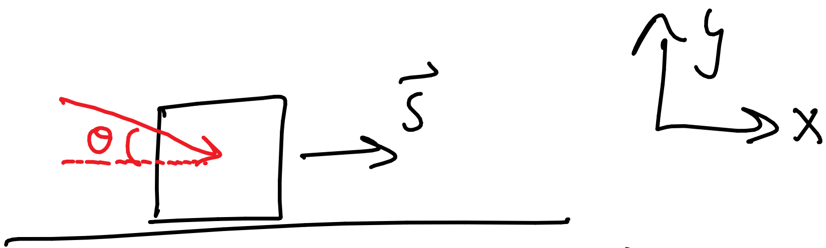
then $F_1 = \frac{W_1}{s}$

$= \frac{60.0\,J}{5.0\,m}$

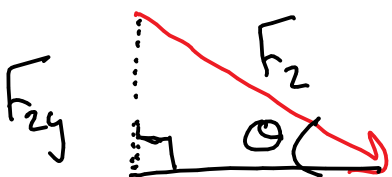
$$\boxed{F_1 = 12.0\,N}$$

8/19

What if also given $\theta = 30°$ and also asked to solve for F_2?



$\vec{s}$ in x-direction



$F_{2x} = F_2 \cos\theta \Rightarrow$

$$W_2 = (F_{2x})\, s$$

$$W_2 = F_2 \cos\theta \; s$$

↑ goal

soh cah toa

(rewrite relationship)

$$F_2 = \frac{W_2}{(\cos\theta \cdot s)}$$

$$F_2 = \frac{60.0\,J}{(\cos 30°)(5.0\,m)}$$

(given #s)

$$F_2 = \frac{12.0}{\cos 30°}\,N$$

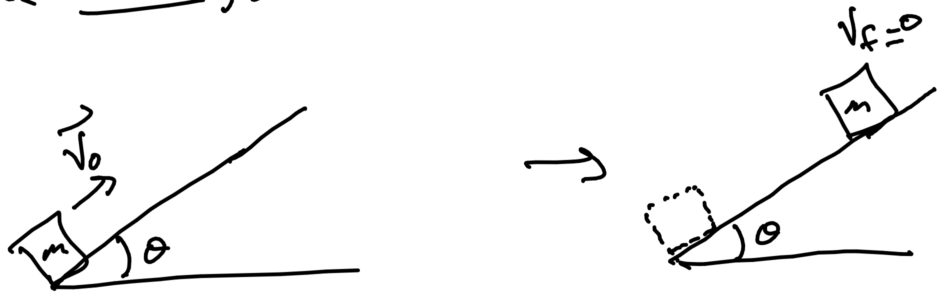
$$\boxed{F_2 = 13.9\,N}$$

⟨Conservation of Energy⟩

like HW#7 Prob. 6, 7, 8 | 6.38, 6.43, 6.48

Cons. of E s.t. $E_0 = E_f$ becomes
$KE_0 = PE_f$ or $PE_0 = KE_f$

Like 6.48, but $v_0 = 9.0\ \frac{m}{s}$



[Case where all KE_0 become PE_f.]

Use Conservation Law: $E_0 + W_{nc} = E_f$

Hmm! let's set y or h = 0 @ the base of the ramp. $PE_0 = 0$
$v_f = 0$

so $KE_0 = PE_f$

10/19

$KE_o = \frac{1}{2} m v_o^2$; $PE_f = mgh_f$

* Is ramp smooth? $W_{nc} = 0$ *
" " rough? $W_{nc} = F_{nc} s$ (align forces)

smooth ramp: $W_{nc} = 0$

$E_o + W_{nc} = E_f \rightarrow E_o = E_f$

That's why

$KE_o = PE_f$

$v_o = 9.0 \frac{m}{s}$
$g = 10.0 \frac{m}{s^2}$

$\frac{1}{2} m v_o^2 = mgh$

$\frac{1}{2} v_o^2 = gh$

goal to find h

$$\boxed{h = \frac{v_o^2}{2g}}$$

$h = 4.05 m$

11/19

Momentum Ch.7 HW#8

momentum $= \vec{p} \equiv$ mass $\cdot$ velocity $= m\vec{v}$

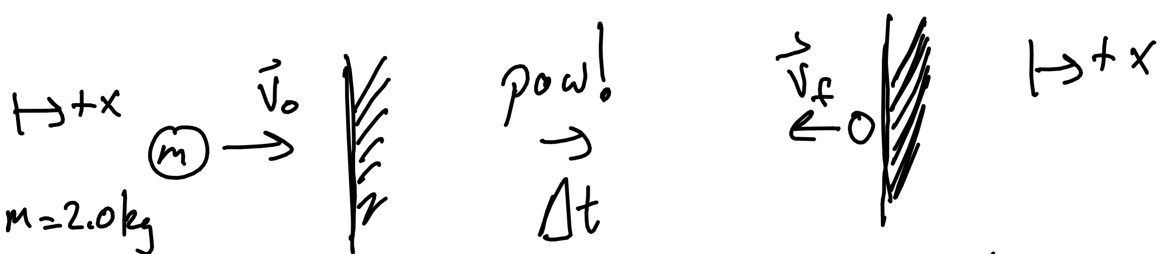
$\vec{F}$ cause $\boxed{\vec{a} = \dfrac{\Delta \vec{v}}{\Delta t}}$; $\vec{F} = m\vec{a}$

$$\Delta \vec{p} = m \Delta \vec{v} = m\,\underline{(\vec{a}\,\Delta t)}$$

Change in momentum $= \Delta \vec{p} = \vec{F}\,\Delta t =$ Impulse $= \vec{J}$

1D rebound - simpler version of HW#8, Prob 7,12

* ball hits wall, rebounds straight back



$V_o = 4.2 \frac{m}{s}$

$t_o = 0$

$V_f = 3.6 \frac{m}{s}$

$t_f = t$

Goal: Find $\Delta \vec{p}$, ΔKE of the ball

12/19

Concept   Using each law

$$\vec{p}_0 + \vec{J} = \vec{p}_f \,, \quad E_0 + W = E_f$$

analyze $\vec{J}, W$ the wall does on the ball.

$p_0 = mv_0$ $KE_0 = \frac{1}{2}mv_0^2$ with $m = 2.0$ kg

$p_f = mv_f$ $KE_f = \frac{1}{2}mv_f^2$ $v_0 = 4.2$ m/s

$v_f = 3.6$ $\frac{m}{s}$

(a)

$$J = \Delta p$$

$$J = p_f - p_0$$

$$J = mv_f - mv_0$$

(b)

$$W_{net} = \Delta KE$$

$$W_{net} = KE_f - KE_0$$

$$W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_0^2$$

(a)

$$J = m(v_f - v_0)$$

$$J = (2.00\text{ kg})(-3.6 - 4.2)\frac{m}{s}$$

$$\boxed{J = -15.6\ \text{kg}\cdot\frac{m}{s}}$$

(b) $W = \Delta KE = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_0^2$

$$W = \frac{1}{2} m \left(v_f^2 - v_0^2 \right)$$

$$W = \frac{1}{2} (2.00\,kg) \left[(-3.6)^2 - (4.2)^2 \right] \frac{m^2}{s^2}$$

$$W = (1.00) \left[3.6^2 - 4.2^2 \right] J$$

$$W = (12.96 - 17.64)\,J$$

$$\boxed{W = -4.68\,J}$$

(c)

If it hit @ $h = 1.5m$ off the ground, how fast should it be going when it hits the ground?

* Just finished analyzing $\Delta\vec{p}$, ΔKE and the old KE is now the initial KE_0 *

$V_0 = 3.6 \frac{m}{s}$
$h_0 = 1.5 m$
$h_f = 0$
$V_f = ?$

$$E_0 = E_f$$

$$PE_0 + KE_0 = \cancel{PE_f}^{\,0} + KE_f$$

$$mgh_0 + \frac{1}{2}mv_0^2 = \frac{1}{2}mv_f^2$$

$$\frac{1}{2}v_f^2 = \frac{1}{2}v_0^2 + gh_0$$

$$V_f^2 = V_0^2 + 2gh_0$$

$$\boxed{V_f = \sqrt{V_0^2 + 2gh_0} = 6.6 \frac{m}{s}}$$

Focus on Conservation of Momentum

2 Types:
- Explosions
- Collisions

Math: $\vec{p}_0 + \vec{J}_{ext} = \vec{p}_f$

typically $\vec{J}_{int}$ only: $\vec{J}_{ext} = 0$

That means simpler case: $\vec{p}_0 = \vec{p}_f$

[Similar to HW #8 Prob. 6 7.18]

"Explosion" Type: 2 pieces attached come apart

<u>Case 1</u> $\left.\begin{matrix} V_1 = 0 \\ V_2 \neq 0 \end{matrix}\right\}$ First mass stops, second continues.

Use $p_o = p_f$ $\xrightarrow{\text{specifically}}$ $(m_1+m_2)V_o = m_1\cancel{V_1}^{\,0} + m_2 V_2$

$$(m_1+m_2)V_o = m_2 V_2$$

* given m_1, m_2, V_o solve for V_2

$$\boxed{V_2 = \frac{(m_1+m_2)V_o}{m_2}}$$

if $m_1 = 8.0\ kg$, $m_2 = 3.0\ kg$, & $V_o = 2.00 \frac{m}{s}$,

then $\boxed{V_2 = 7.3 \frac{m}{s}}$.

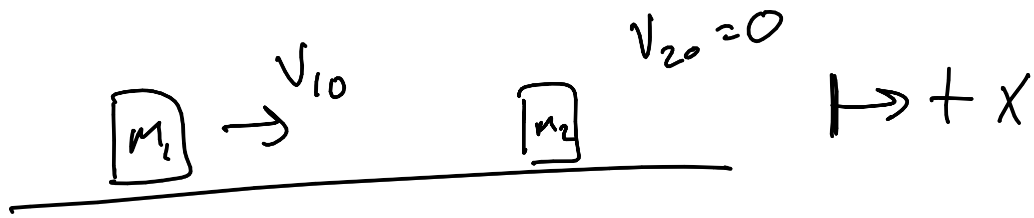
<u>Case 2</u>: V_1 & V_2 both not zero.

You must solve for or be given V_1 to solve for V_2!

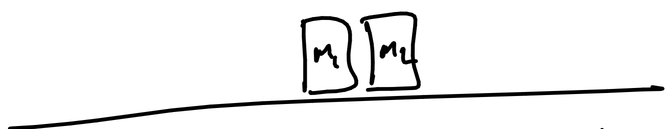
17/19

Consider one object collides with a second object that was originally motion-less (at rest).

t_0

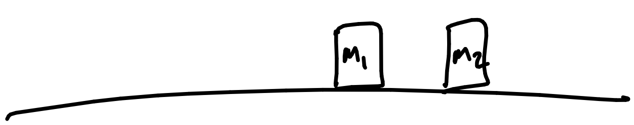


masses collide



solve for speed immediately afterwards

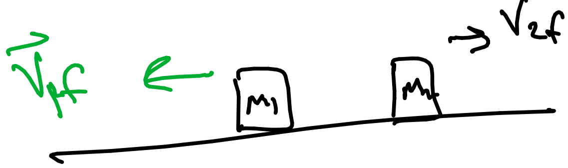
t_f



v_{1f}, v_{2f} ?

↑ info in problem statement

Case 1 m_1 rebounds



Cons of Momentum

$$\boxed{p_o = p_f} \quad \text{b/c} \quad \vec{J}_{ext} = 0$$

Apply details

$$m_1 v_{1o} + m_2 \cancel{v_{2o}}^{\,0} = m_1 v_{1f} + m_2 v_{2f}$$

2nd initially at rest

$$m_1 v_{1o} = m_1 v_{1f} + m_2 v_{2f}$$

which values given?

Ask yourself: which one am I supposed to solve for?

If given: $v_{2f} = 3.00 \frac{m}{s}$, $v_{1f} = -1.00 \frac{m}{s}$

$m_2 = 1.00\,kg$, $m_1 = 2.00\,kg$

solve for v_{1o}

<Using the Specific Details>

Solve for V_{1o} if $m_1 = 2.00\,kg$, $m_2 = 1.00\,kg$

and $V_{1f} = -1.00\,\frac{m}{s}$, $V_2 = +3.00\,\frac{m}{s}$.

$$m_1 V_{1o} = m_1 V_{1f} + m_2 V_{2f}$$

[rewrite or solve for V_{1o}]

$$V_{1o} = \frac{m_1 V_{1f} + m_2 V_{2f}}{m_1}$$

(plug in #'s)

$$V_{1o} = \frac{(2.00)(-1.00) + (1.00)(3.00)\,\frac{kg\cdot m}{s}}{(2.00\,kg)}$$

$$V_{1o} = \frac{(-2.00 + 3.00)}{2.00}\,\frac{m}{s}$$

$$V_{1o} = \frac{1.0}{2.0}\,\frac{m}{s}$$

$$\boxed{V_{1o} = 0.5\,\frac{m}{s}}$$