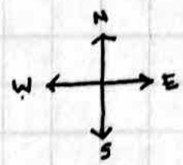
PHYSICS 211

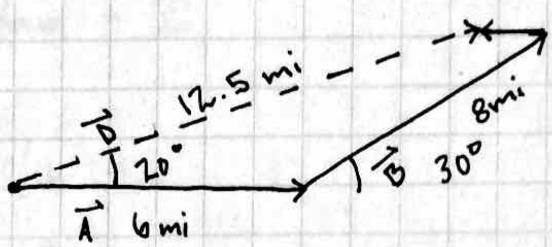
OFFICE HOURS: MW 12:30 - 2:00, TTH 9-10:30

PHYSICS HELP ROOM, WNGR 145, 12:00 - 6:00 M-F

LECTURE 4/1

EXAMPLE





"⟨12.5mi, 20° N of E⟩"

$\vec{A_x} = 6mi$

$\vec{B_y} = 4mi$

$\vec{B_x} = 6.93 mi$

$\vec{C_x} = -1 mi$

$\vec{D} = \langle 11.93, 4 \rangle$

$|\vec{D}| = \sqrt{(11.93)^2 + 16}$

$|\vec{D}| = 12.8 mi$

4/6/11

$$V_{AVG} = \frac{\text{DISTANCE}}{\text{ELAPSED TIME}}$$

AVE SPEED

$$V_{AVG} = \frac{\text{DISPLACEMENT}}{\text{ELAPSED TIME}} = \frac{\Delta x}{\Delta t}$$

INSTANTANIOUS VELOCITY

$$V_{INST} = \frac{dx}{dt}$$

4/8/11

$$x = \frac{at^2}{2}$$

4/11/10

OBJECT ACCELARATING ONLY DUE TO THE FORCE OF GRAVITY $\Rightarrow$ FREEFALL

$X = X_0 + vt$: POSITION

$V = V_0 + at$: ACCELARATION

$= V_0 \int dt + a \int t\,dt$

$= V_0 t + \frac{1}{2} a t^2$

$V_0^2 + 2a\,\Delta X$

4/13/11

*PRACTICE PROBLEMS ON WEBSITE

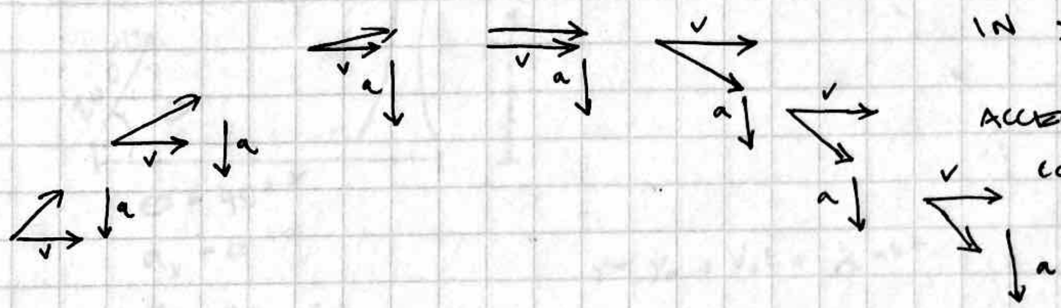
$V_{AVG} = \frac{1}{2}(V_0 + v)$ $\quad X = \frac{1}{2}(V_0 + V)t$

READ 2D KINEMATICS SLIDES ON BLACKBOARD/WEBSITE

KEEP X PARTS/Y PARTS SEPARATE

4/15/11

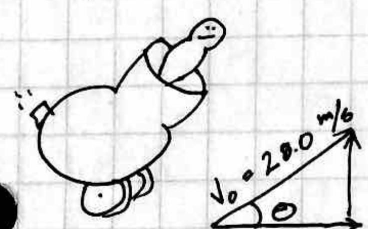
MIDTERM: 7:30 PM ~~[crossed out]~~ CORDLEY 1109



VELOCITY NEVER CHANGES IN X-DIRECTION

ACCELARATION IN Y-DIRECTION CONSTANT

EX.



$\theta = 22.0°$

$V_x = \cos(\theta) \cdot V_0$

$V_x = 26.0$ m/s

$\underbrace{x = V_x t}$

$x = (26.0\,\text{m/s})(2.14\,\text{s})$

$\boxed{x = 55.7\,\text{m}}$

$t = ?$

$y_0 = 0 = y_{FINAL}$

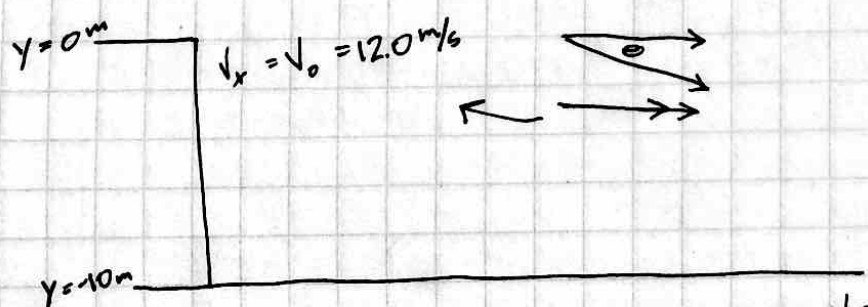
$y = y_0 + V_{0y} t + \frac{t^2 a}{2}$

$t = \frac{-2V_{0y}}{a}$

$t = \frac{-2(10.5\,\text{m/s})}{-9.8\,\text{m/s/s}}$

$t = 2.14\,\text{s}$

PROJECTED ~~MODELS~~ OBJECTS FOLLOW PARABOLIC MOTION.



$V_x = V_0 \cos(\theta)$

$= V_0(1)$

$= 12\,\text{m/s}$

$y = y_0 + V_0 t + \frac{1}{2} a t^2$

$x = V_x t$

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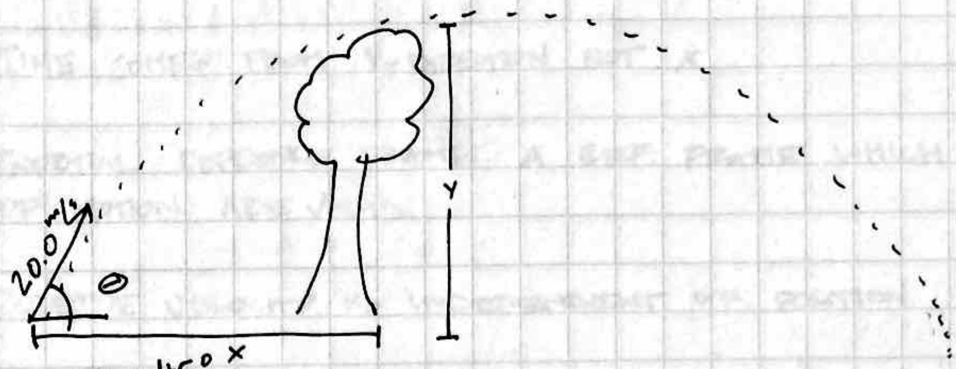


$\theta = 45°$

$a_x = 0$

$V_x = 20\cos(\theta)$
$= 14.14\,m/s$

$y = y_0 + V_0 t + \frac{1}{2} a t^2$

HEIGHT
~~TIME~~ TO TREE?

4/18/11

TIME COMES FROM Y-DIRECTION NOT X

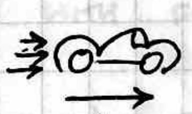
INERTIAL REFERENCE FRAME: A REF. FRAME WHICH NEWTONS LAWS OF MOTION ARE VALID.

RELATIVE VELOCITY IS INDEPENDENT OF POSITION.

$$V_{BC} = -V_{CB}$$

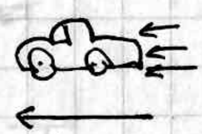
$$V_{AC} = V_{AB} + V_{BC}$$

EX.



$V_o = +50 \text{ mph} = V_{OE}$

RELATIVE TO EARTH



$V_T = -60 \text{ mph} = V_{TE}$

$$V_{TC} = V_{TE} + V_{EC} \qquad V_{EC} = -V_{CE}$$

$$\overrightarrow{V_{TC}} = -60 \text{ mph} + (-50 \text{ mph}) = -110 \text{ mph}$$

$$\overrightarrow{V_{CT}} = 50 \text{ mph} + 60 \text{ mph} = 110 \text{ mph}$$

IF THE CAR PASSES THE TRUCK, ALL VELOCITIES STAY THE SAME. POSITION INDEPENTENT

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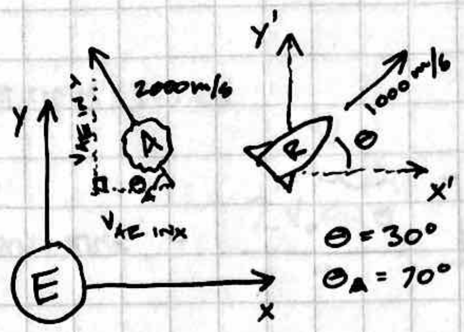


X AND X' ARE PARALLEL

Y AND Y' ARE PARALLEL

WHAT IS THE ASTEROIDS VELOCITY WITH RESPECT TO THE ROCKET

$$\vec{V}_{AR} = \vec{V}_{AE} + \vec{V}_{ER} \quad , \quad \vec{V}_{ER} = -\vec{V}_{RE}$$

$$V_{AR\ in\ x} = V_{AE\ in\ x} + V_{ER\ in\ x} \qquad V_{AR\text{-}y\ in\ X} = V_{AE\ in\ y} + V_{ER\ in\ y}$$

$$V_{AR\ in\ x} = -2000\cos(70°) + (-1000\cos(30°))$$

$$V_{AR\ in\ x} = -1550\ m/s$$

$$V_{AR\text{-}y} = 2000\sin(70°) + (-1000\sin(30°))$$

$$V_{AR\text{-}y} = 1380\ m/s$$

$$V_{AR} = \sqrt{1550^2 + 1380^2}$$

$$V_{AR} = 2075\ m/s$$

* CAN BE DONE BY VECTOR ADDITION HEAD TO TAIL *

$$\theta = \tan^{-1}\left(\frac{1380}{1550}\right)$$

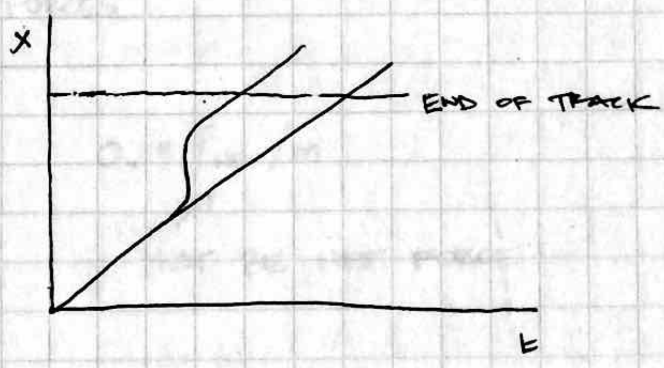
θ = 41.7° UP FROM X-AXIS

4/20/11

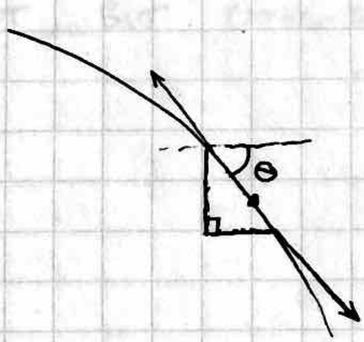
MIDTERM REVIEW

'HANG TIME' $= \dfrac{2\overbrace{V_0 \sin\theta}^{V_y}}{g}$] EQUATION ONLY WORKS FOR SAME LANDING HEIGHT

BALL DEMONSTRATION



BALL W/ DIP COVERS MORE GROUND QUICKER, BUT STILL DOESN'T CATCH UP



TO FIND θ WE NEED V_y/V_x

4/22/11

CHRIS COFFIN X ← HARD TESTS :(

INERTIA: TENDENCY FOR OBJECT TO STAY IN MOTION

MORE MASS = MORE INERTIA

FORCE IS A PUSH OR A PULL

MYTH THE FORCE REQUIRED TO PUSH AN OBJECT ALONG AT A <u>CONSTANT</u> SPEED IS GREATER THAN THE RETARDING FORCES.

$a = F_{NET}/m$ $\qquad\qquad \sum F_x = \cancel{F_{N}}$

↗ MUST BE NET FORCE

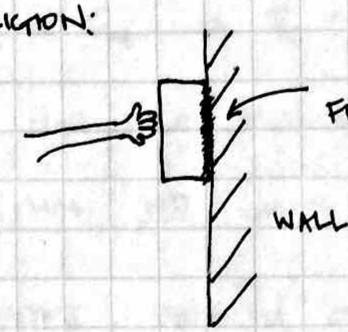
UNITS NAMED AFTER HUMANS MUST BE <u>LOWER CASE</u> WHEN WRITTEN OUT, BUT CAPITALIZED WHEN ABBREVIATED

4/25/11

$$F_{GRAVITY} = \frac{GMm}{d^2}$$ [redacted]

FROM THIS WE CAN DERIVE : $g = 9.81\ m/s^2$

FRICTION:



FRICTION IS RESISTANCE FROM ELECTRONS

$F_{WALL\ ON\ BOX} = F_{NORMAL}$

NORMAL FORCE IS <u>NOT</u> THE WEIGHT

* THE NORMAL FORCE IS THE FORCE OF A SURFACE EXCEPTS ON AN OBJECT WHEN THAT OBJECT IS IN CONTACT WITH THAT SURFACE.

FRICTION:

* TWO TYPES OF FRICTION:
- KINETIC
- STATIC

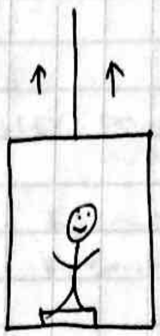
$F_f \propto F_N \Rightarrow F_f = \mu F_N$

μ HAS VALUE BETWEEN 0 AND 1

μ HAS <u>NO</u> UNITS

WEIGHT: MEASURE OF THE FORCE DETERMINED BY A SPRING SCALE UPON WHICH AN OBJECT IS PLACED

5/2/11



$$F_{NET} = F_g + ma$$

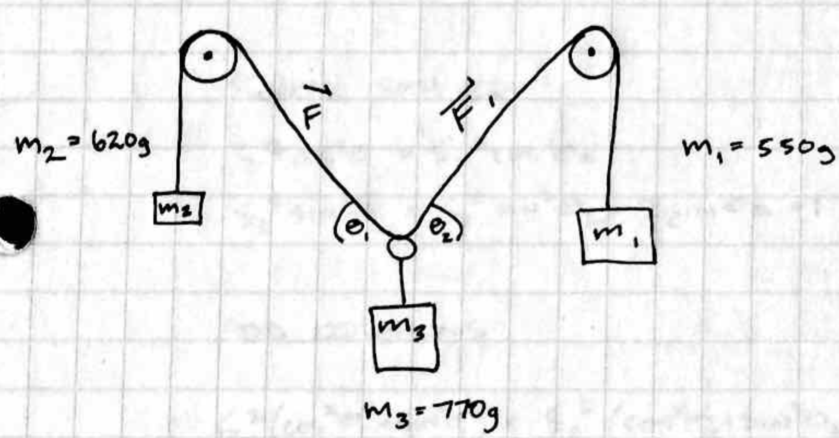
$$F_{NET} = (800N) + (80kg)(2m/s/s)$$

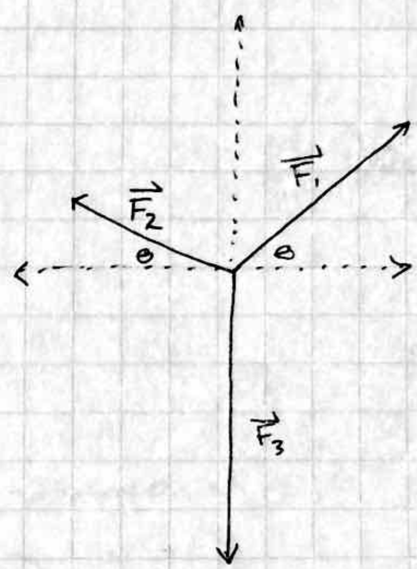
$$= 960 N$$

TRANSLATIONAL EQUILLIBRIUM = 'STRAIGHT-LINE' EQUILLIBRIUM

PULLEYS ARE CONSIDERED MASSLESS AND FRICTIONLESS

STRING TENSION IS ALWAYS THE SAME FORCE EVERYWHERE IN THE STRING.





X-DIRECTION:

$$F_1 \cos\theta_1 - F_2 \cos\theta_2 = 0$$

Y-DIRECTION

$$\vec{F_1} + \vec{F_2} + \vec{F_3} = ma = 0$$

$$\vec{F_1} = F_1 \cos\theta + F_1 \sin\theta$$

$$\vec{F_2} = -F_2 \cos\theta + F_2 \sin\theta$$

$$\vec{F_3} = -\vec{F_3} J$$

5/4/11

PULLEY PROBLEMS:

DIVIDE BOTH EQUATIONS BY F_3: $S_1 = \frac{F_1}{F_3}$ $S_2 = \frac{F_2}{F_3}$

$= 0.805$ 0.714

$F_1 \cos\theta_1 - F_2 \cos\theta_2 = 0$

$F_1 \sin\theta_1 + F_2 \sin\theta_2 = 0$

* KNOW FOR TEST *

$S_1 \cos\theta_1 - S_2 \cos\theta_2 = 0$

$S_1 \sin\theta_1 + S_2 \sin\theta_2 - 1 = 0$

REWRITE:

$S_1 \cos\theta_1 = S_2 \cos\theta_2$

$S_1 \sin\theta_1 = -S_2 \sin\theta_2 + 1$

SQUARE BOTH EQ:

$S_1^2 \cos^2\theta = S_2^2 \cos^2\theta_2$

$S_1^2 \sin^2\theta = S_2^2 \sin^2\theta_2 - 2S_2 \sin\theta_2 + 1$

ADD EQUATIONS

$S_1^2(\cos^2\theta_1 + \sin^2\theta_1) = S_2^2(\cos^2\theta_2 + \sin^2\theta_2) - 2S_2 \sin\theta_2 + 1$

$S_1^2 = S_2^2 - 2S_2 \sin\theta_2 + 1$

$\sin\theta_2 = \frac{S_2^2 - S_1^2 + 1}{2S_2} = 0.604$

TRY SOLVING SIMULTANIOUSLY ON CALCULATOR

$\theta_2 = 37°$

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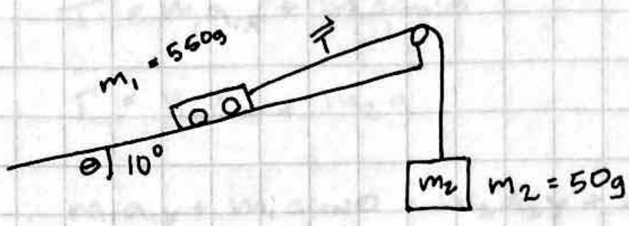
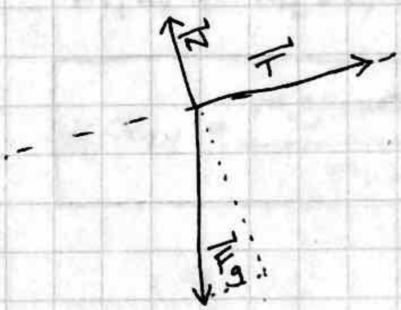
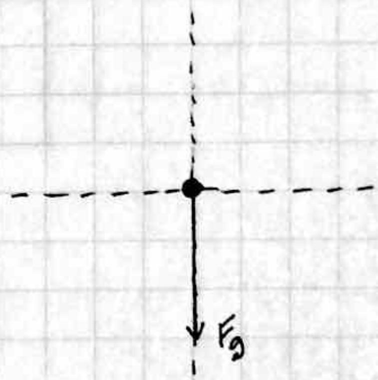


CART IS MOTIONLESS, SO
TENSION = FORCE OF GRAVITY

FREE BODY DIAGRAM





CART:

$m_1 a_{1x} = T - m_1 g \sin\theta$

$m_1 a_{1y} = F_N - mg\cos\theta = 0$

EQUAL TO ZERO BECAUSE CART IS NOT MOVING IN Y. IF FRICTION IS INCLUDED THEN $m_1 a_{1y} \neq 0$

MASS:

$m_2 a_{2y} = T - m_2 g$

$m_2 a_{2x} = 0 =$ NO X-FORCE

T IS SAME EVERYWHERE IN STRING

$|a|$ IS SAME FOR m_1 AND m_2

$|a_{1x}| = |a_{2y}|$

$a_{1x} = -a_{2y}$

5/4/11

$T = m_1 a_{1x} + m_1 g \sin\theta$

$T = M_2 a_{2y} + m_2 g$

$m_1 a_{1x} + m_1 g \sin\theta = m_2 a_{2y} + m_2 g$

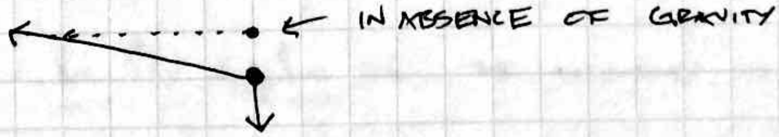
$-m_1 a_{2y} + m_1 g \sin\theta = m_2 a_{2y} + m_2 g$

$-m_1 a_2 g - m_2 a_{2y} = m_2 g - m_1 g \sin\theta$

$$\boxed{a_{2y} = \frac{m_1 g \sin\theta - m_2 g}{m_1 + m_2}}$$

5/6/11

BALL ON STRING:

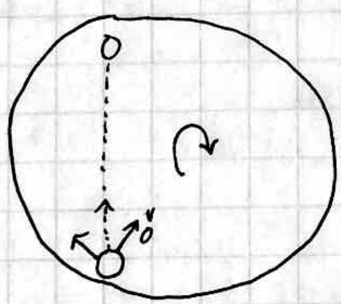


ANY OBJECT TRAVELING IN A CIRCLE EXPERIENCES A <u>CENTRIPITAL</u> FORCE

STRING WILL NEVER GO HORIZONTAL, DUE TO GRAVITY

DIRECTION OF a_c IS PERPENDICULAR TO THE VELOCITY. a_c <u>CAN</u> <u>NOT</u> CHANGE THE VELOCITY

CENTRIPITAL ACCELERATION $= \frac{v^2}{R}$



BALL WILL COME BACK

NEWTON'S THIRD LAW:
"EVERY ACTION HAS AN EQUAL AND OPPOSITE REACTION"

NEWTON'S LAW DOES NOT AFFECT FBD

5/7/11

SUPPOSE $f(x) < g(x)$ ON $[0, \infty)$

THEN

$\lim_{x \to \infty} f(x) \leq \lim_{x \to \infty} g(x)$ THE INEQUALITY HOLDS AS X - GROWS W/ OUT BOUND

IF $\lim_{x \to \infty} f(x) = \infty$ THEN $\lim_{x \to \infty} g(x) = \infty$ IF $0 \leq f(x) \leq g(x)$

AND $\lim_{x \to \infty} g(x) < \infty$

THEN IF $\lim_{x \to \infty} f(x)$ EXISTS IT IS FINITE

THE REASONING EXTENDS TO SEQUENCES AND INFINITE SERIES

IF $\sum b_n < \infty$ THEN $\sum a_n < \infty$. HERE WE KNOW $\sum_{n=1}^{\infty} a_n$ AND $\sum_{n=1}^{\infty} b_n$ EXISTS

INTEGRAL TEST IS A SPECIAL CASE OF COMPARISON TEST

$a_n = f(n)$, $b_n = \int_{n-1}^{n} f(x)\,dx$ THEN $a_n \leq b_n$

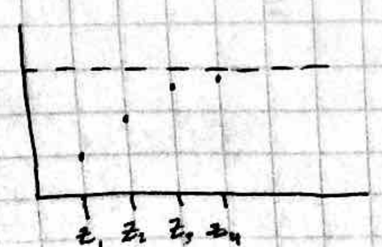
IF YOU THINK A SERIES WILL CONVERGE, BOUND IT ABOVE BY A CONVERGENCE SERIES. VISE-VERSA FOR DIVERGENCE

DETERMINE IF $\sum_{n=3}^{\infty} \frac{1}{n-2}$ CONVERGES

FOR ALL $n \in \mathbb{N}$, $n-2 \leq n$, IF $n-2>0$ THEN $\frac{1}{n} \leq \frac{1}{n-2}$

THEORUM:

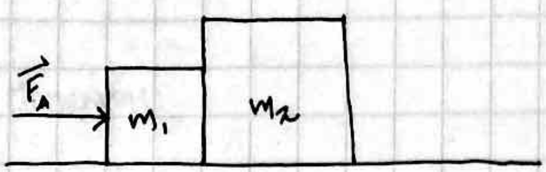
LET Z_n BE AN INCREASING BOUNDED SEQUENCE OF NUMBERS



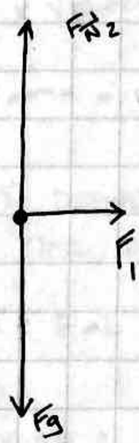
$\lim_{n \to \infty} Z_n = L$ WHERE L IS $\leq \{Z_n\}$

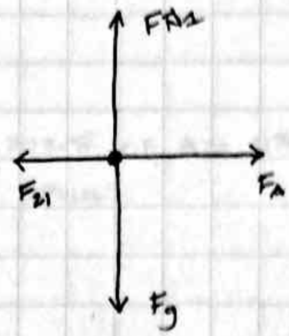
5/9/11

$m_2 = 3m_1$



Box 2:





Box 1:

X-DIRECTION FORCES

$x: F_A - F_{21} = m_1 a_{1x}$

$y: F_{N_1} - m_1 g = m_1 a_{1y} = 0$

Box 2:

$x: F_{12} = m_2 a_{2x}$

$y: F_{N2} - m_2 g = 0$

$$a_{1x} = a_{2x} = a_x$$

$$F_A - F_{21} = m_1 a_x$$
$$F_{12} = m_2 a_{2x}$$

$$F_A \underbrace{- F_{21} + F_{12}}_{\text{CANCEL}} = \cancel{m_2 a_x}\ (m_1 + m_2) a_x$$

$$F_A = (m_1 + m_2) a_x$$

$$a_x = \frac{F_A}{(m_1 + m_2)}$$ } SAME AS COMBING MASSES IN THIS CASE

$$F_{12} = a_2 a_x = \frac{m_2 F_A}{(m_1 + m_2)} = \frac{3m_1 F_A}{4m_1} \boxed{= \frac{3}{4} F_A}$$

5/16/2011

MOMENTUM:

MASS x VELOCITY

$$\sum F = ma = m\frac{dv}{dt} = \frac{d(mv)}{dt} = \frac{dp}{dt}$$

IMPULSE: DEFINED TO BE THE AVERAGE FORCE OF AN OBJECT MULTIPLIED BY THE TIME DURING WHICH THE FORCE IS APPLIED.

$$J = F\Delta t$$

$$J = \Delta p = \int_{t_1}^{T_F} F\,dt$$

UNITS IN NEWTONS/SECOND

ALLOWS US TO DO FORCE PROBLEMS WHERE FORCE IS NOT CONSTANT.

THE IMPULSE EQUALS THE CHANGE IN MOMENTUM.

$$J = F_{AVE}\Delta t = m\Delta v = \Delta p$$

$$\sum F = 0 = \frac{dP}{dt} = 0$$

THE TOTAL MOMENTUM ON AN OBJECT DOES NOT CHANGE WITH TIME IF THE TOTAL (NET) EXTERNAL FORCES ACTING ON A SYSTEM EQUALS ZERO.

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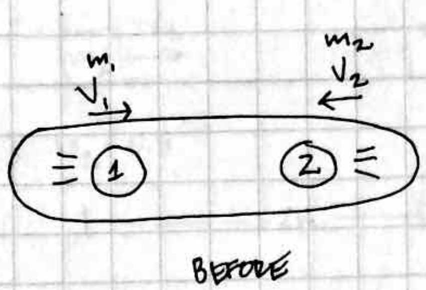
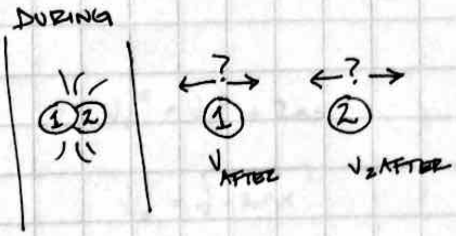
THE IMPULSE EQUALS THE CHANGE IN MOMENTUM





$$\sum \vec{P}_{BEFORE} = \sum \vec{P}_{AFTER}$$

MOMENTUM IS CONSERVED, NOT VELOCITY.

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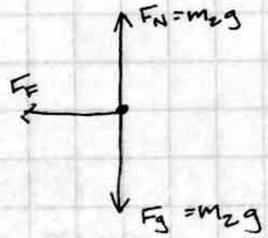
$m_2 = 0.5$

$V_f^2 = V_0^2 + 2ax$

$V_0 = \sqrt{-2ax}$



$F_{NET} = ma$

$m_1 V_1 = 4 m_2 V_2$

SOLVING FOR V_1:

$= -17.7$ m/s

$F_F = \mu F_N = \mu m_2 g$

$\cancel{m_2} a = \mu \cancel{m_2} g$

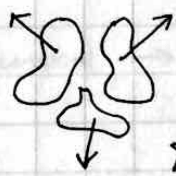
$a = -\mu g$

NOTICE SIGN

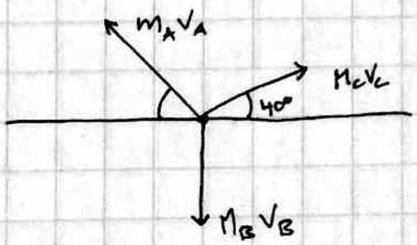
$V_0 = \sqrt{-2(-0.5)(9.8)(2)}$

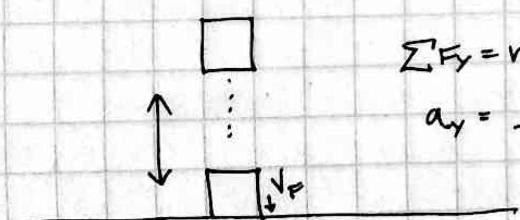
$= 4.43 = V_2$

$V = 0$



$\sum P_{AFTER} = 0$





$\sum F_y = m a_y$

$a_y = \frac{F_g}{m}$

$V_F^2 = V_0^2 + 2 a \Delta y$

$V_F^2 = V_0^2 + 2gH$

$V_F^2 = V_0^2 + 2\left(\frac{F_g}{m}\right)H$

5/23/2011

POTENTIAL ENERGY: ENERGY DUE TO POSITION
KINETIC ENERGY: ENERGY DUE TO MOTION

$U_g = mgh$

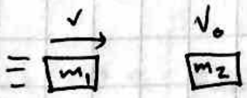
$E_{MECH} = K + U$ $\Delta E_{MECH} = \Delta K + \Delta U = 0$

5/25/2011

A BALL IS DROPPED FROM A HIGH TOWER AND IS IN FREEFALL WHICH OF THE FOLLOWING IS TRUE?

THE K.E. INCREASES IN EQUAL DISTANCE INTERVALS

TOTALLY INELASTIC COLLISION ⟶ $\overset{P}{KE}$ NOT CONSERVED



PRIME DESIGNATION AFTER

$$P: \cancel{m}_1 v_1 + 0 = \cancel{m}_1 v_1' + \cancel{m}_2 v_2'$$

$$v_1 = v_1' + v_2'$$

$$K = \cancel{\tfrac{1}{2} m_1} v^2 + \boxed{0} = \cancel{\tfrac{1}{2} m_1} v_1^2 + \cancel{\tfrac{1}{2} m} v_2^2$$

$$v_1^2 = v_1'^2 + v_2'^2$$

SQUARE $v_1 = v_1' + v_2'$

$$v_1^2 = v_1'^2 + v_2'^2 + 2v_1 v_2'$$

$$v_1^2 + v_2^2 = v_1'^2 + v_2'^2 + 2v_1' v_2'$$

$$2v_1' v_2 = 0$$

$$v_1' v_2' = 0$$

EITHER $v_1' = 0$ OR $v_1^2 = 0$

6/1/11

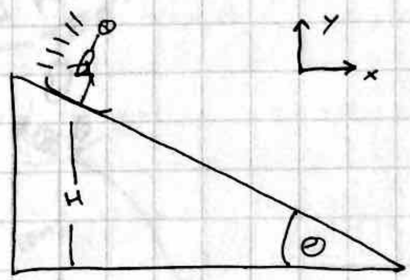
$$J = \Delta p = \int F dt$$

$$W = \Delta k = \int F dx$$

A CONSERVATIVE FORCE DOES WORK ON A OBJECT WHEN AN OBJECT MOVES FROM POINT A TO POINT B.

$W_{NC} = \Delta K + \Delta U$

$W_{CONS} = -\Delta U$



$\theta = 30°$
$m = 50kg$
$\mu_K = 0.230$
$H = 40m$
$V_o = 2.0 m/s$

$* a = 2.95 m/s^2 *$

USING ENERGY TECHNIQUES:

$W_{NC} = \Delta K + \Delta U$

$W_{NC} = \left(\frac{1}{2}mv_f^2 - \frac{1}{2}mv_I^2\right) + \left(\frac{1}{2}mgh_F - mgh_I\right)$

$W_{NC} = \text{WORK OF FRICTION} = \underbrace{F_f \cdot x \cdot \cos(180°)}$

180° NOT 0°

$F_f = \mu N$ $\quad F_N = mg\cos\theta$

GET FROM FBD

$F_f = \mu mg\cos\theta$

$V_{FRIC} = (\mu mg\cos\theta)(x)(\cos(180))$

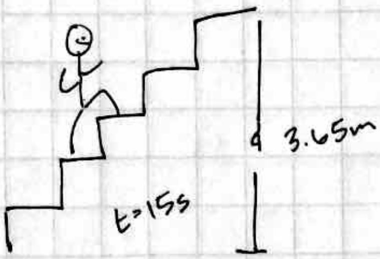
$(\mu mg\cos\theta)(x)\cos(180) = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 + mgh_f - mgh_i$; $x = \frac{h_1}{\sin(30)} = 80m$

$V_f = \left(2\mu g x \cos\theta \cos 180 + v_1^2 + 2gh_1 - 2gh_F\right)^{1/2}$

POWER IS THE TIME RATE OF CHANGE OF WORK

$P = \frac{W}{t}$ $\quad J/s = W$

1 HORSEPOWER = 550 ft lb/s = 746



$W_A = F_A \cdot S = mgh = \Delta PE$

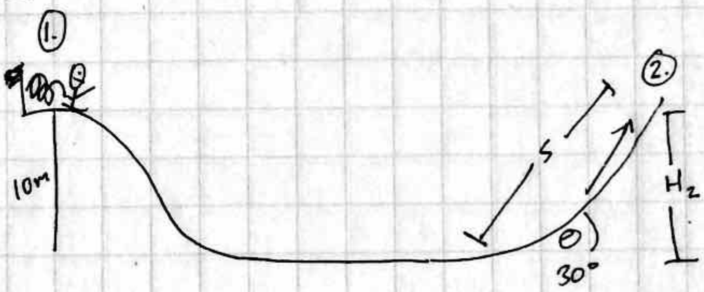
$W_A = (45)(9.8)(3.65) = 1610J$

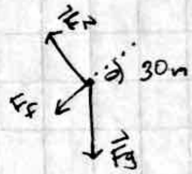
$P = \frac{W}{T}$

$P = \frac{1610}{15} = \boxed{107W}$

$107\left(\frac{1\text{-}HP}{746}\right) = 0.144 HP$

KNOW FOR TEST!





$W_{nc} = \Delta K + \Delta U$ $\quad V_1 = V_2 = 0$ $\quad F_f = \mu F_N = \mu mg\cos\theta$

$W_{NC} = \Delta U = \Delta U_g + \Delta U_s$

$S \cdot \mu mg\cos\theta \cdot \cos(180) = (mgh_2 - mgh_1) + \frac{1}{2}(kx_f^2 - \frac{1}{2}kx_I^2)$

$W = \Delta U + \Delta K$

$\frac{1}{2}m(10^2) = \frac{1}{2}m(7^2)$

$\sin(30°) = \frac{h_2}{S}$ $\quad S = \frac{h_2}{\sin(30)}$

$\Delta KE = -\Delta PE$

$\frac{1}{2}\cancel{m}V_F^2 - \frac{1}{2}\cancel{m}V_I^2 = \cancel{m}g\Delta H$

$h_2\left[\mu mg \frac{\cos(30°)}{\sin(30)}\cos(180) - mg\right] = -mgh_1 - \frac{1}{2}kx_1^2$ $\quad \frac{1}{2}V_F^2 - \frac{1}{2}V_I^2 = g\Delta H$

SOLVE FOR h_2 $\quad h_2 = 16.0\,m$

$W_F = -4083J$