Physics 113 - September 25, 2012

Exam I - Oct 4 (08:00 in Hoyt)
Will arrange for pre-exam Q+T session
Exam on material thru P.S. 41 and Workshop 3
Allowed 1 side of 8.5x11 inch sheet w/ 57 formulas, etc.

Yes we will have class on Oct. 4
... For those of you lucky enough to
have lab + workshop on Oct 4, It will
be a Stellar day to remember!

hooray!

Recall - No lecture in Hoyt on 9/27/12
Turn in P.S. 4 to locker in B+L by end of 9/27/12
Newton's Laws

I: Law of Inertia
A body persists in its state of motion unless acted on by an external net force.

II: Force Law
The acceleration of an object is proportional to the net force applied to it and inversely proportional to the mass of the object.
\[ F = ma \]

III Law of Action and Reaction
For every action there is an equal and opposite reaction.

The Path to Enlightenment

1. Understand problem, draw neat diagram of overall problem
2. Draw free body diagram of each relevant object - label with forces
3. Choose convenient coordinate system for each object
4. Apply Newton’s Second Law \( F = ma \) in appropriate orthogonal coordinates (coordinates chosen for each body must be related to those chosen for other bodies)
5. Keeping symbols in place correctly, solve resulting set of equations simultaneously
6. Check answer with limiting cases and dimensional analysis!
Let's continue with Newton's laws

Why does mass not crash thru floor?

Normal force — usually $N$ or $F_N$

Recall Newton's 3rd Law
Another Example

Recall

Put system in place and let it go

Describe subsequent motion of system

Find tension in rope and acceleration
Choose coordinates like so →

"Free Body Diagram"

FBD of $M_1$

FBD of $M_2$

motion of $M_1$ is along plane ... so makes sense to choose that direction as one of the axes for that mass

$F_{g2} = m_2g$

$|\vec{T}_2| = |\vec{T}_1| = |\vec{T}|$

$F_{g1} = m_1g$ down
Newton's 2nd law applied to mass 2

\[ \sum F = m \ddot{a} \]

\[ \sum F_2 = m_2 \ddot{a}_2 = m_2 \ddot{a}_y \]

1. \[ F_y = m_2 a_y \]
2. \[ F_y = m_2 g = T - m_2 g \]

Tension in the rope is just \( T \) same for each mass.
Apply Newton's 2nd law to mass 1.

Resolve vectors along axes.

Parallel to surface of inclined plane "||" perpendicular to surface of inclined plane "\perp\"
\[ \sum F_i = m_i \vec{a}_i, \quad \text{\textit{\(\perp\)} = parallel} \]

in \( y \) direction \quad \text{\textit{\(\perp\)}} = \text{Perpendicular}

in direction along \( z \) or \( \perp \) to surf. of plane

\[ m_1 a_y = m_1 g \sin \alpha - T \]

\[ m_1 a_z = 0 = N - m_1 g \cos \alpha \]

\[ M_2 a_y = T - m_2 g \]

Earlier From Mass 2 (p.6)

2 equations
2 unknowns \( a_y, T \)

This is what problem asks us to determine

Soluble
Do the algebra and convince yourself that:

\[ a_y = \frac{m_1 g \sin \alpha - m_2 g}{m_1 + m_2} \]

\[ T = \frac{m_1 m_2 g (1 + \sin \alpha)}{m_1 + m_2} \]

T is a force

units are Newtons (N)

\[ F = Ma \Rightarrow 1 \text{ N} = 1 \text{ kg} \cdot \frac{\text{m}}{\text{s}^2} \]

Are we correct?

\[ \Rightarrow \text{check units} \]

\[ \Rightarrow \text{limiting cases} \]

D. Look at \( a_y \) if \( M_1 >> M_2 \)

E. Look at \( a_y \) if \( M_1 << M_2 \)

F. Let \( \alpha = 90^\circ \Rightarrow \sin \alpha = 1 \)

Solutions simplify to what we found in last lecture
End of material for Exam I

Beginning of material for Exam II
(of course all this material will make use of what comes before)

friction

microscopic force of friction
Rub hands together

\[ \vec{F}_{\text{fr}} = \text{force of friction of orange on blue} \]

\[ \vec{F}_{\text{fr}} = \text{force of friction} \]

(Yes there is also an equal and opposite force of blue on orange ... not shown)
Kinetic Friction - Force of friction between Surfaces Moving With respect to each other

\[ |\vec{F}_{fr}| \propto |\vec{N}| \]

\[ |\vec{F}_{fr}| = \mu_k |\vec{N}| \]

Coefficient of kinetic friction

is proportional too

Force of friction opposes the motion
Static Friction - Force of friction between Surfaces not moving with respect to each other

\[ F_{fr} \]

Force of friction opposes \( \vec{F} \) which is trying to move books

\[ |F_{fr}| = \frac{\mu_s}{N} \]

Coefficient of static friction

\( \mu_s N \) = limiting value that static frictional force can have

\[ F_{fr,\text{static}} \leq \mu_s N \]
Suppose system is at rest in equilibrium (no accel, no motion)

Let \( M_2 = 20 \text{kg} \)
\( M_1 = 10 \text{kg} \)

Determine the smallest \( M_2 \) (between surface of table and \( M_1 \)) that can lead to this situation
FBD mass 2

\[ \sum F_y = m_2 a_{y_2} = 0 = T - m_2 g \]

\[ T = m_2 g \]
FBD Mass 1

\[ F_{Fr} \]

\[ +x \]

\[ +y \]

\[ N \]

\[ m_1 g \]

\[ \sum F_x = m_1 a_x \Rightarrow 0 = N - m_1 g \]

\[ N = m_1 g \]

\[ T = m_2 g \] \text{From last page}

\[ \sum F_y = m_1 a_y \Rightarrow 0 = F_{Fr} - T \]

\[ F_{Fr} = T \]

\[ M_s N = T \]

\[ M_s m_1 g = m_2 g \]

\[ M_s = \frac{m_2}{m_1} \] \text{Units?}

\[ \text{Ans. to Problem} \]

\[ \text{Units?} \]