Physics 101: Lecture 08

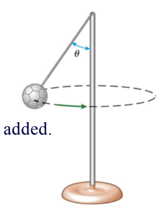
Circular Motion
Review of Newton's Laws

Checkpoint 4, Lecture 7

In the game of tetherball, a rope connects a ball to the top of a vertical pole as shown. In one case, a ball of mass m_1 is attached to the rope. In the second case, a ball of mass $m_2 = 2\, m_1$ is attached to the rope. In both cases the speed of the ball is the same.

What is the tension T_1 in the rope with ball m_1 compared to the tension T_2 in the rope with ball m_2?

A. $T_1 = T_2$
B. $T_1 = 2\, T_2$
C. $T_1 = 0.5\, T_2$
D. None of the above because the weight of the ball needs to be added.



Common Incorrect Forces (Spooky Rules!)
Items below are NOT forces

- Acceptation: $F_{Net} = ma$
  - Centripetal Acceleration
- Force of Motion (Inertia not a force)
  - Forward Force,
  - Force of velocity
  - Momentum of car moving forward
- Centrifugal Force (No such thing!)
  - Centripetal (really friction)
  - Inward force (really friction)
- Internal Forces (don't count, cancel)
  - Car
  - Engine
  - Thrust (force moving car forward)

EXAM 1

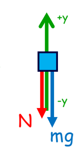
- Exam 1 will be held Wed 2/21 – Fri 2/23
- You MUST sign up for a time slot here:
https://my.physics.illinois.edu/undergrad/onlineexams/signup-student.asp
- Exam is computer-administered in Loomis 257
- Exam covers Lectures 1-8 (kinematics and dynamics—Newton's Laws; friction; circular motion)
- No lab the week of exam (good sign-up slot!)
- Discussion **IS** held the week of the exam
- Contact Dr. Schulte w/ Qs about sign up: eschulte@illinois.edu
- Exam is all multiple choice (3 & 5 choice Qs)
- I will hold review session, time TBA

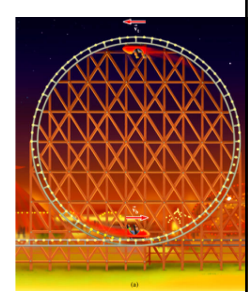
Roller Coaster Example

What is the minimum speed you must have at the top of a roller coaster loop or radius 20 m, to keep the wheels on the track?

Big Idea: N#2 applied to car at top of loop
Justification: N#2 relates forces and a, and a is related to speed for circular motion

Plan:
1. Select car as body, draw a FBD, pick coordinate system
2. Apply N#2 in y-dir., knowing a and v are related
3. Set N=0 at top so that wheels barely remain on track.
4. Solve for v.





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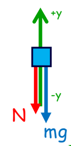


Y Direction: $F_{Net} = ma$

$-N - mg = m(-a) = -m\,v^2/R$

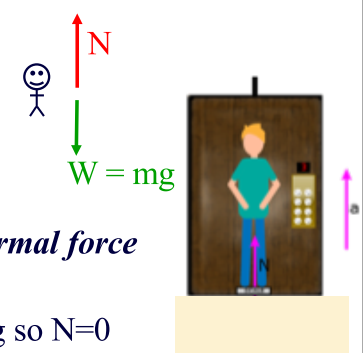
Let N = 0, just touching at top

$-mg = -m\,v^2/R$

$v = \text{sqrt}(g*R) = 14$ m/s

Apparent Weight

- Recall: $F_{Net} = m\,a$
  - Consider a person accelerating up in an elevator.
  - Draw FBD
  - Apply Newton's 2nd!
    - » $F_{net} = ma$
    - » $N - mg = ma$
    - » Algebra: $N = m(g+a)$



- Apparent weight is ***normal force*** from scale or floor.
- Note: in free fall $a_y = -g$ so $N=0$

Apparent Weight Examples

A person's mass is 50 kg. What is the person's apparent weight when riding on an elevator $N = m(g+a)$

1. Going up with constant speed 5 m/s

   $a = 0$ so $N = mg = 490$ N

2. Going down with constant speed 4 m/s

   $a = 0$ so $N = mg = 490$ N

3. Accelerating up at a rate of 9.8 m/s^2

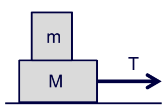
   $a = +9.8$ m/s so $N = 2\,mg = 980$ N

4. Accelerating down at a rate of 9.8 m/s^2

   $a = -9.8$ m/s so $N = 0\,mg = 0$ N

A neat example that puts it all together

Two blocks are stacked one on top of the other on a table as shown. There is no friction between M and the table but there is friction between M and m. A string is used to pull M as shown and the blocks accelerate together along the surface. If the coefficient of static friction is μ_s=0.6, with what maximum tension can you pull on M before m starts to slide on top of M? Use M=0.4 kg and m=0.22 kg.



Big Idea: 2 Step problem: First apply N#2 to m to determine maximum acceleration. Then apply N#2 to BOTH blocks together to relate T to maximum acceleration

Justification: N#2 will relate forces and a, and max. a will be related to max. T

Plan: 1) Draw a FBD for m with usual coordinate system

2) Apply N#2 to m and set friction to max. to determine max. a.

3) Solve for max. a.

From previous analysis of m: $a_{max} = \mu_s g$

Next analyze m+M.

Plan: 1) Draw FBD for m & M together as one body with usual coordinate system

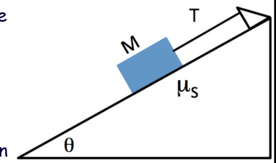
2) Apply N#2 to both blocks to relate T to a_{max}.

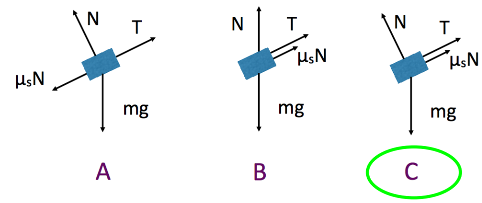
3) Substitute for a_{max} what you got from previous part to obtain a final expression for T

Are we having fun yet? Are you learning to play the physics game?

Let's do some old exam 1 problems for practice

A block of mass M = 3 kg is placed on an inclined plane with an angle θ = 36 degrees. A string anchored near the top of the ramp is attached to the block in order to prevent the block from sliding down the ramp. (Without the string, static friction alone would be insufficient to keep the block from slipping.) The coefficient of static friction is = 0.08 and the tension in the string is T.
Which is the correct free body diagram of the forces on the block when it is at rest?





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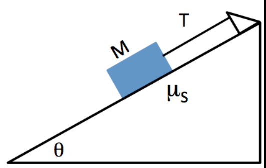
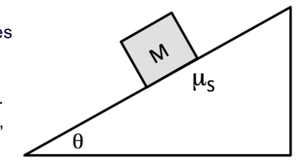
What is the minimum tension in the string needed to hold the block in place ?

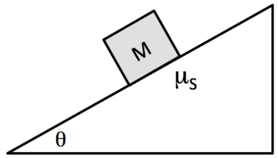


a. 15.38 N
b. 5.13 N
c. 19.18 N
d. 22.4 N
e. 25.17 N

A box of mass M sits on an inclined plane that makes an angle θ with the horizontal. Static friction keeps the box from moving. The coefficient of static friction between the box and the inclined plane is μ_s. Suppose the angle of the incline is increased slowly, and that the maximum value for which the box does not start to slip is found to be θ_{max}. What is the value of the coefficient of static friction in terms of θ_{max}.?



a. $\sin(\theta_{max})$
b. $\tan(\theta_{max})$
c. $\cos(\theta_{max})$



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When the angle of the inclined plane is set to $\theta=(\theta_{max})/2$, what is the magnitude of the static frictional force acting on the box?

a. $Mg\sin(\theta)$
b. $\mu_s Mg\sin(\theta)$
c. $Mg/2$
d. $\mu_s Mg\cos(\theta)$
e. $\mu_s Mg\sin(\theta)$