Spring 2014

PHYS-2010

Lecture 44

Thank you for being such a great class !

Good Luck on the Final Exam!!!

HAVE A GREAT SUMMER!!!

Announcements

- Extra Office Hour by TA Rosemary Wulf this Sunday, May 4, 1:30-4:00 pm in DUANE G1B30.

- **Extra credit opportunity --- ** online survey

http://www.colorado.edu/sei/surveys/Sp14/CLASSsp14-phys-2010-post.html

- **Final Exam:**
  - Monday, May 5, 1:30-4:00, in G1B30.
  - Cumulative, but with more focus on last chapters.
  - Practice exam posted on D2L.

Final Exam Info

- Final Exam is Monday Afternoon, May 5, 1:30 - 4 pm.
- Location: G1B30 (all students)
- Practice Exam is posted on D2L.
- The exam will have ~ 40 multiple choice questions. The exam will be closed book. You can bring 2 double-sided sheets of your own notes (4 pages total). Calculators are allowed, but no sharing of calculators. A formula sheet will be included with your exam booklet.
- Final Exam will be **cumulative** --- will cover material including Giancoli Chapters 1-10 and 11.1-11.2, with more focus on the last few chapters; all CAPA homework assignments, lecture material, and labs and recitations.

Materials for Exam Preparation

- Giancoli Textbook and example problems in the text.
- Prof. Dubson's Chapter Notes (see link on web page).
- Clicker questions as posted in lecture notes.
- CAPA and written homework problems.
- Practice exam and solutions on D2L.
- Three midterm exams and solutions on D2L.
- Lab manuals and Recitation problems.

PHYSICS 2010 Final Exam Review Session

Note that this review is not covering everything. Rather it is highlighting key points and concepts.

CH. 2 Kinematics in 1D

2.1 Reference frames and displacement
2.2 Average velocity
2.3 Instantaneous velocity
2.4 Acceleration
2.5 Motion at constant acceleration
2.6 Solving problems
2.7 Falling objects
2.8 Graphical analysis of linear motion

Motion under constant acceleration

- Constant acceleration (a = const) in 1D:

(a) $$v = v_o + a\,t$$

(b) $$x = x_o + v_o t + (1/2)a\,t^2$$

(c) $$v^2 = v_o^{\,2} + 2a(x - x_o)$$

(d) $$\bar{v} = \frac{v_o + v}{2}$$

What are some example problems?

Motion under constant acceleration

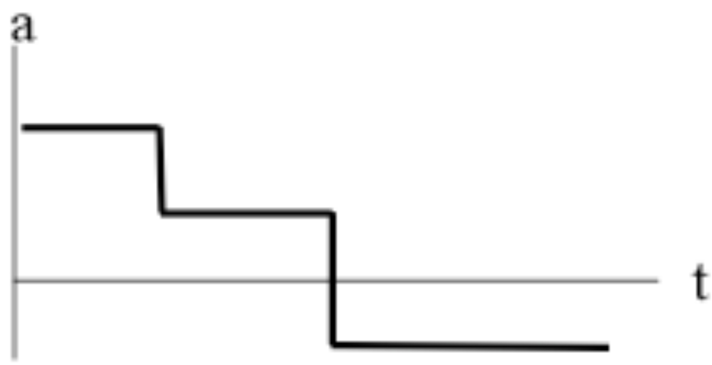
- graphing: x vs. t, v vs. t, a vs. t
- $v = \dfrac{\Delta x}{\Delta t}$ = slope of a graph of x vs. t
- $a = \dfrac{\Delta v}{\Delta t}$ = slope of graph of v vs. t
- average vs. instantaneous value of velocity, acceleration
- "acceleration is <u>not</u> velocity, …."

<u>Finally</u>: algebra, trigonometry, unit conversion.

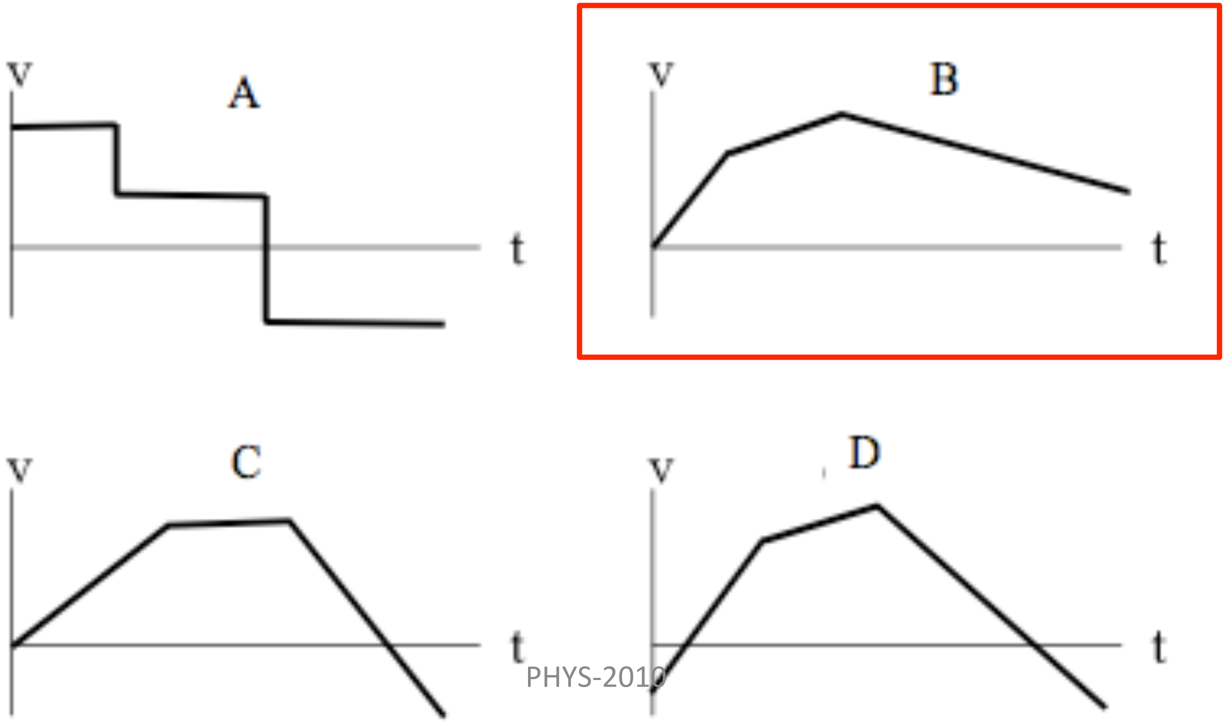
Clicker Question

Room Frequency BA

RI-3 An object's acceleration vs. time is:



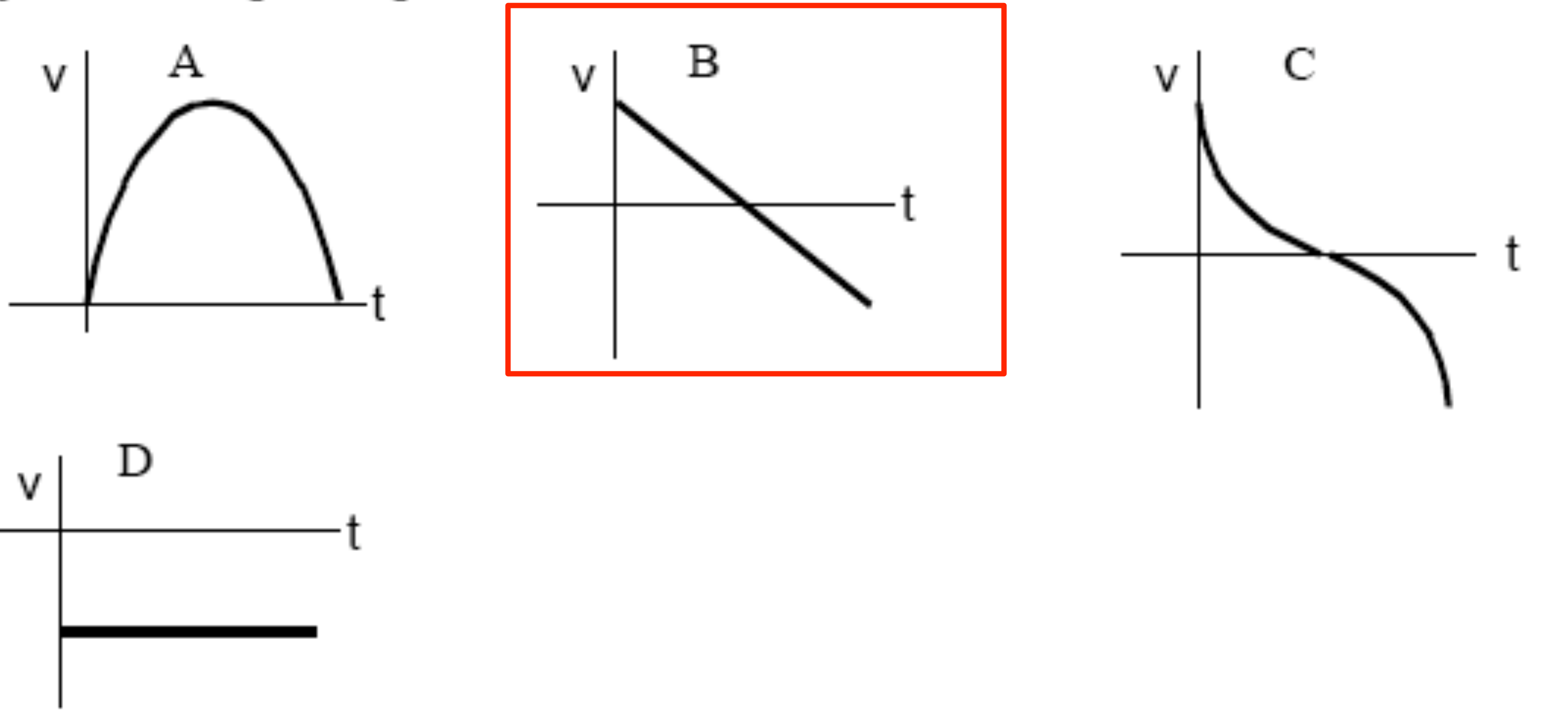
Which graph best represents the object's velocity vs. time?



Clicker Question

Room Frequency BA

At t = 0, a projectile is fired straight upward from a cannon. It goes up and then comes down. Assume that there is **no** air resistance. Upward is chosen as the positive y-direction. Which of the following graphs most accurately shows velocity vs. time for the projectile during its flight?



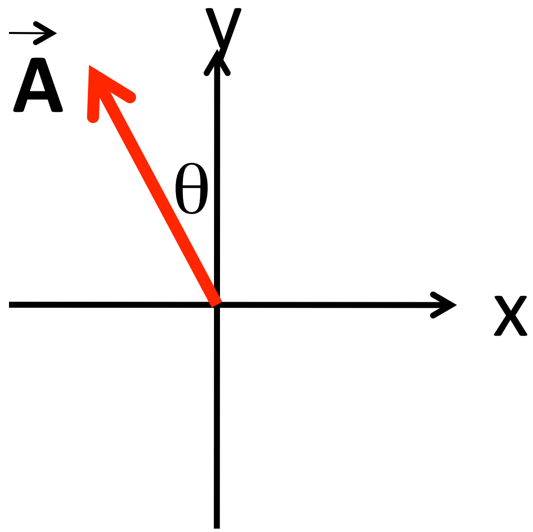
CH. 3 Kinematics in 2D: Vectors

3.1 Vectors and scalars
3.2 Addition of vectors graphically
3.3 Vector subtraction and multiplication by a scalar
3.4 Adding vectors by components
3.5 Projectile motion
3.6 Solving problems

Clicker Question

Room Frequency BA

The vector **A** has magnitude |**A**| = 6 cm and makes an angle of θ = 30 degrees with the positive y-axis as shown.



What is the x-component of the vector A?

A) +4.0 cm

B) -3.0 cm

C) +5.2 cm

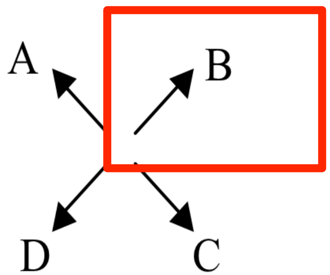
D) - 5.2 cm

E) None of the above

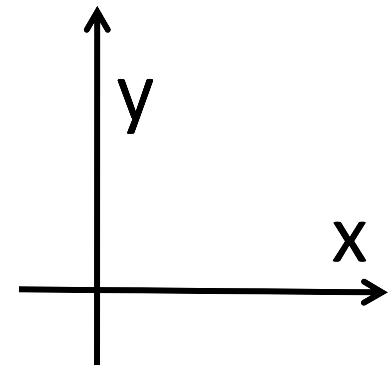
Clicker Question

Room Frequency BA

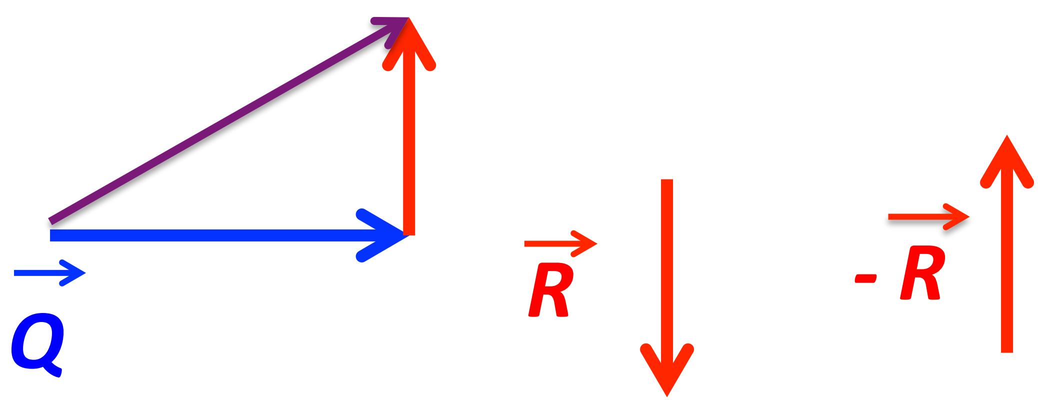
Vectors **Q** and **R** have the same magnitude. If vector **Q** is in the +x direction and vector **R** is in the –y direction, what is the direction of vector **T** = **Q** – **R?**



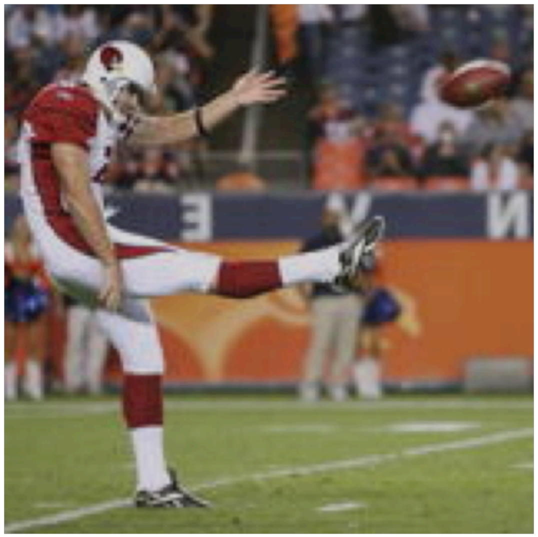
E) None of these



T = Q – R = Q + (-R)



Football Punter Physics



For a specific play, the punter wants to kick the ball as far down the field as possible (i.e. maximum range).

What is the optimal angle to kick the ball at *assuming the same initial speed when kicked regardless of the angle*?

Football obeys the laws of physics.
Constant acceleration case (ignoring air resistance).

Projectile Motion

$$x = x_0 + v_{0x}t + \tfrac{1}{2}a_x t^2$$

$$x_0 = 0$$

$$v_{0x} = |\vec{v}_0|\cos\theta$$

$$a_x = 0$$

$$x = (|\vec{v}_0|\cos\theta)t$$

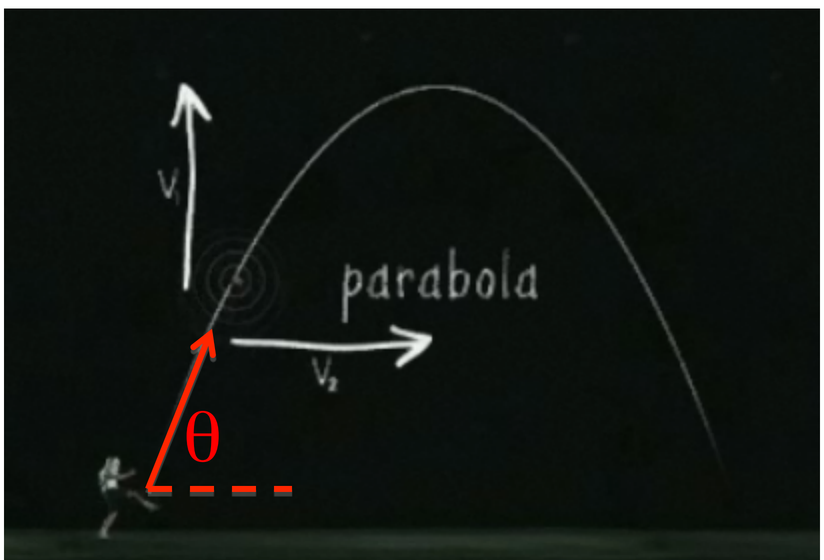
$$y = y_0 + v_{0y}t + \tfrac{1}{2}a_y t^2$$

$$y_0 = 0$$

$$v_{0y} = |\vec{v}_0|\sin\theta$$

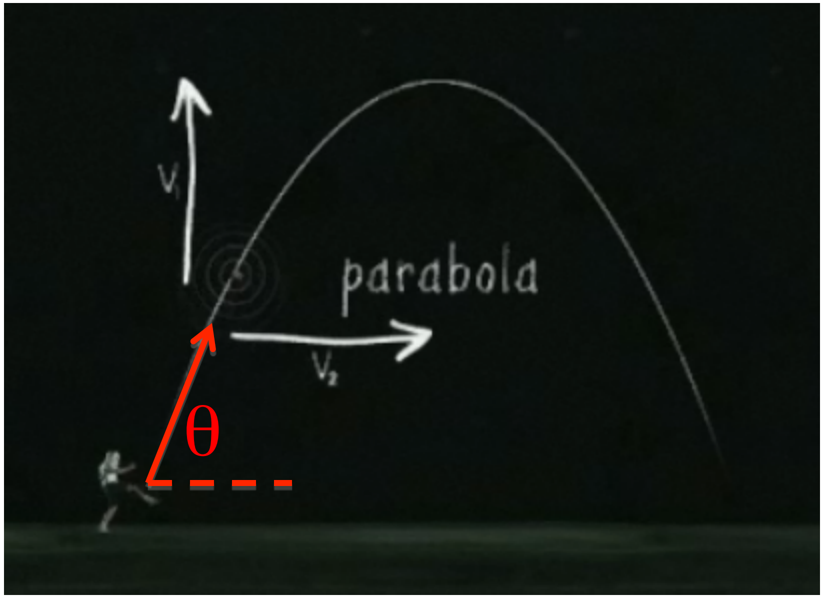
$$a_y = -g$$

$$y = (|\vec{v}_0|\sin\theta)t - \tfrac{1}{2}gt^2$$



Clicker Question

Room Frequency BA



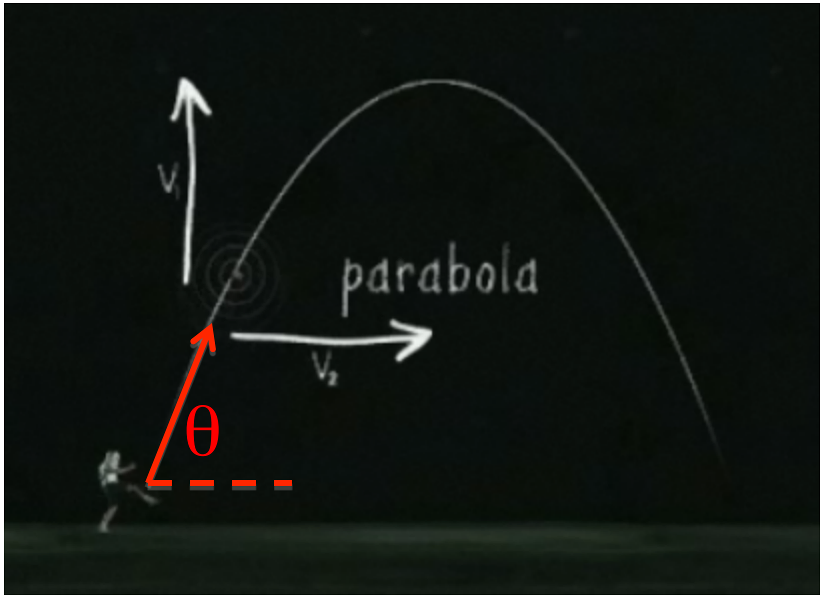
$$x = (|\vec{v}_0|\cos\theta)t$$
$$y = (|\vec{v}_0|\sin\theta)t - \tfrac{1}{2}gt^2$$

Clearly at t =0, x=0 and y=0 (our initial conditions).

At what later time does the football hit the ground?

A) t = 10 seconds
B) t = $|v_0|$ tanθ
C) t = Sqrt(2$|v_0|$sinθ/g)
D) $\boxed{t = 2|v_0|\sin\theta/g}$
E) None of the above

$$0 = (|\vec{v}_0|\sin\theta)t - \tfrac{1}{2}gt^2$$
$$0 = t\left[(|\vec{v}_0|\sin\theta) - \tfrac{1}{2}gt\right]$$
$$(|\vec{v}_0|\sin\theta) - \tfrac{1}{2}gt = 0$$
$$t = 2(|\vec{v}_0|\sin\theta)/g$$



$$x = (|\vec{v}_0|\cos\theta)t$$
$$y = (|\vec{v}_0|\sin\theta)t - \tfrac{1}{2}gt^2$$

Time of football flight (i.e. hang time)

$$t = 2(|\vec{v}_0|\sin\theta)/g$$

Now plug into x-equation to find out position when it hits the ground.

$$x = (|\vec{v}_0|\cos\theta)\left[2|\vec{v}_0|\sin\theta/g\right]$$

$$x = \frac{2|\vec{v}_0|^2\cos\theta\sin\theta}{g} = \boxed{\frac{|\vec{v}_0|^2\sin 2\theta}{g}}$$

* Uses trigonometry identity 2cosθsinθ=sin2θ

Clicker Question

Projectile Motion

Room Frequency BA

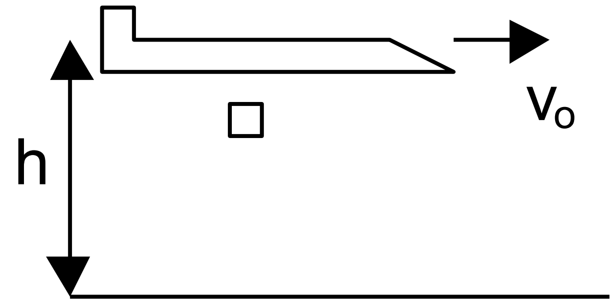
A flaming physics textbook is dropped from an airplane flying at height *h* at constant horizontal velocity and speed v_o. Neglecting air resistance, the text will...

A) quickly lag behind the plane

B) remain vertically under the plane

C) move ahead of the plane

D) it depends how fast the plane is flying.



What is the speed with which the text hits the ground?

A) $v_0 + \sqrt{2gh}$

B) $\boxed{\sqrt{v_0^2 + 2gh}}$

C) Neither

[Hint: For 1D motion along Y: $v^2 = v_0^2 + 2a_y\,(y-y_0)$.]

Chapter 4: Newton's Laws

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + .. = \sum_i \vec{F}_i$$

NI: $\vec{F}_{net} = 0 \quad \Leftrightarrow \quad \vec{v} = \text{constant}$

NII: $\vec{F}_{net} = m\,\vec{a}$

NIII: $\vec{F}_{AB} = -\vec{F}_{BA}$

Force and motion problems:

1) Free-body diagram
2) Coordinate system
3) $\sum F_x = m\,a_x \;,\; \sum F_y = m\,a_y$

Friction f

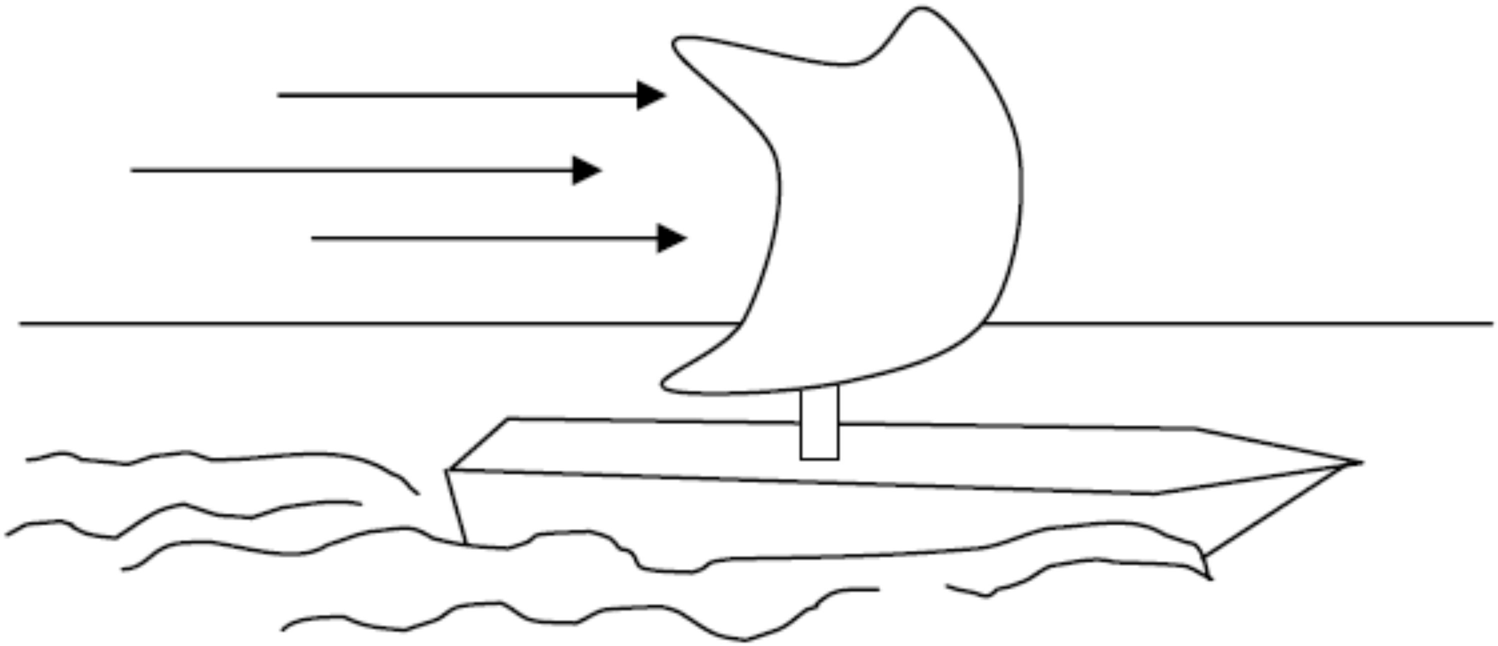
- sliding friction: $f = \mu_K N$
- static friction: $0 < f < f_{max} = \mu_S N$

Clicker Question

Room Frequency BA

A sailboat is being blown across the sea at a **constant** velocity.

What is the direction of the net force on the boat?



A) Left ←

B) Right →

C) Net force is zero

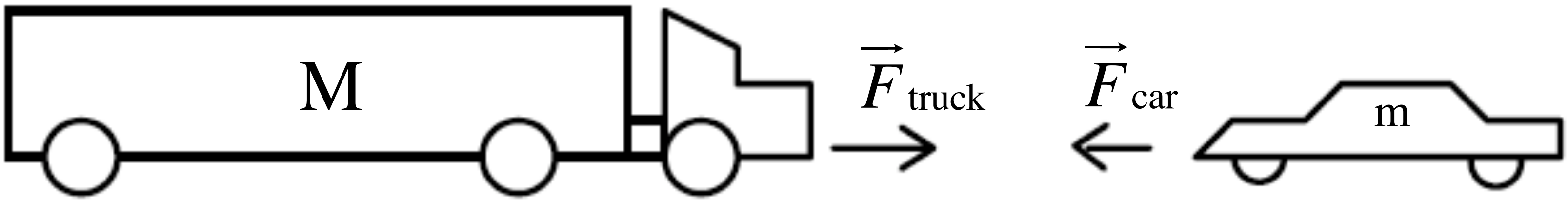
D) Down ↓

E) Up ↑

Clicker Question

Room Frequency BA

A moving van collides with a sports car in a high-speed head-on collision. *Crash!*



During the impact, the truck exerts a force with magnitude F_{truck} on the car and the car exerts a force with magnitude F_{car} on the truck. Which of the following statements about these forces is true:

A) The magnitude of the force exerted by the truck on the car is the same size as the magnitude of the force exerted by the car on the truck: $F_{truck} = F_{car}$

B) $F_{truck} > F_{car}$

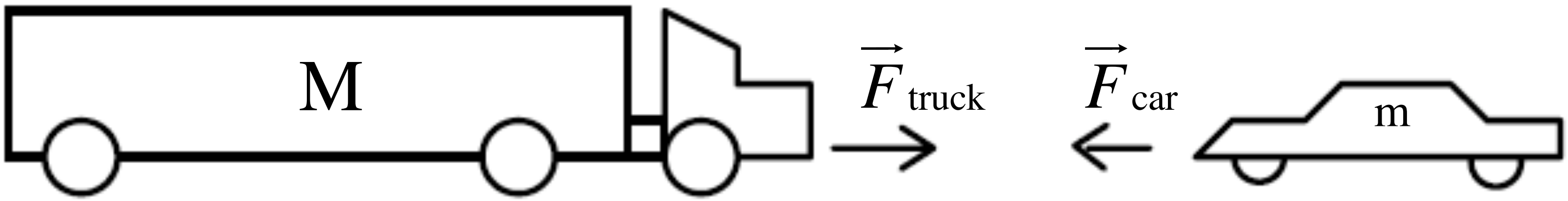
C) $F_{truck} < F_{car}$

Guaranteed by Newton's Third Law

Clicker Question

Room Frequency BA

A moving van collides with a sports car in a high-speed head-on collision. *Crash!*



During the collision, the imposed forces cause the truck and the car to undergo accelerations with magnitudes a_{truck} and a_{car}. What is the relationship between a_{truck} and a_{car}?

A) $a_{truck} > a_{car}$

B) $a_{car} > a_{truck}$

C) $a_{truck} = a_{car}$

D) Indeterminate from information given.

Newton's 3rd Law: $|F_{truck}| = |F_{car}|$

Newton's 2nd Law: F = ma

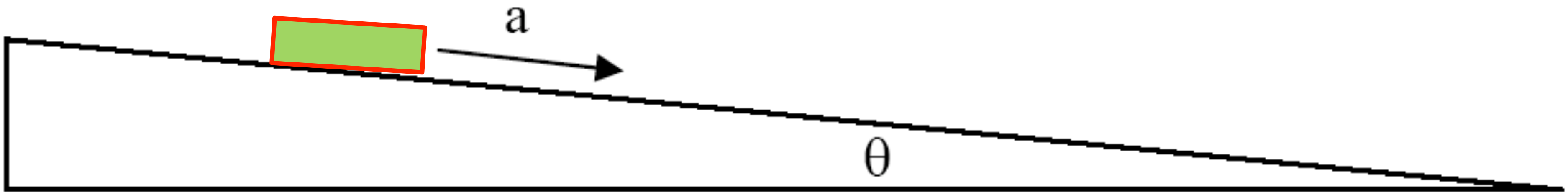
Remember: A large part of what you'll be expected to do is to apply Newton's Laws. You can't just memorize and apply formulas.

Steps for Linear Motion:

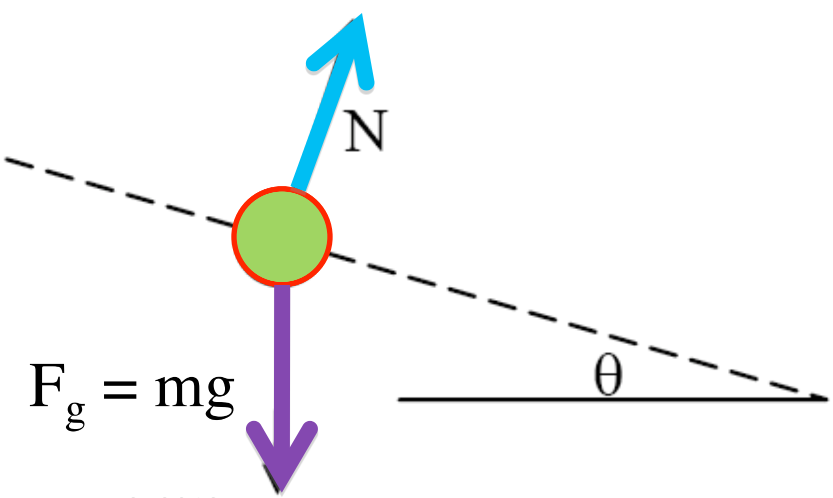
1. Draw a free-body diagram identifying and labeling all forces.
2. Choose a coordinate system – typically with the forces pointing in the coordinate directions (x,y) as much as possible.
3. Write down Newton's 2nd law in each coordinate direction (typically), summing the forces. The equation perpendicular to the direction of motion often allows you to find the Normal Force, which is needed to determine the force of friction.

   $\Sigma F_x = ma_x$ $\Sigma F_y = ma_y$ (for rectilinear motion)

   If a force is not in a coordinate direction, you must find its components in the coordinate directions.
4. If there are several masses, Newton's 2nd law is needed for each.



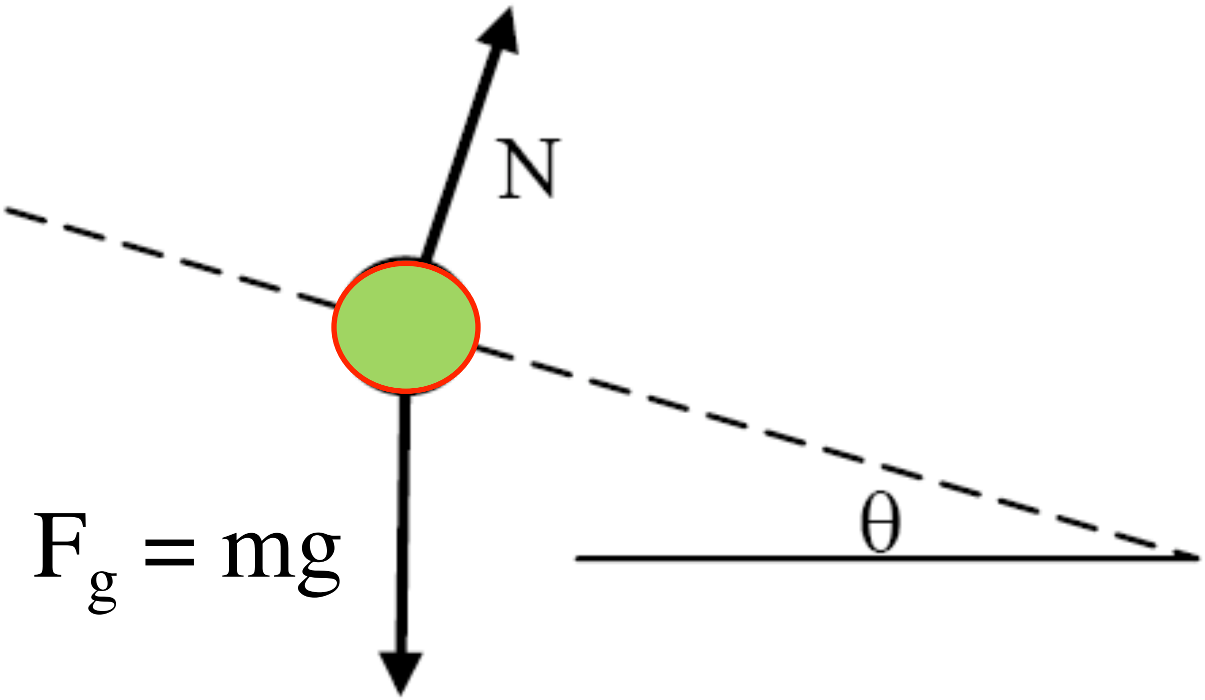
Step 1: Draw a free-body diagram

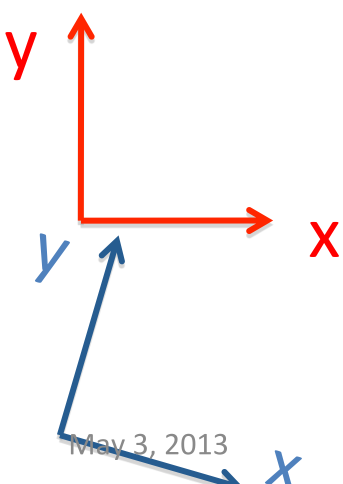


Note that "Normal Force" is always Perpendicular (i.e. normal) to the surface.

In this case, it is not in the opposite direction to the gravitational force.

Step 2: Choose a coordinate system



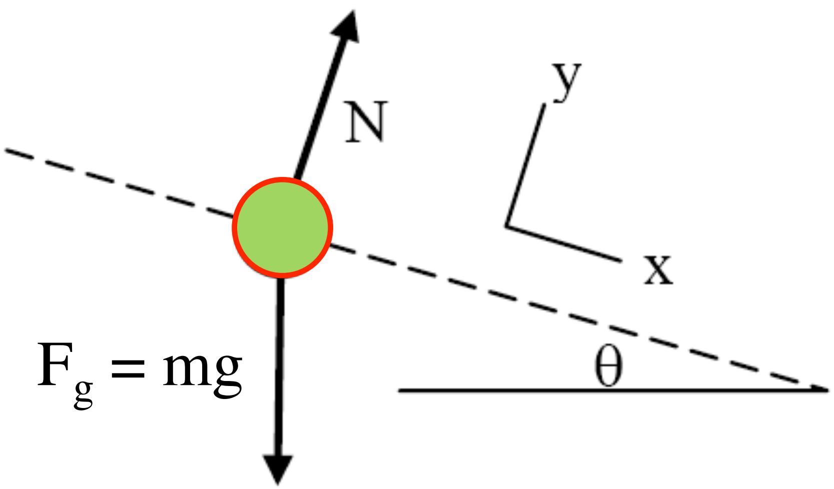


We could choose our "usual" axes. However, we know that we will have motion in both the x and y directions.

If we pick these rotated axes, we know that the acceleration along y must be zero.

Step 3: Write down the equations

$$\Sigma F_x = m\, a_x \;,\; \Sigma F_y = m\, a_y$$



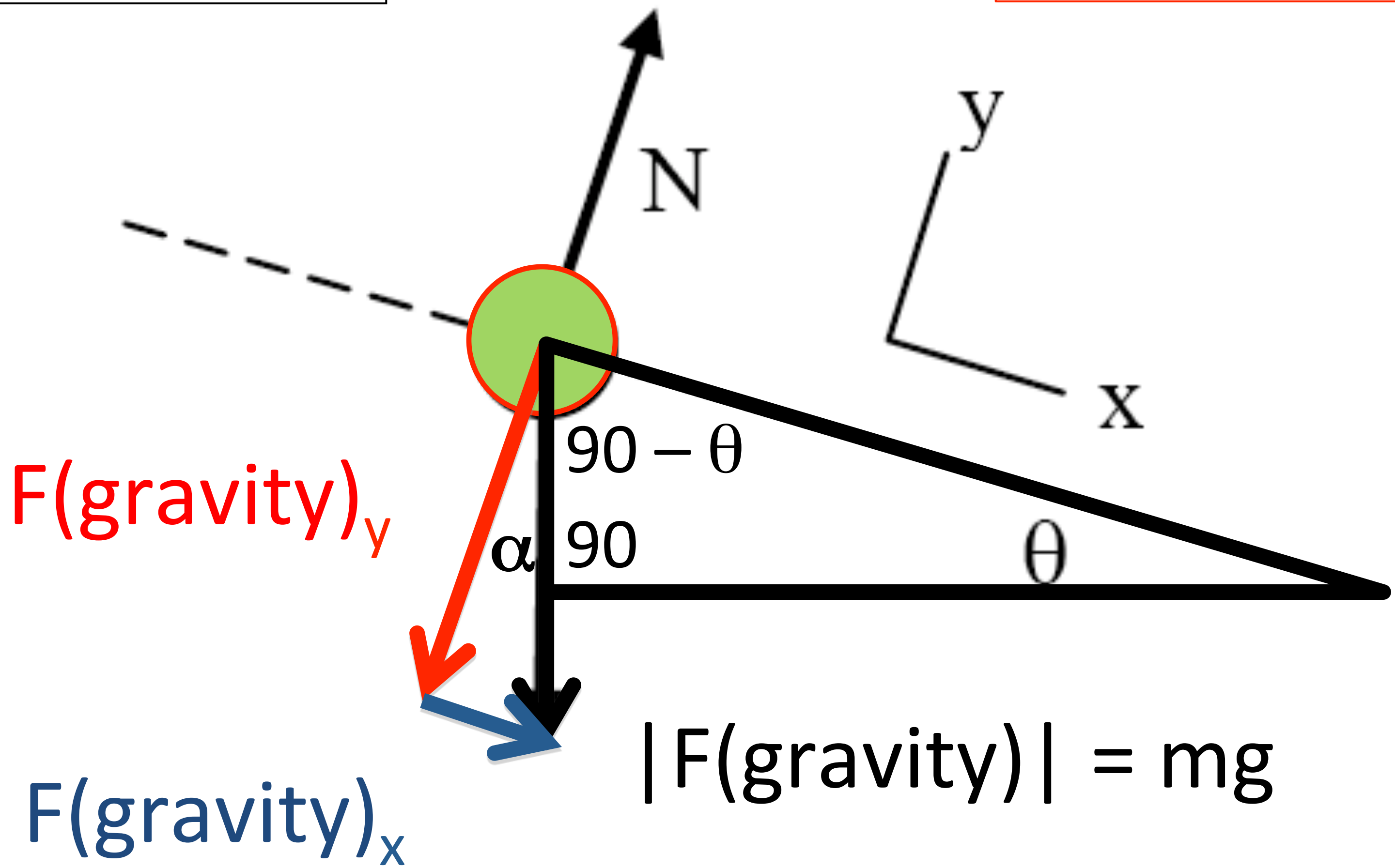
Problem:

F_g doesn't point in a coordinate direction.

Must break it into its x- and y-components.

Clicker Question

Room Frequency BA



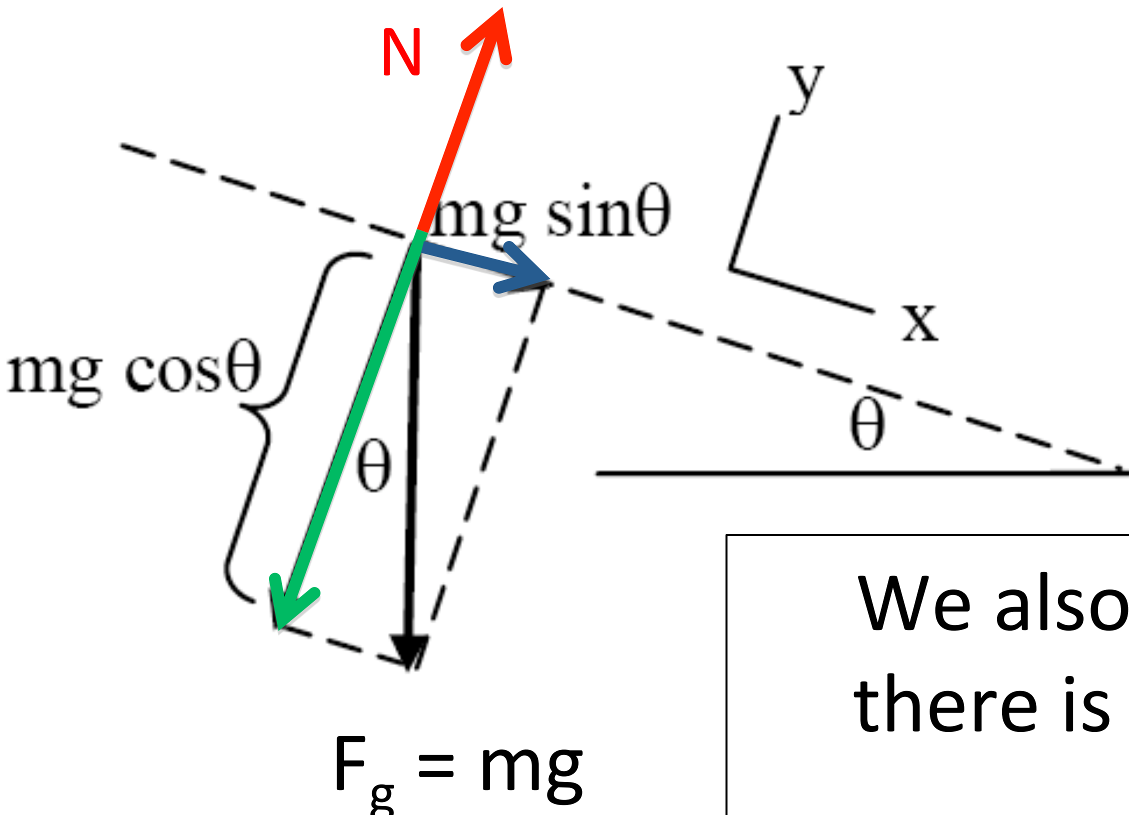
What is the angle α labeled above?

A) α = 90 degrees B) $\boxed{\alpha = \theta}$

C) $\alpha = 90 - \theta$ D) Cannot be determined

Step 3: Write down the equations

$$\Sigma F_x = m a_x \,,\ \Sigma F_y = m a_y$$



$\mathbf{F_x = mg \sin(\theta)}$

$\mathbf{F_y = N - mg \cos(\theta)}$

We also know that $a_y = 0$, there is no motion in that direction.

$\mathbf{F_y = ma_y = 0 = N - mg \cos(\theta)}$

Step 4: Solve the Equations

$$F_x = ma_x = mg\sin(\theta)$$

$$\boxed{a_x = g\sin(\theta)}$$

$$F_y = ma_y = N - mg\cos(\theta)$$

$$a_y = \frac{N}{m} - g\cos(\theta) = 0$$

$$\boxed{N = mg\cos(\theta)}$$

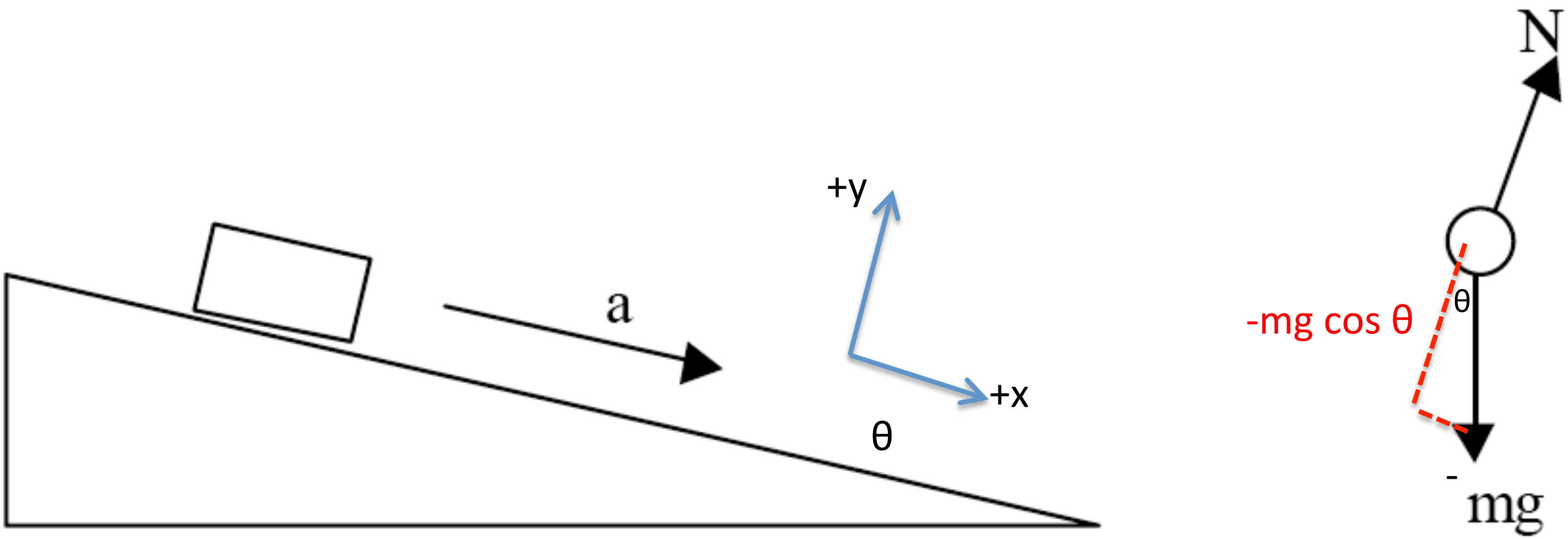
As expected, maximum acceleration if straight down (θ=90 degrees), a_x = g.

Recall x-y definition

Clicker Question

Room Frequency BA

A mass **m** accelerates down a frictionless inclined plane.



Which statement is true?

A) $N < mg$

B) $N > mg$

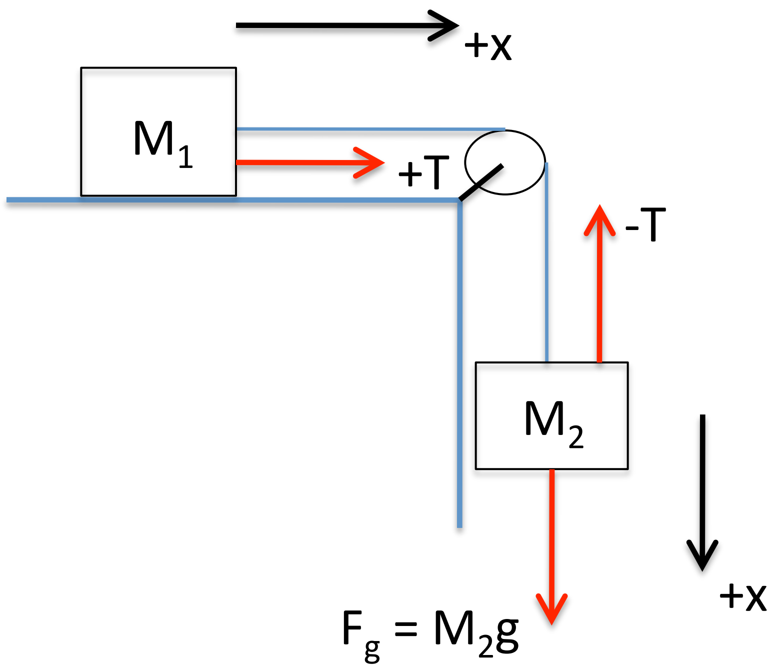
C) $N = mg$

$$0 = F_y = N - mg\cos\theta$$

$$N = mg\cos\theta < mg$$

Clicker Question

Room Frequency BA



Frictionless table & pulley.

1) Choose coordinates
2) Identify forces.
3) Write down F = ma for each object

Mass 1: $M_1a = T$

Mass 2: $M_2a = M_2g - T$

What is F = ma for mass M_2?

(A) $M_2a = T$

(B) $M_2a = T - M_2g$

(C) $\boxed{M_2a = M_2g - T}$

(D) $M_2a = M_2g$

Clicker Question

Room Frequency BA

You are pushing horizontally with a force of 5000 Newtons on a car that has a weight of 10,000 Newtons.

The car is not moving.

What can you say for certain about the coefficient of friction?

A) $\mu_s = 0$

B) $\mu_s = 0.1$

C) $\mu_s = 0.5$

D) $\mu_k = 0.5$

E) None of the above

$F_{net} = 0 = F_{push} - F_{friction}$

$0 = F_{push} - \mu_s \times \text{Normal}$

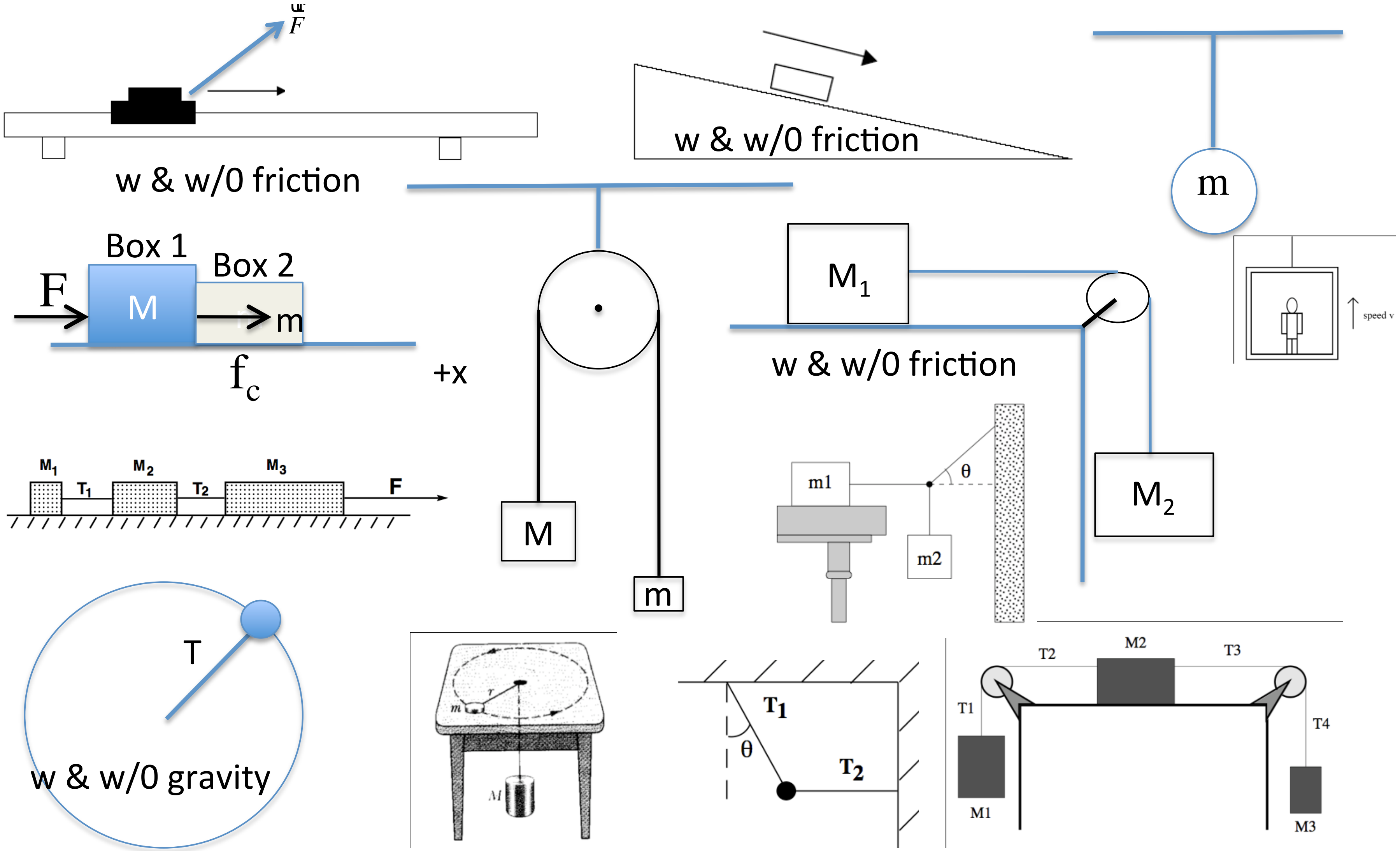
$\mu_s \times Mg = F_{push}$

$\mu_s = F_{push}/Mg = 5000/10k$

$\mu_s = 0.5$

But actually, μ_s could be even larger since we do not know if we have reached the maximum.

Incomplete Gallery of Problems Involving Newton's Laws:



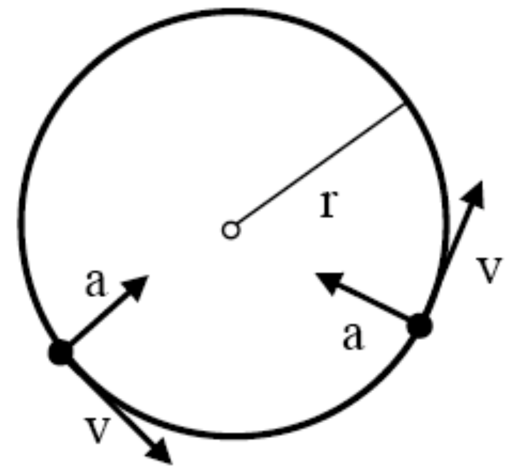
Practice setting up the free-body diagram and $F_{net} = ma$

Chapter 5: Uniform Circular Motion with Gravity

For **circular motion** with constant speed v,

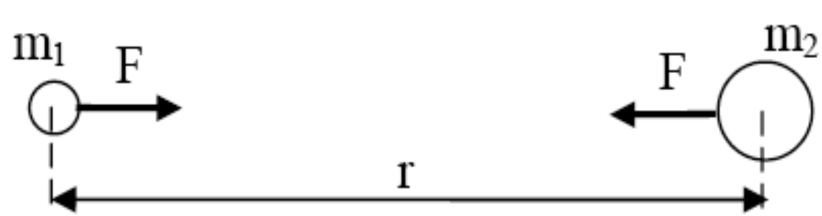
$$a = |\vec{a}| \equiv \frac{v^2}{r}$$

$\vec{a}$ and $\vec{F}_{net}$ are toward the center (centripetal)



Gravity

$$F = G\,\frac{m_1\ m_2}{r^2}$$



Remember: A large part of what you'll be expected to do is to apply Newton's Laws. You can't just memorize and apply formulas.

Steps for Uniform Circular Motion:

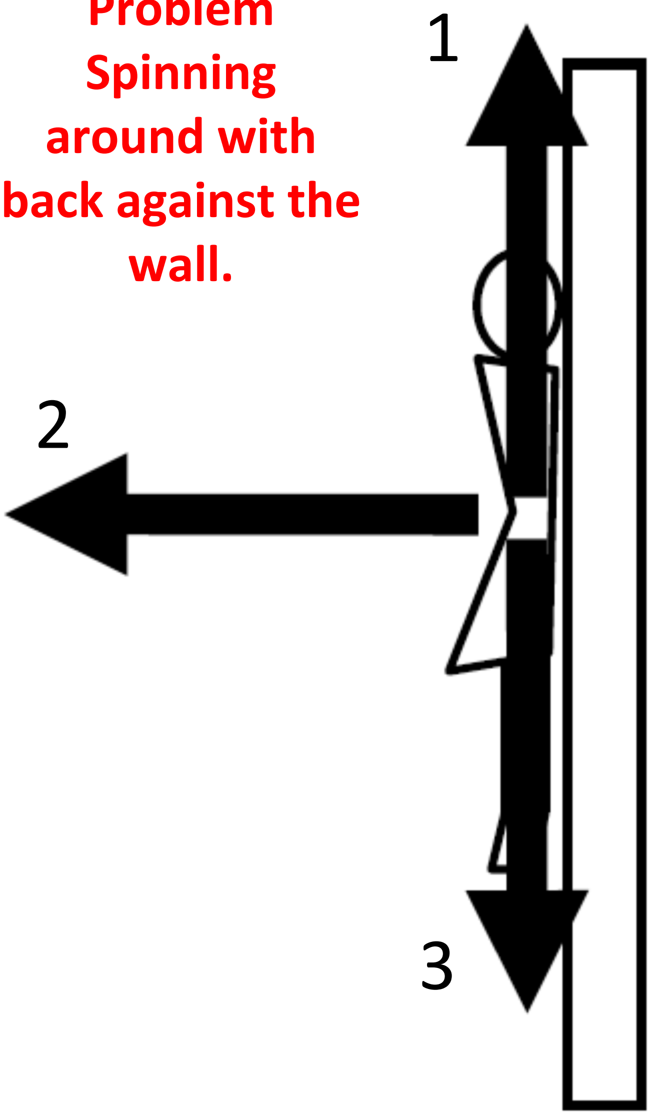
1. Draw a free-body diagram identifying and labeling all forces.
2. Choose a coordinate system – one of the directions will point in the radial direction. Others directions: tangent direction (T) or vertical (y).
3. Write down Newton's 2^{nd} law in each coordinate direction (typically), summing the forces.

   $\Sigma F_R = ma_R = mv^2/r$ $\Sigma F_T = ma_T$ (for uniform circular motion)
4. If there is more than one mass, then Newton's 2^{nd} law may be needed for each mass.

Clicker Question

Room Frequency BA

Wall-of-Death Problem Spinning around with back against the wall.



What are the three forces #1, 2, 3?

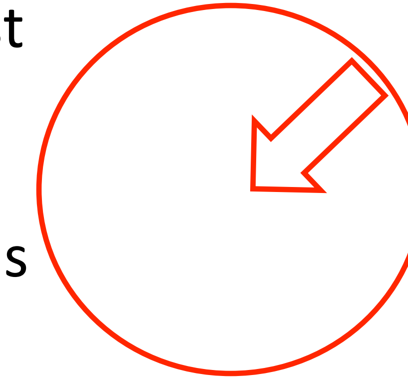
A) 1 - gravity
2 - centrifugal force
3 – friction

B) 1 – friction
2 – normal force of the wall
3 – gravity

C) 1 - centripetal force
2 – normal force of the wall
3 – friction

D) 1 – friction
2 – centrifugal force
3 - gravity

For every case of uniform circular motion, there must be a force directed towards the center.



We say there is a centripetal force. However, there is always a specific force that is acting. There is no "circle force". Circular motion does not cause a force.

Ball circling around tied to a string.

Centripetal force → Tension Force

Wall of Death ride

Centripetal force → Normal Force

Race Car driving in circle

Centripetal force → Friction Force

GRAVITY

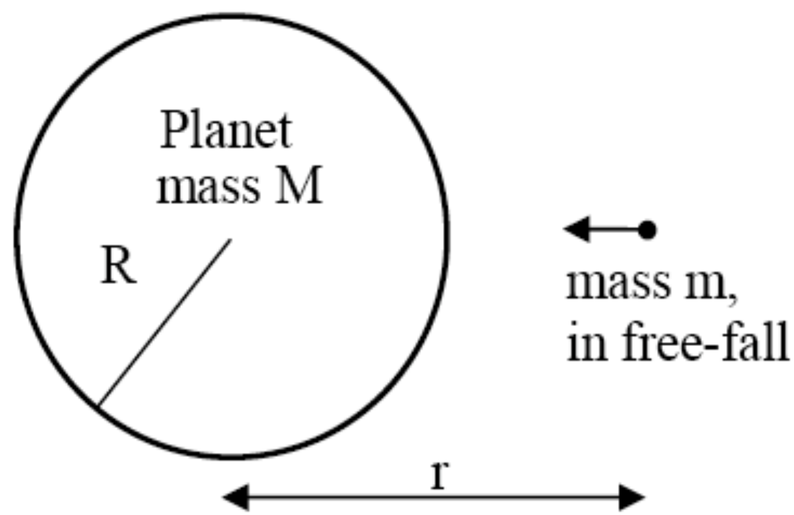
$$|\vec{F}|_{gravity} = G\frac{mM}{R^2}$$

Acceleration due to gravity

$$F_{net} = m\,a$$

$$\frac{G\,M\,m}{r^2} = m\,g \quad \Rightarrow \quad g = \frac{G\,M}{r^2}$$

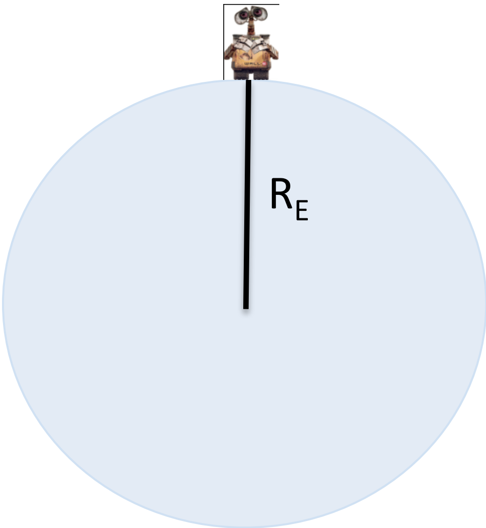
r = distance to center of planet



Orbits, Kepler's laws

Big *G*, Little *g*

Consider the force of gravity exerted by the Earth with mass $\mathbf{M_E}$ on a person of mass **m** on its surface?



$$|\vec{F}|_{gravity} = G\frac{mM_E}{{R_E}^2}$$

$$|\vec{F}|_{gravity} = \left(6.67\times10^{-11}\,Nm^2/kg^2\right)\frac{m\left(5.98\times10^{24}\,kg\right)}{\left(6.37\times10^6\,m\right)^2}$$

$$|\vec{F}|_{gravity} = m\times\left(9.81m/s^2\right)$$

$$|\vec{F}|_{gravity} = mg$$

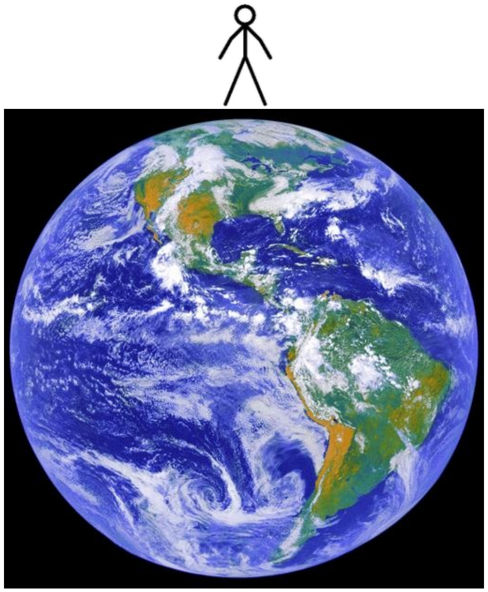
Gravitational force on an object on the surface of the Earth!

Clicker Question

Room Frequency BA

You are standing on the surface of the Earth.

The Earth exerts a gravitational force on you $\mathbf{F}_{\mathbf{earth}}$, and you exert a gravitational force on the Earth $\mathbf{F}_{\mathbf{person}}$.



Which of the following is correct:

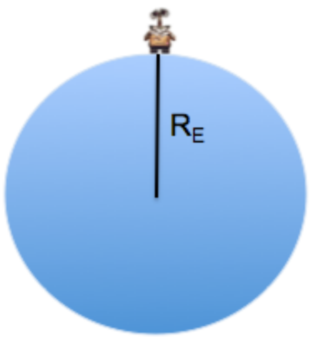
A) $F_{earth} > F_{person}$

B) $F_{earth} < F_{person}$

C) $\boxed{F_{earth} = F_{person}}$ Newton's Third Law

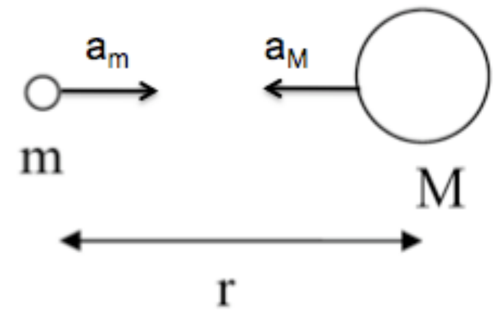
D) It's not so simple, we need more information.

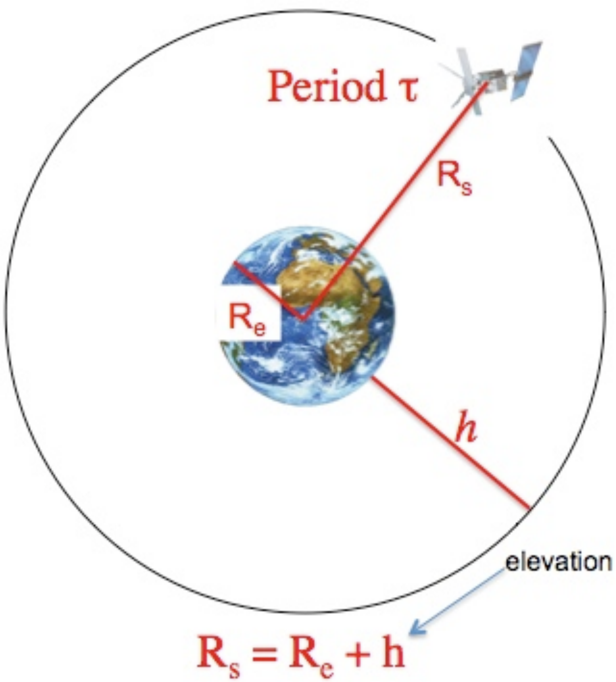
Incomplete Gallery of Problems Involving Newton's Law of Universal Gravitation:



$$mg = F_g = G\frac{mM}{R_E^2} \rightarrow \boxed{g = a_g = G\frac{M}{R_E^2}}$$

Can use this to "weigh" the Earth:





$$\boxed{v = \sqrt{\frac{GM}{R_s}} \qquad R_s = \frac{GM}{v^2} \qquad \tau^2 = \left(\frac{4\pi^2}{GM}\right)R_s^3}$$

Chapter 6: Work and Energy

- work done by force F: $W_F = F_{\parallel} \cdot d$, work can be (+), (–), or zero
- work-energy principle: $W_{net} = \Delta KE$
- If no thermal energy generated, $E_{mech} = KE + PE = \text{constant}$
- If thermal energy generated, $KE + PE + E_{thermal} = \text{constant}$
- Hooke's Law: $F_{spring} = -k\,x$ (k = spring constant)
- $PE_{grav} = m\,g\,h$ $PE_{elastic} = (1/2)\,k\,x^2$
- Power $P = \dfrac{\Delta W}{\Delta t}$

Clicker Question

Room Frequency BA

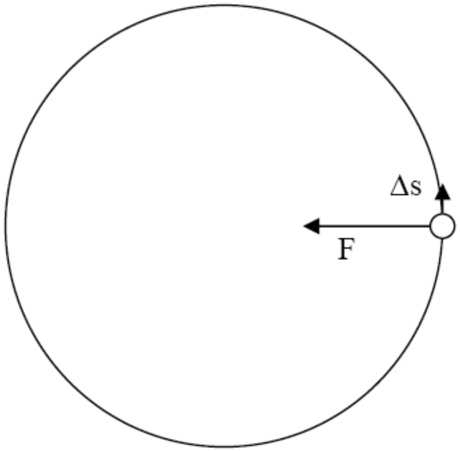
A rock of mass m is twirled on a string in a horizontal plane.

The work done **by the tension in the string on the rock is**

A) Positive

B) Negative

C) Zero



The work done by the tension force is zero, because the force of the tension in the string is perpendicular to the direction of the displacement:

$$W = F\cos 90° = 0$$

Conservation of Mechanical Energy

$E_{mechanical}$ = KE + PE = constant (isolated system, no dissipation)

KE = ½ mv^2

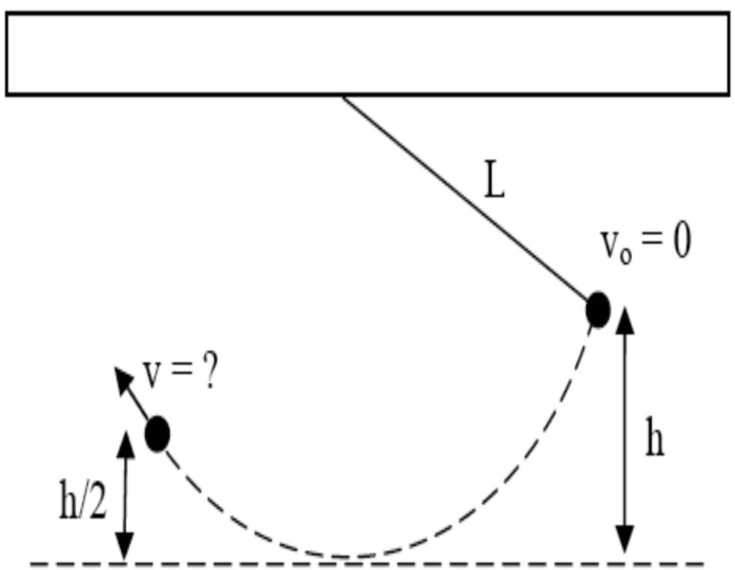
PE_{grav} = mgy

$$KE_i + PE_i = KE_f + PE_f$$

Conservation of Mechanical Energy

$E_{mechanical}$ = KE + PE = constant (isolated system, no dissipation)

Consider mass ***m*** swinging attached to a string of length ***L***.
The swing is released from rest at a height ***h***.
What is the speed ***v*** of the swing when it reaches height *h/2*?



$$ME_i = ME_f$$

$$KE_i + PE_i = KE_f + PE_f$$

$$\cancelto{0}{\frac{1}{2}mv_i^2} + \cancel{m}gh = \frac{1}{2}\cancel{m}v_f^2 + \cancel{m}g\frac{h}{2}$$

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

$$v_f = \sqrt{gh}$$

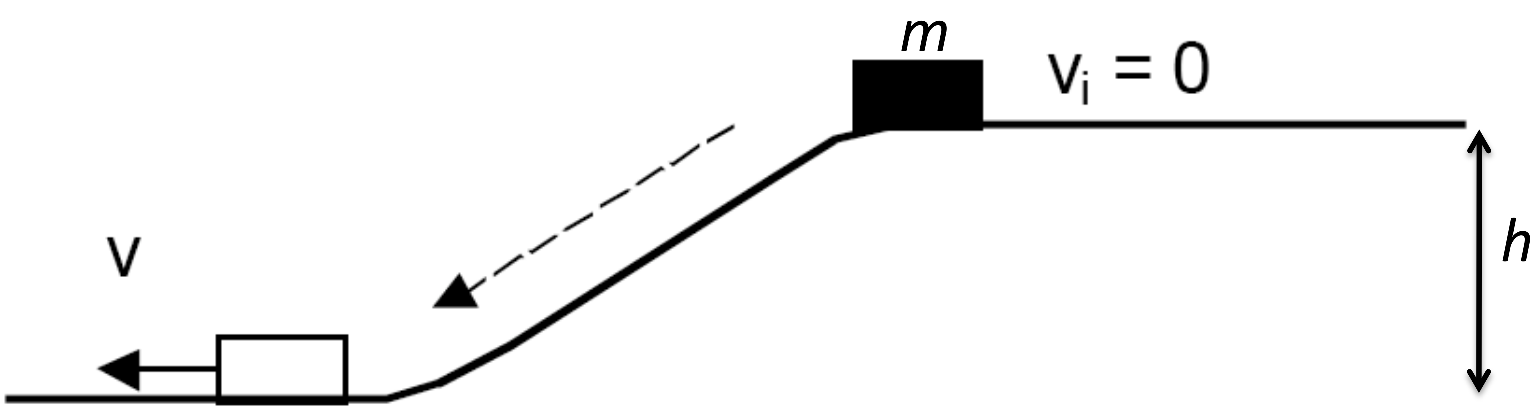
KE = ½ mv^2

PE_{grav} = mgy

Clicker Question

Room Frequency BA

A block of mass *m* slides down a **rough** ramp of height *h*. Its initial speed is zero. Its final speed at the bottom of the ramp is v.



Which is the amount of thermal energy, $E_{thermal}$, released from the block's motion down the ramp?

$A)\ mgh + \frac{1}{2}mv^2$ $\boxed{B)\ mgh - \frac{1}{2}mv^2}$

$C)\ \frac{1}{2}mv^2 - mgh$ $D)\ \frac{1}{2}mv^2$

$E)\ mgh$

$$KE_i + PE_i + E_i^{thermal} = KE_f + PE_f + E_f^{thermal}$$

$$0 + mgh + 0 = \frac{1}{2}mv^2 + 0 + E_{thermal}$$

$$E_{thermal} = mgh - \frac{1}{2}mv^2$$

A block of mass **m** is released from rest at height **H** on a frictionless ramp. It strikes a spring with spring constant **k** at the end of the ramp.

How far will the spring compress (i.e. x)?

$$KE_i + PE_i + \cancel{W}^{\,0}_{frict} + \cancel{W}^{\,0}_{external} = KE_f + PE_f$$

$$0 \quad + \mathbf{mgH} + 0 + \quad 0 \quad = \quad 0 + (\mathbf{0} + \tfrac{1}{2}\,\mathbf{kx^2})$$

gravitational

elastic

$$\boxed{x = \sqrt{\frac{2mgH}{k}}}$$

Chapter 7: Momentum

- Conservation of momentum: for system isolated from outside forces,

  $$\vec{p}_{tot} = m_1\vec{v}_1 + m_2\vec{v}_2 = \text{constant}$$

- $\text{Impulse} = \Delta\vec{p} = \vec{F}_{net} \cdot \Delta t$

- elastic vs. inelastic collisions. KE is conserved only in perfectly elastic collisions.

Clicker Question

Room Frequency BA

In which situation is the magnitude of the total momentum the largest?

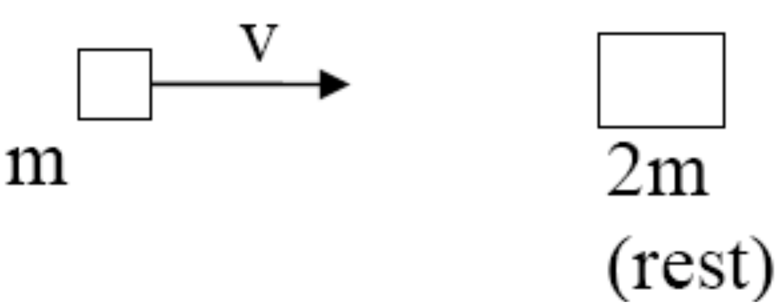
A) Situation I.

B) Situation II.

C) Same in both.

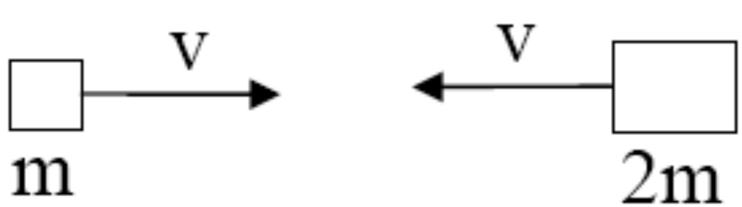
Magnitudes are the same $|p_{total}|=mv$

I:



$$p_{total} = mv + 0 = mv$$

II:



$$p_{total} = mv\text{-}2mv\text{=-}mv$$

Clicker Question

Room Frequency BA

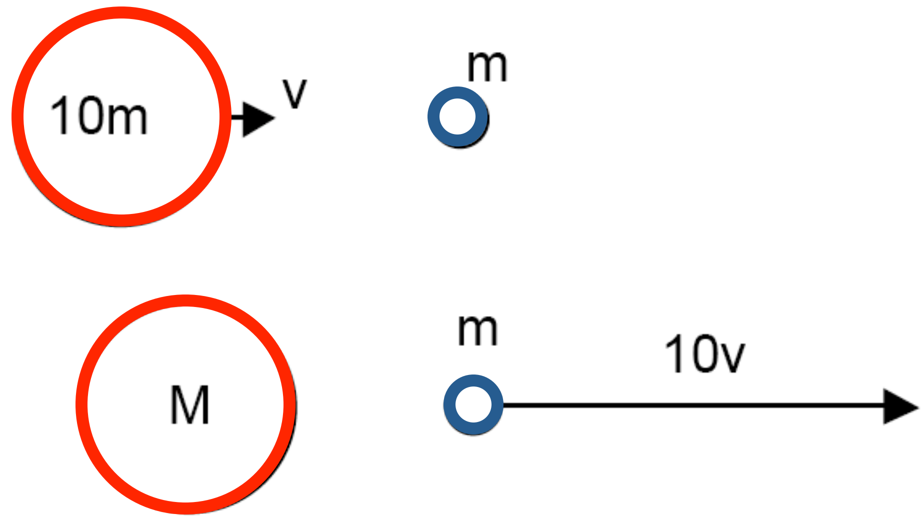
A big ball of mass **M = 10m** and speed **v** strikes a small ball of mass **m** at rest.

After the collision, could the big ball come to a complete stop and the small ball take off with speed 10 v?

A) Yes this can occur.

B) No, because it violates conservation of momentum.

C) No, because it violates conservation of energy



$$p_{initial} = (10m)v = 10mv$$

$$p_{final} = m(10v) = 10mv$$

$$KE_{initial} = \frac{1}{2}(10m)v^2 = 5mv^2$$

$$KE_{final} = \frac{1}{2}m(10v)^2 = 50mv^2$$

Chapter 8: Rotations

Notice analogy between rotation about a fixed axis and 1D translation along the x-axis:

- $\theta(\text{rads}) = \dfrac{s}{r}$, $\quad \omega = \dfrac{\Delta\theta}{\Delta t}$, $\quad \alpha = \dfrac{\Delta\omega}{\Delta t}$ $\quad$ (like x, $\quad v = \dfrac{\Delta x}{\Delta t}$, $\quad a = \dfrac{\Delta v}{\Delta t}$)
- $v = r\,\omega$, $a_{tan} = r\,\alpha$
- torque $|\tau| = r \cdot F_{\perp}$
- moment of inertia $I = \sum_i m_i r_i^2$
- $\tau_{net} = I \cdot \alpha$ $\quad$ (like $F_{net} = m\,a$)
- $KE_{rotation} = (1/2)\, I\, \omega^2$ $\quad$ (like $KE_{trans} = (1/2)\, m\, v^2$)
- Rolling motion: $KE_{tot} = KE_{trans} + KE_{rot} = \dfrac{1}{2} m\, v^2 + \dfrac{1}{2} I\, \omega^2$

Rotational Motion

Describing rotational motion

	Translation	↔	**Rotation**	
Last Week	x	↔	θ	angle of rotation (rads)
	$v = \frac{\Delta x}{\Delta t}$	↔	$\omega = \frac{\Delta\theta}{\Delta t} = \frac{v}{r} = \frac{2\pi}{\tau} = 2\pi f$	angular velocity (rad/s)
	$a = \frac{\Delta v}{\Delta t}$	↔	$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{a_{\tan}}{r}$	angular acceleration (rad/s^2)
Monday	F	↔	$\tau = r\,F_\perp$	torque (N m)
	M	↔	$I = \sum m\,r^2$	moment of inertia (kg m^2)
	$F_{net} = M\,a$	↔	$\tau_{net} = I\,\alpha$	Newton's 2nd Law
	$KE_{trans} = (1/2)M\,v^2$	↔	$KE_{rot} = (1/2)\,I\,\omega^2$	Kinetic energy (joules J)

$$\Delta KE + \Delta PE = \text{constant} \quad \leftrightarrow \quad \Delta KE_{trans} + \Delta KE_{rot} + \Delta PE = \text{constant}$$

(Conservation of Mechanical Energy)

$$p_{tot} = \sum_i m_i v_i = \text{constant} \leftrightarrow \quad L_{tot} = \sum_i I_i \omega_i = \text{constant}$$

angular momentum (kg m^2/s)

Clicker Question

Room Frequency BA

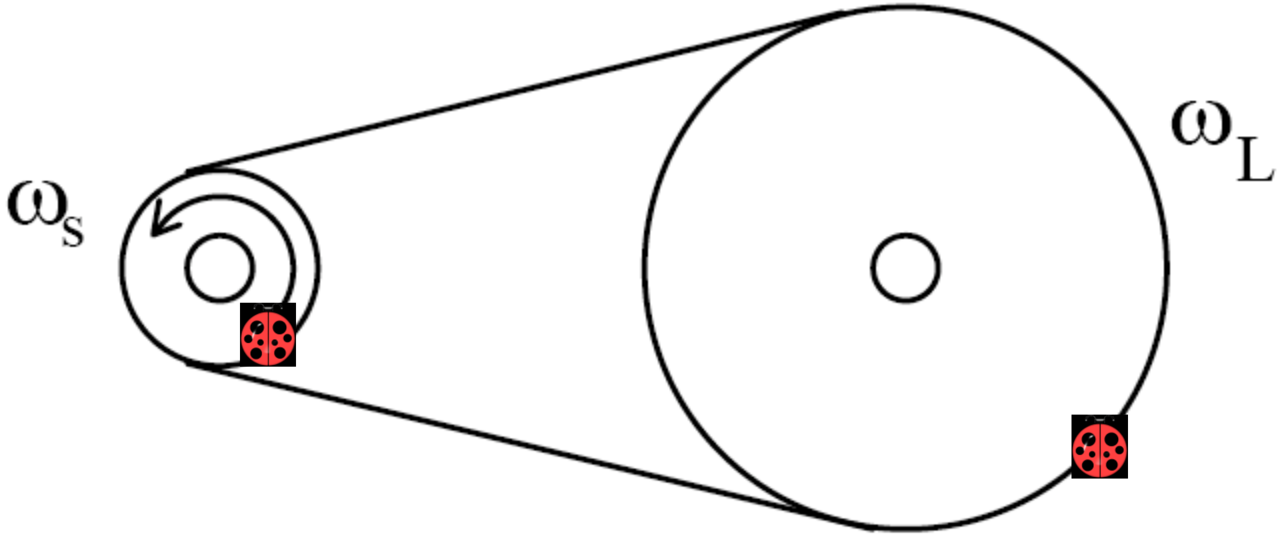
A small wheel and a large wheel are connected by a belt. The small wheel turns at a constant angular velocity ω_S.

There is a bug S on the rim of the small wheel and a bug L on the rim of the big wheel? How do their speeds compare?

A) $v_S = v_L$

B) $v_S > v_L$

C) $v_S < v_L$



Clicker Question

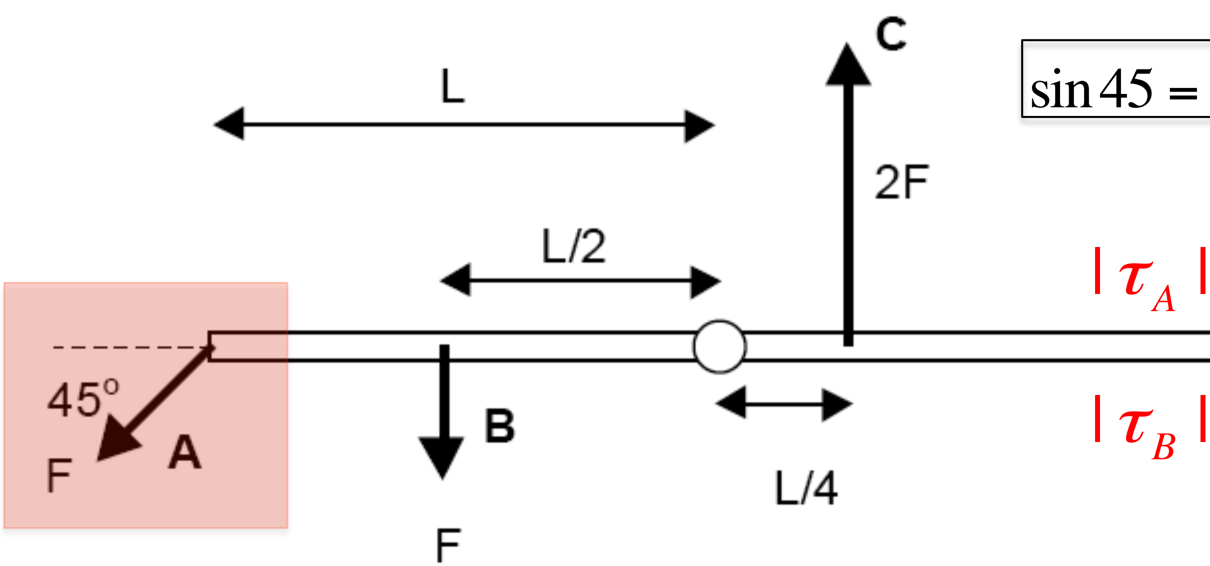
Room Frequency BA

Torque

$$\tau \equiv rF_{\perp}$$

Three forces labeled A, B, and C are applied to a rod which pivots on an axis through its center.

Which force causes the largest size torque?



$$\sin 45 = \cos 45 = 1/\sqrt{2} = 0.707$$

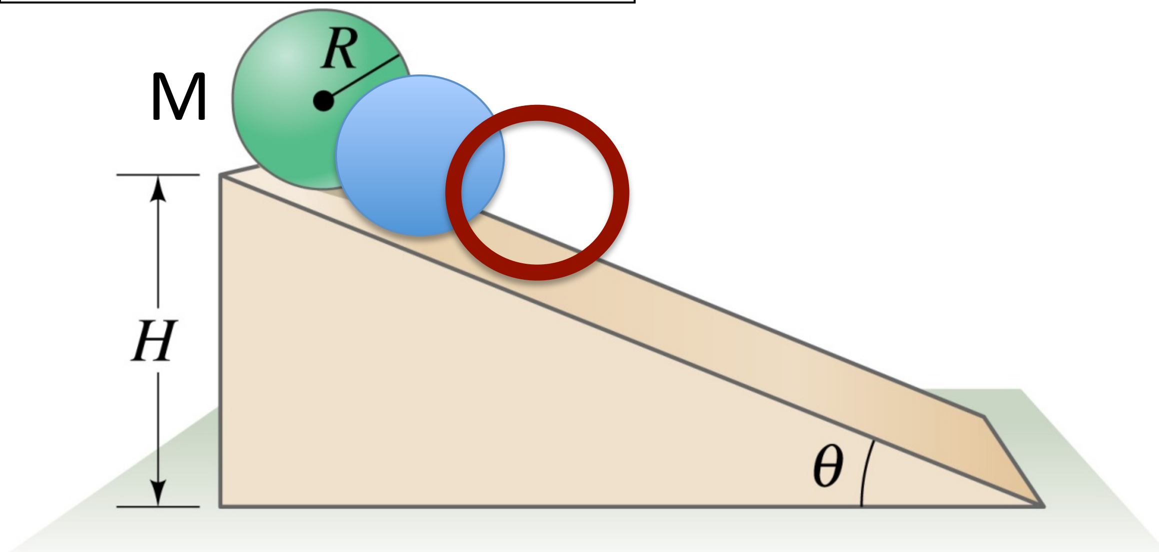
$$|\tau_A| = LF \sin 45 = 0.707 LF$$

$$|\tau_B| = \frac{L}{2} F = 0.5 LF$$

$$|\tau_C| = \frac{L}{4}(2F) = 0.5 LF$$

Clicker Question

Room Frequency BA



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$$KE_{tot} = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$$

$$I_{sphere} = \frac{2}{5}MR^2$$

$$I_{hoop} = MR^2$$

$$I_{disk} = \frac{1}{2}MR^2$$

Which object has the largest total kinetic energy at the bottom of the ramp?

A) Sphere B) Disk C) Hoop D) All the same.

$$KE_i + PE_i = KE_f + PE_f$$

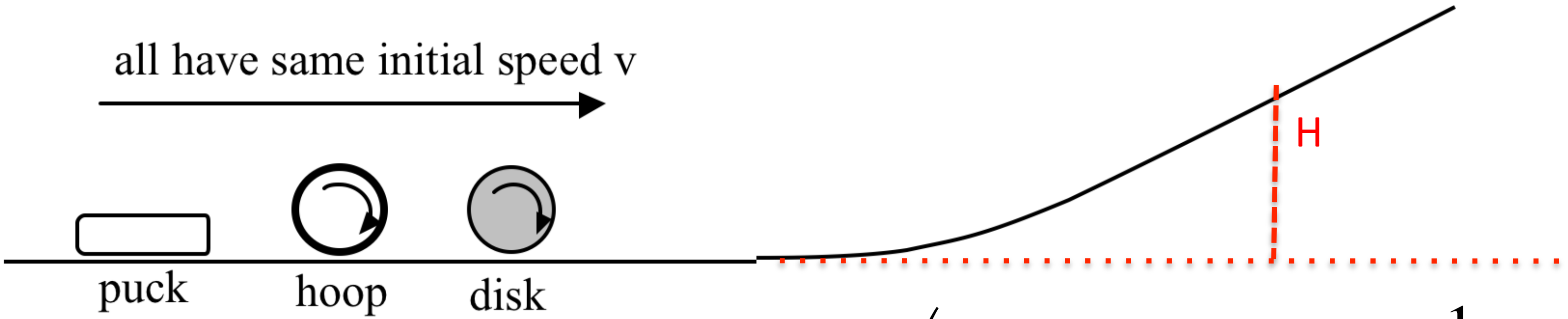
$$0 + MgH = KE_f + 0$$

$$KE_f = MgH$$

All have the same total KE.

Clicker Question

Room Frequency BA



$$\left(I_{hoop} = MR^2, I_{disk} = \frac{1}{2}MR^2 \right)$$

Which object will go furthest up the incline?

A) Puck B) Disk $\boxed{\text{C) Hoop}}$ D) Same height.

$$KE_i + PE_i = KE_f + PE_f$$

$$\frac{1}{2}Mv^2 + \frac{1}{2}I\left(\frac{v}{r}\right)^2 = MgH$$

The hoop has the largest moment of inertia, and therefore the highest total kinetic energy.

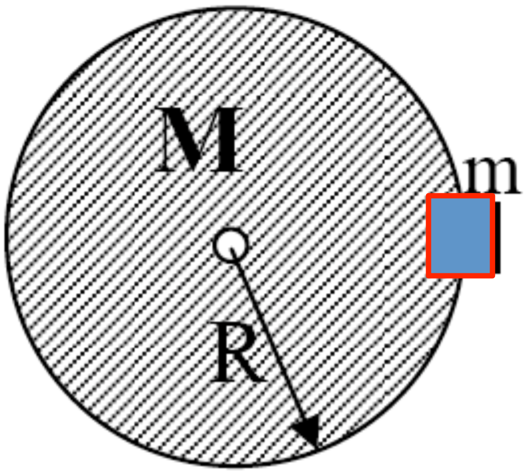
Clicker Question

Room Frequency BA

Consider a solid disk of mass **M** and radius **R** with an axis through its center.

$$I = \frac{1}{2}MR^2 + mR^2$$

An ant of mass **m** is placed on the rim of the disk.



The mass-disk system is rotating.

The ant walks toward the center of the disk.

The magnitude of the system's angular momentum L:

A) increases B) decreases C) remains constant

Unless an outside torque is applied, L = Iω = constant.

As ant moves inward, the kinetic energy of the system:

A) increases B) decreases C) remains constant

Because I reduces, ω increases from the ant's motion.

Ch. 9 Statics and Static Equilibrium

Static Equilibrium: An object is

(1) not translating (not moving up, down, left, right)

(2) not rotating (not spinning CW or CCW).

Not translating:

$$\boxed{\begin{array}{c}\vec{F}_{net} = 0 = \sum_i \vec{F}_i \\[2em] \sum F_x = \sum F_y = 0\end{array}}$$

(net force is zero)

(each component of the net force is zero)

Not rotating:

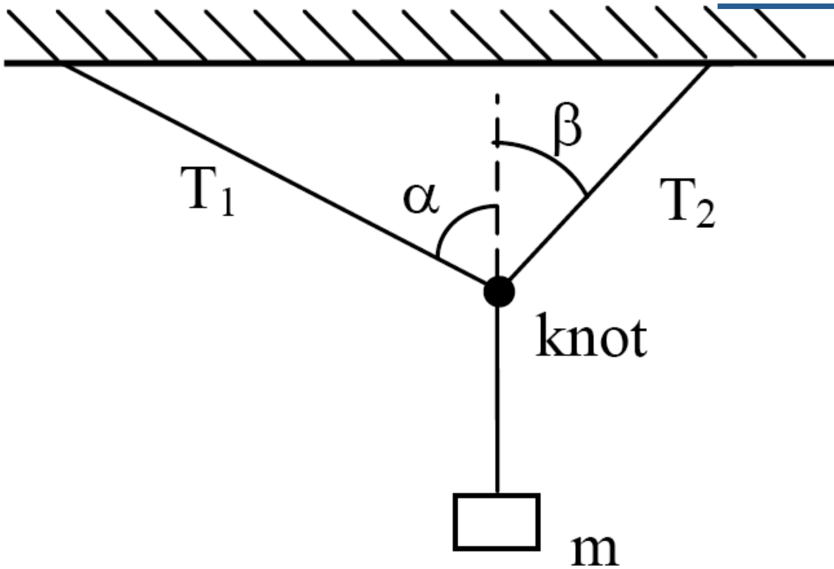
$$\boxed{\tau_{net} = 0 = \sum_i \tau_i}$$

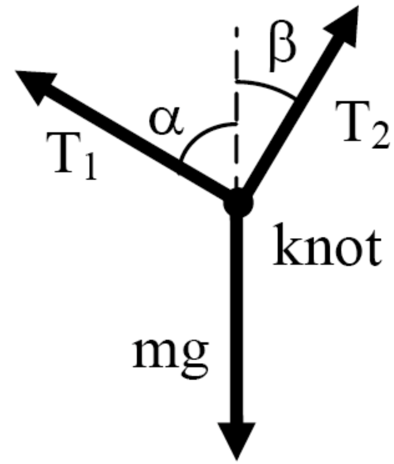
(net torque is zero)

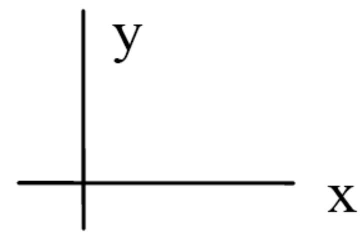
A mass m is hanging (statically) from two strings.
The mass m, and the angles α and β are known.

What are the tensions T_1 and T_2?

Note: No lever arm. Thus no torques.







$$\sum F_x = 0 \quad \Rightarrow \quad -T_1 \sin\alpha + T_2 \sin\beta = 0$$

$$\sum F_y = 0 \quad \Rightarrow \quad +T_1 \cos\alpha + T_2 \cos\beta - mg = 0$$

Two equations with two unknowns,
can solve for T_1 and T_2 after some algebra.

Ch. 10 Fluids

$$P = \rho g h$$ Hydrostatic Pressure Equation

Pascal's Principle

$$F_{OUT} = \left(\frac{A_{OUT}}{A_{IN}} \right) F_{IN}$$

The buoyant force equals the weight of displaced fluid.

Archimedes' Principle

$$F_{buoy} = m_{fluid} g = \rho_{fluid} V g$$

Floating Object

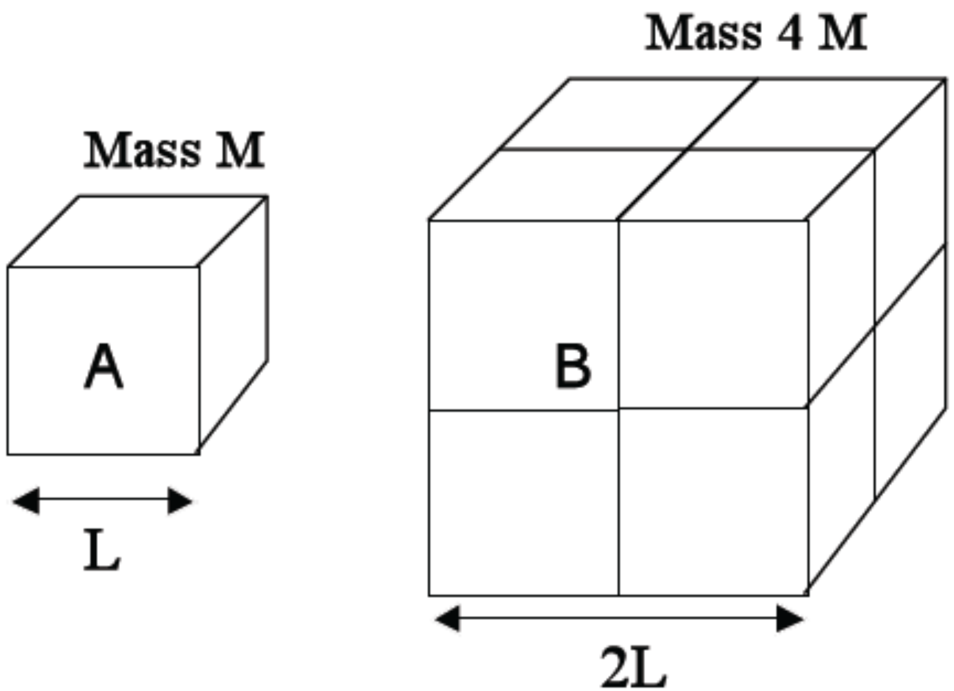
$$\frac{V_{displaced}}{V_{object}} = \frac{\rho_{object}}{\rho_{fluid}}$$

Clicker Question

Room Frequency BA

Cube A has edge length L and mass M. Cube B has edge length 2L and mass 4M. Which has greater density?

A) A has larger density
B) B has larger density
C) A and B have the same density.

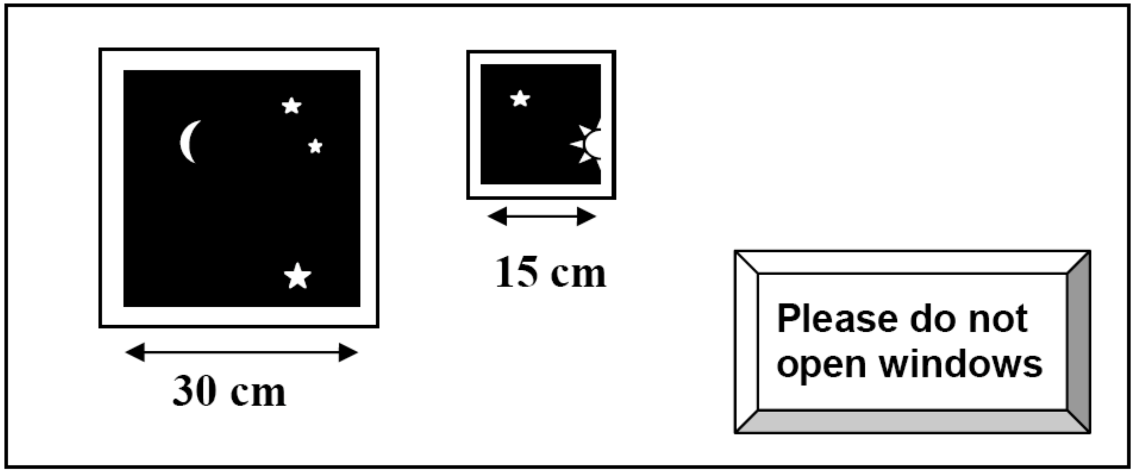


Cube A has larger density. $\rho_A = M/L^3$, $\rho_B = (4M)/(2L)^3 = (1/2)M/L^3$ so object A has twice the density of object B.

Clicker Question

Room Frequency BA

The air pressure inside the Space Station is P = 12 psi. There are two square windows in the Space Station: a little one and a big one. The big window is 30 cm on a side. The little window is 15 cm on a side. How does the **pressure** on the big window compare to the **pressure** on the little window?



A) same pressure on both windows

B) 2 times more pressure on the big window

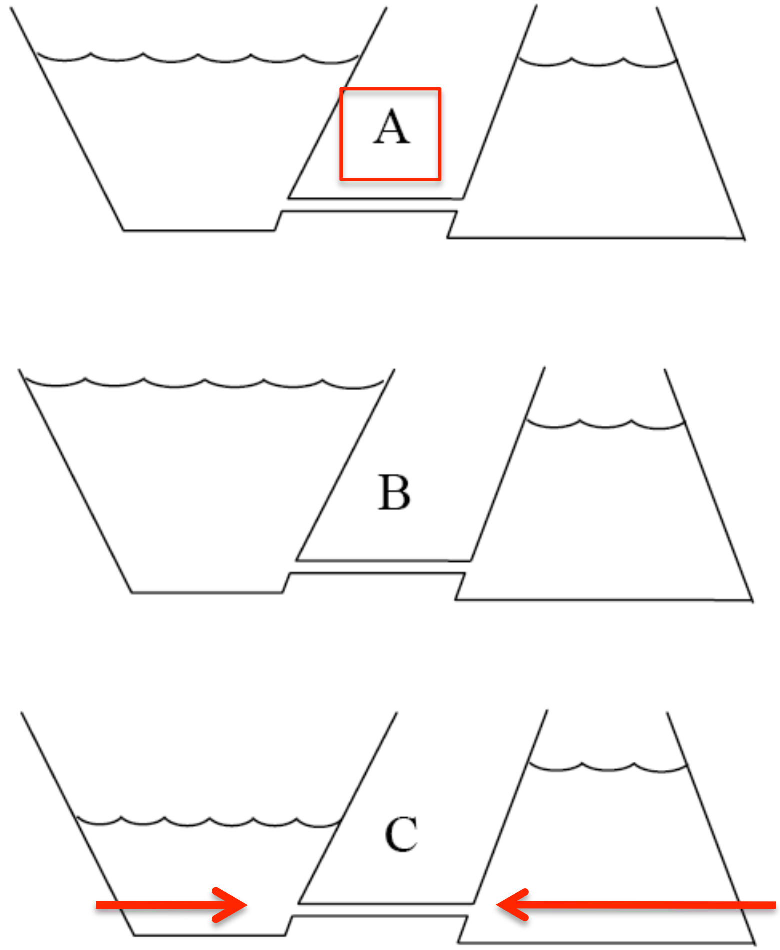
C) 4 times more pressure on the big window

D) 9 times more pressure on the big window

Clicker Question

Room Frequency BA

As shown, two containers are connected by a hose and are filled with water. Which picture correctly depicts the water levels?



Different depths would give different pressures! The net force on the fluid at the connection tube would not be zero and there would be flow!

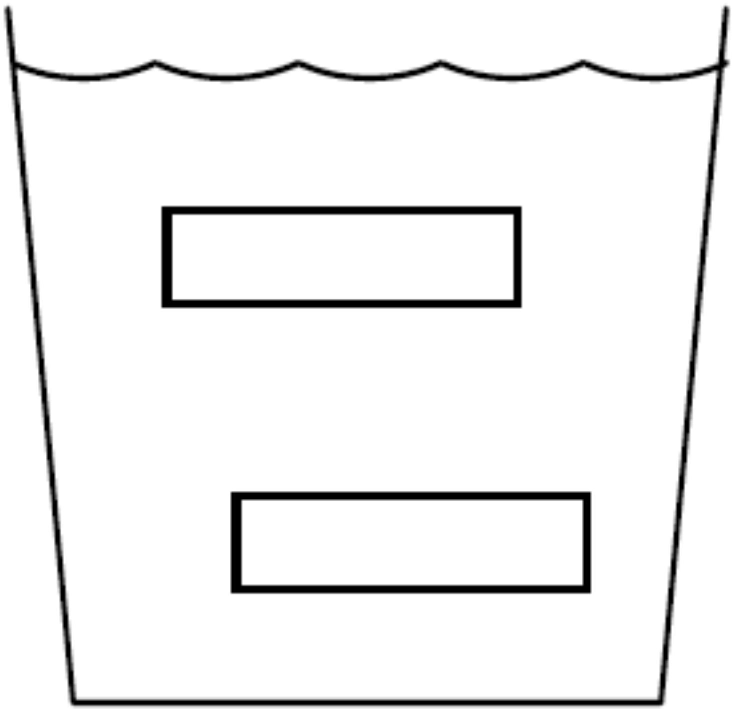
$$\boxed{P = \rho g h}$$

Pressure only depends on the depth; at a given depth the pressure is the same.

Clicker Question

Room Frequency BA

Two identical bricks are held under water in a bucket. One of the bricks is lower in the bucket than the other. The upward buoyant force on the lower brick is…..



A) greater

B) smaller

C) the same as

the buoyant force on the higher brick.

The weight of displaced fluid does not depend on depth

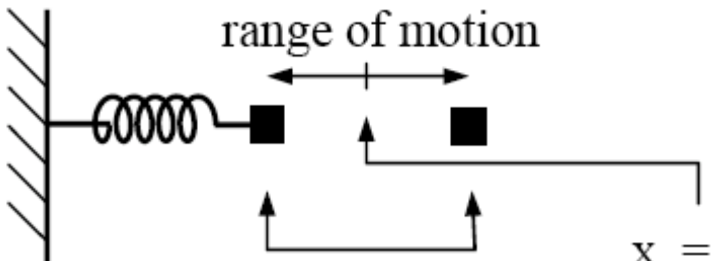
$$\boxed{F_{buoy} = m_{fluid}g = \rho_{fluid}Vg}$$

CH. 11 Vibrations

Simple Harmonic Oscillator

Understand these things:

F=-kx=ma   (Hooke's Law)



$$\omega = \sqrt{\frac{k}{m}}$$

$$f = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

$$T = \frac{1}{f} = 2\pi\sqrt{\frac{m}{k}}$$

$|x| = A$
$v = 0$
$PE = max$
$KE = min$
$|F| = max$
$|a| = max$

$x = 0$
$|v| = max$
$PE = min$
$KE = max$
$|F| = 0$
$|a| = 0$

$$E_{tot} = \tfrac{1}{2}\, mv^2 + \tfrac{1}{2}\, kx^2 = \tfrac{1}{2}\, kA^2 \; (Cons\ of\ E)$$

Interpret plots of displacement, velocity, and acceleration. Amplitude & period.