Physics 2A: Lecture 7

Today's Agenda

- Uniform Circular Motion
- Centripetal acceleration
- Examples
  - Car on track
  - Carnival ride
  - Loop-de-loop

Start Recording!

Clicker Question 1:

$a_c = \frac{v^2}{R}$

Suppose you are driving through a valley whose bottom has a circular shape. If your mass is m, what is the magnitude of the normal force F_N exerted on you by the car seat as you drive past the bottom of the hill?

$\Sigma F_y = ma_y$

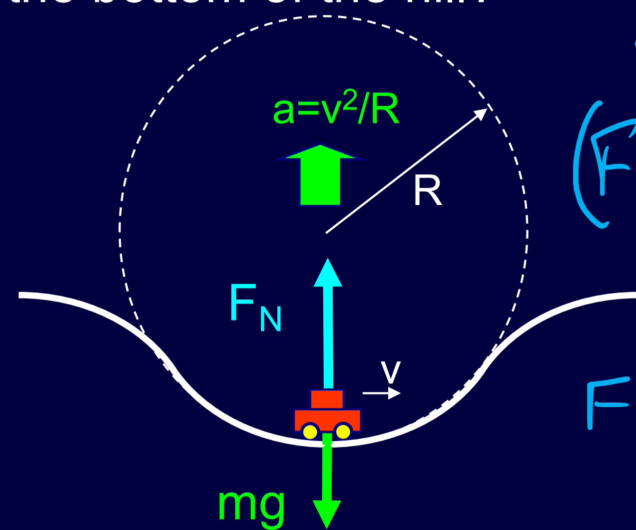
$(F_N - mg) = ma_c$

$F_N > mg = +$

$F_N < mg = -$

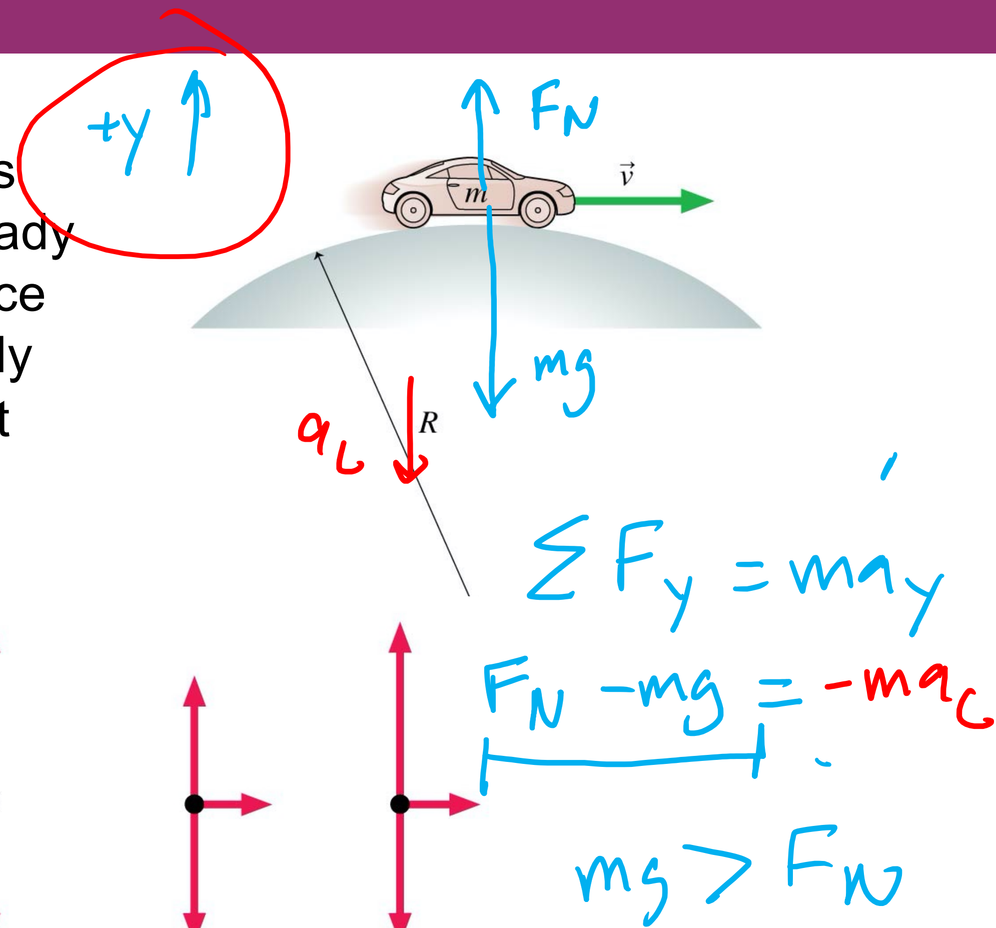
$F_N = ma_c + mg$

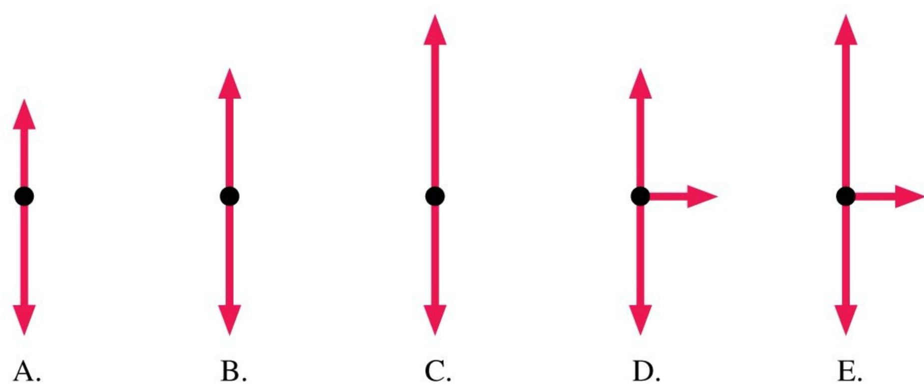
A. $F_N < mg$
B. $F_N = mg$
C. $F_N > mg$



Clicker 2:

A car that's out of gas coasts over the top of a hill at a steady 20 m/s. Assume air resistance is negligible. Which free-body diagram describes the car at this instant?



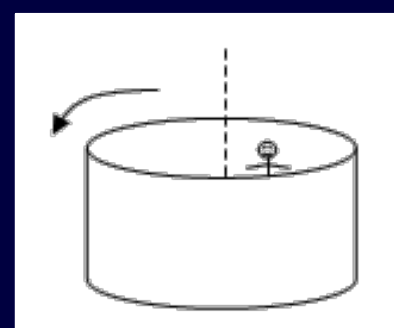


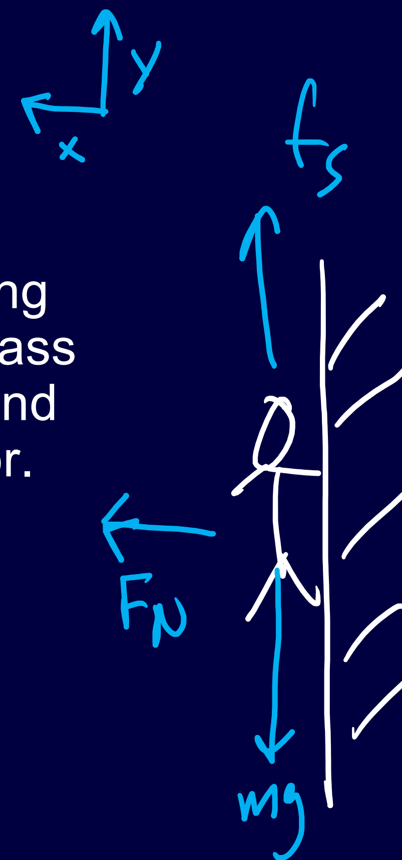
Clicker Question 3:

Harvey is riding a carnival ride which consists of a rotating cylindrically shaped room of radius R = 8 m. Harvey's mass is 85 kg. The floor drops out from below Harvey's feet, and he sticks to the wall rather than descending with the floor. The coefficient of static friction of the wall is μ_s = 0.766 .

How many forces act on Harvey?

(a) 1
(b) 2
(c) 3
(d) 4
(e) 5





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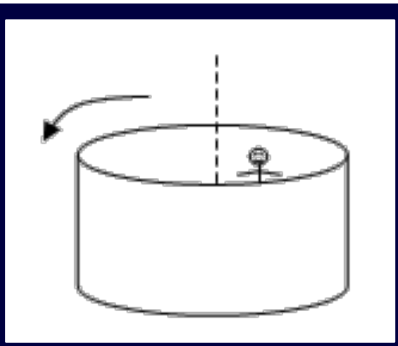

How many forces act on Harvey?

whats the unbalanced force in this case $\Sigma F = ma$

Clicker Question 4:

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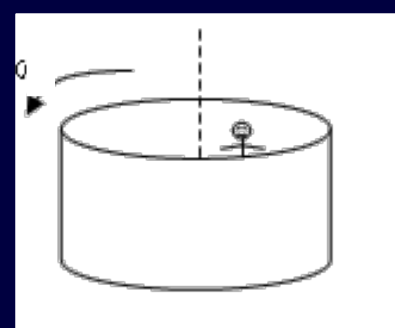
What force provides the centripetal acceleration required to keep Harvey moving in a circle?

(a) Gravity
(b) Static Friction
(c) Normal Force



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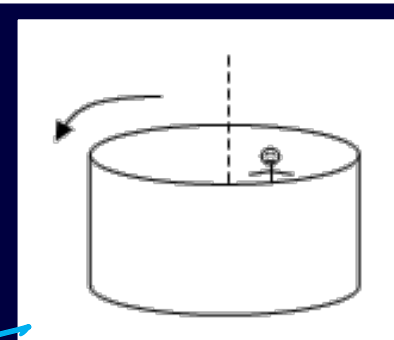

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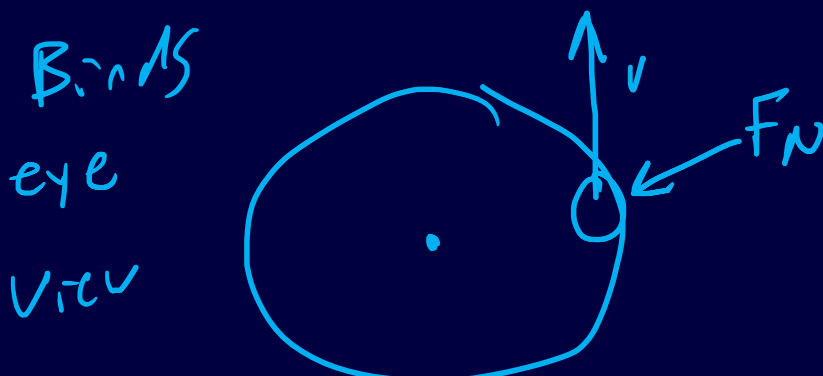

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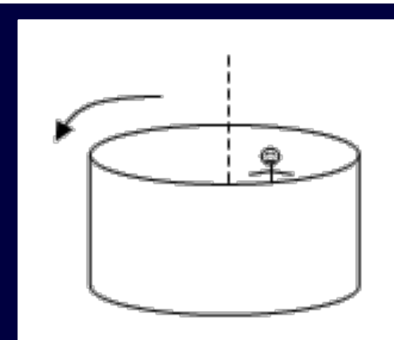


What force provides the centripetal acceleration required to keep Harvey moving in a circle?

$$\Sigma F = m a_c$$

0

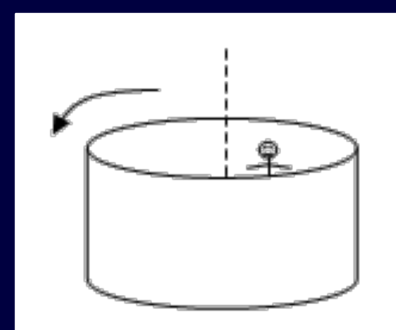
Student: why is there no force opposing the centripetal acceleration? Shouldnt the forces be balanced or else the person will fly towards the center?

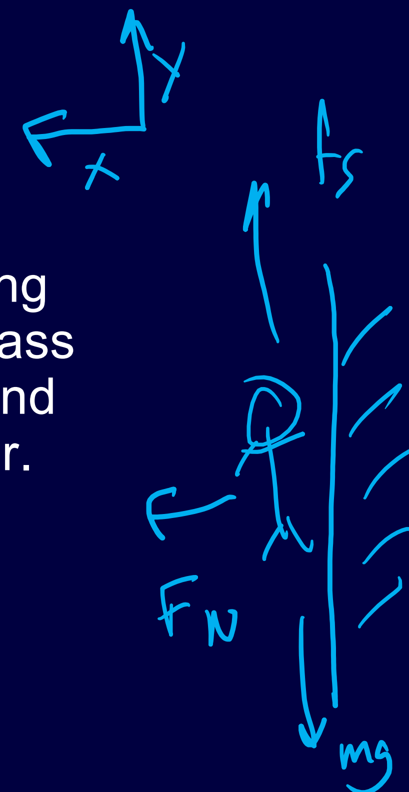
Clicker Question 5:

Harvey is riding a carnival ride which consists of a rotating cylindrically shaped room of radius R = 8 m. Harvey's mass is 85 kg. The floor drops out from below Harvey's feet, and he sticks to the wall rather than descending with the floor. The coefficient of static friction of the wall is μ_s = 0.766 .

What are the equations of motion for Harvey?

(a) $F_S = \mu_s mg$, $F_N = mg$
(b) $F_S = mg\sin\theta$, $F_N = mg\cos\theta$
(c) $F_S = mg$, $F_N = ma_C$
(d) $F_S = ma_C$, $F_N = mg$
(e) $F_S = mg$, $F_N = 0$





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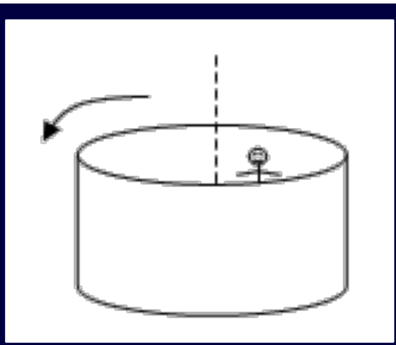


What are the equations of motion for Harvey?

$\Sigma F_x = ma$

$F_N = m a_c$

$\mu_s F_N = mg$

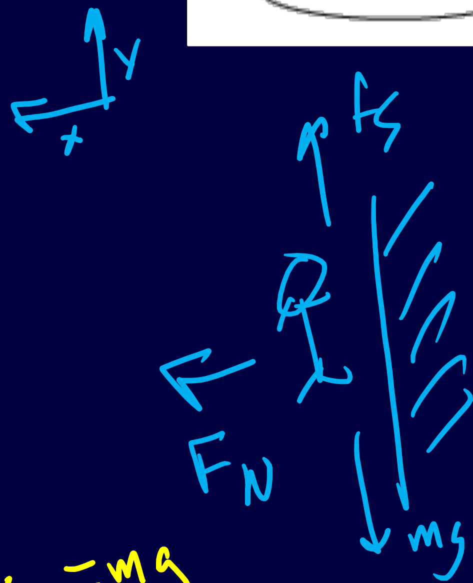
$\mu_s m \frac{v^2}{r} = mg$

$\Sigma F_y = m a_y = 0$

$f_s - mg = 0$

$f_s = mg$

$f_{s\,max} = \mu_s F_N = mg$



$v^2 = \frac{gr}{\mu_s} \Rightarrow v = \sqrt{\frac{gr}{\mu_s}} = 10.12$ m/s

Clicker Question 6:

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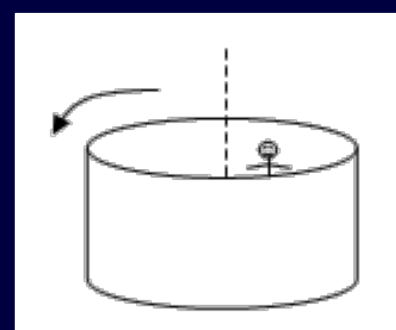
Harvey's speed must be at least

(a) 0.80 m/s
(b) 2.00 m/s
(c) 3.20 m/s
(d) 5.60 m/s
(e) 10.12 m/s



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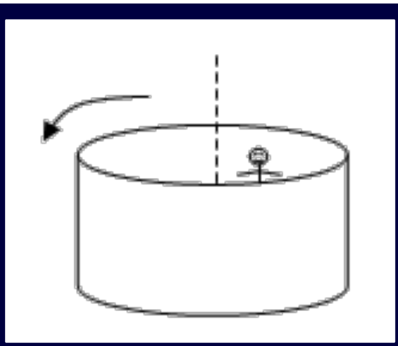


Harvey’s speed must be at least

Two Stage Quizzes

- **First stage:** Thursdays from 5-6pm taken synchronously. You may only use an equation sheet you provide and a calculator as aides.
- Optional Regrade: Same quiz problems, this time with written explanations. Completed and uploaded to gradescope and canvas by 11:59 the Sunday after a quiz (you can earn 1/3 of the points you missed back).
- **Second Stage:** a 15-minute oral quiz with questions relating to the quiz problems on the Monday/Tuesday following each quiz.
- Your quiz grade will be the average of the first and second stages.

Oral Quiz Scheduling

- We will be holding our oral quizzes on the Monday/Tuesdays after each quiz.
- We will schedule these quizzes individually during the following times:
  - Monday: 9-12pm and 2-7pm
  - Tuesday: 9-12pm and 2-7pm
- You will need to have six 15-minute windows of availability during these times

Quiz 1 Stage 1 Today

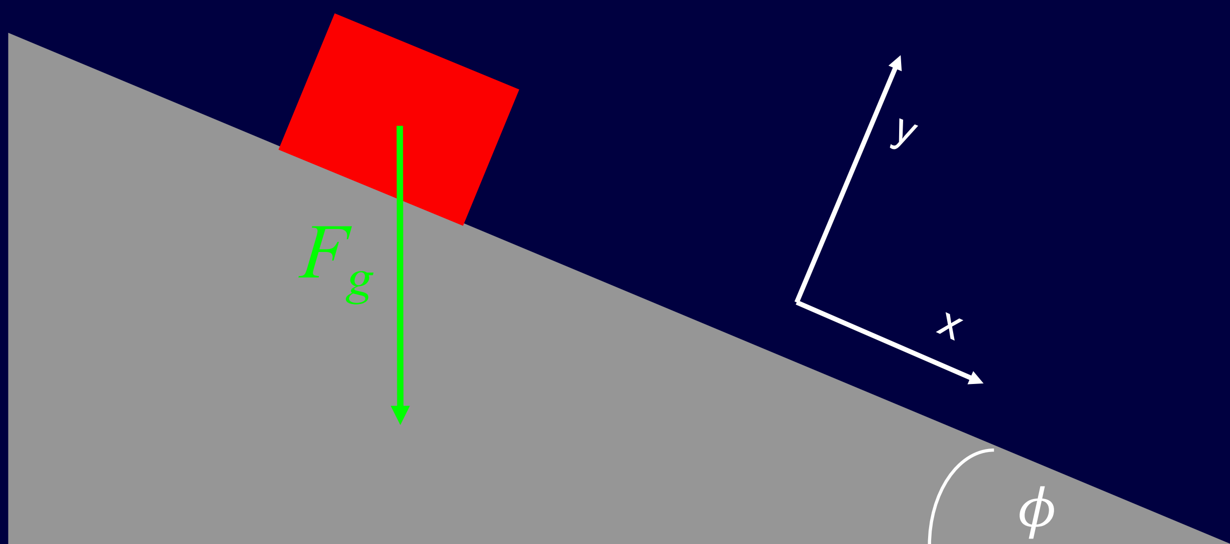
- One sheet for equations, front and back, handwritten
- You may only use the equation sheet you provide and a calculator as aides.

Clicker Question 7:

A box rests on an incline. The force of gravity pulls straight down as shown. When dealing with inclined planes we will often find it convenient to rotate our coordinate system as shown. How would you express the gravitational force in the new *x*-direction?

(a) $F_g \cos(\phi)$ (b) $F_g \sin(\phi)$ (c) $-F_g \cos(\phi)$ (d) $-F_g \sin(\phi)$

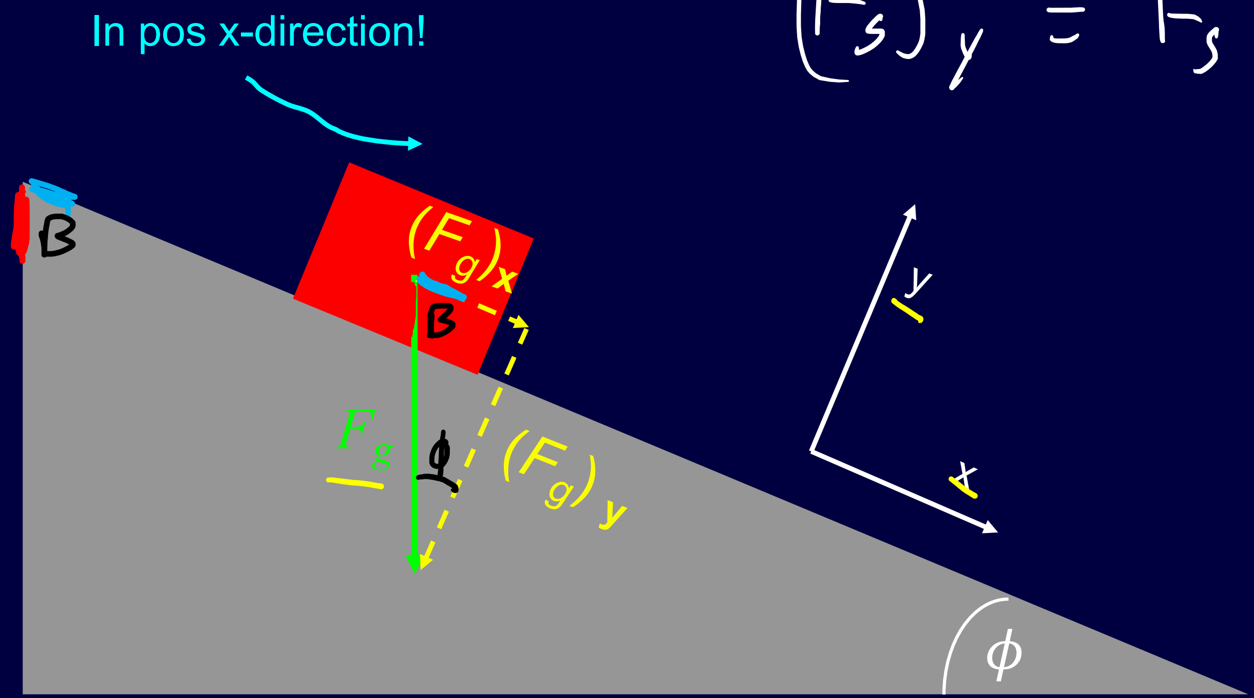
(e) None of the above



Example: Inclined surface

$$(F_g)_x = F_g \sin\phi$$

$$(F_g)_y = F_g \cos\phi$$



Constant acceleration in 2-D

- Same equations, but treat each direction separately
- x-direction
  - $x_F = x_0 + v_{0x}t_F + ½\, a_x t_F^2$
  - $v_{Fx} = v_{0x} + a_x t_F$
  - $v_{Fx}^2 = v_{0x}^2 + 2a_x(\Delta x)$
- y-direction
  - $y_F = y_0 + v_{0y}t_F + ½\, a_y t_F^2$
  - $v_{Fy} = v_{0y} + a_y t_F$
  - $v_{Fy}^2 = v_{0y}^2 + 2a_y(\Delta y)$

v_{ox} is initial velocity in x

v_{oy} is initial velocity in y

a_x is x acceleration

a_y is y acceleration

Clicker Question 8:

Suppose I throw a ball straight down a 80m cliff with a velocity of 24m/s. What speed does the ball hit the ground with?

(a) 24.6 m/s
(b) 28.4 m/s
(c) 34.5 m/s ✓
(d) 46.3 m/s
(e) 57.5 m/s

$v_0 = -24\ m/s$

$a = -g$

$y_0 = 80m$

$y_F = 0$

$+y$

$g = 9.81\ m/s^2$

~~time~~

$\Delta y = y_F - y_0 = 0 - 80m = -80m$

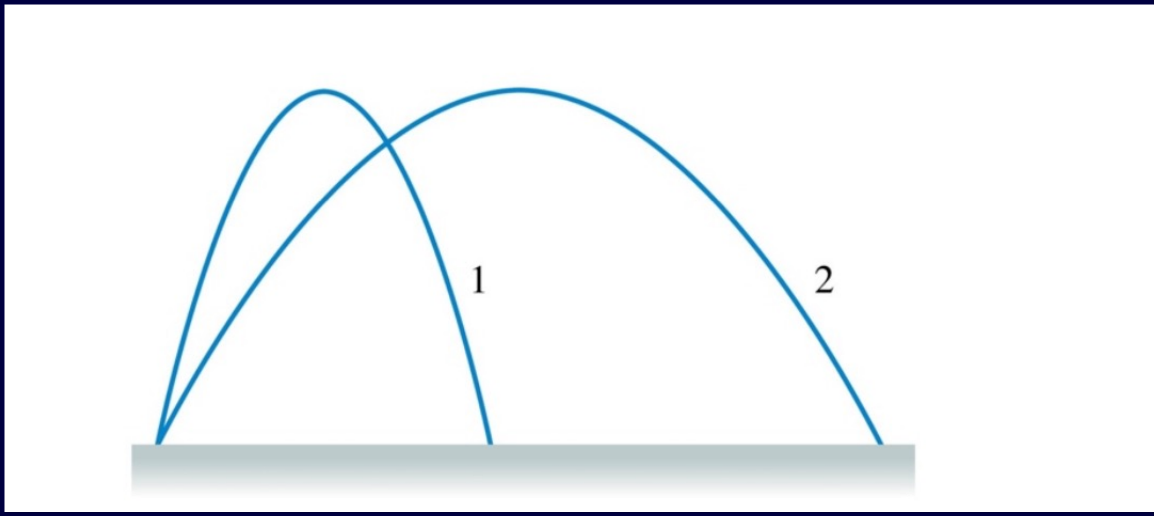
$v_F^2 = v_0^2 + 2a\Delta y = v_0^2 + 2(-g)(-80m)$

$v_F = \sqrt{(-24\ m/s)^2 + 2g(80m)} = 46.3\ m/s$

Clicker Question 9:

Projectiles 1 and 2 are launched at the same time, over level ground with different speeds. Both reach the same height. Which hits the ground first? Ignore air resistance.

(A) Projectile 1 hits first.
(B) Projectile 2 hits first.
(C) They hit at the same time.
(D) There’s not enough information to tell.



You want to shoot a ball to a friend of yours standing on a nearby building. There is a picture below of this set-up for your reference. The ball is launched with a speed of 42 m/s, and leaves from a position of 1.5 m above the ground. However, there is a billboard sign between you and the building. You stand such that the ball just barely gets over the billboard at its highest point in its trajectory. (a) At what angle, above the horizontal do you need to shoot the ball for this to happen?

$y_F = 67.5\,m$

$y_0 = 1.5\,m$

$x_0 = 0\,m$

$v_0 = 42\,m/s$

$v_{0x} = 21.69\,m/s$

$v_{0y} = 35.18\,m/s$

$a_y = -g$

$a_x = 0$

$v_{Fy}^2 = v_{0y}^2 - 2g\Delta y$

$0 = v_{0y}^2 - 2g[67.5\,m - 1.5\,m]$

$v_{0y} = \sqrt{2g(66\,m)}$

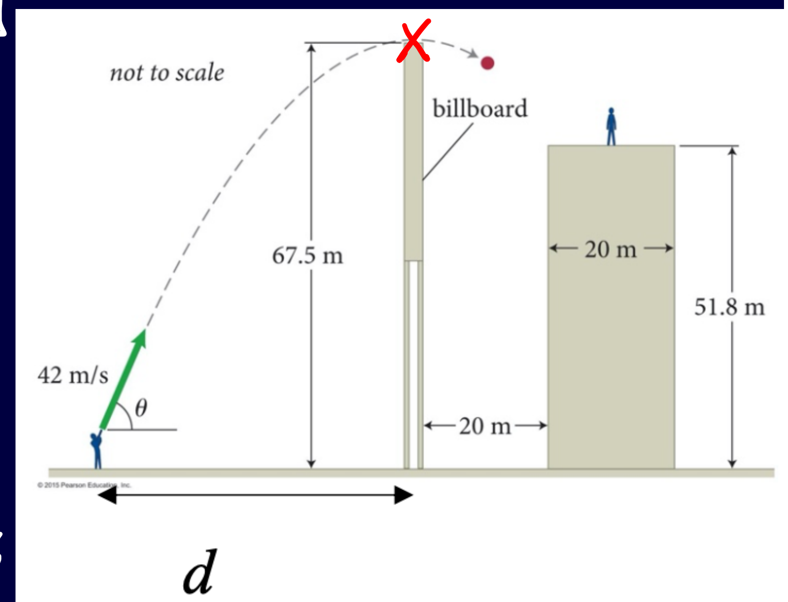
$= 35.18$

42 m/s, 35.18 m/s, θ

$v_{0x} = 42\cos 58.9 = 21.69\,m/s$

$\sin\theta = \frac{35.18}{42}$

$\theta = 58.9$



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$x_F = x_0 + V_{0x} t + \frac{1}{2} g t^2$

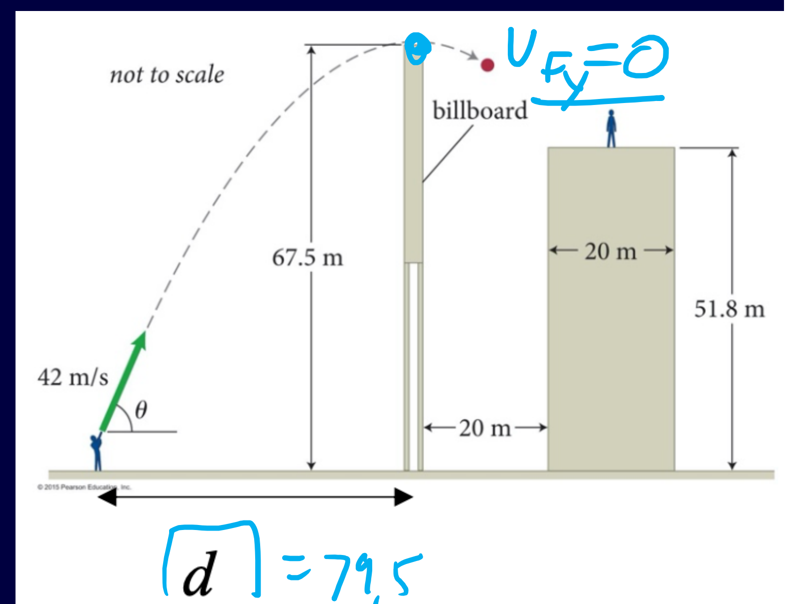
$x_F = 21.69 \text{ m/s } t$

$= 21.69 \text{ m/s } [3.675] = 79.5 \text{ m}$

$V_{Fy} = V_{0y} - g t$

$0 = 35.18 \text{ m/s} - g t$

$t = 3.675$



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$y_F = 51.8$

Quad

$y_F = y_0 + v_{0y} t + \frac{1}{2} g t^2$

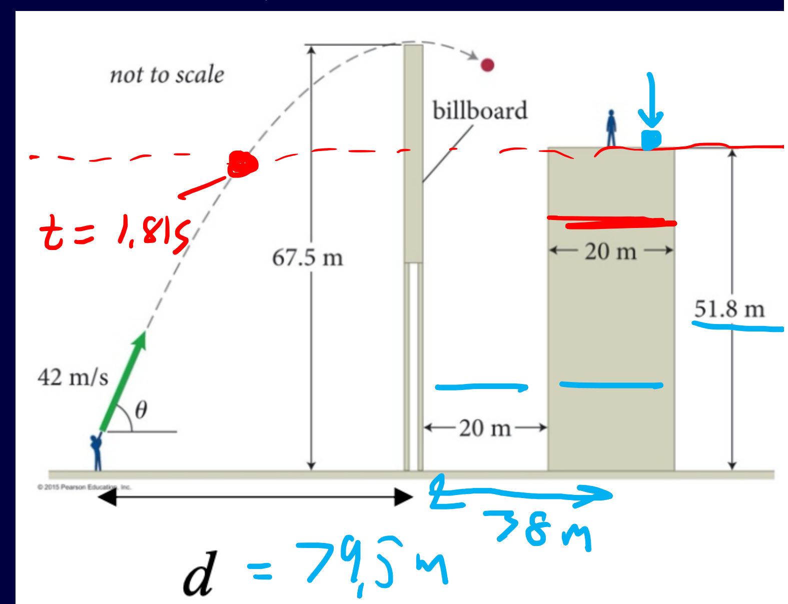
$51.8\,m = 1.5\,m + 35.18\,m/s\;t - \frac{1}{2} g t^2$

$0 = -50.3\,m + 35.18\,t - \frac{1}{2} g t^2$ (c = −50.3 m, b = 35.18, a = −½g)

$t = 5.45\,s$ (A), $1.81\,s$ (B)

$x_F = 21.69\,m/s\;t = 118.2\,m$

$118.2\,m - 79.5\,m \approx 38\,m$



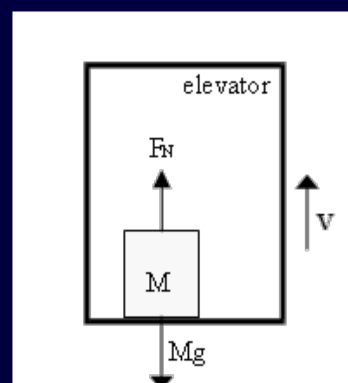
Clicker Question 10:

Suppose a box having a mass M sits on the floor of an elevator that is moving upward and speeding up. Compare the weight of the box (Mg) to the magnitude of the normal force exerted by the elevator floor on the box (F_N).

(a) $F_N < Mg$

(b) $F_N = Mg$

(c) $F_N > Mg$ ✓



+y ↑

↑ F_N ↓ mg

$\Sigma F = ma$

$\uparrow (F_N - mg) = +ma$

F

Clicker Question 11:

An airplane is flying from San Diego to Los Angeles. Many forces act on the plane, including gravity, air resistance, the trust of the engine, and the lift of the wings. At some point during its trip the velocity of the plane is measured to be constant (which means its altitude is also constant). At this time, the total force on the plane:

(A) is pointing upward
(B) is pointing downward
(C) is pointing forward
(D) is pointing backward
(E) is zero

$\vec{a} = 0$

$\sum \vec{F} = m\vec{a} = 0$