# Physics 111: Week 1–4 Review

**Bin Chen**

NJIT Physics Department

# Common Exam #1 Information

- Phys 111-013: Monday, Oct 08, 4:15 – 5:45 PM, KUPF 107
- All are multiple choice questions (most, if not all, only have one choice).
- Budget your time. If you get stuck on one question, move on.
- We will use Scantron Card. Bring your pencils.
- Physical constants and key equations are provided. Derived equations are NOT provided (e.g., time for a free-fall object to hit the floor from a height h). See example test on our course website for the provided equations.

# Week 1: Units (Chap. 1)

- Three fundamental physical quantities: meter (m), kilogram (kg), and second (s)
- Derived units: area, volume, velocity, etc.
- Unit conversion

# Week 1: 1D Kinetic Motions (Chap. 2)

- Kinematic variables in one dimension

| | | | |
|---|---|---|---|
| Position | $x(t)$ | m | L |
| Velocity | $v(t)$ | m/s | L/T |
| Acceleration | $a(t)$ | m/s$^2$ | L/T$^2$ |

  - All depend on time
  - All are vectors: magnitude and direction vector
- Properly interpret position-time and velocity-time diagrams
- Equations for motion with constant acceleration: missing quantities

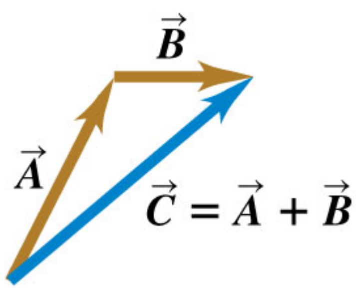
| | Missing quantities |
|---|---|
| $v = v_0 + at$ | $x, x_0$ |
| $x = x_0 + \frac{1}{2}(v_0 + v)t$ | $a$ |
| $x = x_0 + v_0 t + \frac{1}{2}at^2$ | $v$ |
| $v^2 = {v_0}^2 + 2a(x - x_0)$ | $t$ |

**See also Table 2.4 of your textbook (page 49)**

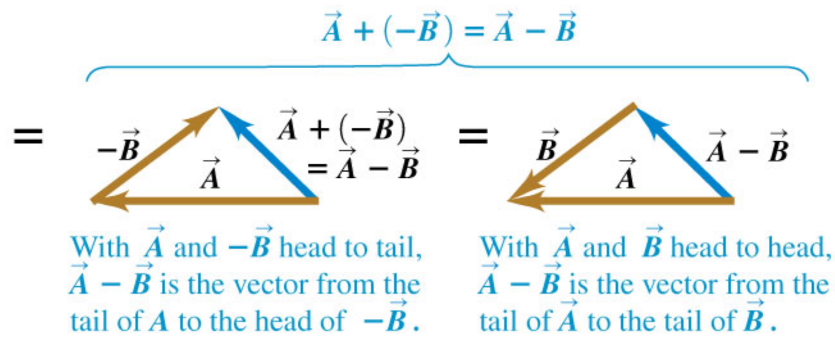
# Week 2: Vectors

## Vector Addition

(a) We can add two vectors by placing them head to tail.




## Vector Subtraction



# Week2: Vector Math

- Consider two vectors

$$\vec{A} = A_x\hat{\imath} + A_y\hat{\jmath}$$

$$\vec{B} = B_x\hat{\imath} + B_y\hat{\jmath}$$

- Then

$$\vec{A} + \vec{B} = (A_x\hat{\imath} + A_y\hat{\jmath}) + (B_x\hat{\imath} + B_y\hat{\jmath})$$

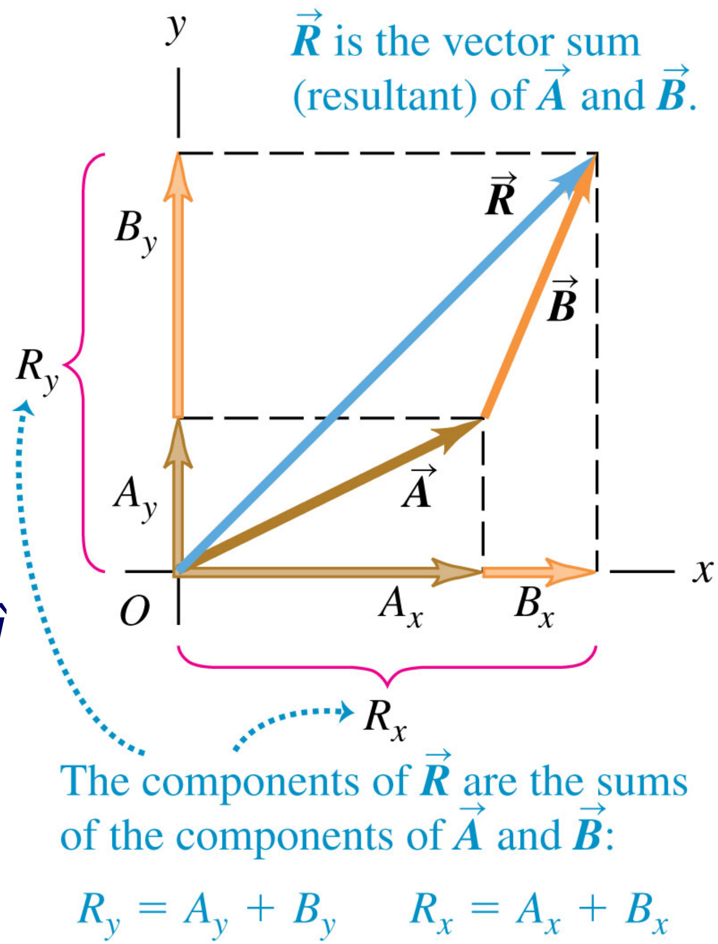
$$=(A_x+B_x)\hat{\imath} + (A_y+B_y)\hat{\jmath}$$

- $\vec{R} = \vec{A} + \vec{B} = (A_x + B_x)\hat{\imath} + (A_y+B_y)\hat{\jmath}$

  $\vec{R} = C_x\hat{\imath} + C_y\hat{\jmath}$

- So we have reproduced

$$R_x = A_x + B_x,\ R_y = A_y + B_y$$



# Week 2: (Vector) Position, Velocity, Acceleration (Chap. 3)

- Position $\vec{r} = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$
- Average velocity $\vec{\upsilon}_{\text{av}} = \dfrac{\vec{r}_2 - \vec{r}_1}{t_2 - t_1} = \dfrac{\Delta\vec{r}}{\Delta t}$
- Instantaneous velocity $\vec{\upsilon} = \lim\limits_{\Delta t \to 0} \dfrac{\Delta\vec{r}}{\Delta t} = \dfrac{d\vec{r}}{dt}$

$$\upsilon_x = \frac{dx}{dt} \quad \upsilon_y = \frac{dy}{dt} \quad \upsilon_z = \frac{dz}{dt} \quad \text{(components of instantaneous velocity)}$$

- Acceleration $\vec{a} = \lim\limits_{\Delta t \to 0} \dfrac{\Delta\vec{\upsilon}}{\Delta t} = \dfrac{d\vec{\upsilon}}{dt}$

$$a_x = \frac{d\upsilon_x}{dt} \quad a_y = \frac{d\upsilon_y}{dt} \quad a_z = \frac{d\upsilon_z}{dt} \quad \text{(components of instantaneous acceleration)}$$

- $\vec{r}(t)$, $\vec{v}(t)$, and $\vec{a}(t)$ are not necessarily along the same direction.

# Week 2: Projectile Motion (Chap. 3)

- Projectile motion is one type of 2-D motion under constant acceleration, where $a_x = 0$, $a_y = -g$.
- The key to analyzing projectile motion is to treat the x- and y-components **separately** and apply 1-D constant acceleration kinematics equations to each direction:

**horizontal direction**

$$v_x = v_{0x} + a_x t$$

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

$$v_x^2 = {v_{0x}}^2 + 2a_x(x - x_0)$$

**Vertical direction**

$$v_y = v_{0y} + a_y t$$

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

$$v_y^2 = {v_{0y}}^2 + 2a_y(y - y_0)$$

$a_x = 0 \quad a_y = -g$ (projectile motion, no air resistance)

# Week 3: Newton's Laws (Chap. 4)

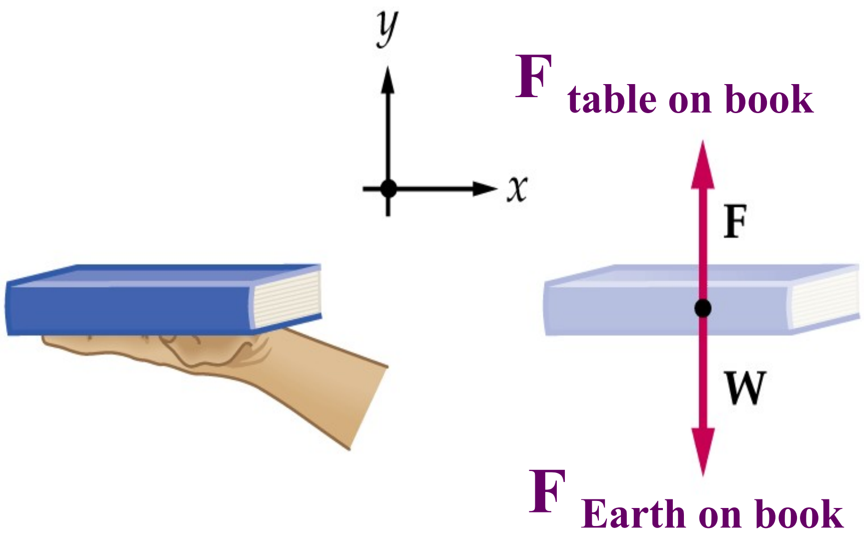
- Forces as vectors
- Net Force: $\vec{F}_{net} = \sum \vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots\ldots$
- Newton's 1st law:

> An object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force

- Newton's 2nd law: $\vec{\boldsymbol{F}}_{\text{net}} = \Sigma \vec{\boldsymbol{F}} = m\vec{\boldsymbol{a}}$
- Newton's 3rd law: $\vec{\boldsymbol{F}}_{A \text{ on } B} = -\vec{\boldsymbol{F}}_{B \text{ on } A}$

# Free Body Diagram

- Be sure to include **only the forces acting on the object of interest**
- Include any **field forces** acting on the object
- **Do not** assume the normal force or tension force equals to the weight




(a) Physical picture

(b) Free-body diagram

# Week 4: Application of Newton's Law (Chap. 5)

- Equilibrium problems: object at rest or moving at constant velocity

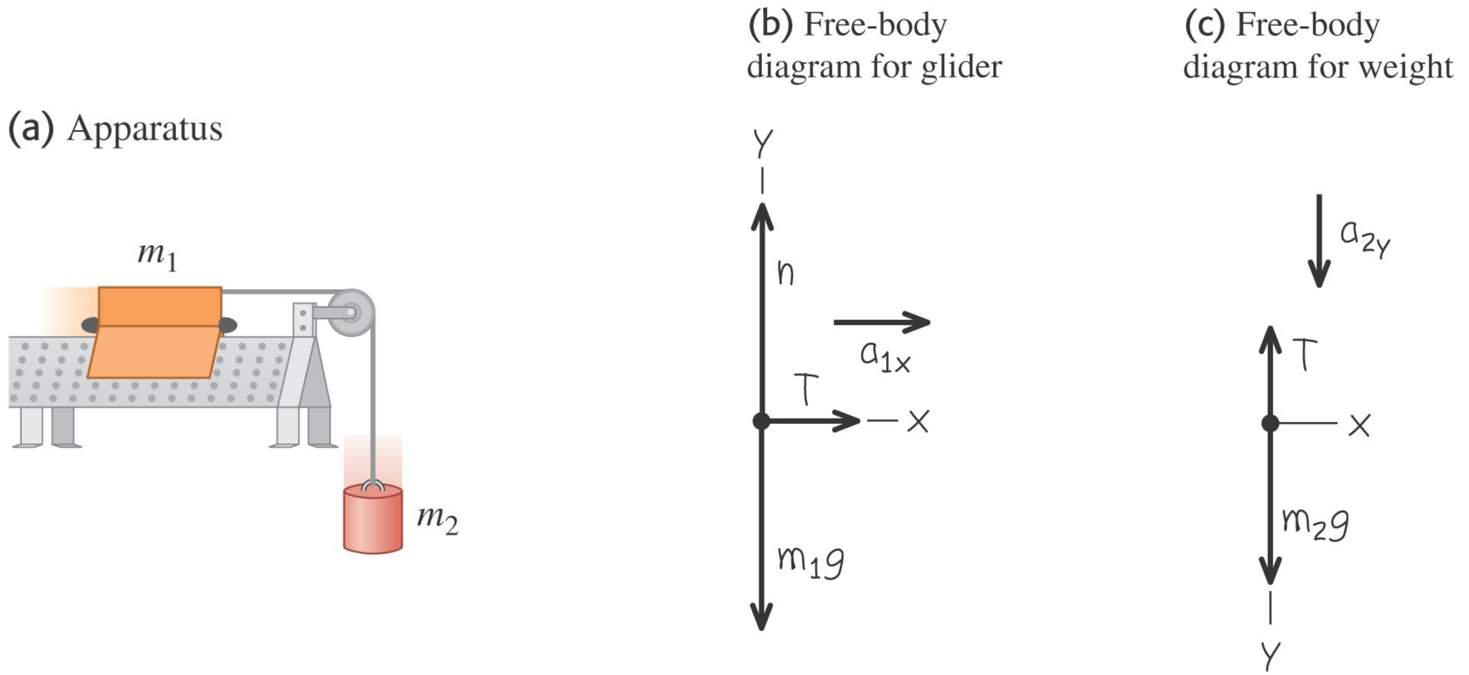
$$F_{\text{net},x} = \sum F_x = 0 \qquad F_{\text{net},y} = \sum F_y = 0$$

- Accelerating objects: net force is not zero, use Newton's 2nd Law.

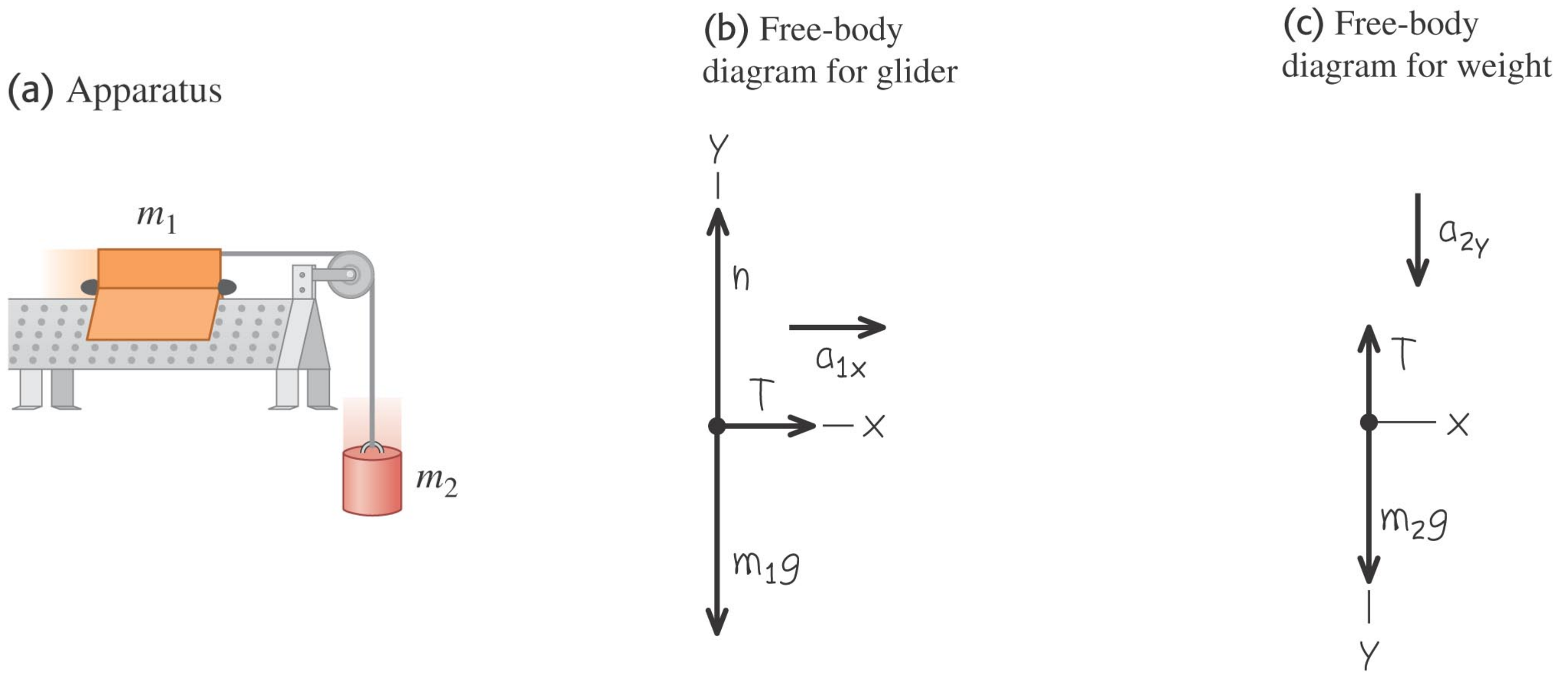
$$F_{net,x} = \sum F_x = ma_x \qquad F_{net,y} = \sum F_y = ma_y$$

# Two Connected Objects

- The glider on the air track and the falling weight move in different directions, but their accelerations have the same magnitude. Find the acceleration and tension in the string (Textbook Example 5.12).



# Two Connected Objects

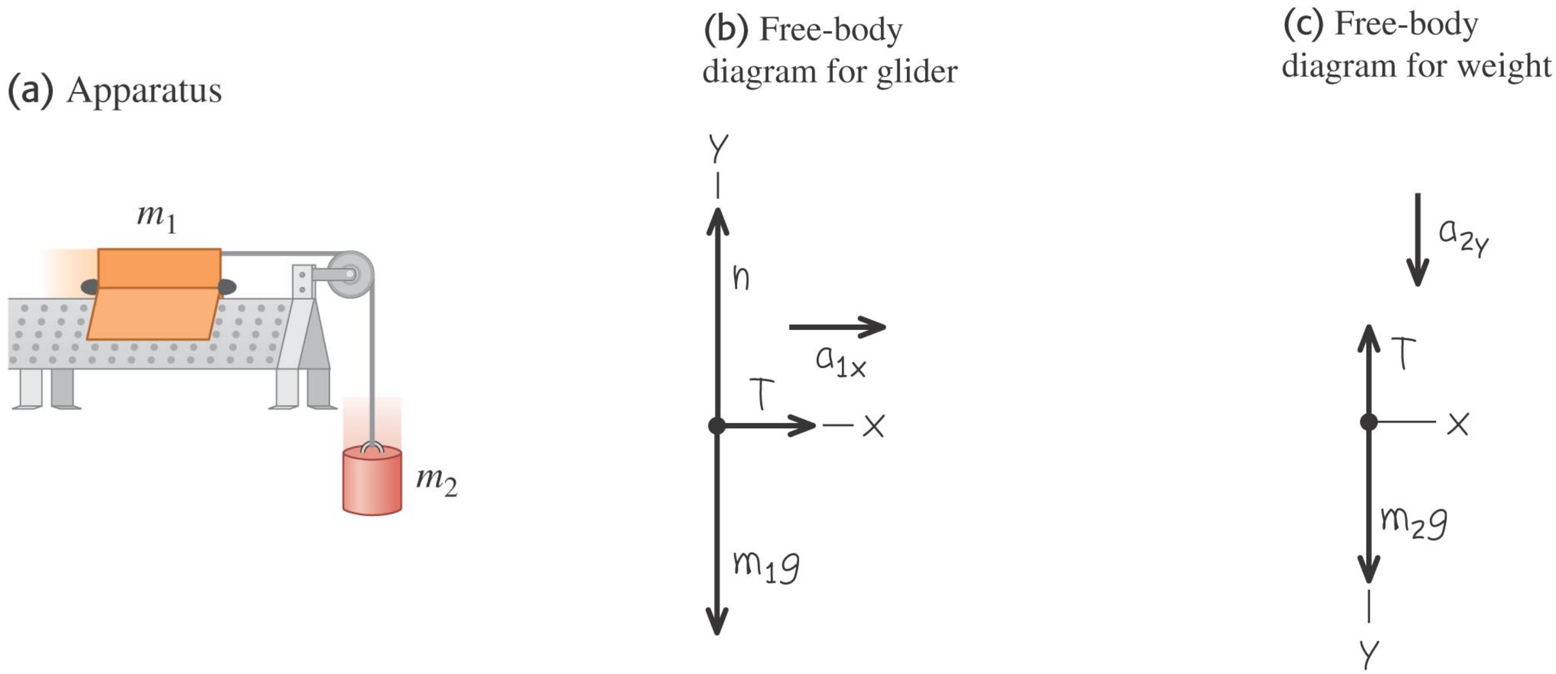



Glider: $\sum F_x = T = m_1 a_{1x} = m_1 a$

Glider: $\sum F_y = n + (-m_1 g) = m_1 a_{1y} = 0$

Lab weight: $\sum F_y = m_2 g + (-T) = m_2 a_{2y} = m_2 a$

# Two Connected Objects




Glider: $T = m_1 a$

Lab weight: $m_2 g - T = m_2 a$

**Acceleration**

$$a = \frac{m_2}{m_1 + m_2} g$$

**Tension**

$$T = \frac{m_1 m_2}{m_1 + m_2} g$$

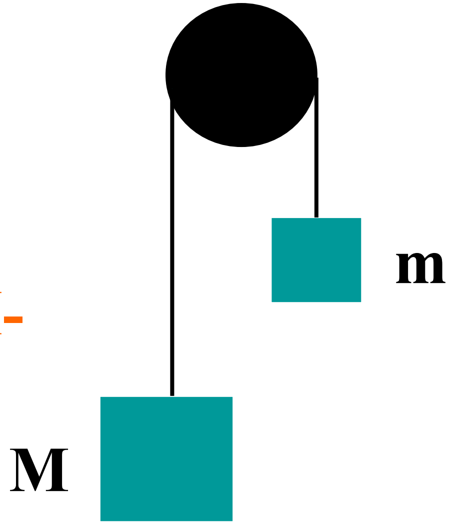
A bucket of M = 15 kg and a counter weight of m = 5 kg is connected by a rope at two opposite sides of a frictionless pulley. The bucket is initially held by a person at rest. Then the person let it go. What is the tension force on the rope in N when the bucket is falling?

A. 50
B. 150
C. 100
D. 75
E. 125

**Bucket: $Mg - T = Ma$ (1)**

**Counterweight: $T - mg = ma$ (2)**

**(1)+(2): $(M-m)g=(M+m)a$, so $a=(M-m)g/(M+m)$, plug back in (1), we have: $T = 2Mm/(M+m)$**



# Practice Problems

# 1D Motion

A train enters a train station at an initial speed of 20 m/s and decelerates at a constant acceleration. It travels 100 m before it fully stops. How much time, in seconds, does it take?

A. 5
B. 10
C. 20
D. 2.5
E. 1

## 1D Motion

In Mission Impossible 6, one agent jumped out from a plane but lost his conscious. He was descending a constant speed of 20 m/s. Tom Cruise tried to save his colleague. He started from a zero vertical speed, but accelerated downward at 10 $m/s^2$. How far did he travel, in m, before he managed to reach his colleague and save him?

A. 100
B. 200
C. 80
D. 40
E. 20

A fighter jet flying horizontally at 3000 m above the ground at a speed of 100 m/s shoots a bullet with a vertical speed of 198 m/s. What is the maximum height does the bullet reach above the ground, in m?

A. 2000
B. 3000
C. 5000
D. 7000
E. 9000

## 2D Motion

- In Mission Impossible 6, Tom Cruise jumps off a rooftop and landed on a nearby building that is 5 m lower. The horizontal distance between the two buildings is 10 m. Assume he jumps off the edge nearly horizontally. How fast in m/s should he run in order to make it to the other side (without dying)?

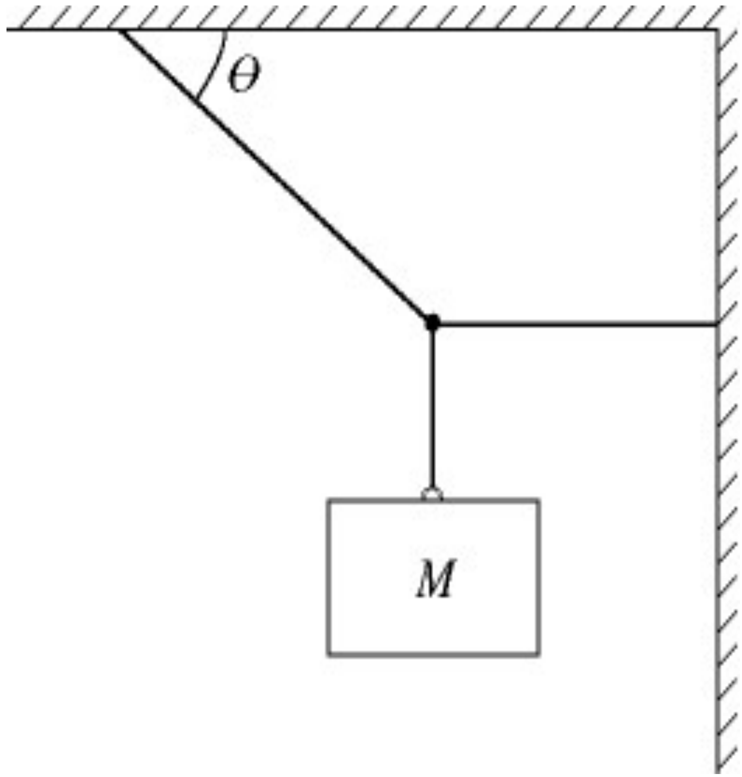
A) 5 m/s B) 10 m/s C) 20 m/s

D) 7 m/s E) 15 m/s

**Already discussed in a previous class**

## Force balance

In the figure, a block of mass $M$ hangs at rest. The rope that is fastened to the wall is horizontal and has a tension of 52 N. The rope that is fastened to the ceiling has a tension of 91 N, and makes an angle $\theta$ with the ceiling. What is the angle $\theta$?




A) 55°
B) 35°
C) 30°
D) 63°
E) 45°

## Newton's second law: Motion along a slope

A glider starts from rest and slides down an icy slope of 30 degrees. Assume there is no friction. How far along the slope, in meters, did the glider go when it reaches 5 m/s?

A. 1.25
B. 2.5
C. 5
D. 10
E. 20

## Newton's second law: two connected bodies

A bucket with a mass 20 kg, hangs on a rope over the side of well. The bucket is tied to rock with a mass of 20 kg, which initially sits at rest on the horizontal ground. Suddenly the rock lost contact with the ground and the bucket starts to fall. Assuming no friction, what is the acceleration of the bucket, in $m/s^2$?

A. 9.8
B. 4.9
C. 19.6
D. 0
E. 2.5

## Newton’s second law: two connected bodies

Two boxes, one with M=20 kg, and another with m = 10 kg, connected by a rope were initially sitting on an icy lake (with no friction). A person comes up and pull the heavier box M with a horizonal force of 90 N, so the two boxes start to accelerate. What is the tension force on the rope, in N?

A. 0
B. 30
C. 60
D. 90
E. 120

# Back up problems

## Force balance

A traffic light weighing 100 N is supported by two ropes as shown in the figure. The tensions in the ropes are closest to

A) 50 N.
B) 56 N.
C) 63 N.
D) 66 N.
E) 83 N.