Chapter 4

Forces and Newton's Laws of Motion

continued

Exam

- Arrive ON TIME – by 12:40 or you will not take the exam.
- Only Section 2 students.
- Sit ONLY in your assigned seat.
  Latest assignments will be on the website
- 1 Sheet (both sides) of information prepared by YOU – not commercially .

Quiz 4

1. **C&J page 111 (middle), Check Your Understanding #21**

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2. **A crate, mass *m* = *700* kg, is on a scale in an airplane that hits a strong downdraft causing a downward acceleration with magntitude 3.8 m/s^2. What apparent weight does the scale read?**
   - **a)** 0 N
   - **b)** 4200 N
   - **c)** 9700 N
   - **d)** 2700 N
   - **e)** 6900 N

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   - **a)** 0 N
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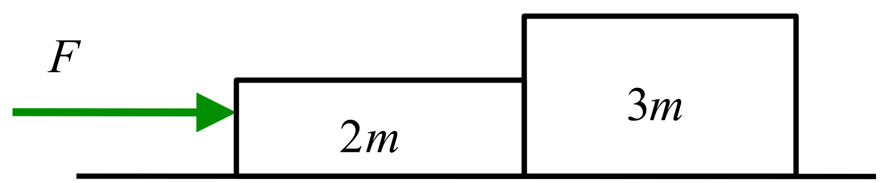
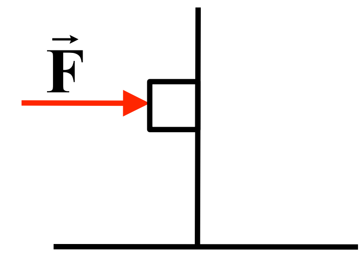
   - **d)** 2700 N
   - **e)** 6900 N

3. **On a frictionless surface, two boxes with the masses shown are pushed together by a force with magnitude *F*. What is the force that the larger mass block exerts on the smaller mass block?**
   - **a)** $F/3$
   - **b)** $F/5$
   - **c)** $2F/3$
   - **d)** $3F/5$
   - **e)** $3F/2$



4. **A block of mass 10 kg is initally at rest and pressed against a wall with a force of *F*. The coefficient of static friction is 0.5, and the coefficient of kinetic friction is less than this. What is the minimum force magnitude to keep the block at rest.**



a) 50 N

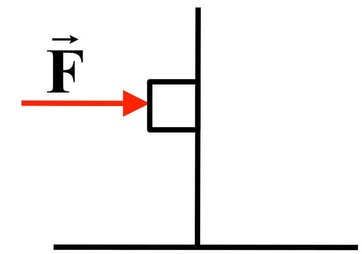
b) 100 N

c) 150 N

d) 200 N

e) No amount of force will keep it at rest.

4. **A block of mass 10 kg is initally at rest and pressed against a wall with a force of *F*. The coefficient of static friction is 0.5, and the coefficient of kinetic friction is less than this. What is the minimum force magnitude to keep the block at rest.**



a) 50 N

b) 100 N

c) 150 N

d) 200 N

e) No amount of force will keep it at rest.

5. **I. A person pulls with a force magnitude *F* on a string attached to a wall.**
II. A person at each end of the same string pulls on it with a force *F*.

Consider the two statements above. Which statement below is true?

a) The tension at the center of the string is zero

b) The string tension in II. is half as big as the tension in I.

c) The string tension in II. is the same as the tension in I.

d) The string tension in II. is twice as big as the tension in I.

e) The string tension in II. is four times as big as the tension in I.

Quiz 4

1. **C&J page 111 (middle), Check Your Understanding #21** — d) Balanced forces

2. **An passenger, mass *m* = *700* kg, is on a scale in an airplane that hits a strong downdraft causing a downward acceleration with magntitude 3.8 m/s². What apparent weight does the scale read?**

   a) 0 N
   b) 4200 N
   c) 9700 N
   d) 2700 N
   e) 6900 N

$$\text{Weight} = mg = (700\text{ kg})(9.8\text{ m/s}^2) = -6900\text{ N}$$

$$\text{Acceleration is } -3.8\text{ m/s}^2,\text{ net force } = ma = -2700\text{ N}$$

$$\text{Net force } = -mg + F_\perp,\text{ Scale reads } F_\perp.$$

$$-2700\text{ N} = -6900\text{ N} + F_\perp \Rightarrow F_\perp = (6900 - 2700)\text{ N} = 4200\text{N}$$

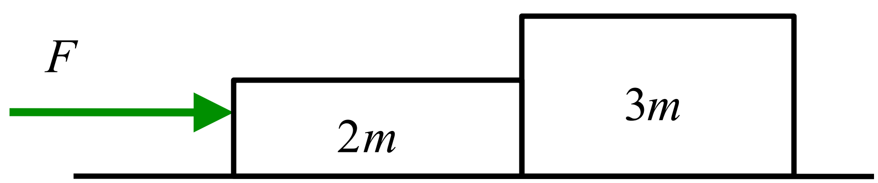
3. **On a frictionless surface, two boxes with the masses shown are pushed together by a force with magnitude *F*. What is the force that the larger mass block exerts on the smaller mass block?**

   a) $F/3$
   b) $F/5$
   c) $2F/3$
   d) $3F/5$
   e) $3F/2$

$$a = \frac{F}{5m};$$

net force of $2m$ on $3m$

$$F_{2m} = (3m)a = \frac{3}{5}F$$



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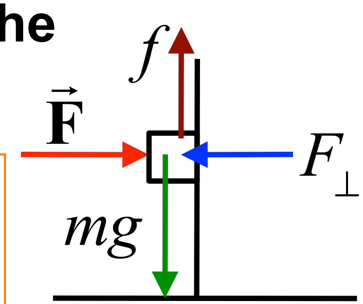

a) 50 N

b) 100 N

c) 150 N

d) 200 N

e) No amount of force will keep it at rest.

$$F_\perp = F$$

$$f = \mu F_\perp = \mu F;\ \text{slides if, } mg > f$$

$$mg = \mu F_\perp; \quad F_\perp = \frac{mg}{\mu} = \frac{10\,\text{kg}(9.8\ \text{m/s}^2)}{0.5} = 200\ \text{N}$$

5. I. A person pulls with a force magnitude *F* on a string attached to a wall. II. A person at each end of the same string pulls on it with a force *F*.

Consider the two statements above. Which statement below is true?

a) The tension at the center of the string is zero

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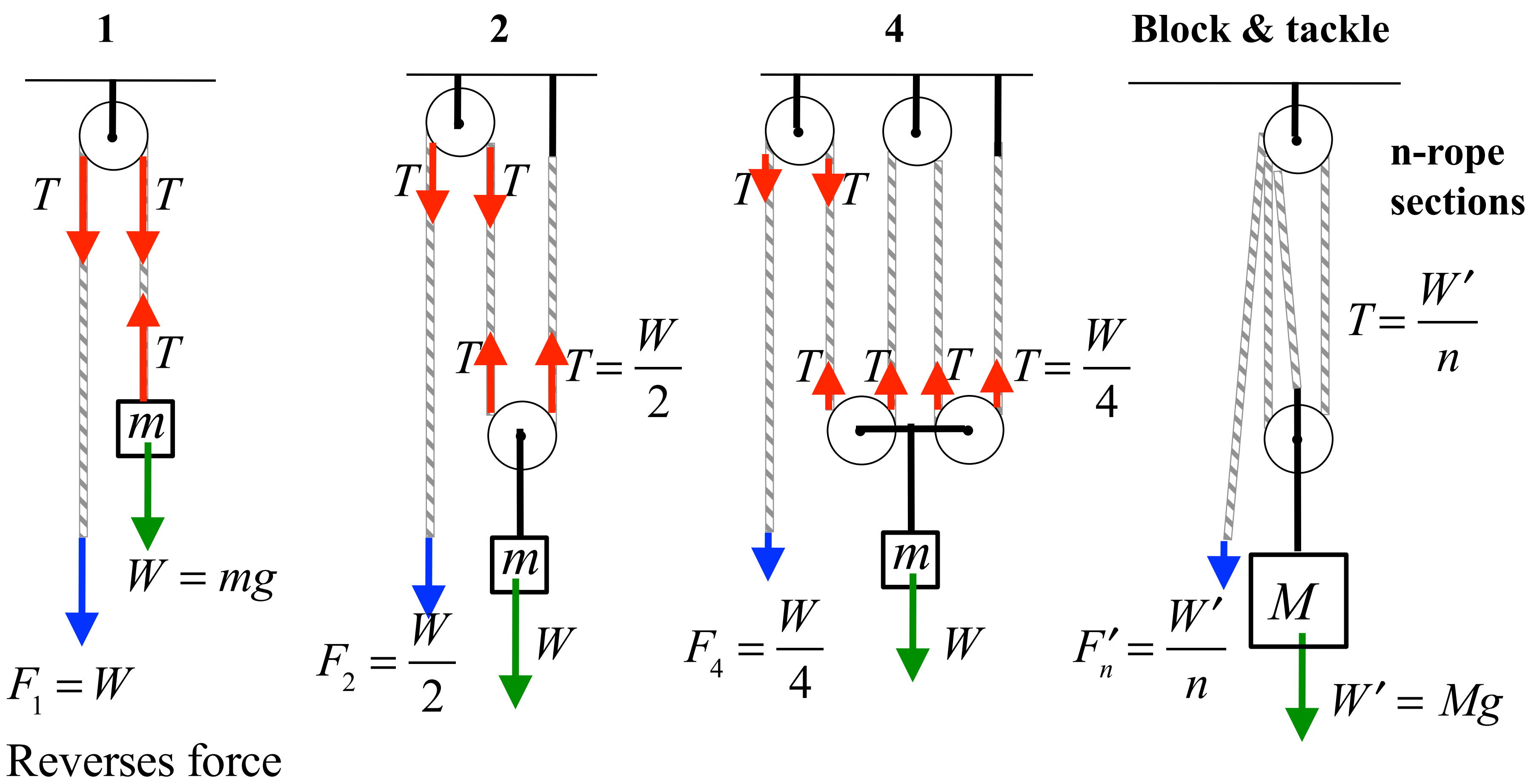
4.11 Equilibrium Application of Newton's Laws of Motion

Pulleys (massless, frictionless)

1. **Tension magnitdue is the same at every location on the rope.**
2. **The same tension acts on object at each end of each *section* of rope**

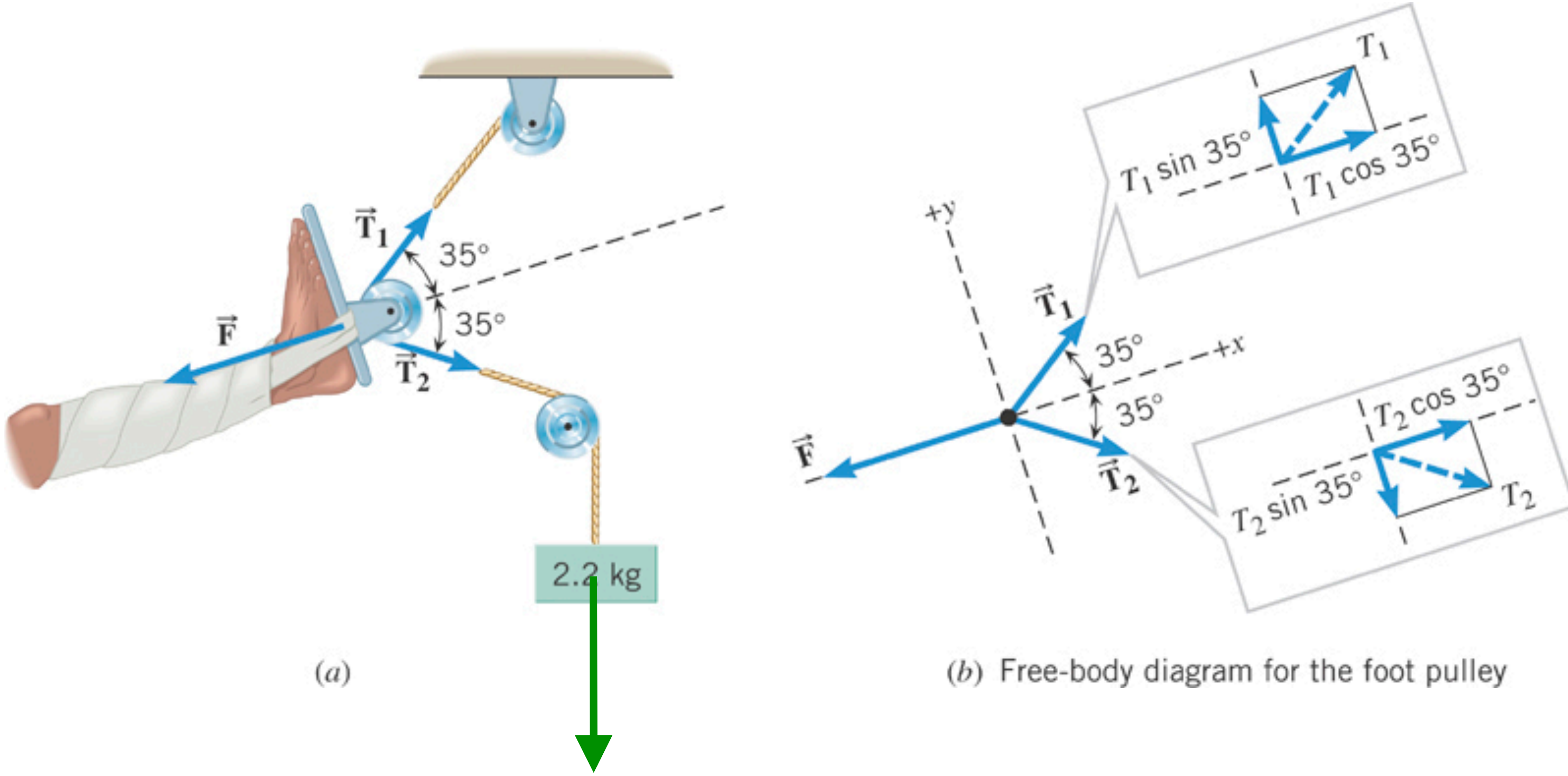
Cases with mass at rest (force vectors labeled with *magnitude*)

 # = number of rope sections supporting the weight of the mass



4.11 Equilibrium Application of Newton's Laws of Motion

Equilibrium requires net force = zero, in every direction (x and y)



(a)

(b) Free-body diagram for the foot pulley

1) $T = W = mg$

2) Net force vector $= 0$

3) Use x direction along leg

4) y is perpendicular to x

$T_1 = T_2 = T = mg$ (rope and pulleys insure this)

$x: \quad +T\cos 35^\circ + T\cos 35^\circ - F = 0$

$F = 2mg\cos 35^\circ = 2(2.2\text{ kg})(9.8\text{ m/s}^2)(.82)$

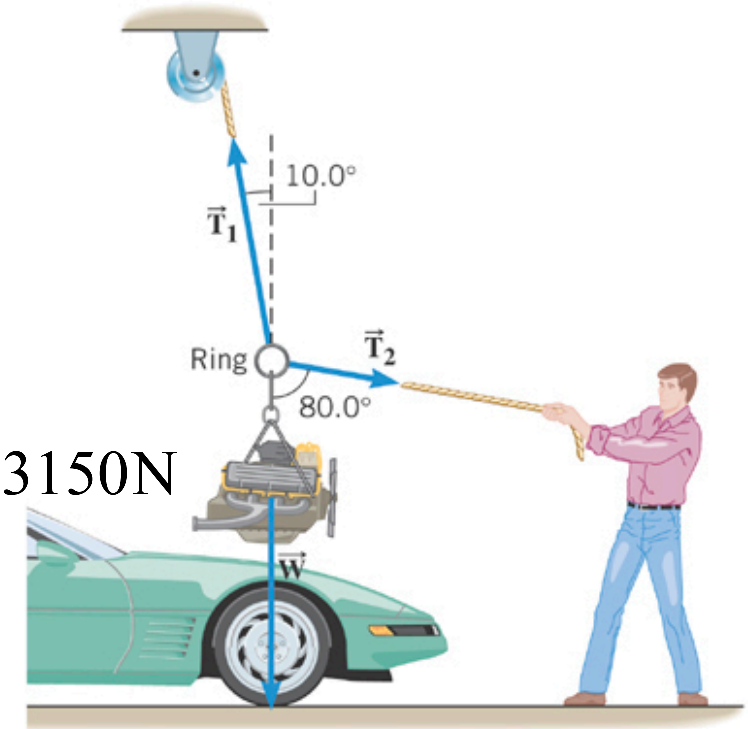
$= 35\text{ N}$

4.11 Equilibrium Application of Newton's Laws of Motion

$$x: T_1 \sin 10° - T_2 \sin 80° = 0$$

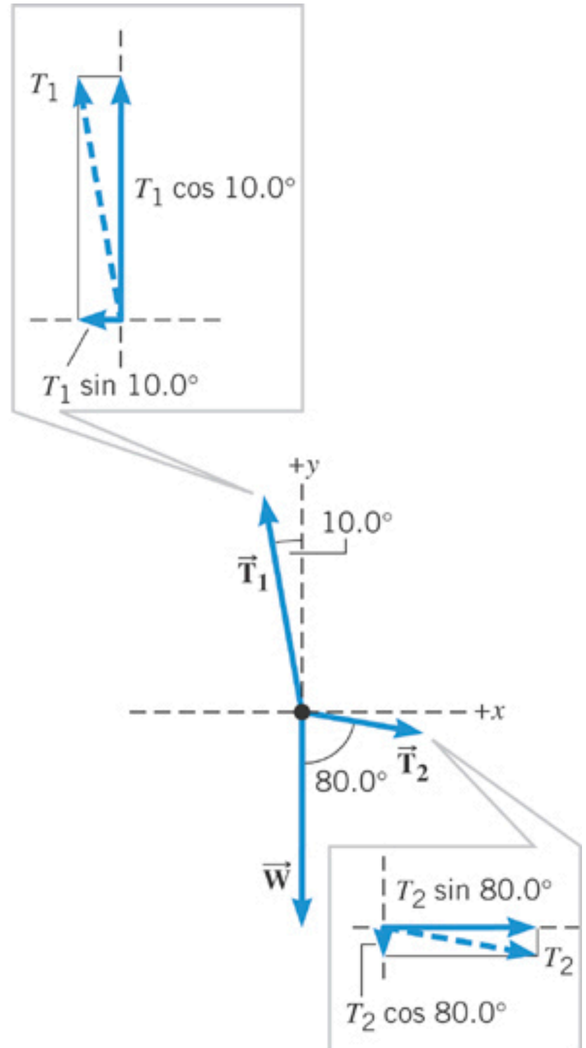
$$y: T_1 \cos 10° - mg - T_2 \cos 80° = 0$$

from x, solve for $T_1 = T_2 \sin 80° / \sin 10°$



$$W = mg = 3150\text{N}$$

(a)



(b) Free-body diagram for the ring

from y, solve for T_2

$$T_2 = mg \big/ \left[\cos 10° \sin 80° / \sin 10° - \cos 80° \right] = 580\text{N}, \ T_1 = 3300\text{N}$$

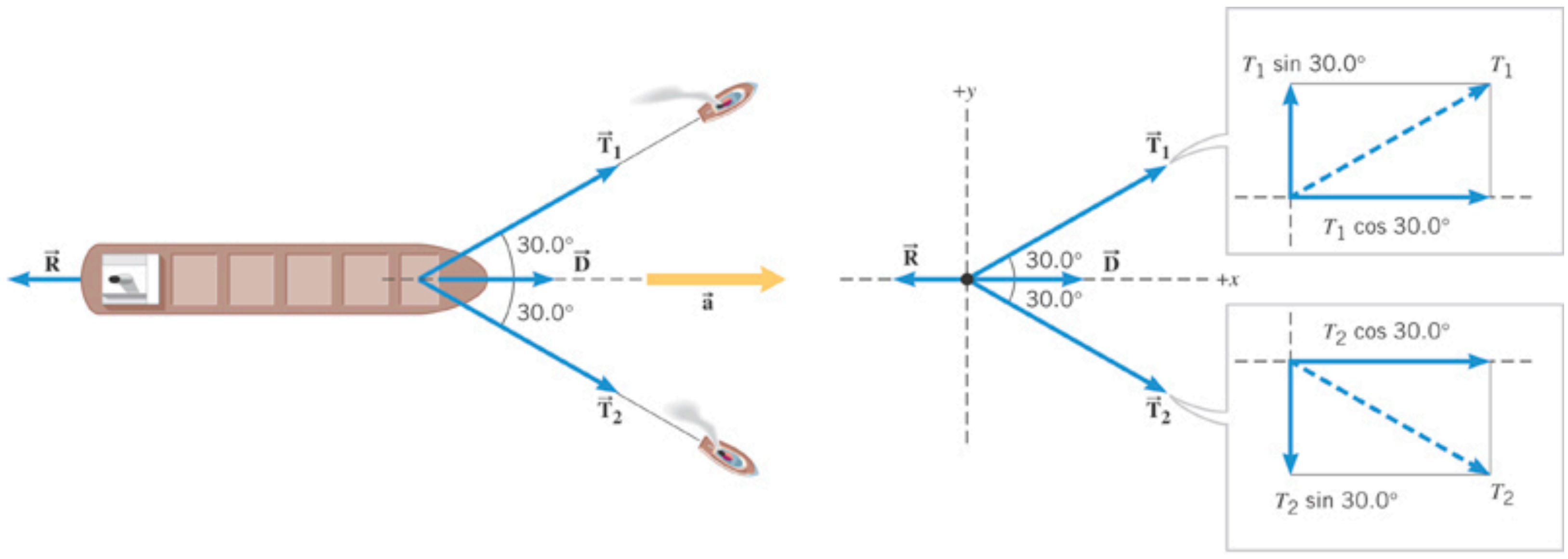
4.12 Nonequilibrium Application of Newton's Laws of Motion

When an object is accelerating, it is not in equilibrium.

$$\sum F_x = ma_x$$

$$\sum F_y = ma_y$$

4.12 Nonequilibrium Application of Newton's Laws of Motion



(b) Free-body diagram for the tanker

The acceleration is only along the *x* axis :

$$a_x = 2.00 \times 10^{-3}\,\mathrm{m/s^2}$$

$$a_y = 0$$

$$y : T_1 = T_2 = T \text{ to make } a_y = 0$$

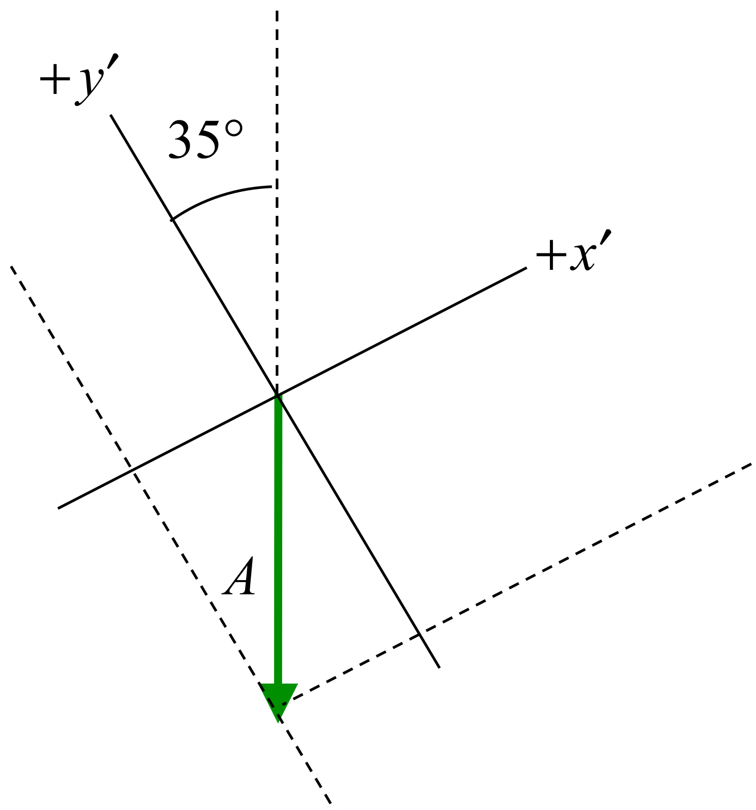
$$x : 2T\cos 30° + D - R = ma_x$$

$$T = \left(ma_x - D + R\right) / \left(2\cos 30°\right) = 1.53 \times 10^5 \text{ N}$$

Review Chapters 1-4

Units, Scalars, Vectors
Vector decomposition and vector addition.

Vector A points directly downward. What are the two components of the vector A along the axes rotated by 35° from the (x,y) axes.



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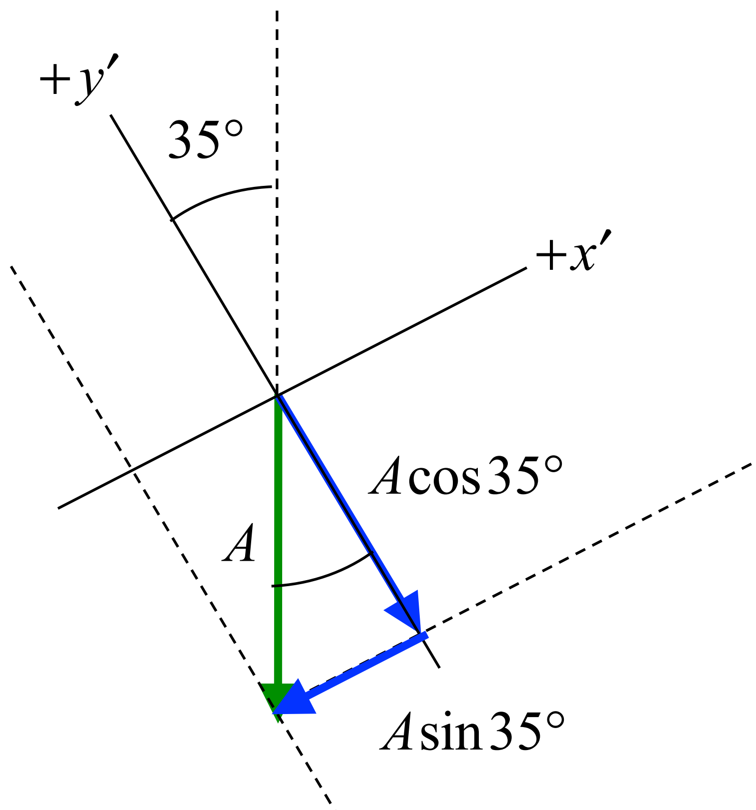

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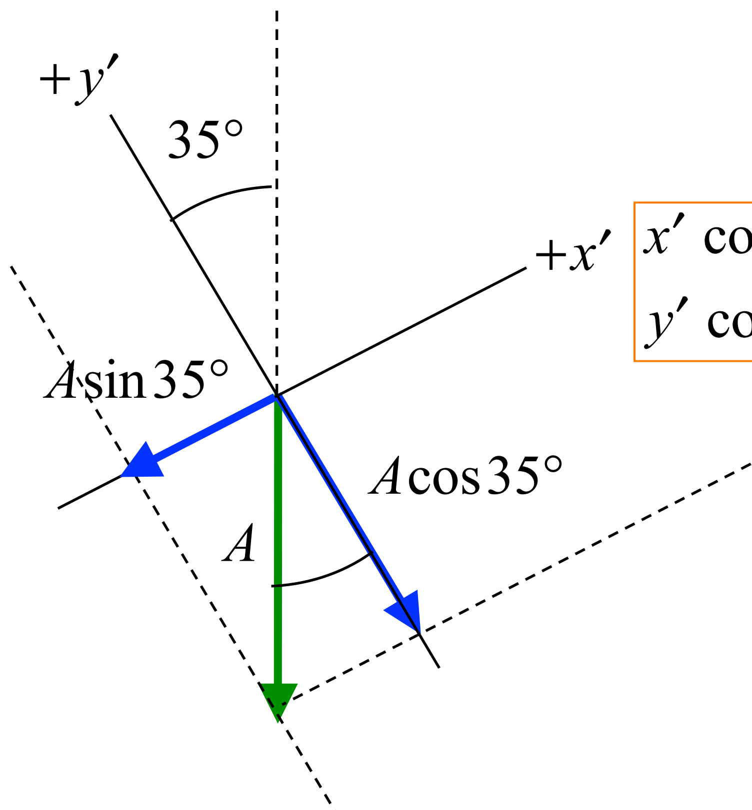


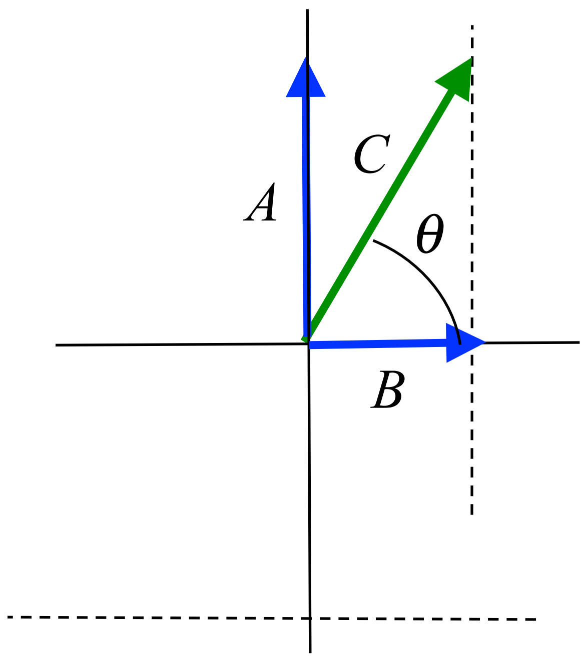
x' component : $A\sin 35°$

y' component : $A\cos 35°$

Review Chapters 1-4

Units, Scalars, Vectors
Vector addition and vector decomposition.

Vector A points along +*y* and vector B points along +*x* . What is the magnitude and direction of vector C = A + B?



$$C = \sqrt{A^2 + B^2}; \quad \theta = \tan^{-1}\left(\frac{A}{B}\right)$$

Review Chapters 1-4

Velocity, Acceleration, Displacement, initial values at $t = 0$
1D motion equations for constant acceleration

$$v = v_o + at$$

$$x = \tfrac{1}{2}(v_o + v)t$$

$$v^2 = v_o^2 + 2ax$$

$$x = v_o t + \tfrac{1}{2}at^2$$

$t =$ time relative to the start of the clock ($t = 0$)

$x =$ displacement over the time t

$v_0 =$ velocity at time $t = 0$

$v =$ final velocity after time t or displacement x

$a =$ constant acceleration (typical units: $\mathrm{m/s^2}$)

Review Chapters 1-4

1D motion equations for constant acceleration

Bird runs north at a speed of 13.0 m/s, and slows down to 10.6 m/s in 4.0 seconds. What is the direction of the bird's acceleration? What is the bird's velocity after an additional 2.0 seconds?

$v_0 = +13.0 \text{ m/s, north}$

$t = 0$

$v = +10.6 \text{ m/s}$

$t = 4 \text{ s}$

Review Chapters 1-4

2D motion equations for constant acceleration

Bird runs north at a speed of 13.0 m/s, and slows down to 10.6 m/s in 4.0 seconds. What is the direction of the bird's acceleration? What is the bird's velocity after an additional 2.0 seconds?

$v_0 = +13.0 \text{ m/s, north}$ $\quad\quad$ $v = +10.6 \text{ m/s}$

$t = 0$ $\quad\quad$ $t = 4 \text{ s}$

$$a = \frac{v - v_0}{t} = \frac{(10.6 - 13.0) \text{ m/s}}{4.0 \text{ s}} = -0.60 \text{ m/s}^2 \text{ (points south)}$$

$$t = (4 + 2) \text{ s} = 6 \text{ s}$$

$$v = v_0 + at = 13.0 \text{ m/s} + (-0.60 \text{ m/s}^2)(6 \text{ s})$$

$$= (13.0 - 3.6) \text{m/s} = 9.4 \text{ m/s}$$

Review Chapters 1-4

2D motion equations for constant acceleration

x-direction

$$v_x = v_{ox} + a_x t$$

$$x = \tfrac{1}{2}\left(v_{ox} + v_x\right)t$$

$$v_x^2 = v_{ox}^2 + 2a_x x$$

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

y-direction

$$v_y = v_{oy} + a_y t$$

$$y = \tfrac{1}{2}\left(v_{oy} + v_y\right)t$$

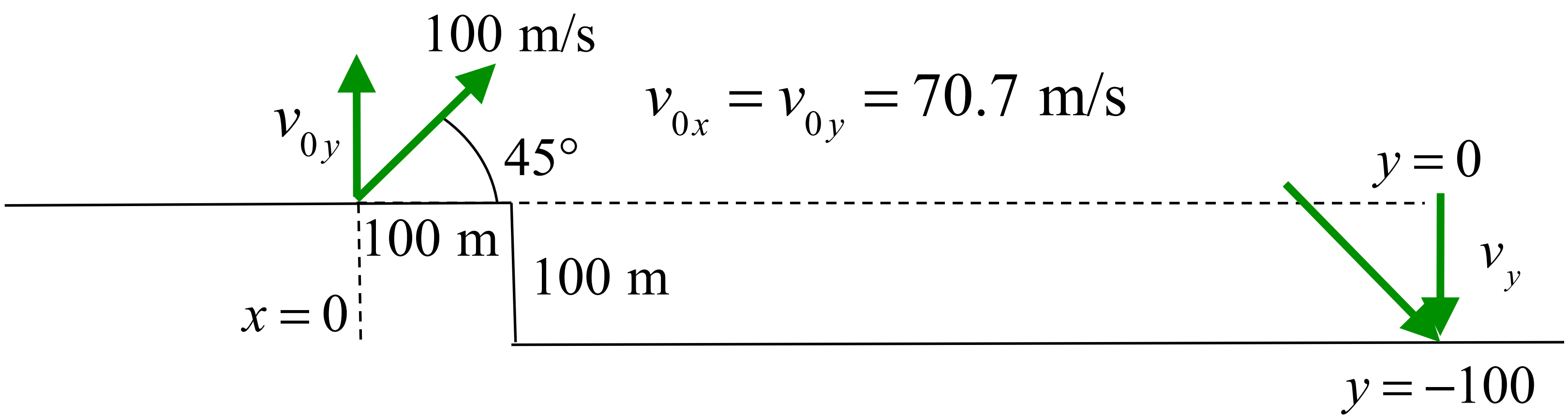
$$v_y^2 = v_{oy}^2 + 2a_y y$$

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

Review Chapters 1-4

2D motion equations for constant acceleration

An projectle is fired at an angle of 45° with respect to the horizontal at a velocity of 100 m/s. There is a 100 m deep cliff, 100 m from the point of release. What is the range of the projectile?



Review Chapters 1-4

2D motion equations for constant acceleration

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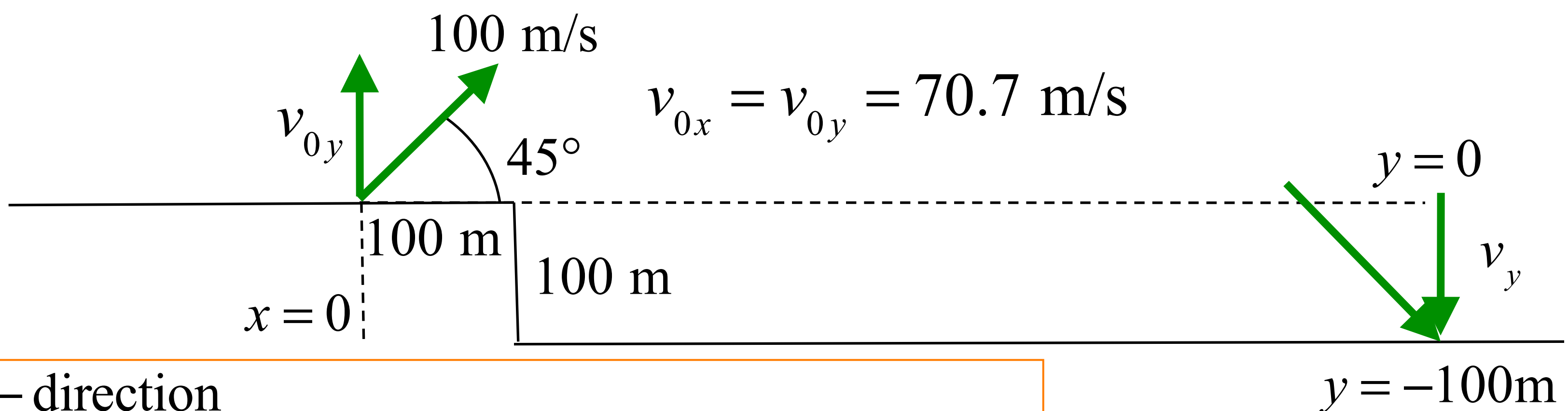


y – direction

$$v_y^2 = v_{0y}^2 - 2gy = (70.7)^2 \text{ m}^2/\text{s}^2 - 2(9.8 \text{ m/s}^2)(-100 \text{ m})$$

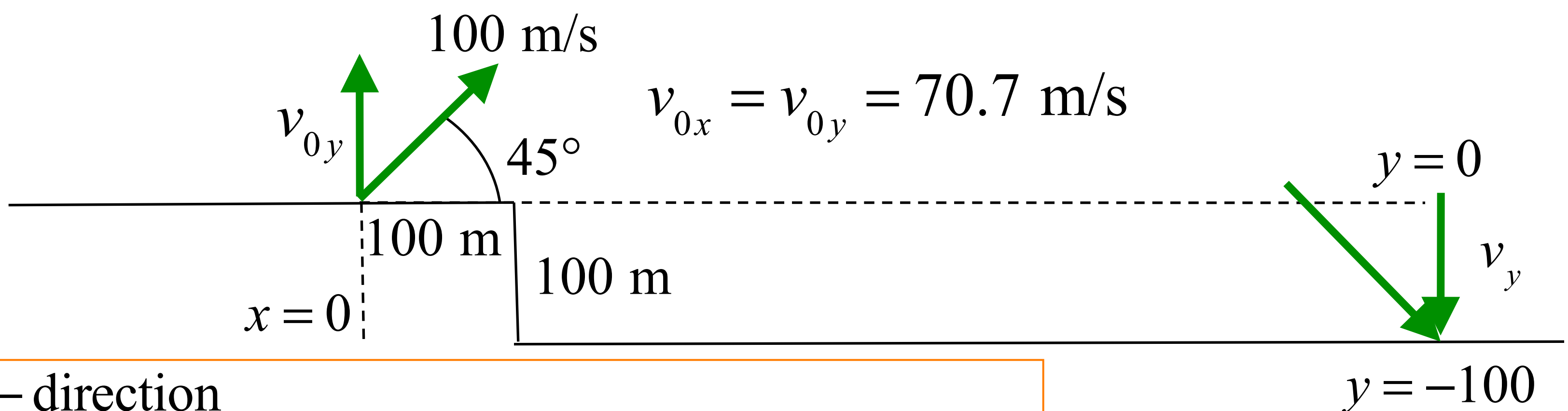
$$v_y = -83.4 \text{ m/s}$$

$$t = \frac{y}{0.5(v_{0y} + v_y)} = \frac{-100 \text{ m}}{0.5(70.7 - 83.4)\text{m/s}} = 15.7 \text{s}$$

Review Chapters 1-4

2D motion equations for constant acceleration

An projectle is fired at an angle of 45° with respect to the horizontal at a velocity of 100 m/s. There is a 100 m deep cliff, 100 m from the point of release. What is the range of the projectile?



$y-$direction

$$v_y^2 = v_{0y}^2 - 2gy = (70.7)^2\ \text{m}^2/\text{s}^2 - 2(9.8\ \text{m/s}^2)(-100\ \text{m})$$

$$v_y = -83.4\ \text{m/s}$$

$$t = \frac{y}{0.5(v_{0y} + v_y)} = \frac{-100\ \text{m}}{0.5(70.7 - 83.4\ )\text{m/s}} = 15.7\text{s}$$

$x-$direction

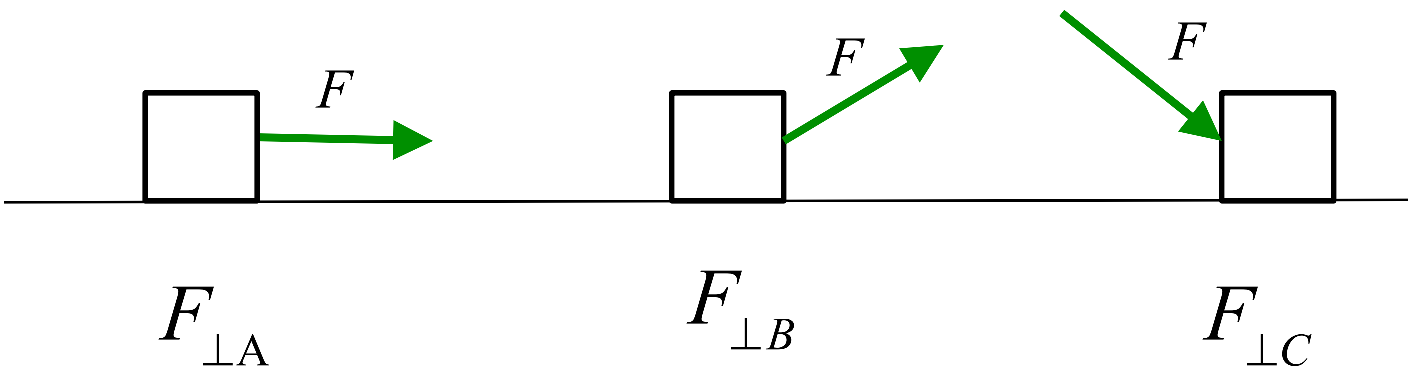
$$x = v_{0x}t = \left(70.7\ \text{m/s}\right)\left(15.7\text{s}\right)$$

$$= 1110\ \text{m}$$

Review Chapters 1-4

Newton's laws of motion
Forces: gravity, tension, compression, normal, static and kinetic friction

A force of magnitude, *F*, acts on three identical blocks. Rank the normal force on the three blocks.



Review Chapters 1-4

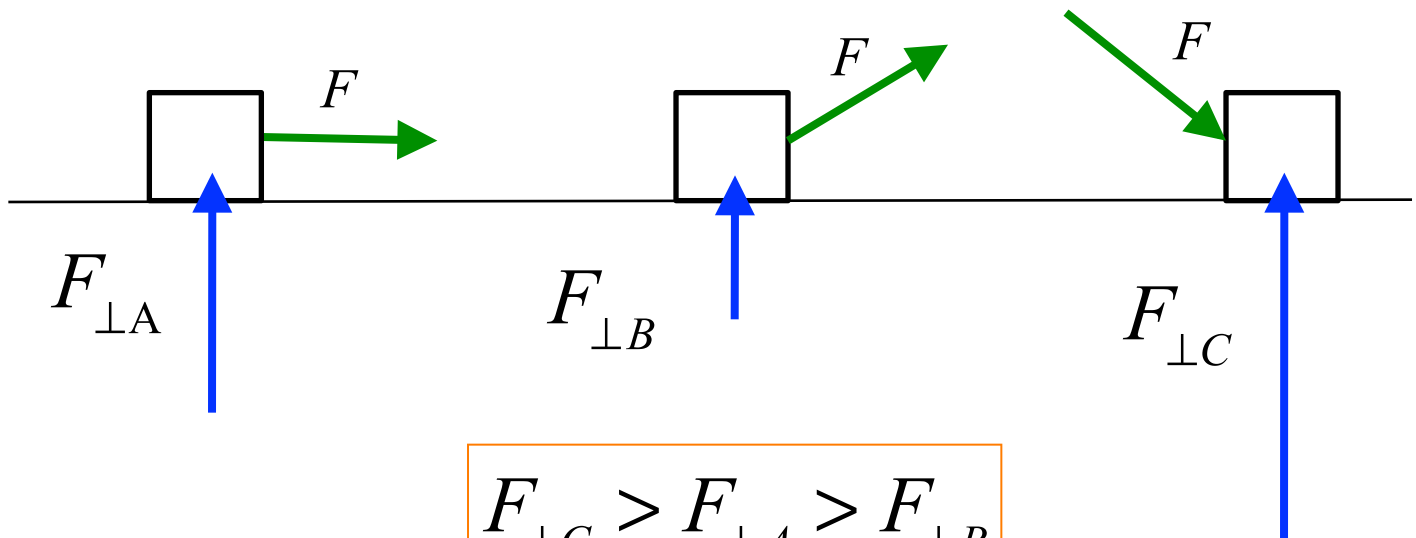
Newton's laws of motion
Forces: gravity, tension, compression, normal, static and kinetic friction

A force of magnitude, *F*, acts on three identical blocks of mass m. Rank the normal force on the three blocks.

F doesn't affect normal force

Adds upward force component to $-mg$

Adds downward force component to $-mg$



$$F_{\perp C} > F_{\perp A} > F_{\perp B}$$

Review Chapters 1-4

Newton's laws of motion
Forces: gravity, tension, compression, normal, static and kinetic friction

There is a graviational force, F, between two masses, m_1 and m_2, at a separation distance of R is F. If the distance between the masses is increased by a factor of 2, what is the effect on the gravitational force?

$$F = G\frac{m_1 m_2}{R^2}; \text{ new } r = 2R$$

$$F' = G\frac{m_1 m_2}{r^2} = G\frac{m_1 m_2}{(2R)^2}$$

$$= G\frac{m_1 m_2}{4R^2} = \frac{1}{4}G\frac{m_1 m_2}{R^2}$$

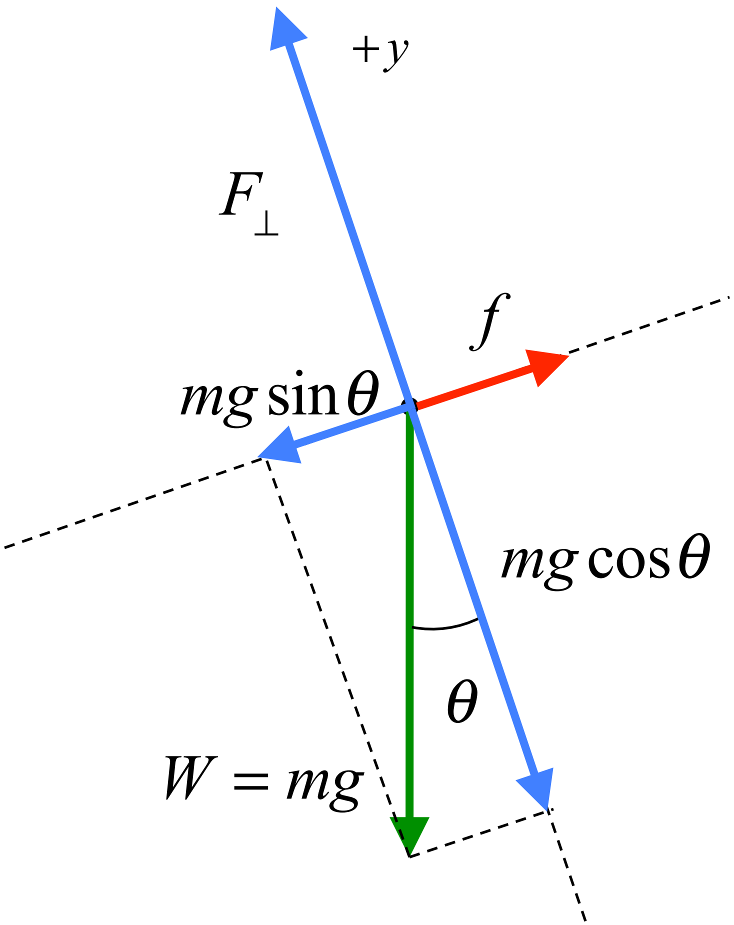
$$= \frac{1}{4}F$$

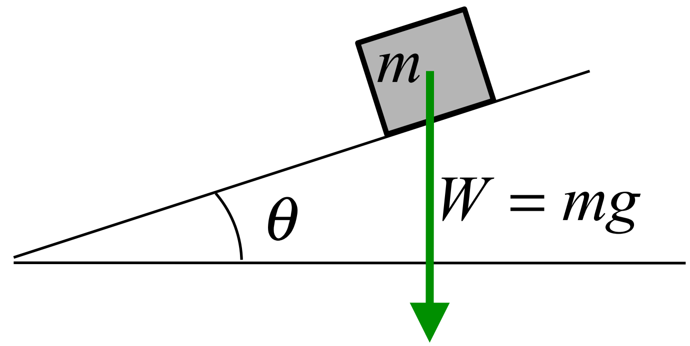
Review Chapters 1-4

Newton's laws of motion

Forces: gravity, tension, compression, normal, static and kinetic friction

A mass *m* rests on a inclined plane with angle θ. If the coefficient of friction is 0.5, at what angle will the mass just begin to slide?





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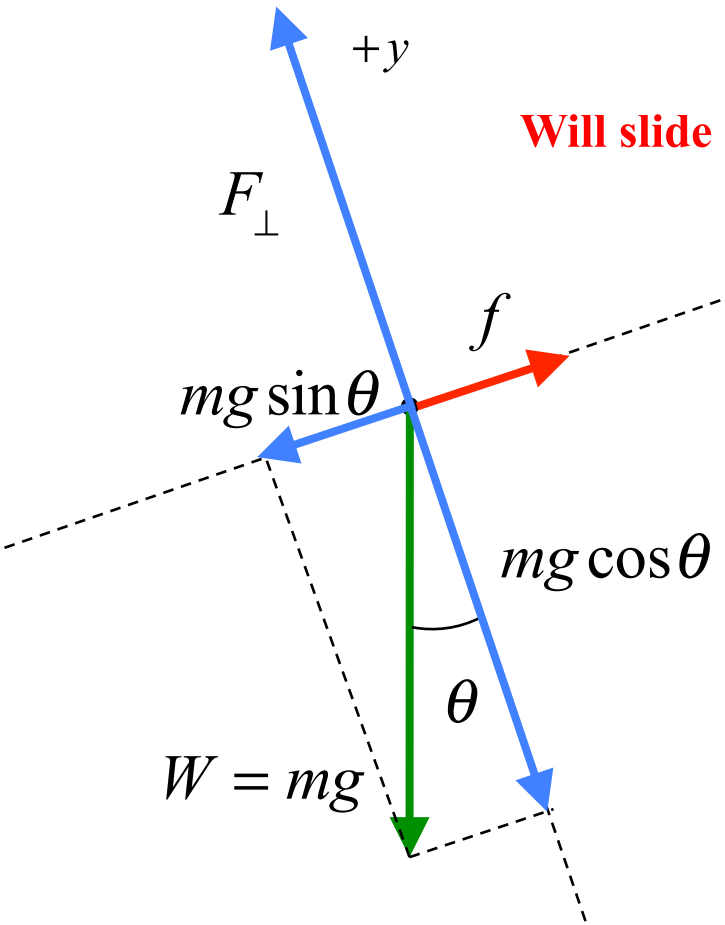
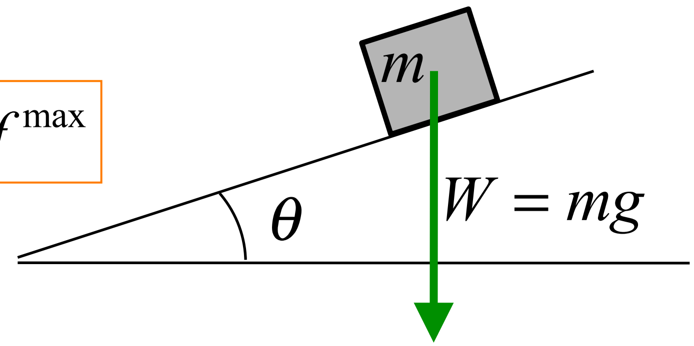


Will slide if $mg\sin\theta > f^{\max}$



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Newton's laws of motion

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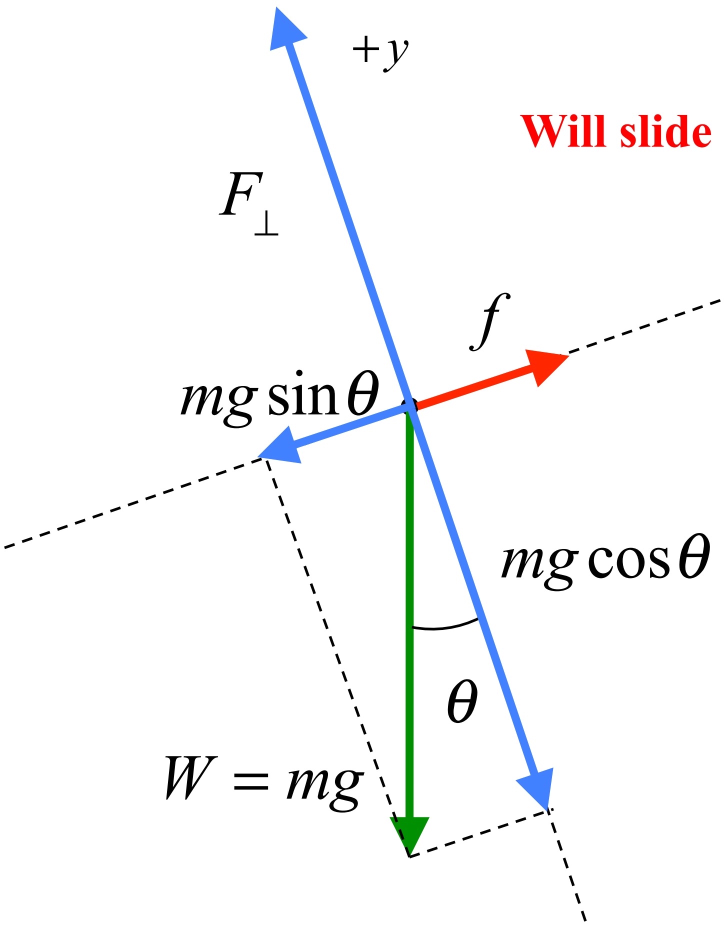

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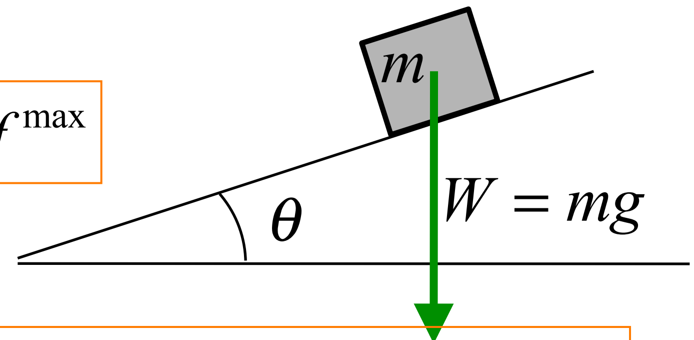


$$f^{\max} = \mu F_{\perp} = \mu mg\cos\theta$$

$$mg\sin\theta > \mu mg\cos\theta$$

$$\mu = \frac{\sin\theta}{\cos\theta} = \tan\theta$$

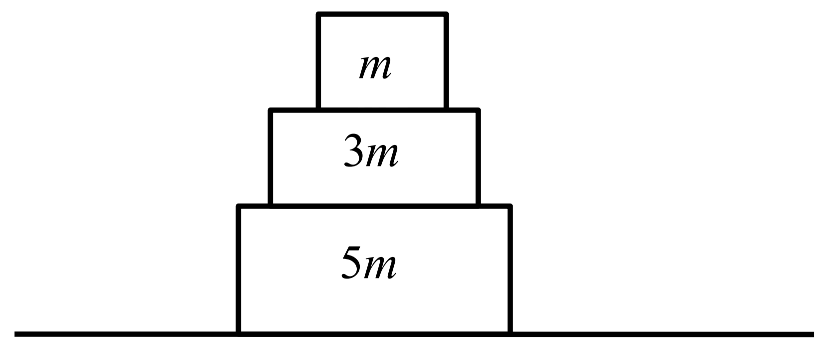
$$\theta = \tan^{-1}\mu = \tan^{-1}0.5$$

$$= 26.5^{\circ}$$

Review Chapters 1-4

Newton's laws of motion
Forces: gravity, tension, compression, normal, static and kinetic friction

Three masses shown are stacked. What is the normal force of the 5*m* mass on the 3*m* mass?



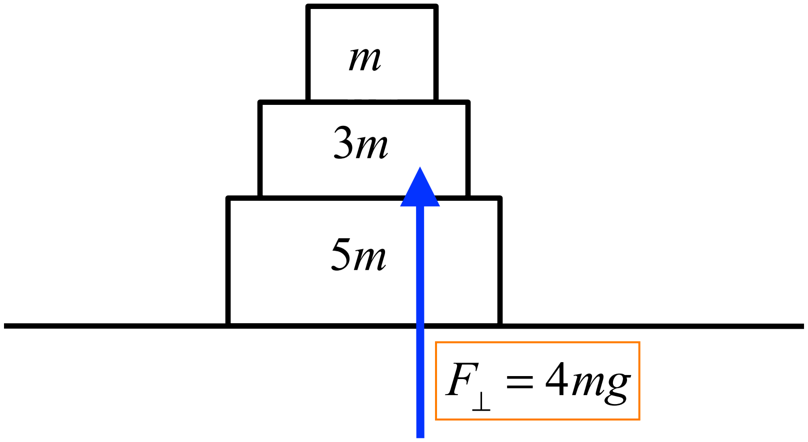
Review Chapters 1-4

Newton's laws of motion
Forces: gravity, tension, compression, normal, static and kinetic friction

Three masses shown are stacked. What is the normal force of the 5*m* mass on the 3*m* mass?

$$F_{\perp} = 3mg + mg = 4mg$$

How does the 5m mass know that there is a 1m mass on top?



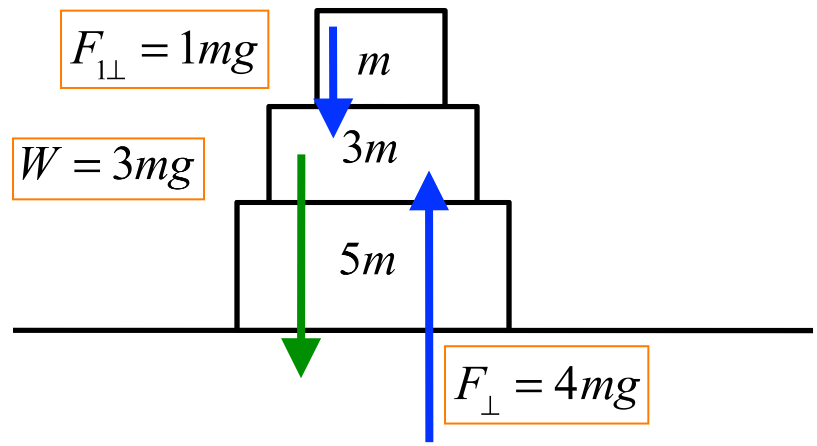
a) **The 5*m* mass can see the 1*m* mass on the top.**
b) **The 1*m* mass pushes down on the 3m mass, & 3m mass has a weight of 3*mg*.**
c) **The 5*m* mass pushes up on the 3m mass and the 3m mass pushes up on 1*m*.**
d) **The 1*m* mass and the 3*m* mass are glued together to make a 4*m* mass.**
e) **All 3 masses must be glued together.**

Review Chapters 1-4

Newton's laws of motion
Forces: gravity, tension, compression, normal, static and kinetic friction

Three masses shown are stacked. What is the normal force of the 5*m* mass on the 3*m* mass?

$$F_{\perp} = 3mg + mg = 4mg$$



How does the 5m mass know that there is a 1m mass on top?

a) **The 5*m* mass can see the 1*m* mass on the top.**
b) **The 1*m* mass pushes on the 3m mass, and the 3m mass has a weight of 3*mg*.**
c) **The 5*m* mass pushes up on the 3m mass and the 3m mass pushes up on 1*m*.**
d) **The 1*m* mass and the 3*m* mass are glued together to make a 4*m* mass.**
e) **All 3 masses must be glued together.**