

Chapter 4

Forces and Newton's Laws of Motion

continued

Quiz 4

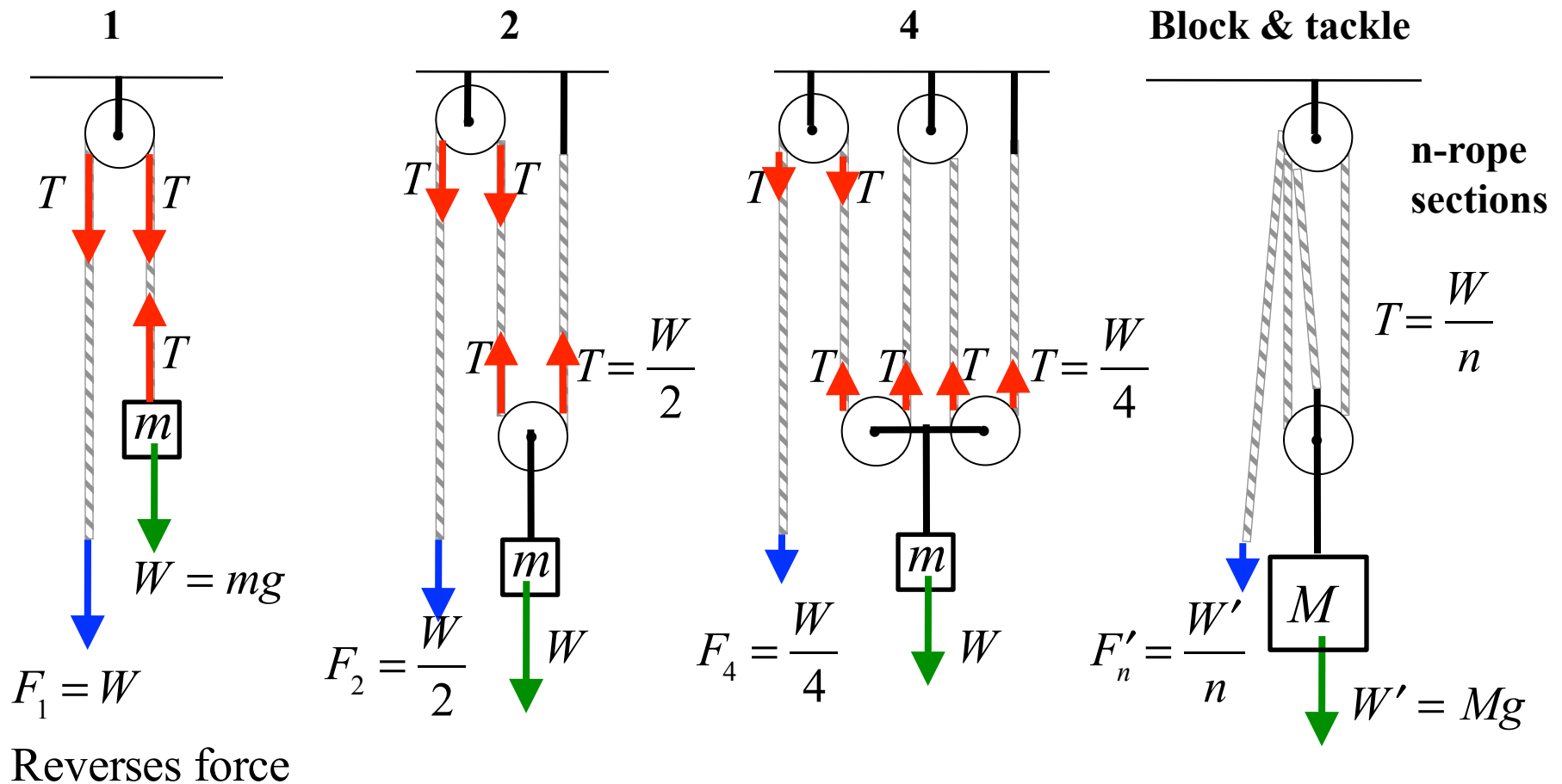
4.11 Equilibrium Application of Newton's Laws of Motion

Pulleys (massless, frictionless)

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

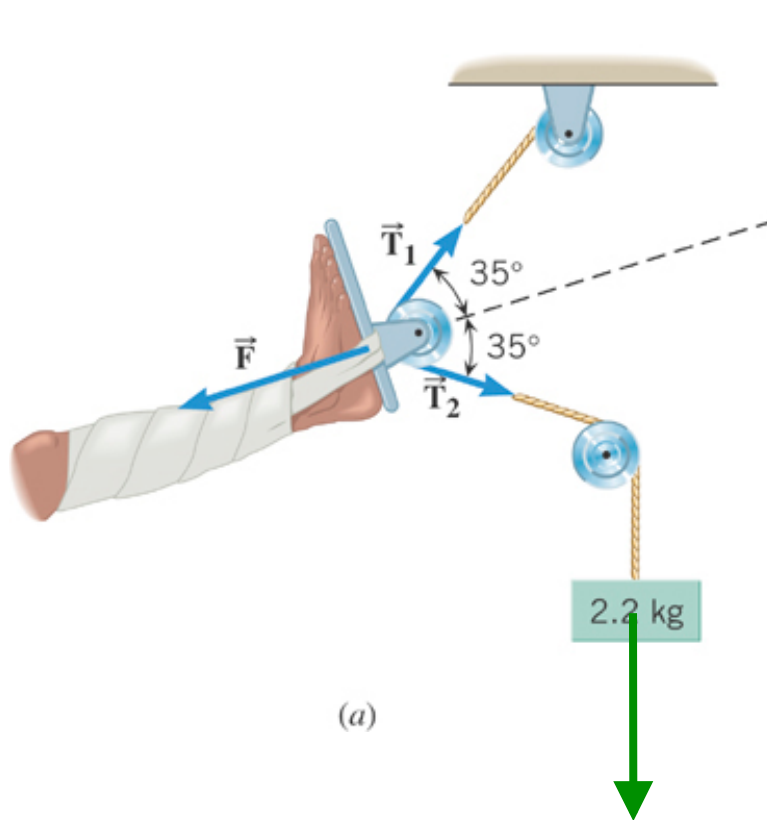
Cases with mass at rest (force vectors labeled with *magnitude*)

= number of rope sections supporting the weight of the mass

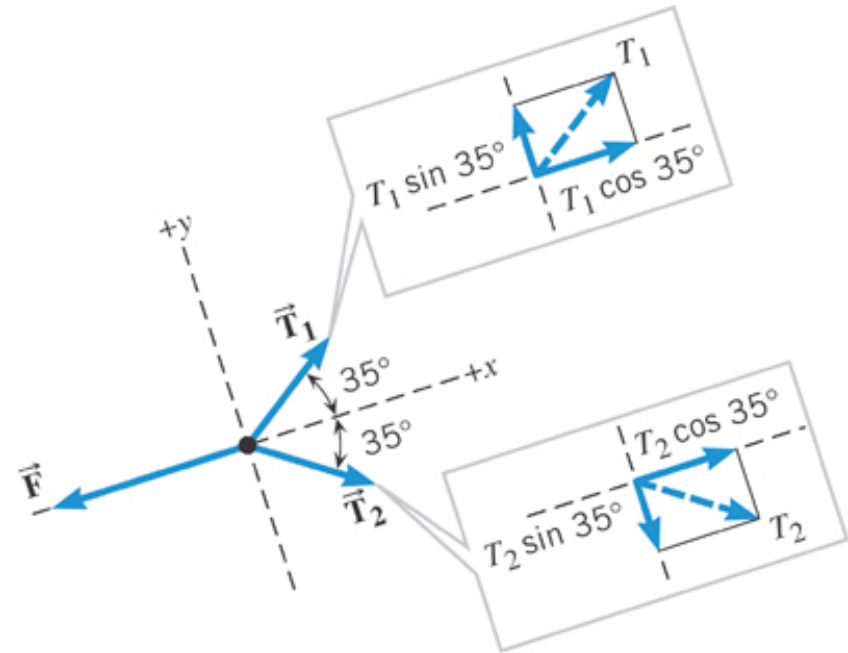


4.11 Equilibrium Application of Newton's Laws of Motion

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



(a)



(b) Free-body diagram for the foot pulley

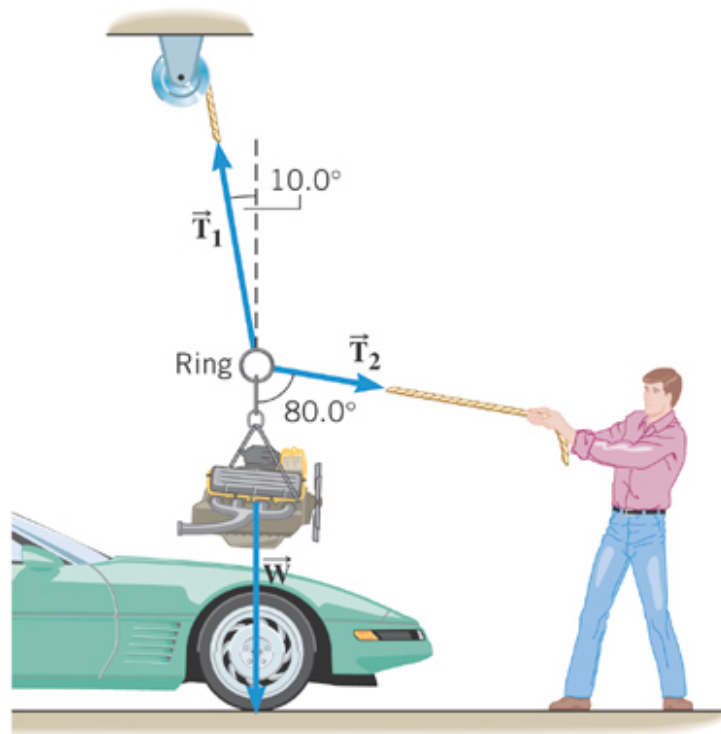
- 1) $T = W = mg$ $T_1 = T_2 = T = mg$ (rope and pulleys insure this)
- 2) Net force vector = 0 $x: +T \cos 35^\circ + T \cos 35^\circ - F = 0$
- 3) Use x direction along leg $F = 2mg \cos 35^\circ = 2(2.2 \text{ kg})(9.8 \text{ m/s}^2)(.82)$
- 4) y is perpendicular to x $= 35 \text{ N}$

4.11 Equilibrium Application of Newton's Laws of Motion

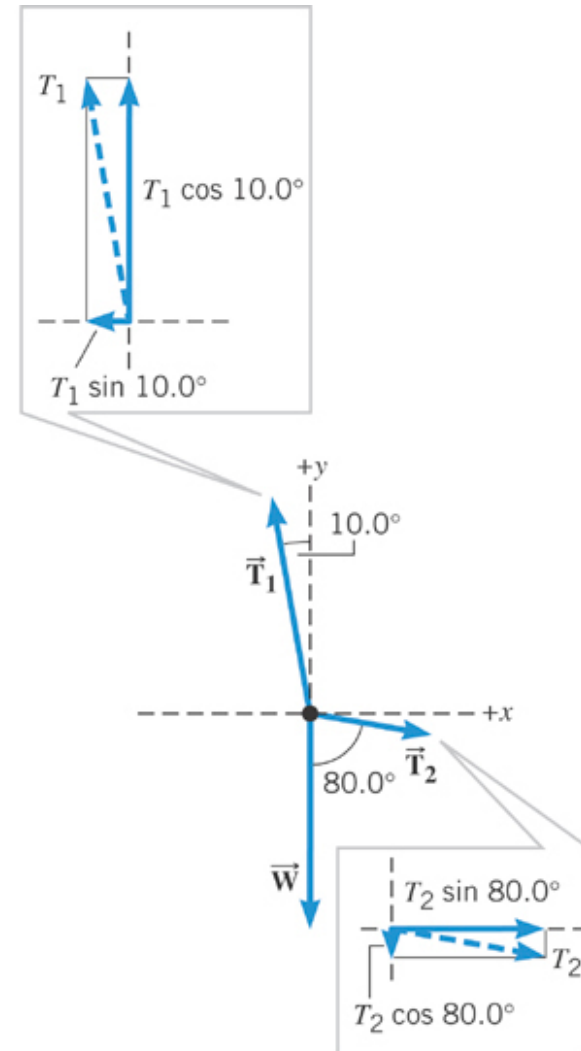
$$x : T_1 \sin 10^\circ - T_2 \sin 80^\circ = 0$$

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

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



(a)



(b) Free-body diagram for the ring

from y , solve for T_2

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

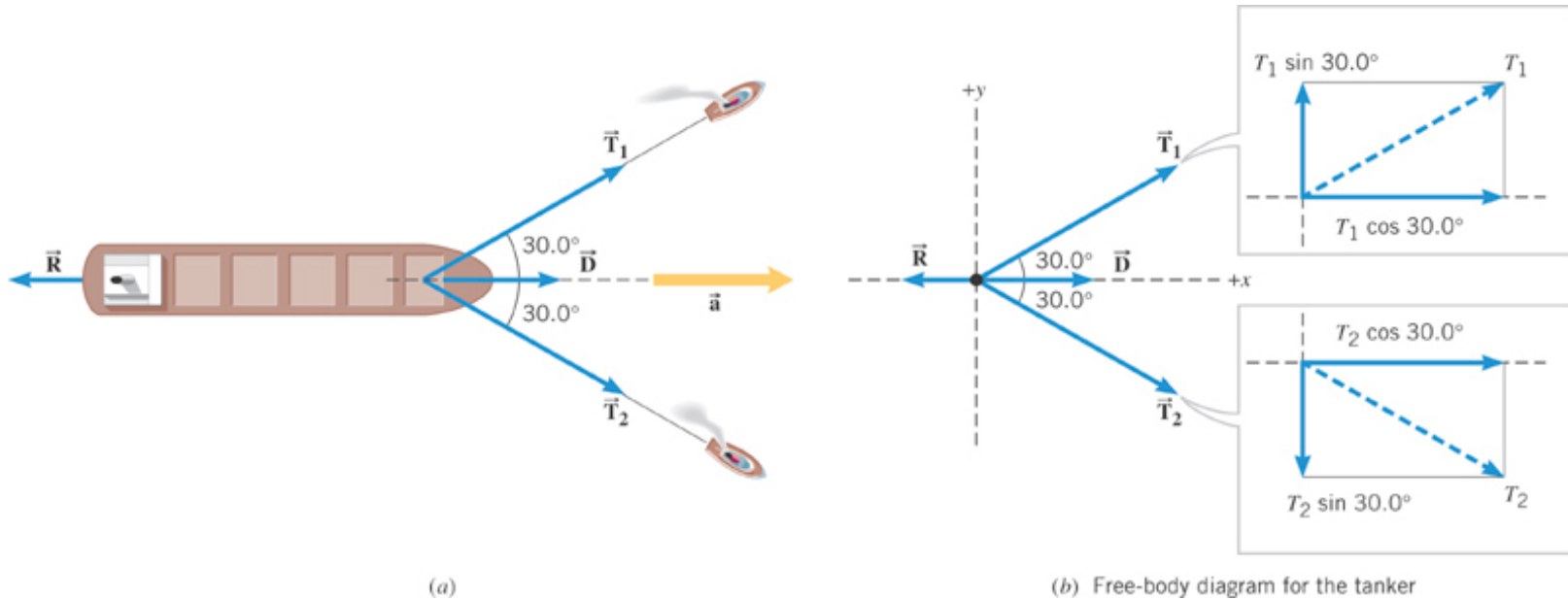
4.12 *Nonequilibrium Application of Newton's Laws of Motion*

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



$$a_x = 2.00 \times 10^{-3} \text{ m/s}^2$$
$$a_y = 0$$

The acceleration is only along the x axis :

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

$$x: 2T \cos 30^\circ + D - R = ma_x$$

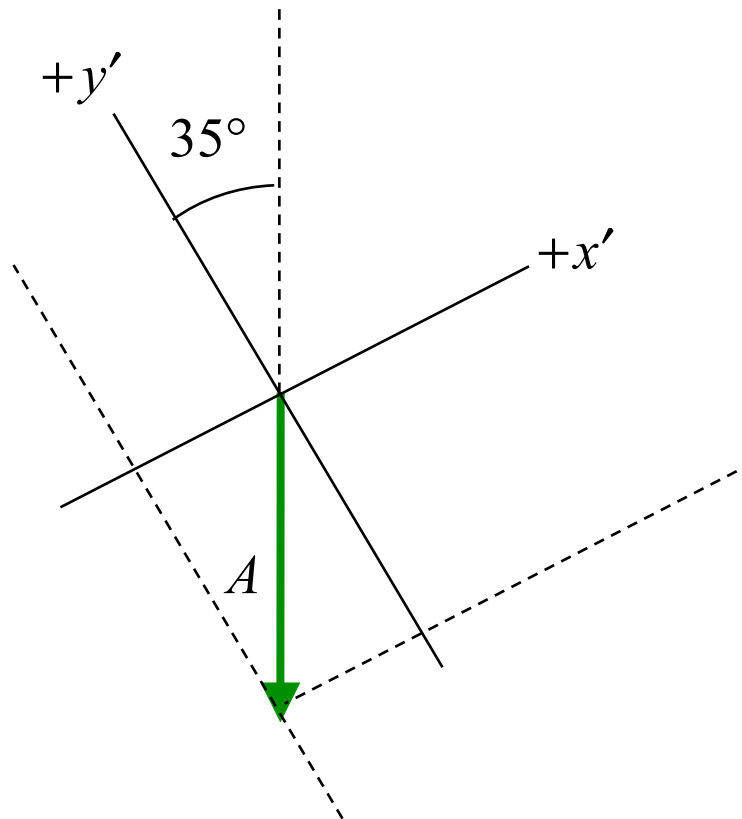
$$T = (ma_x - D + R) / (2 \cos 30^\circ) = 1.53 \times 10^5 \text{ N}$$

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.

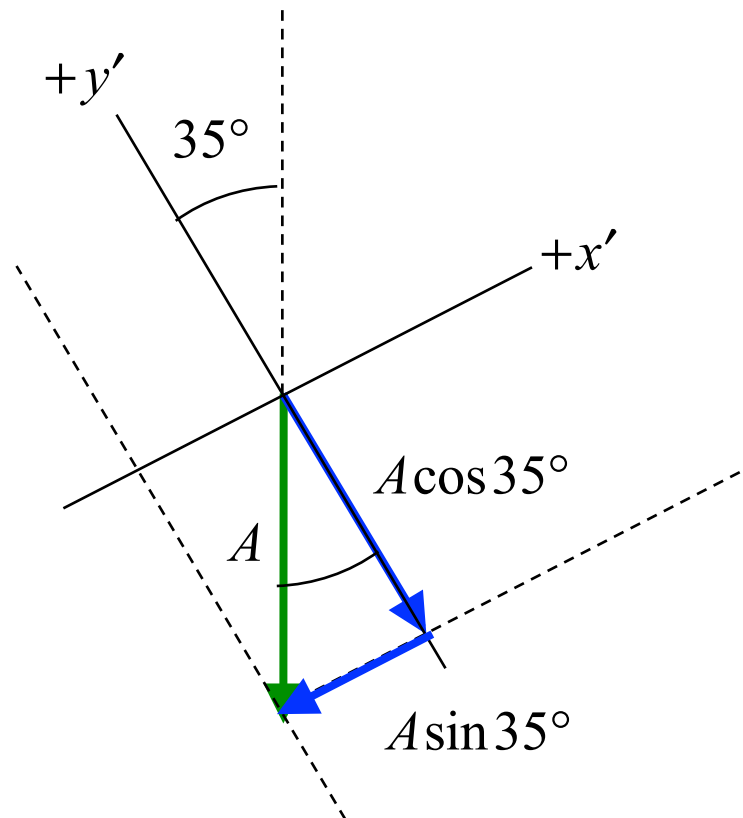


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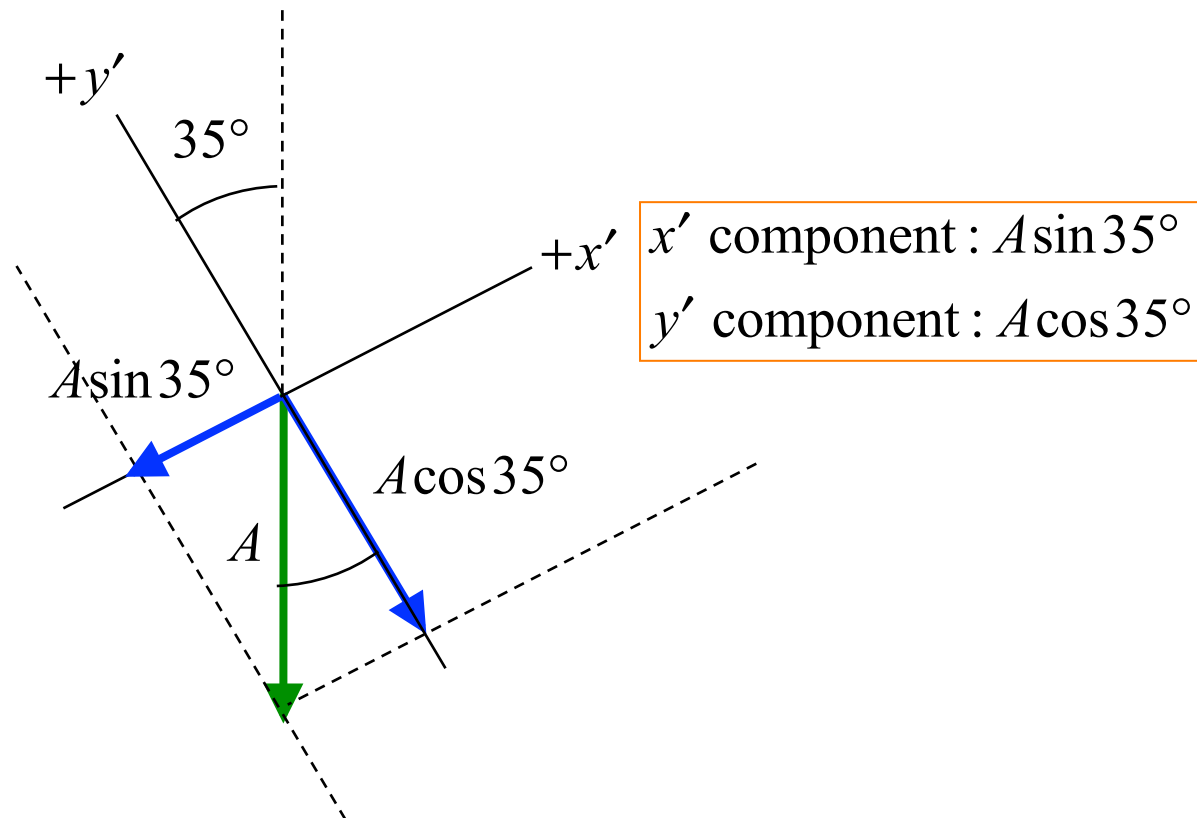


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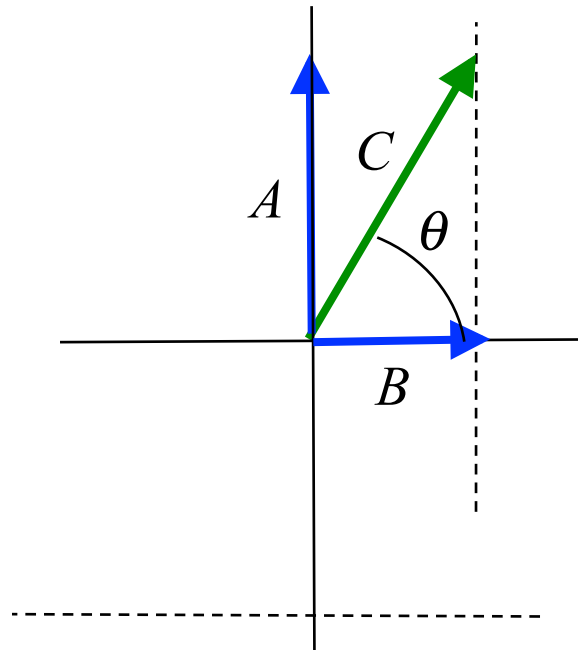


Review Chapters 1-4

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

$$v = v_o + at$$

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

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

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

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

x = displacement over the time t

v_o = velocity at time $t = 0$

v = final velocity after time t or displacement x

a = constant acceleration (typical units: 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?

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

$$t = 0$$



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

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



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

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

$$\begin{aligned} v &= v_0 + at = 13.0 \text{ m/s} + (-0.60 \text{ m/s}^2)(6 \text{ s}) \\ &= (13.0 - 3.6) \text{ m/s} = 9.4 \text{ m/s} \end{aligned}$$

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?

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

$$t = 0 \quad \longrightarrow$$

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

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

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

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Review Chapters 1-4

2D motion equations for constant acceleration

x-direction

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

$$x = \frac{1}{2}(v_{ox} + v_x)t$$

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

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

y-direction

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

$$y = \frac{1}{2}(v_{oy} + v_y)t$$

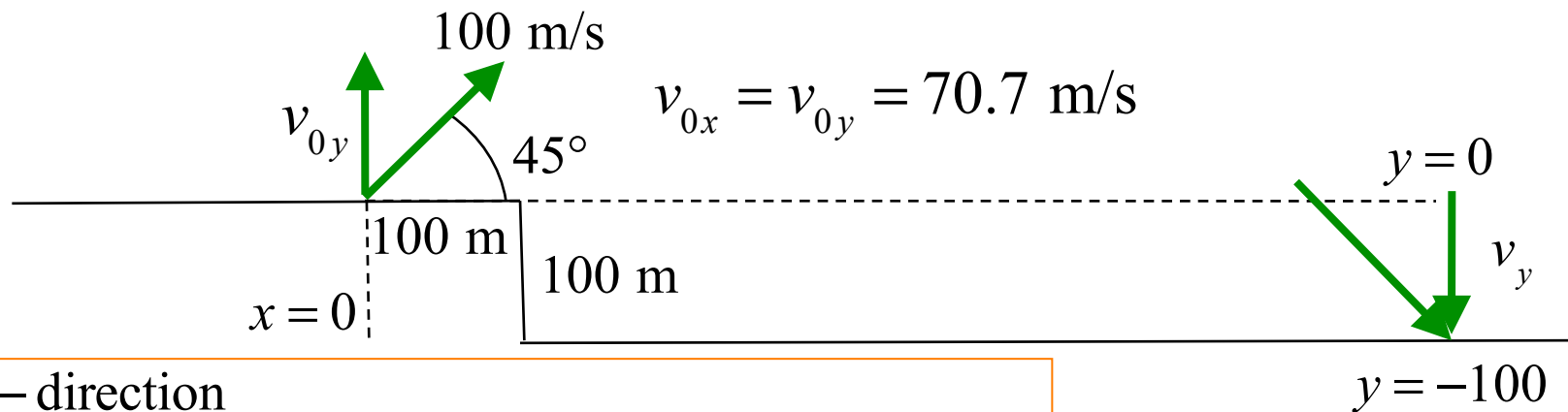
$$v^2 = v_{oy}^2 + 2a_y y$$

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

Review Chapters 1-4

2D motion equations for constant acceleration

An projectile 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

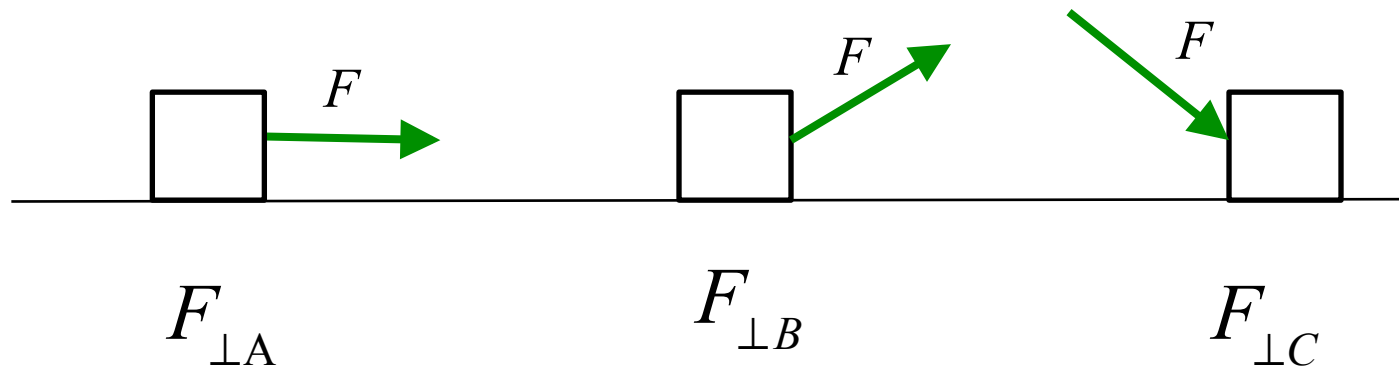
$$x = v_{0x}t = (70.7 \text{ m/s})(15.7 \text{ s}) = 1110 \text{ m}$$

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.

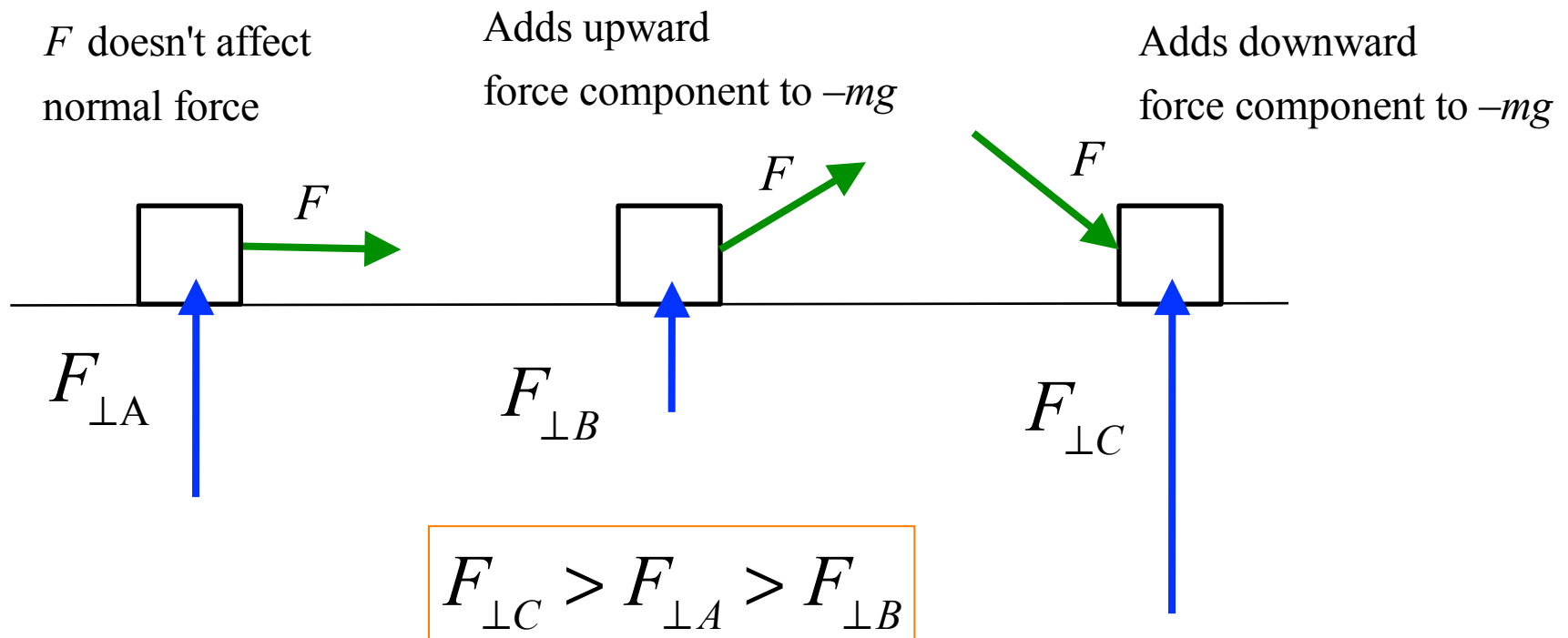


Review Chapters 1-4

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.



Review Chapters 1-4

Newton's laws of motion

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

There is a gravitational 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?

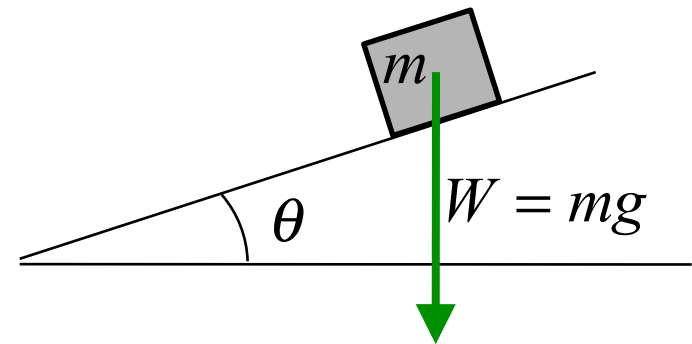
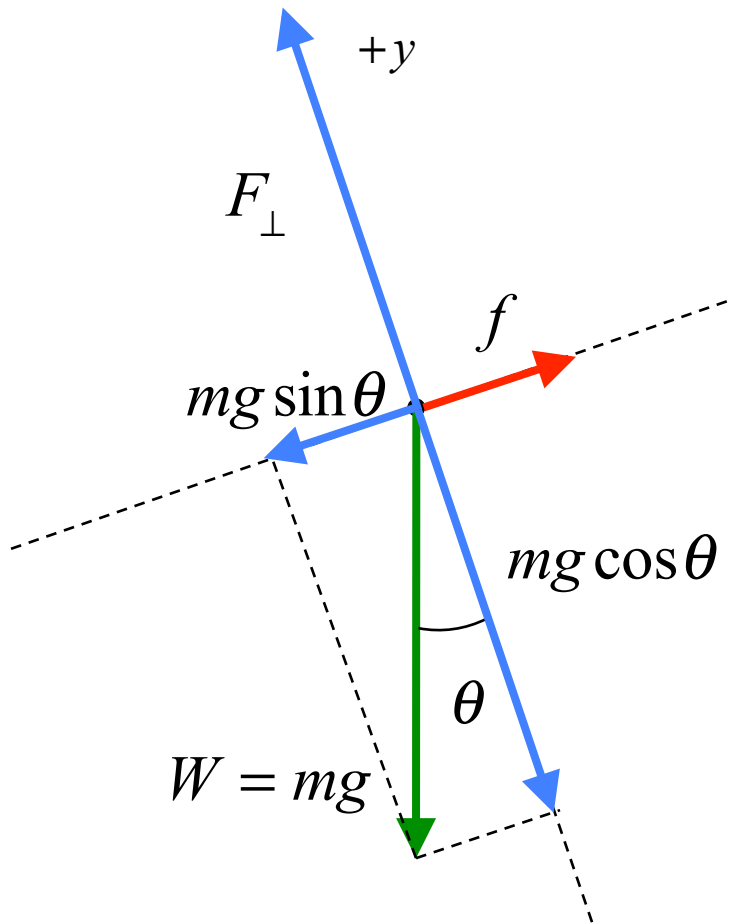
$$\begin{aligned} F &= G \frac{m_1 m_2}{R^2}; \text{ new } r = 2R \\ F' &= G \frac{m_1 m_2}{r^2} = G \frac{m_1 m_2}{(2R)^2} \\ &= G \frac{m_1 m_2}{4R^2} = \frac{1}{4} G \frac{m_1 m_2}{R^2} \\ &= \frac{1}{4} F \end{aligned}$$

Review Chapters 1-4

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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?

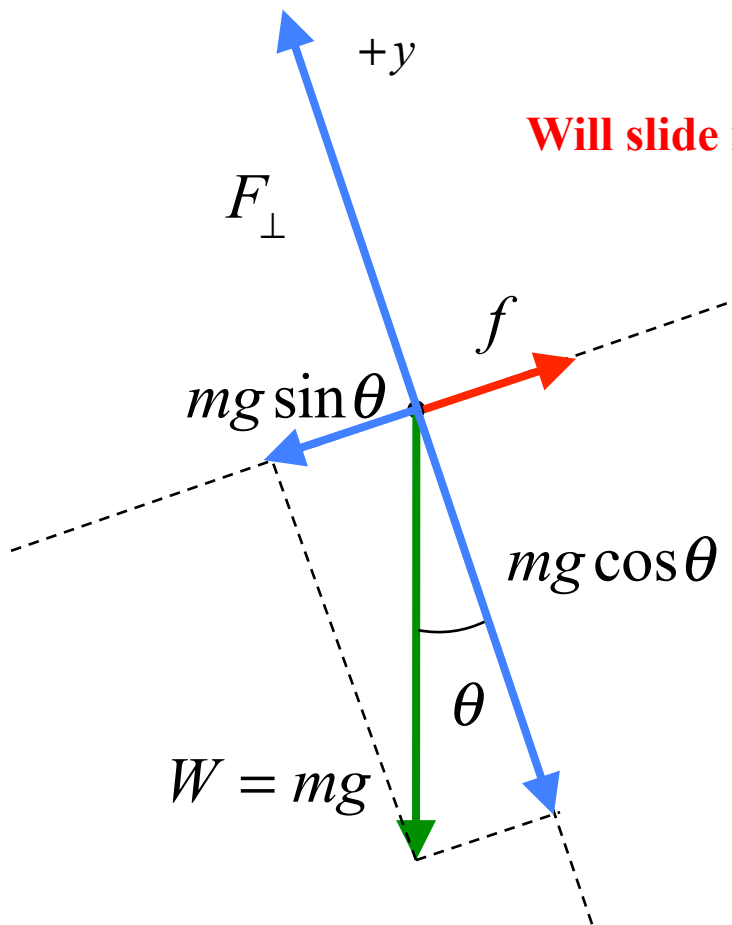


Review Chapters 1-4

Newton's laws of motion

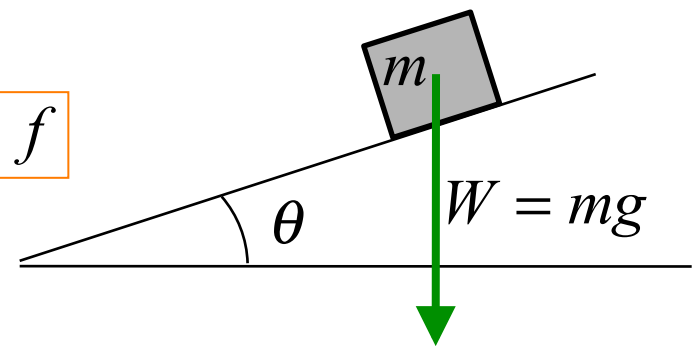
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Will slide if

$$mg \sin \theta > f$$

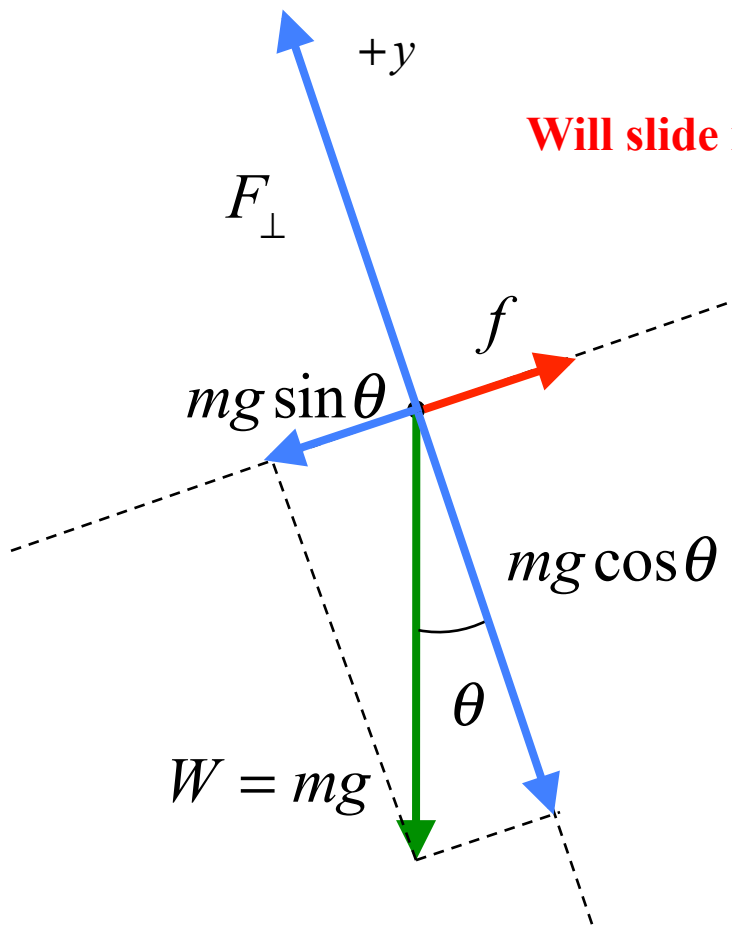


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Newton's laws of motion

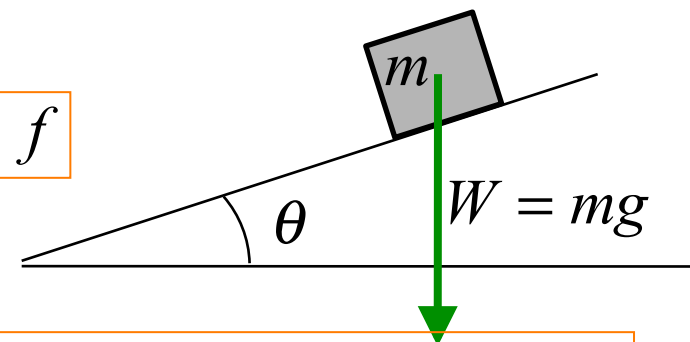
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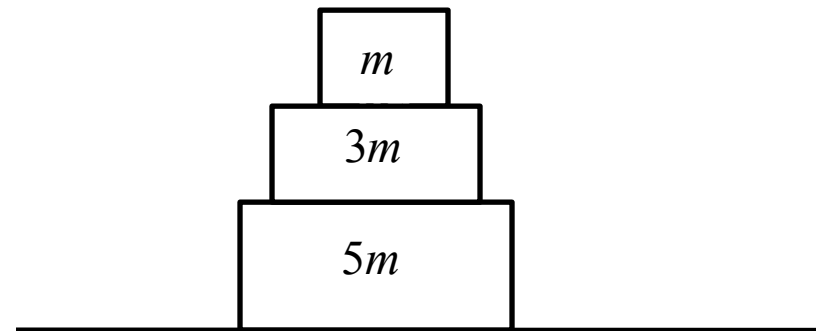
$$\begin{aligned} f &= \mu F_{\perp} = \mu mg \cos \theta \\ mg \sin \theta &> \mu mg \cos \theta \\ \mu &= \frac{\sin \theta}{\cos \theta} = \tan \theta \\ \theta &= \tan^{-1} \mu = \tan^{-1} 0.5 \\ &= 26.5^{\circ} \end{aligned}$$

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 $5m$ mass on the $3m$ mass?



Review Chapters 1-4

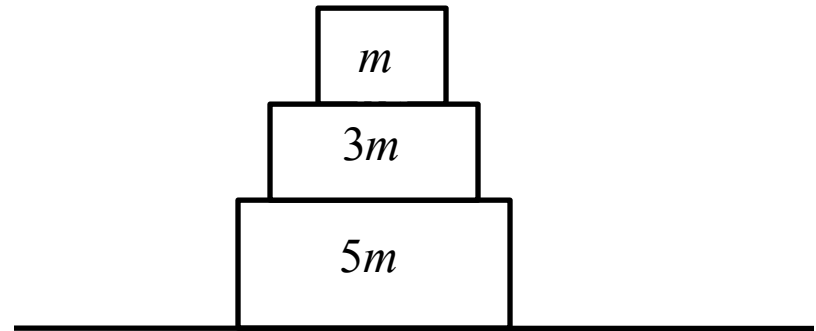
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Three masses shown are stacked. What is the normal force of the $5m$ mass on the $3m$ mass?

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

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



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

Review Chapters 1-4

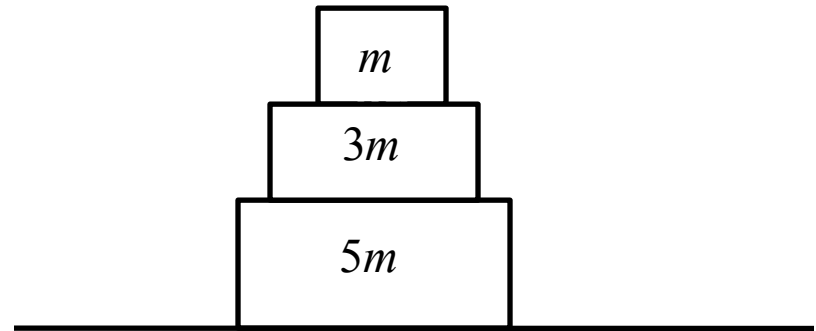
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