Chapter 4

Forces and Newton's Laws of Motion

continued

Quiz 4

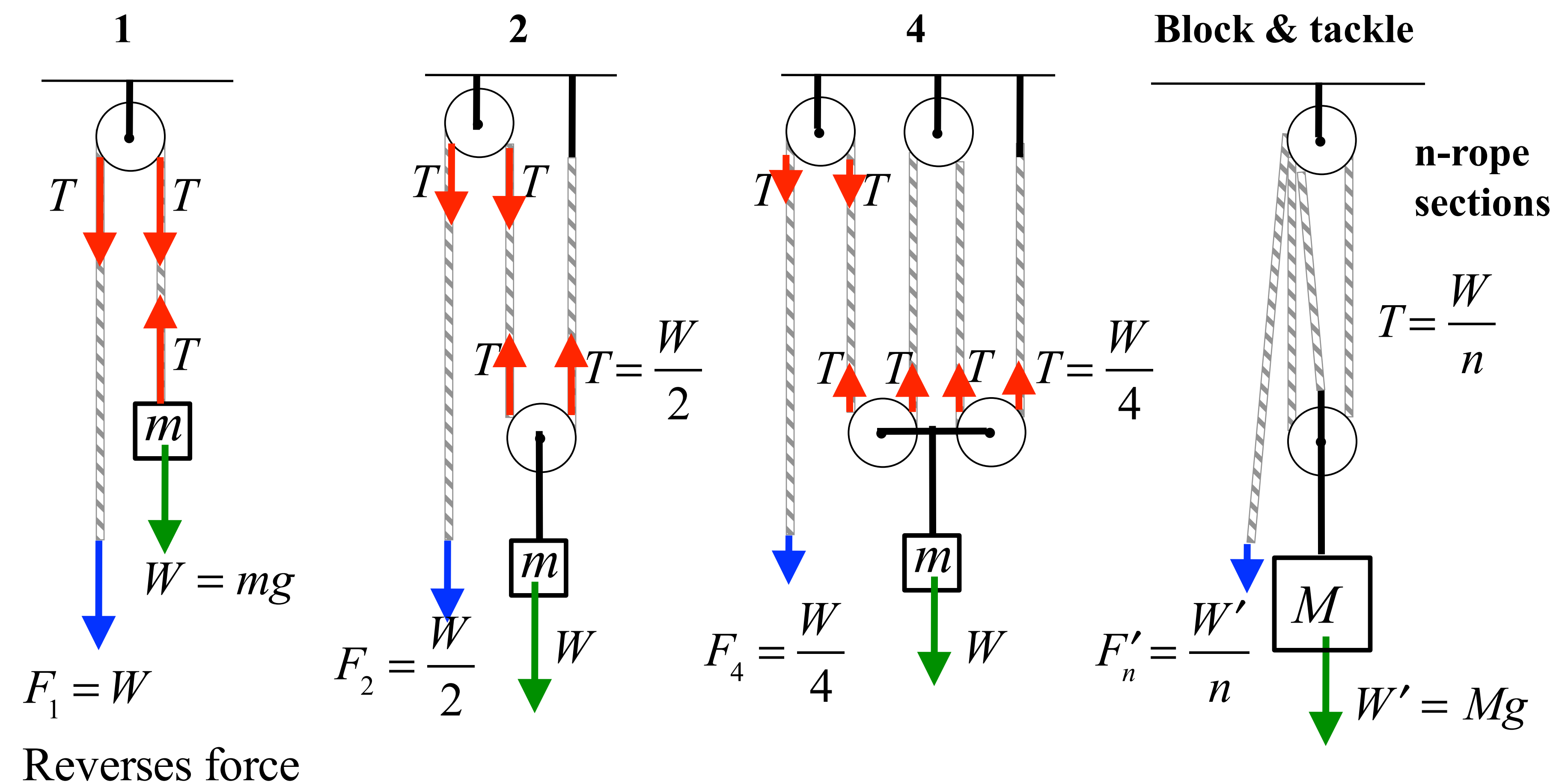
4.11 Equilibrium Application of Newton's Laws of Motion

Pulleys (massless, frictionless)

1. **Tension 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**

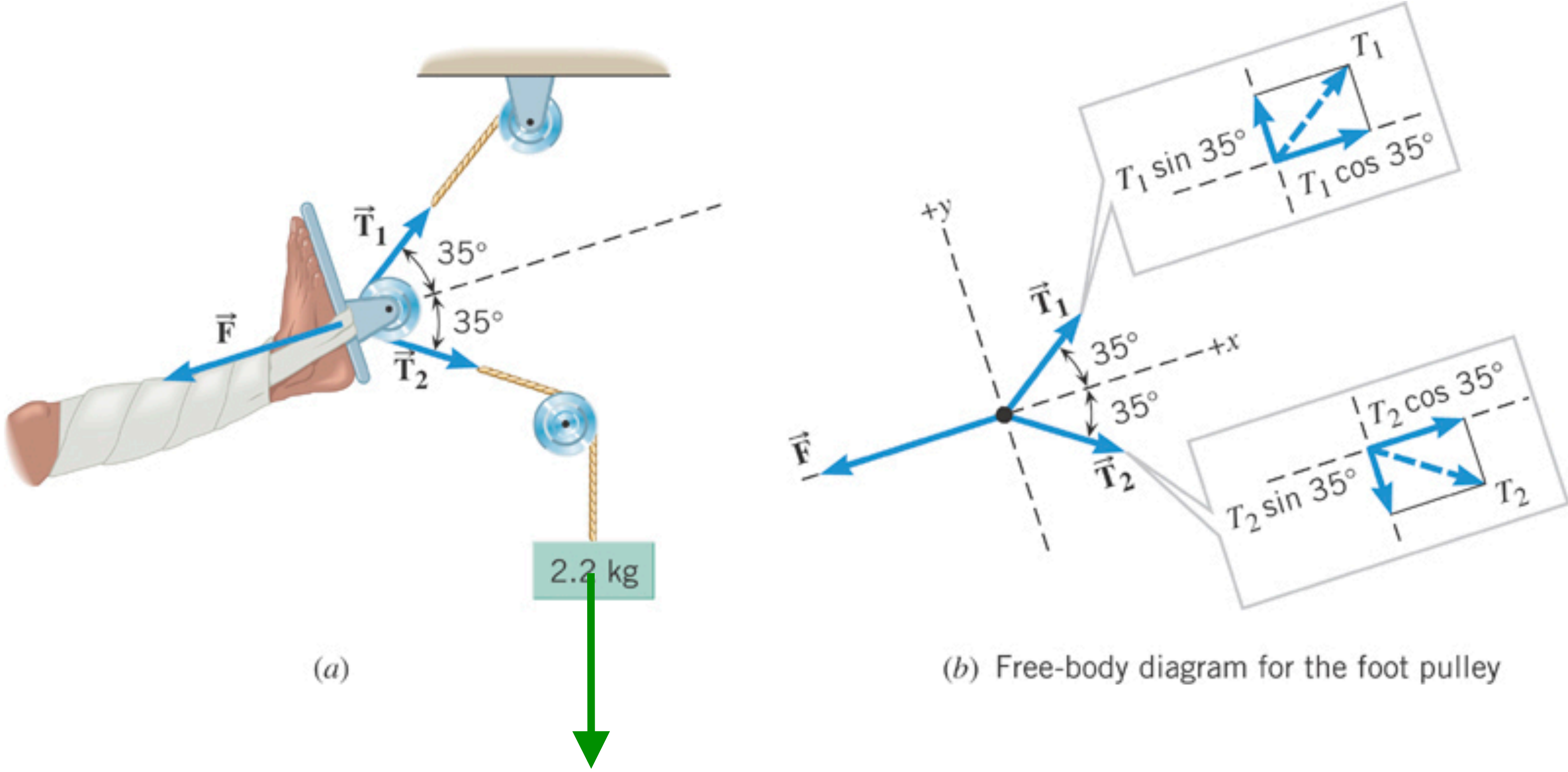
Cases with mass at rest (force vectors labeled with *magnitude*)

 # = 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) $T = W = mg$ $\quad$ $T_1 = T_2 = T = mg$ (rope and pulleys insure this)

2) Net force vector $= 0$ $\quad$ $x: \quad +T\cos 35^\circ + T\cos 35^\circ - F = 0$

3) Use x direction along leg $\quad$ $F = 2mg\cos 35° = 2(2.2\text{ kg})(9.8\text{ m/s}^2)(.82)$

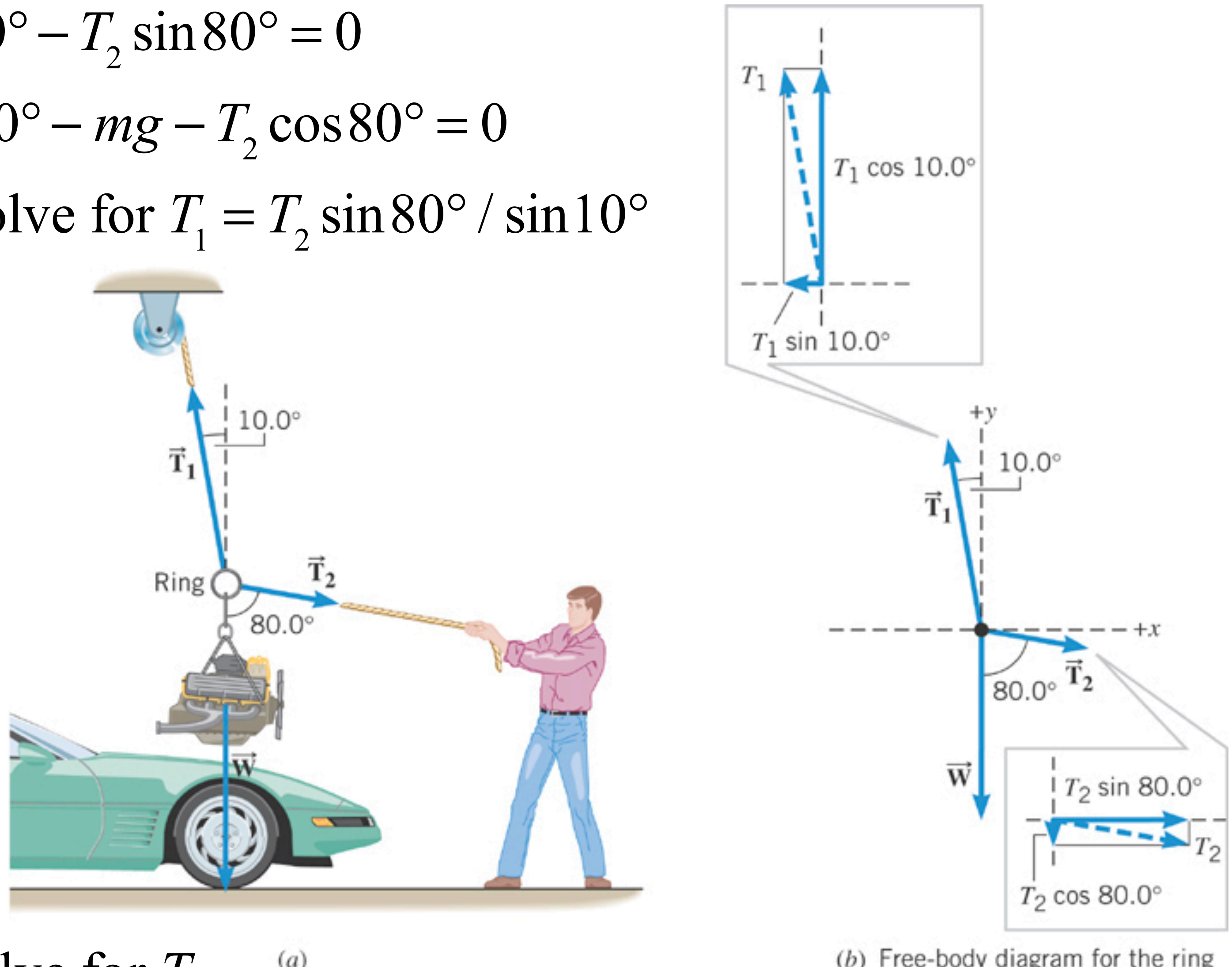
4) y is perpendicular to x $\quad$ $= 35\text{ N}$

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 $T_1 = T_2 \sin 80° / \sin 10°$



(b) Free-body diagram for the ring

from y, solve for T_2

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

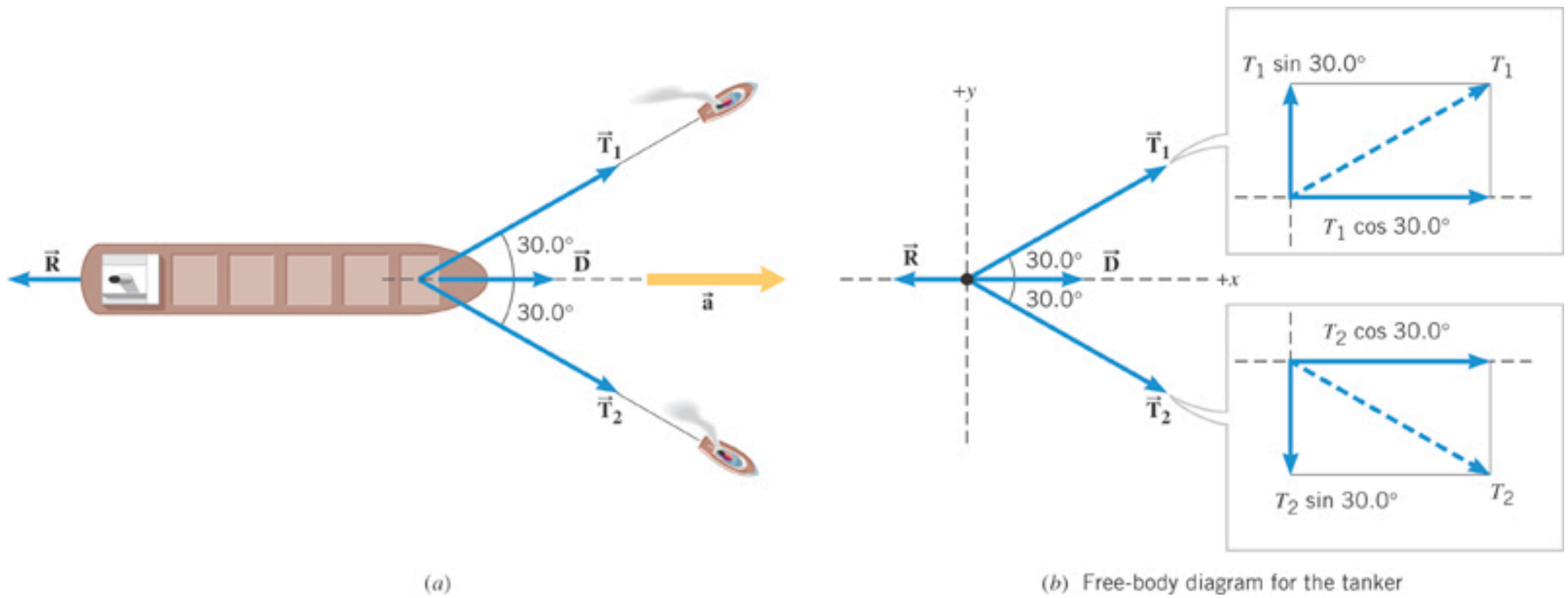
4.12 Nonequilibrium Application of Newton's Laws of Motion

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

$$a_x = 2.00\times10^{-3}\,\text{m/s}^2$$

$$a_y = 0$$

The acceleration is only along the *x* axis :

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

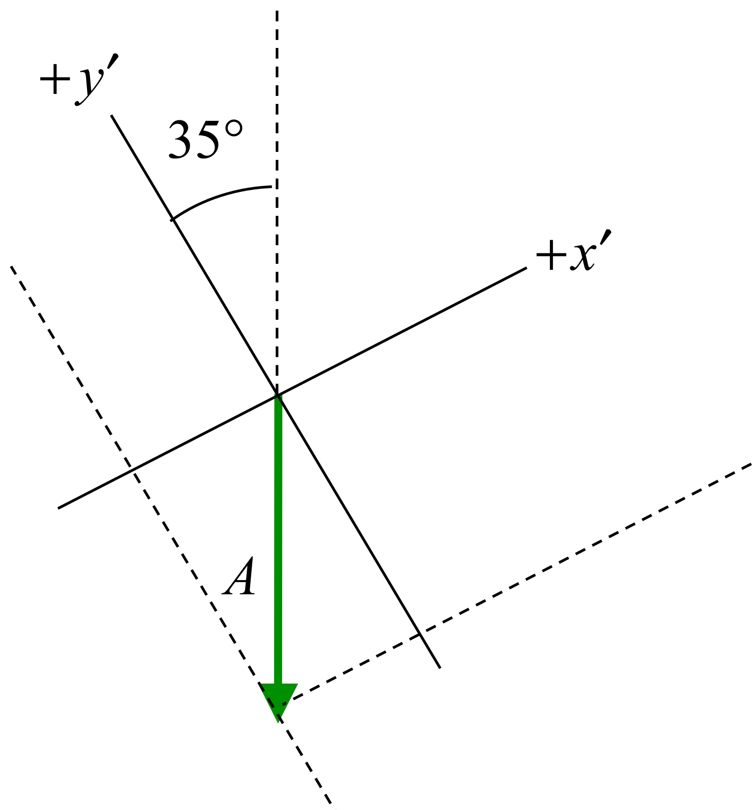
$$x: 2T\cos 30° + D - R = ma_x$$

$$T = \left(ma_x - D + R\right)/\left(2\cos 30°\right) = 1.53\times10^5 \text{ N}$$

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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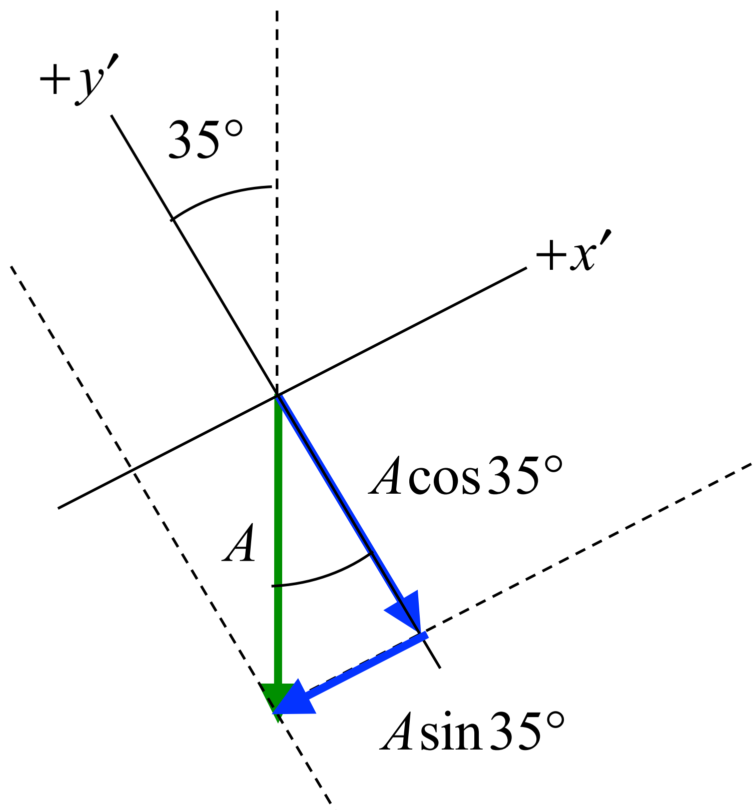

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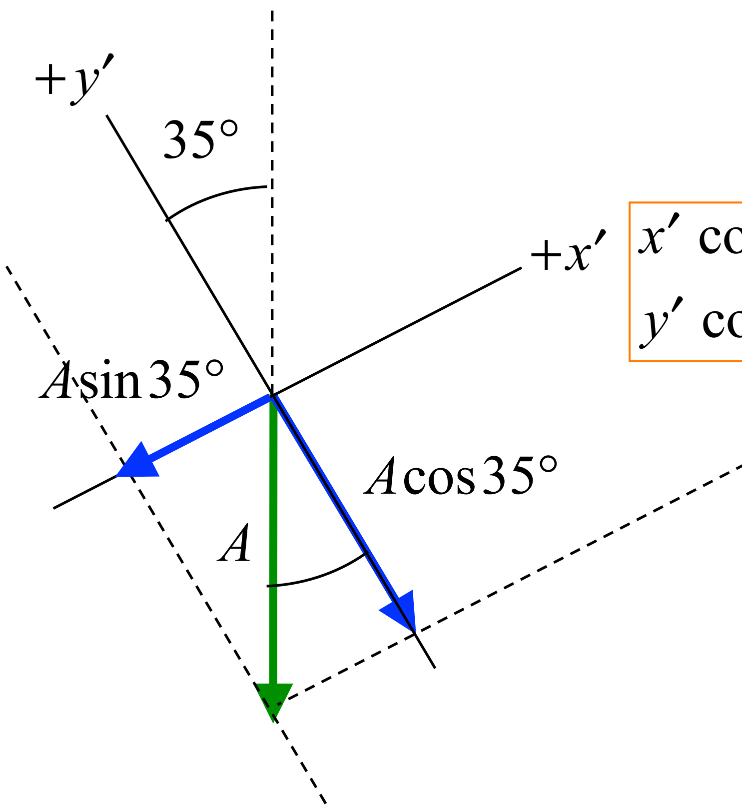


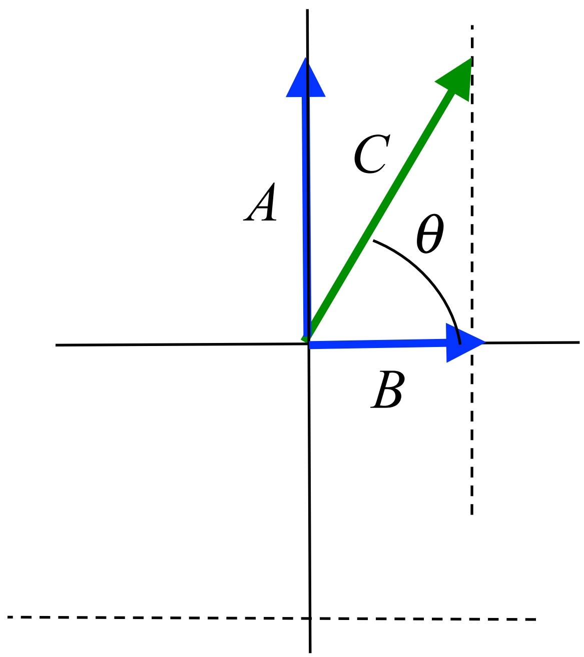
x' component : $A\sin 35°$

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?



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

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?

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

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

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

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

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

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

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?

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

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

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

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

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

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

Review Chapters 1-4

2D motion equations for constant acceleration

x-direction

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

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

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

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

y-direction

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

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

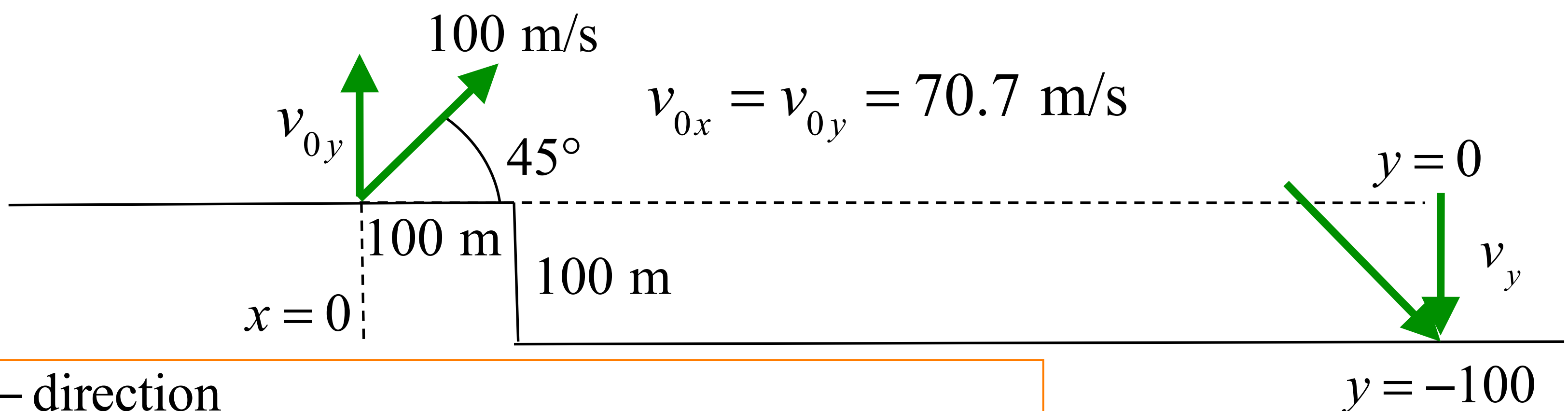
$$v^2 = v_{oy}^2 + 2a_y y$$

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

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?



$$v_{0x} = v_{0y} = 70.7 \text{ m/s}$$

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

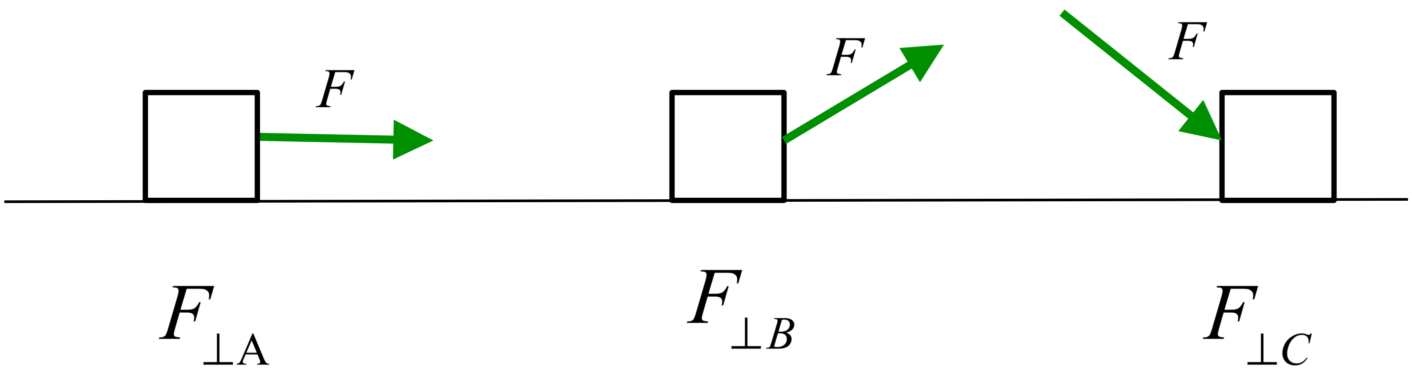
$$x = v_{0x}t = (70.7 \text{ m/s})(15.7\text{s})$$

$$= 1110 \text{ m}$$

Review Chapters 1-4

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

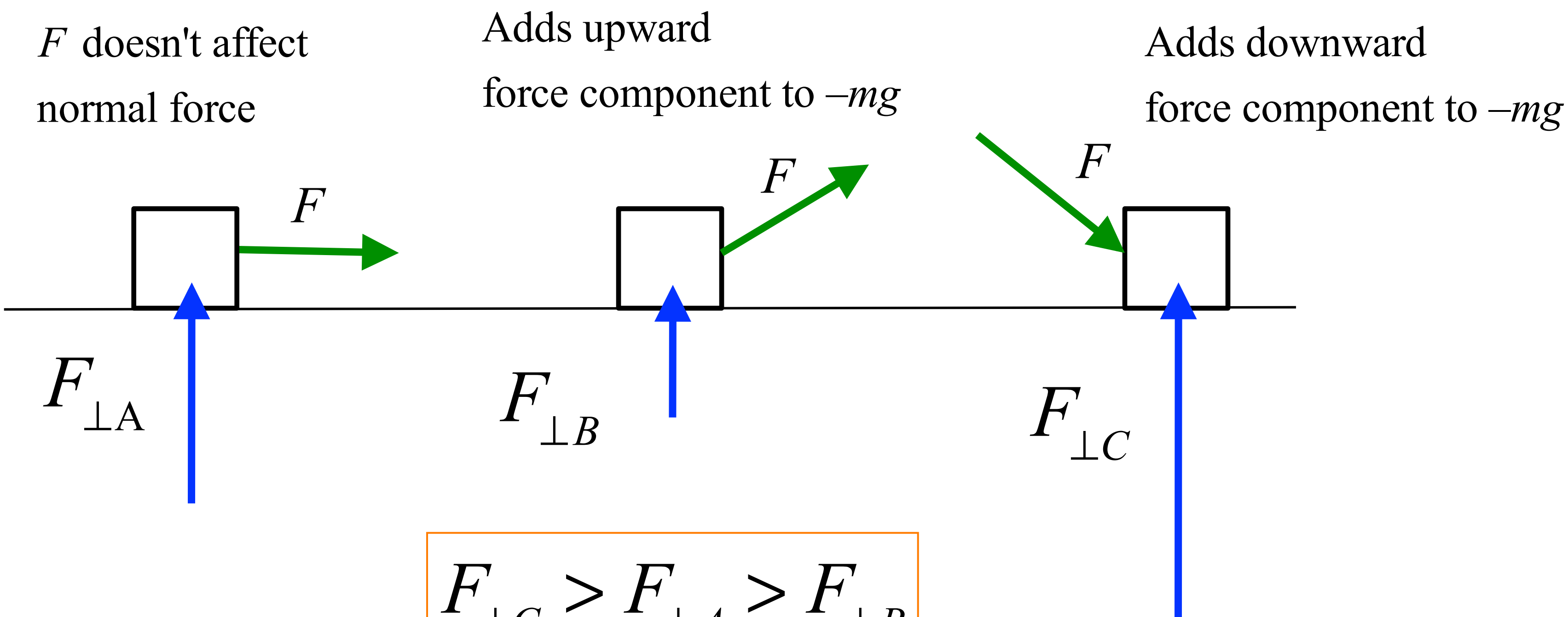
A force of magnitude, *F*, acts on three identical blocks. Rank the normal force on the three blocks.



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.



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

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?

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

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

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

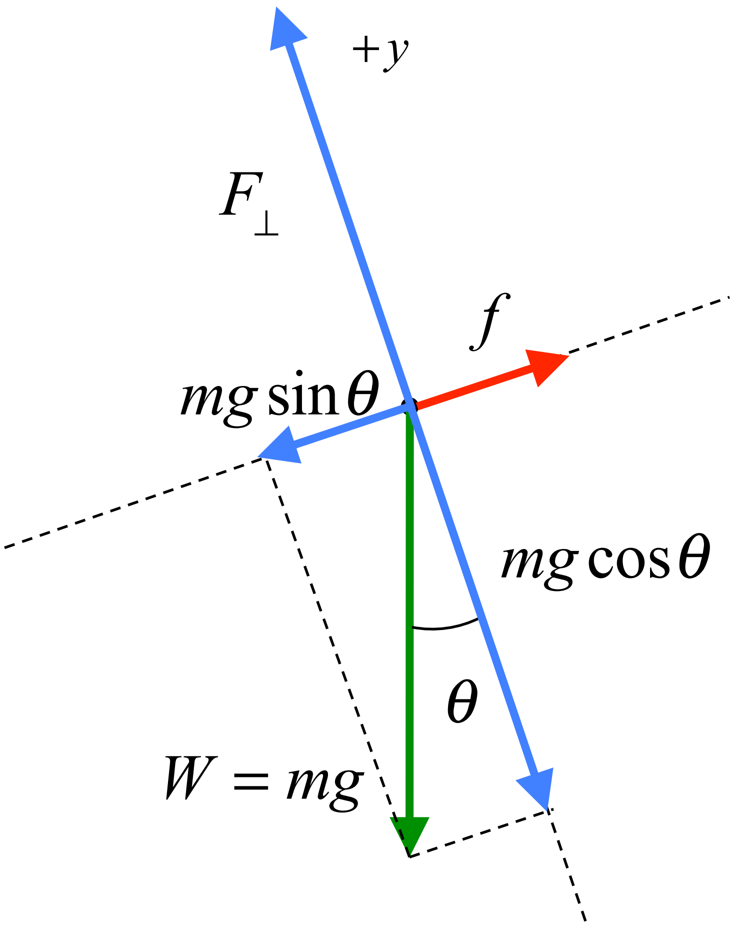
$$= \frac{1}{4}F$$

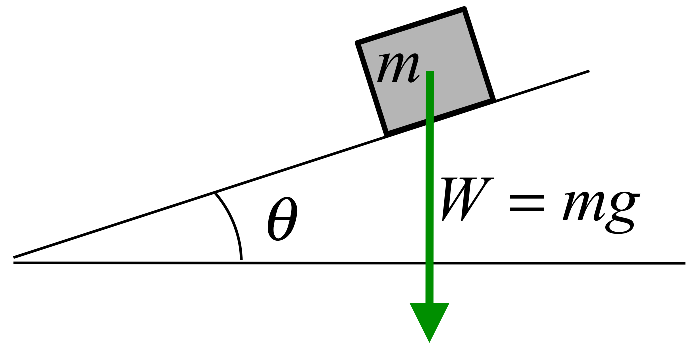
Review Chapters 1-4

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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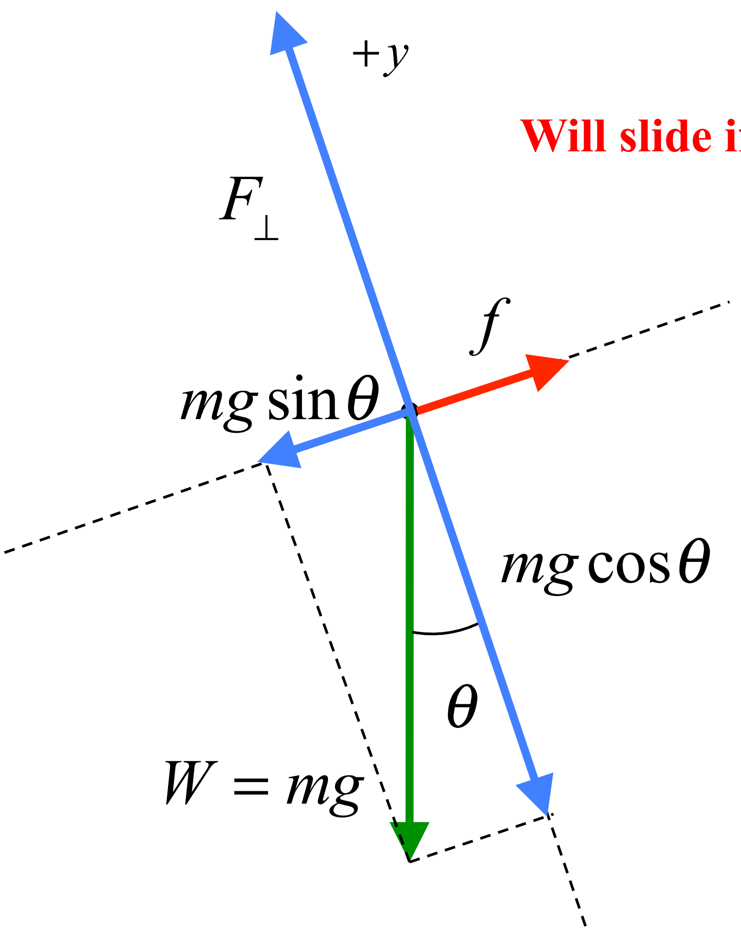
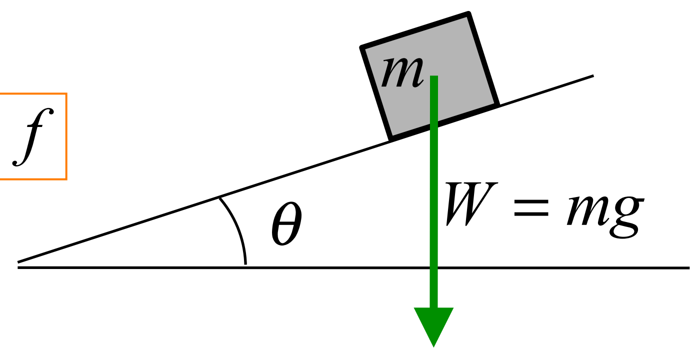


Will slide if $\boxed{mg\sin\theta > f}$



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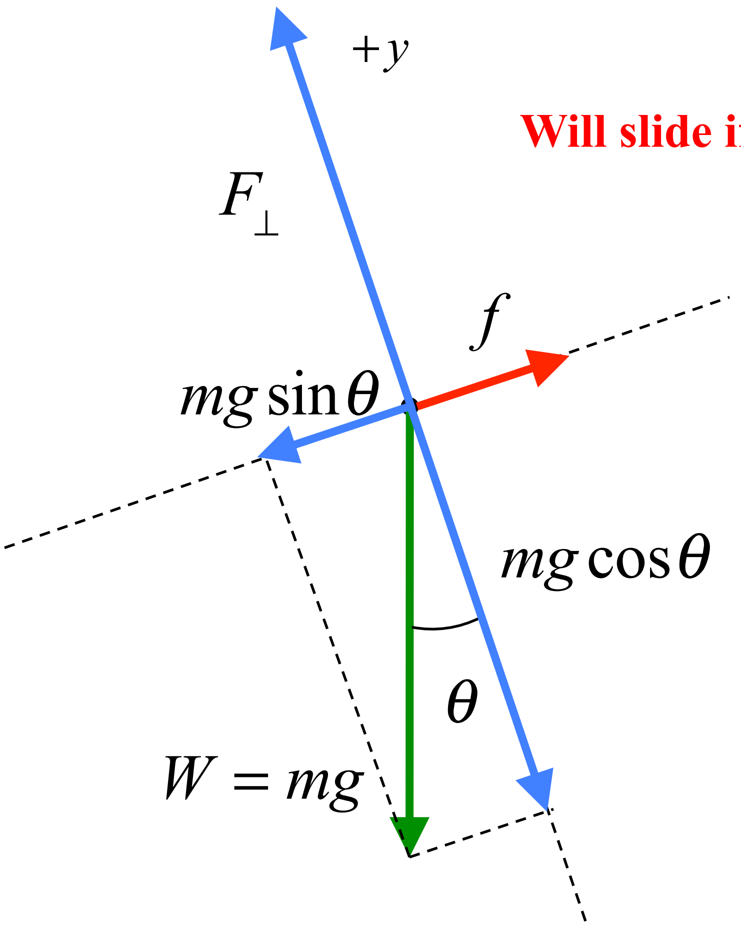

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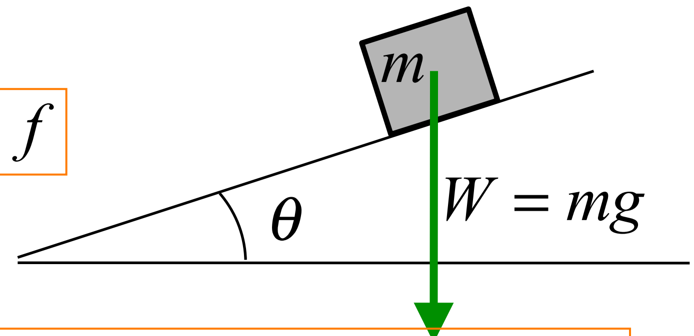


$$f = \mu F_\perp = \mu mg\cos\theta$$

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

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

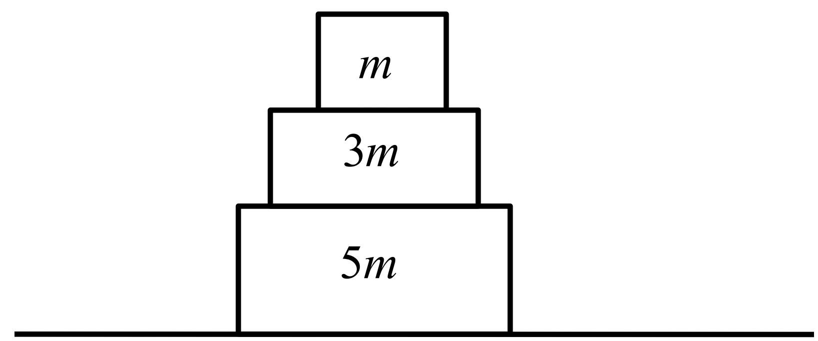
$$\theta = \tan^{-1}\mu = \tan^{-1}0.5$$

$$= 26.5^\circ$$

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?



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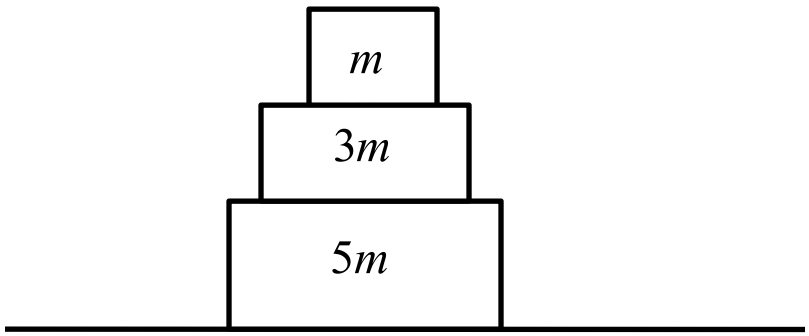
$$\boxed{F_{\perp} = 3mg + mg = 4mg}$$



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.**

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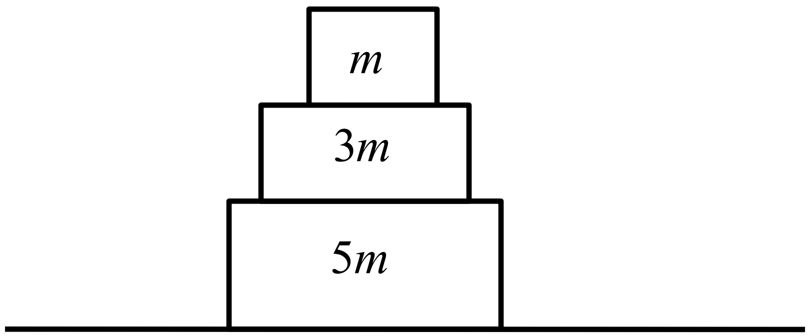

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