Physics 100A Homework 4 – Chapter 5

Newton's First Law

A)If a car is moving to the left with constant velocity then the net force applied to the car is zero.
B) An object cannot remain at rest unless the net force acting on it is zero.
C) An object has constant acceleration if the net force acting on it is constant.

Understanding Newton's Laws

A)An object cannot remain at rest unless the net force acting on it is zero.
B)If a block is moving to the left with constant velocity the net force applied to the block is zero.

C) A block of mass 2 kg is acted upon by two forces: 3N (directed to the left) and 4N (directed to the right). What can you say about the block's motion?

The net force is point to the right, so the object could
- be moving to the right and accelerating to the right (speeding up)
- be moving to the left and accelerating to the right (slowing down)
- be at rest and on the verge of moving to the right

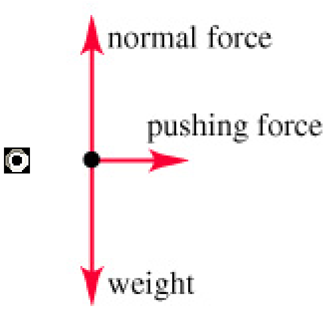
D) A block pulled with a constant force will have a constant acceleration in the same direction as the force.

E) Two forces, of magnitude 4N and10N, are applied to an object. The relative direction of the forces is unknown.

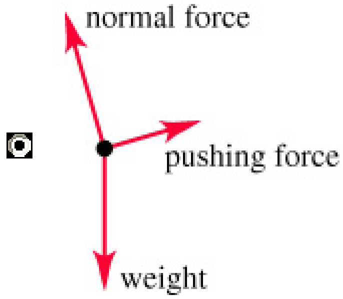
The two limits for adding the forces give that the **magnitude** of the net force must be
$6N \le F_{net} \le 14N$
So 5N is excluded

Free-Body Diagrams
Chadwick is pushing a piano across a level floor (see the figure). (Intro 1 figure) The piano can slide across the floor without friction. If Chadwick applies a horizontal force to the piano, what is the piano's acceleration?

A), B) and C) The three forces acting on the piano are: Chadwick pushing to the right; gravity down; normal force from the floor up.

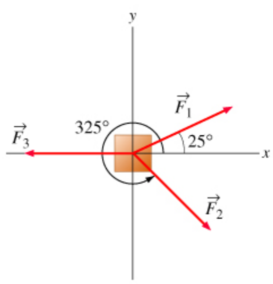


D), E) and F) When going up the inclined plane, the three forces acting on the piano are: Chadwick pushing parallel to the plane; gravity down; normal force up and perpendicular to the incline.



Motion of a Block with Three Forces

Three forces of magnitudes F_1=4.0 N , F_2=6.0 N, and F_3=8.0 N are applied to a block of mass m=2.0 kg, initially at rest, at angles shown on the diagram. In this problem, you will determine the resultant (net) force by combining the three individual force vectors. All angles should be measured counterclockwise.



A)Find the magnitude of the resultant $\vec{F}_r = \vec{F}_1 + \vec{F}_2 + \vec{F}_3$

Add the x and y components independently

$$F_{rx} = F_{1x} + F_{2x} + F_{3x} = F_1 \cos(25) + F_2 \cos(325) + F_3 \cos(180)$$
$$F_{rx} = 4.0\cos(25) + 6.0\cos(325) + 8.0\cos(180) = 0.54N$$

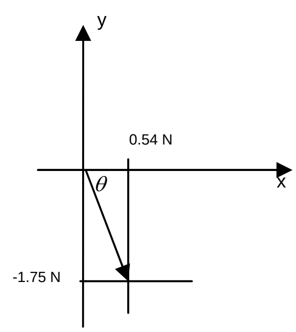
$$F_{ry} = F_{1y} + F_{2y} + F_{3y} = F_1 \sin(25) + F_2 \sin(325) + F_3 \sin(180)$$
$$F_{ry} = 4.0\sin(25) + 6.0\sin(325) + 8.0\sin(180) = -1.75N$$

A) and B) Find magnitude and direction

$$F_r = \sqrt{F_{rx}^2 + F_{ry}^2} = \sqrt{(0.54)^2 + (1.75)^2}\,N = 1.8N$$

$$\theta = \tan^{-1}(1.75/0.54) = 73^\circ$$

From the x-axis 360°-73°=287°



C) and D) Magnitude and direction of the acceleration

$$a = F_r / m = 1.8/2 = 0.9\ \text{m/s}^2$$

It points in the same direction as the force.

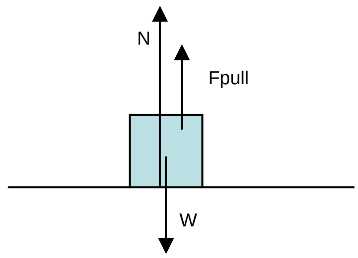
E) How far (in meters) will the block move in 5.0s? Recall that it starts from rest.

$$d = d_0 + v_0 t + \frac{1}{2}at^2 = 0 + 0 + \frac{1}{2}(0.9)(5)^2 = 11.3\,\text{m}$$

The Normal Force

A) A man is pulling up on the suitcase, while it rests on the floor.

$$N + Fpull - W = 0$$
$$N = W - Fpull$$



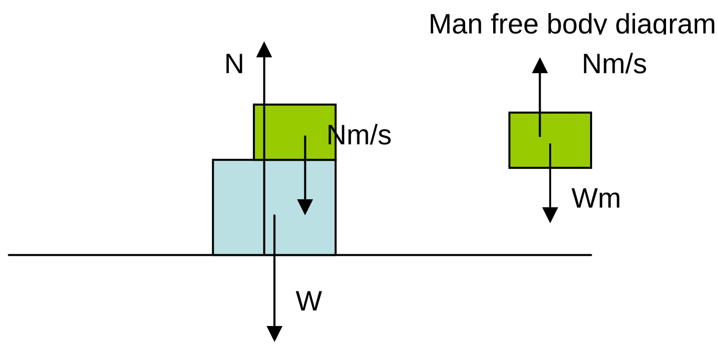
The magnitude of the normal force is equal to the magnitude of the weight of the suitcase minus the magnitude of the force of the pull.

B) The man sits on the suitcase.

Man: $N_{m/s}$-W_m=0 $N_{m/s}$=W_m

Suitcase: N-$N_{m/s}$-W=0 N=$N_{m/s}$+W =

N=W+W_m



5.4 You are pulling your little sister on her sled across an icy (frictionless) surface. When you exert a constant horizontal force of 120 N, the sled has an acceleration of 2.5 m/s^2.

If the sled has a mass of 7.4 kg, what is the mass of your little sister?

4. **Picture the Problem**: You exert a horizontal force that accelerates both your little sister and the sled.

Strategy: Apply Newton's Second Law to the sled + sister combination, and solve for the mass of your sister.

Solution: 1. Use Newton's Second Law to find the total mass of the sled + sister combination: $m_{\text{total}} = \frac{F}{a} = \frac{120\text{ N}}{2.5\text{ m/s}^2} = 48\text{ kg}$

2. Find the mass of your sister by subtracting: $m_{\text{sister}} = m_{\text{total}} - m_{\text{sled}} = 48\text{ kg} - 7.4\text{ kg} = \boxed{41\text{ kg}}$

Insight: A more massive sister would decrease the acceleration of the sled if the pulling force remained the same.

Newton's Third Law Discussed

A) Every force has one and only one 3rd law pair force. T

B) The two forces in each pair act in opposite directions. T

C) The two forces in each pair do not act on the same object. F

D)The two forces in each pair have the same origin. F

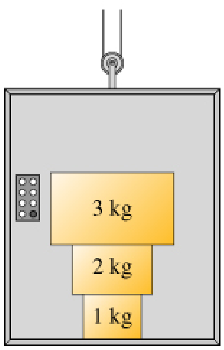
E) The two forces of the pair always act on different objects. F

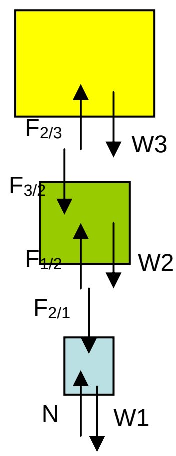
F) The accelerations of the two objects have the same magnitude and direction. F

G) The force on the moon due to the earth is equal in magnitude to, and in the opposite direction from, the force on the earth due to the moon.

Blocks in an Elevator Ranking

Three blocks are stacked on top of each other inside an elevator as shown in the figure.





A) Elevator at rest

Whole system: $N - W_1 - W_2 - W_3 = 0$ $\quad N = W_1 + W_2 + W_3 = (1+2+3)(9.8) = 58.8\,\text{N}$

Block 1: $N - W_1 - F_{1/2} = 0$ $\quad W_1 + W_2 + W_3 - W_1 - F_{1/2} = 0$ $\quad F_{1/2} = W_2 + W_3 = (2+3)*9.8 = 49\,\text{N}$

Block 2: $F_{2/1} - W_2 - F_{3/2} = 0$ $\quad W_2 + W_3 - W_2 - F_{3/2} = 0$ $\quad F_{3/2} = W_3 = (3)*9.8 = 29.4\,\text{N}$

The action and reaction pairs are equal in magnitude.

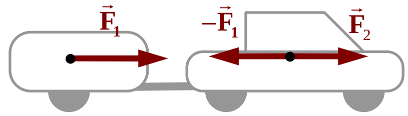
The ranking is then $F_{\text{floor on 1}} > F_{1/2} > F_{2/3}$ There is no contact force between block 3 and 1 so $F_{1/3} = 0$

B)Elevator moving upward with increasing speed (accelerating upward)

There will be a term proportional to the acceleration on the RHS of the equations. This will make all the values higher but the order will remain.

5.18 On vacation, your 1400-kg car pulls a 560-kg trailer away from a stoplight with an acceleration of 1.85 m/s^2.

18. **Picture the Problem**: The free body diagrams for the car and the trailer is shown at right. The diagram assumes there is no friction.



Strategy: In order to determine the forces acting on an object, you must consider only the forces acting on that object and the motion of that object alone. For the trailer there is only one force $\vec{\mathbf{F}}_1$ exerted on it by the car, and it has the same acceleration (1.85 m/s^2) as the car. For the car there are two forces acting on it, the engine $\vec{\mathbf{F}}_2$ and the trailer $-\vec{\mathbf{F}}_1$. Apply Newton's Second and Third Laws as appropriate to find the requested forces.

Solution: 1. (a) Write Newton's Second Law for the trailer: $\sum \vec{\mathbf{F}} = \vec{\mathbf{F}}_1 = m\vec{\mathbf{a}} = (560\text{ kg})(1.85\text{ m/s}^2)\hat{\mathbf{x}} = \boxed{(1.0\text{ kN})\hat{\mathbf{x}}}$

2. (b) Newton's Third Law states that the force the trailer exerts on the car is equal and opposite to the force the car exerts on the trailer: $-\vec{\mathbf{F}}_1 = \boxed{(-1.0\text{ kN})\hat{\mathbf{x}}}$

3. (c) Write Newton's Second Law for the car: $\sum \vec{\mathbf{F}} = M\vec{\mathbf{a}} = (1400\text{ kg})(1.85\text{ m/s}^2)\hat{\mathbf{x}} = \boxed{(2.6\text{ kN})\hat{\mathbf{x}}}$

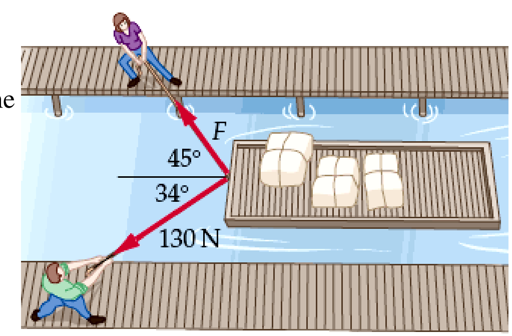
Insight: The engine force $\vec{\mathbf{F}}_2$ must be $(3.6\text{ kN})\hat{\mathbf{x}}$ because it must both balance the 1.0-kN force from the trailer but also accelerate the car in the forward direction, requiring an additional 2.6 kN of force.

Insight: Another way to view the answer to (b) is to say the inertia of the heavier box shields the lighter box from experiencing some of the pushing force. In case (a) the lighter box provides less shielding and the contact force is greater.

5.28 Two crewmen pull a raft through a lock, as shown in the figure. One crewman pulls with a force of 130 N at an angle of 34° relative to the forward direction of the raft. The second crewman, on the opposite side of the lock, pulls at an angle of 45°.

With what force should the second crewman pull so that the net force of the two crewmen is in the forward direction?

28. **Picture the Problem**: The two men pull on the barge in the directions indicated by the figure at right.



Strategy: Place the x-axis along the forward direction of the boat. Use the vector sum of the forces to find the force F such that the net force in the y-direction is zero.

Solution: Set the sum of the forces in the y direction equal to zero:

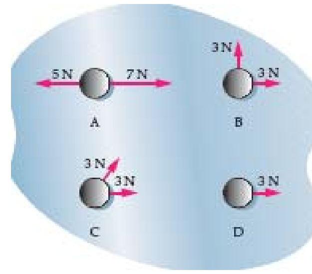
$$\sum F_y = -(130\text{ N})\sin 34° + F\sin 45° = 0$$

$$F = (130\text{ N})\frac{\sin 34°}{\sin 45°} = 100\text{ N} = \boxed{0.10\text{ kN}}$$

Insight: The second crewman doesn't have to pull as hard as the first because a larger component of his force is pulling in the y direction. However, his force in the forward direction (73 N) is not as large as the first crewman (110 N).

5.29 A hockey puck is acted on by one or more forces, as shown in the figure .

29. **Picture the Problem**: The displayed free body diagrams depict the forces exerted on identical hockey pucks.



Strategy: Add the forces as vectors to find the net force. The largest net force will produce the largest acceleration according to Newton's Second Law.

Solution: The net force for case A is $(7-5\text{ N}) = 2\text{ N}$. For case B its magnitude is $\sqrt{3^2+3^2\text{ N}^2} = 4.24\text{ N}$. For case C we must add the components:

$$C_x = 3\text{ N} + (3\text{ N})\cos 45° = 5.12\text{ N} \qquad C_y = (3\text{ N})\sin 45° = 2.12\text{ N}$$

$$C = \sqrt{5.12^2 + 2.12^2\text{ N}^2} = 5.54\text{ N}$$

Finally, the net force in case D is 3 N. Therefore, the ranking of the accelerations, from smallest to greatest, is: $\boxed{\text{A} < \text{D} < \text{B} < \text{C}}$.

Insight: The question could be answered without any calculation. First we note that the net force in case A is 2 N, which is less than the 3-N net force in case D. Second, both cases B and C have net forces larger than 3 N. Third, we note that the two 3-N forces in case C are more nearly in the same direction, as compared with the two 3-N forces in case B. It follows that the puck in case C has the larger acceleration.

5.30 To give a 17-kg child a ride, two teenagers pull on a 3.6-kg sled with ropes, as indicated in the figure . Both teenagers pull with a force of 55 N at an angle of 35° relative to the forward direction, which is the direction of motion. In addition, the snow exerts a retarding force on the sled that points opposite to the direction of motion, and has a magnitude of 57 N.

$\boxed{30.}$ **Picture the Problem**: The two teenagers pull on the sled in the directions indicated by the figure at right.

Strategy: Write Newton's Second Law in the x direction (parallel to $\vec{\mathbf{a}}$) in order to find the acceleration of the sled.

Solution: Write Newton's Second Law in the x direction:

$$\sum F_x = 2F\cos 35° - 57\text{ N} = (m_{\text{sled}} + m_{\text{child}})a_x$$

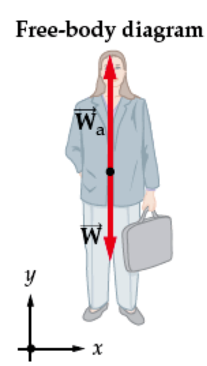
$$a_x = \frac{2F\cos 35° - 57\text{ N}}{m_{\text{sled}} + m_{\text{child}}}$$

$$a_x = \frac{2(55\text{ N})\cos 35° - 57\text{ N}}{19 + 3.7\text{ kg}} = \boxed{1.5\text{ m/s}^2}$$

Insight: Some of the force exerted by the teenagers is exerted in the y direction and cancels out; only the x components of the forces move the sled.

5.41 When you weigh yourself on good old *terra firma* (solid ground), your weight is 140 lb. In an elevator your apparent weight is 120 lb.

41. **Picture the Problem**: The elevator accelerates up and down, changing your apparent weight W_a. A free body diagram of the situation is depicted at right.



Strategy: There are two forces acting on you: the applied force $\vec{\mathbf{F}} = \vec{\mathbf{W}}_a$ of the scale acting upward and the force of gravity $\vec{\mathbf{W}}$ acting downward. The force W_a represents your apparent weight because it is both the force the scale exerts on you and the force you exert on the scale. Use Newton's Second Law together with the known force W_a acceleration to determine the acceleration a.

Solution: 1. The direction of acceleration is $\boxed{\text{downward}}$. A downward acceleration results in an apparent weight less than the actual weight.

2. Use Newton's Second Law together with the known forces to determine the magnitude of the acceleration a.

$$\sum F_y = W_a - W = ma$$

$$|a| = \left|\frac{W_a - W}{m}\right| = \left|\frac{W_a - W}{W/g}\right| = \left|\frac{121-142 \text{ lb}}{142 \text{ lb}}\left(9.81 \text{ m/s}^2\right)\right| = \boxed{1.5 \text{ m/s}^2}$$

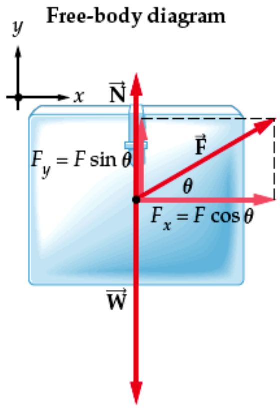
Insight: You feel the effects of apparent weight twice for each ride in an elevator, once as it accelerates from rest and again when it slows down and comes to rest.

Note: You do not need to calculate the absolute value of the acceleration, if you keep the convention of signs.

$W_a - W = -ma$ (acceleration pointing down) a$=(W_a - W)/m$

5.44 A 28 kg suitcase is being pulled with constant speed by a handle that is at an angle of 30° above the horizontal. If the normal force exerted on the suitcase is 180 N, what is the force F applied to the handle?

Forces in y.



$$W = mg = (28)(9.8) = 274.4\text{N}$$

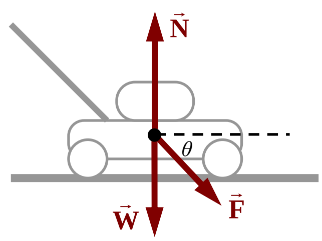
$$N + F\sin\theta - W = 0$$

$$F = \frac{(W-N)}{\sin\theta} = \frac{(274.4-180)}{\sin(30)} = 189\text{N}$$

5.30 A gardener mows a lawn with an old-fashioned push mower. The handle of the mower makes an angle of 35° with the surface of the lawn.

If a 219-N force is applied along the handle of the 19-kg mower, what is the normal force exerted by the lawn on the mower?

50. **Picture the Problem**: The free body diagram of the lawn mower is shown at right.



Strategy: Write Newton's Second Law in the vertical direction to determine the normal force.

Solution: 1. (a) Use Newton's Second Law to find N:

$$\sum F_y = N - F\sin\theta - mg = ma_y = 0$$

$$N = F\sin\theta + mg$$

$$= (219 \text{ N})\sin 35° + (19 \text{ kg})(9.81 \text{ m/s}^2)$$

$$N = 310 \text{ N} = \boxed{0.31 \text{ kN}}$$

2. (b) If the angle between the handle and the horizontal is increased, the normal force exerted by the lawn will $\boxed{\text{increase}}$ because it must still balance the weight plus a larger downward force than before.

Insight: The vertical acceleration of the lawn mower will always remain zero because the ground prevents any vertical motion.