Physics Workshop — Newton's 2nd Law in 1-D — Solutions

1. (a) From Newton's 2nd Law, we know that $F_{net} = ma$. So in this case,

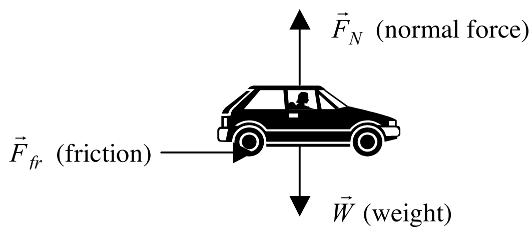
$$\boxed{F_{net} = (1000\ \text{kg})(6.8\ \text{m/s}^2) = 6800\ \text{N}}$$

(b) Using the conversion factor given,

$$\boxed{F_{net} = 6800\ \text{N} \times \left(\frac{\frac{1}{4}\ \text{lb}}{1\ \text{N}}\right) = 1700\ \text{lb}}$$

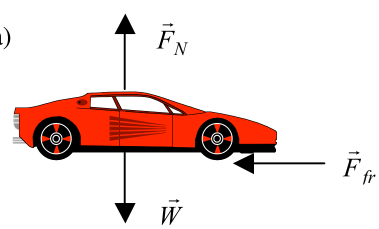
(c) The force accelerating the car forward must have something to do with the ground, because if the car were suspended in the air, it couldn't accelerate no matter what. In fact, the ground pushes the car forward with a force of friction. This is a consequence of Newton's 3rd Law: the car tires push backward on the ground, and in return the ground pushes forward on the tires, making the car accelerate.

(d)

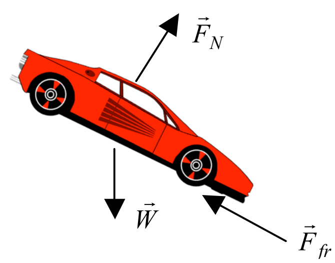


(e) In the horizontal direction, the only force is the force of friction accelerating the car forward. From part (a), we already know the magnitude of this force to be $F_{fr} = 6800$ N. In the vertical direction, the net force must be zero since the car isn't accelerating vertically. So the normal force equals the weight in magnitude: $F_N = W = Mg = (1000\ \text{kg})(9.8\ \text{m/s}^2) = 9800$ N.

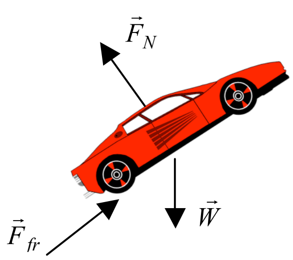
2. (a)



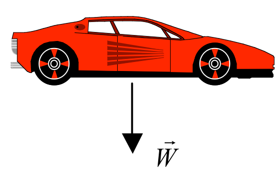
(b)



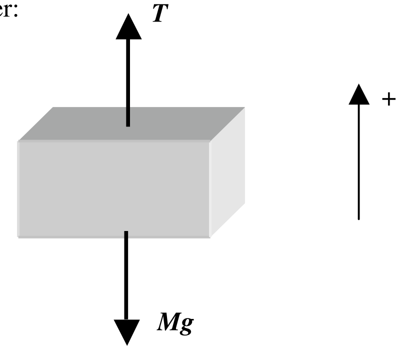
(c)



(d)



2. First note that since the weight of the container is Mg = 89000 N, its mass is 8900 kg (taking g = 10 m/s^2 for simplicity). FBD for the container:



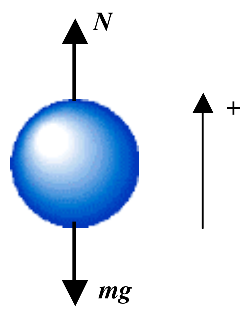
Applying Newton's 2nd Law to this diagram:

$$\begin{aligned}
&\Sigma F = ma: \\
&T - Mg = Ma \\
&T = M(g + a) \\
&\quad = (8900kg)(10m/s^2 + 1m/s^2) \\
&\quad = 97{,}900N
\end{aligned}$$

By Newton's 3rd Law, the force of tension (the force of the cable pulling on the container) has the same magnitude as the force of the container pulling on the cable. Therefore the cable must be able to support 97,900 Newtons.

3. (a) The normal force exerted by the ground is the only upward force exerted on the ball during its bounce, so that's what must be responsible for its upward motion.

(b) FBD:



$$\begin{aligned}
&\Sigma F = ma: \\
&N - mg = ma \\
&N = mg + ma
\end{aligned}$$

From the analysis above, we see that $N > mg$ if $a > 0$, and $N < mg$ if $a < 0$. What is the sign of a as the ball bounces? Just before the ball hits the ground, the ball is traveling downward. An instant later (after the bounce) it is traveling upward. So the direction of its change in velocity is upward, and this is therefore the direction of the ball's acceleration. This represents a positive acceleration in the chosen coordinate system, which proves that the normal force on the ball is greater in magnitude than its weight.

4. The problem with the dogs' argument is that they are comparing two forces that act on different objects! The force that they exert on the sled is a force on the sled, but the force the sled exerts on the dogs is a force on the dogs. In order to determine whether something will move, we need instead to think about all the forces on one particular object. We do this by making a free-body diagram of the object, in this case the dog:

From the diagram, we can see that what enables the dog to move forward is actually the force of friction between its paws and the ground, which must exceed the force of the sled pulling backward. So if the dogs had refused to pull and justified it by telling their master that it was too slippery, they would have had a good case!

Additional Questions

1) The minimum is two: the object's weight and a normal force supporting it (if only the weight acted, the object would be falling rather than motionless). There is no maximum; so long as the net force is zero, the object will remain motionless according to Newton's 1st Law.

2) The most obvious answer to this question is "greed", but strictly speaking that's not a force. In physics terms, the force of friction between your shoes and the ground accelerated you forward. (You can convince yourself of this by imagining trying to run forward on a very icy surface.) The reason this force "knows" to accelerate you forward is Newton's 3rd Law: you push backward on the ground, and in return the ground pushes you forward. That's the way nature works!

3) If the members of each action/reaction pair of forces acted on the same object, then for every force that was exerted on something, there would be another equal and opposite force exerted on the same object, resulting in zero net force. So nothing in the universe could ever accelerate! You'd be stuck in your physics class for all eternity!