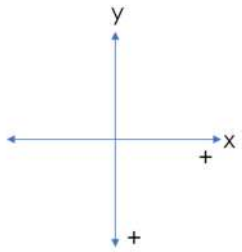
2023A2 NORMAL FORCE

It is good practice with all physics questions to define a coordinate plane. Since forces are vector quantities (they have both magnitude and direction), it is helpful to have a defined positive and negative direction. For this set of questions, since we are dealing with the downward force of gravity, we are going to set our coordinate plane as this:



Where the downward y-direction is positive, and the rightward x-direction is positive.

Level 1: Let's assume a crane is sitting on its wooden platform in the crane pad. If the mass of the crane is 17,943 lbs, what is the force the crane is exerting on the wooden platform? Assume g = 9.8 m/s², give the answer in Newtons (N).

The mass of the crane is in imperial units, but we need to convert it to metric units to get a force in Newtons (N).

$$17{,}943\ lbs \times \frac{0.453592\ kg}{1\ lbs} = 8{,}138.80\ kg$$

Once we have our units converted, we can use our equation for the force of gravity to solve for the force the crane exerts on the wooden platform. For metric units, this becomes:

$$F_{g,crane} = 8{,}138.80\ kg \times 9.8\frac{m}{s^2} = 79{,}760.24\frac{kg \cdot m}{s^2}.$$

$\frac{kg \cdot m}{s^2}$ are the units for a Newton, so our answer is 79,760.24 N.

Level 2: If the mass of the wooden platform is 3,056 lbs, what is the force exerted on the wooden platform by the ground when the crane is sitting on the wooden platform? Assume g = 9.8 m/s2, give the answer in Newtons (N).

In order to solve this question, we have to identify the force exerted on the wooden platform by the ground as the normal force. Since the wooden platform is stationary, we know that the normal force is equal to the force of gravity the wooden platform exerts on the ground. We can't forget, however, that the crane sits on top of the wooden platform. So the force of gravity exerted on the ground is the force of gravity of the crane plus the force of gravity of the wooden platform.

We already have the force of gravity exerted by the crane, so we just need to solve for the wooden platform. First, we'll need to convert the mass, so we have matching units.

$$3{,}056\ lbs \times \frac{0.453592\ kg}{1\ lbs} = 1{,}386.18\ kg$$

Then we can plug the mass into our force of gravity equation:

$$F_{g,platform} = 1{,}386.18\ kg \times 9.8\frac{m}{s^2} = 13{,}584.56\ \frac{kg \cdot m}{s^2}.$$

Next, we need to add together the forces of gravity of the crane and wooden platform to find the total gravitational force exerted by the crane and wooden platform combo.

$$F_{g,total} = 79{,}760.24\frac{kg \cdot m}{s^2} + 13{,}584.56\frac{kg \cdot m}{s^2} = 93{,}344.80\ \frac{kg \cdot m}{s^2}$$

We know that the magnitude of $F_{g,total}$ is equal to the magnitude of the normal force (F_n) the ground exerts on the wooden platform. However, $F_{g,total}$ and F_n are being exerted in different directions. Since we have the downward direction of the force of gravity as positive, the normal force will have the opposite sign.

$$F_n = -93{,}344.80\ N$$