At the end of this worksheet you should be able to

- discuss Newton's laws and provide examples of the application of each.
- discuss the quantities of displacement, velocity, and acceleration.
- apply Newton's first law to solve interesting physical problems.
- apply Newton's second law to solve interesting physical problems for objects that accelerate.
- apply Newton's third law to situations involving the motion of multiple objects.

1. What is the difference between mass and weight? Why can we use them interchangeably at the grocery store?

   mass → amount of matter

   weight → force of gravity

2. What base units are the composite force units of Newtons equal to?

   $$\Sigma F = m \cdot a \leftarrow \text{Newton's } 2^{nd} \text{ Law}$$

   $$[\text{Newtons}] = [kg]\left[\frac{m}{s^2}\right]$$

   $$\frac{\frac{m}{s}}{s} = \frac{m}{s^2}$$

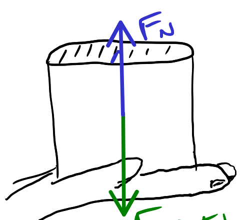
3. My weight in pounds (lbs) is 170 lbs. What is my weight in Newtons, and what is my mass in kilograms?

   $$170\,\text{lbs} \cdot \frac{1 \text{ Newtons}}{0.225 \text{ lbs}} = 756\,N$$

   weight $= F_g = m \cdot g$ → gravitational field strength; on earth $9.8 \frac{N}{kg}$

   $$\frac{F_g}{g} = m = \frac{756N}{9.8 N/kg} = \underline{77.1\,kg}$$

4. If I hold a 5 kg cup motionless in my hand, what force do I provide to the cup?



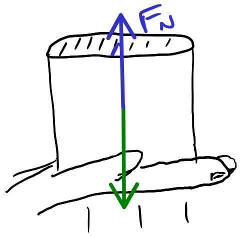
$$F_g = 5kg \cdot 9.8\frac{N}{kg} = 49N$$

	x	y
F_g	0	$-49N$
F_N	0	F_N
	0	0

$$-49N + F_N = 0$$

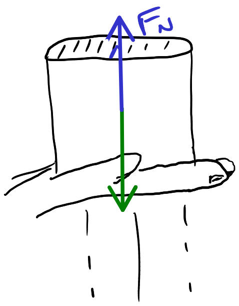
$$\underline{F_N = +49N}$$

5. If I raise a 5 kg cup with my hand, *at constant speed*, then what force do I need to provide from my hand to the cup?



$F_N = 49N$

6. If I accelerate the cup upwards with an acceleration of $+1\,\text{m/s}^2$, then what force does my hand need to provide to the cup?



$\Sigma F = m \cdot a$

$\Sigma F = 5\text{kg} \cdot (+1\,\text{m/s}^2)$

$\Sigma F = +5N$

	x	y
F_g	0	$-49N$
F_N	0	F_N
	0	$+5N$

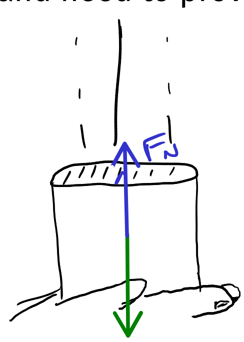
$-49N + F_N = +5N$

$+49 \quad +49$

$F_N = 54N$

7. If I accelerate the cup downwards with an acceleration of $-1\,\text{m/s}^2$, then what force does my hand need to provide to the cup?

$F_1 + F_2 + F_3 + \ldots = \Sigma F$



$\Sigma F = ma$

$= 5\text{kg}(-1\,\text{m/s}^2)$

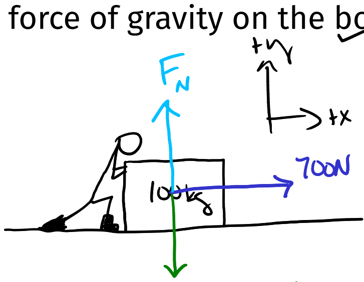
$\Sigma F = -5N$

	x	y
F_g	0	$-49N$
F_N	0	F_N
	0	$-5N$

$-49 + F_N = -5N$

$\boxed{F_N = +44N}$

8. If I push a 100 kg box with an applied force of 700 N along a friction-less surface. Find the force of gravity on the box, the normal force, and the net force.



$F_g = 100\text{kg} \cdot 9.8\,\text{N/kg}$

$= 980N$

	x	y
F_g	0	$-980N$
F_N	0	F_N
F_A	$+700N$	0
ΣF	$+700N$	0

$\_\_\_\_\_ = \Sigma F_y$

$-980 + F_N + 0 = 0$

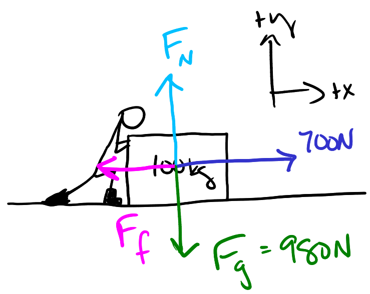
$F_N = 980N$

Bonus: $\Sigma F_x = ma_x \quad \Sigma F_y = ma_y$

What is acceleration? $+700N = 100\text{kg}\, a_x$

$a_x = 7\,\text{m/s}^2$

9. Take the same problem from above and now add friction. The coefficient of friction is $\mu = 0.5$ then what is the net force?



	x	y
F_G	0	$-980N$
F_N	0	$F_N = 980N$
F_A	$+700N$	0
F_f	$-490N$	0
ΣF	$+210N$	0

vector addition

"observation"

$\mu = \frac{|F_f|}{|F_N|}$

$|F_f| = \mu |F_N|$

$|F_f| = 0.5 \cdot 980N$

$= 490N$

Bonus: what is acceleration?

$\Sigma F_x = m a_x$

$210N = 100kg \cdot a_x \Rightarrow a_x = 2.1\,m/s^2$

10. In order to keep a box moving *at constant speed* along a friction-less level surface, what pushing force is required?

0 N

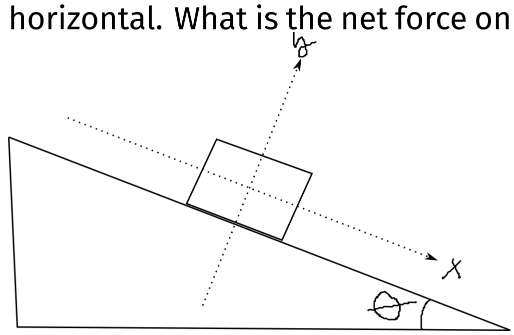
11. If I need to provide a 1000 N force to keep a 100 kg box moving at constant speed along a level floor, then what is the coefficient of friction between the floor and the box?

12. A 1000 kg car is parked on a hill that has an angle of 10° with respect to the horizontal. What is the weight of the car? What is the normal force on the car? What force is keeping the car from sliding down the hill? How large is that force?

13. If the hill that the car is parked on from the previous problem is somehow made steeper to a 20° incline, what is the normal force and the frictional force on the car now? It is still motionless.

14. If the maximum incline that the car can be parked on without sliding is 25°, then what is the coefficient of friction between the tires and the road?

15. A 100 kg box slides down a friction-less inclined plane that has an angle of 30° to the horizontal. What is the net force on the box and then what is the acceleration of the box?



16. A 100 kg box slides down a friction-full inclined plane that has an angle of 30° to the horizontal and a coefficient of friction of $\mu = 0.1$. What is the net force on the box and then what is the acceleration of the box?

17. Let's do the friction-less inclined plane problem *in general* for any mass and incline. Follow the same procedure as before but with the variable m for mass and θ for incline angle. Find an expression for the net force on the mass as a function of θ and for the acceleration as a function of θ.

18. Now let's do the inclined plane with friction *in general*. Just like the previous problem, use m for mass, θ for angle, and now use μ as a variable for coefficient of friction. Find an expression for the acceleration of the mass as a function of θ, m, and μ.

19. In order to *hold* a box on a friction-less inclined plane, that is keep it motionless, what force would be necessary to do that? Is there a difference between the force to hold it motionless on the incline and the force to push it up the incline *at constant speed*?