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?

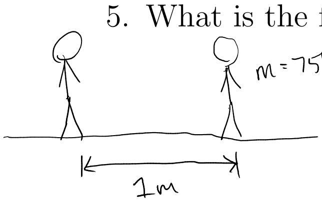
2. What base units are the composite units of Newton's equal to?

3. What is your mass in kg, your weight in Newtons, and your weight in lbs? Start with which ever one you know and convert to the others. If you don't want to use your weight, then make up a weight a person could be and do the same thing.

4. What is the force of gravity between the moon and the earth? You will need to look up some values.

$F_g = m_m \cdot g_e$ | $g_e = \frac{G \cdot m_e}{r^2}$ | $m_e = 5.97 \cdot 10^{24}\,kg$, $m_m = 7.35 \cdot 10^{22}\,kg$, $r = 384000\,km = 3.84 \cdot 10^{8}\,m$

5. What is the force of gravity between two 75 kg people standing 1m apart?



$m = 75kg$ $g_1 = \frac{G \cdot m_1}{r^2} = \frac{6.67 \cdot 10^{-11} \cdot 75kg}{(1m)^2}$

$g = 5 \cdot 10^{-9}\,\frac{N}{kg}$

$F = m_2 g_1 = 75kg \cdot 5 \cdot 10^{-9}\,N/kg = 3.75 \cdot 10^{-7}\,N \rightsquigarrow 0.375\,\mu N$

$0.375 \cdot 10^{-6}\,N$

$\frac{r_2}{r_1} = \left(\frac{g_2}{g_1}\right)^{-1/2} = \left(\frac{2}{1}\right)^{1/2} = \sqrt{2} = 1.41$

6. Find the radius from the center of the earth where Earth's gravitational field strength would

$g = 9.80\,N/kg$

- $\frac{1}{2}$ of its value at the surface.
- $\frac{1}{3}$ of its value at the surface.
- What would be the *altitude* where the gravitational field is $\frac{1}{4}$ its value at the surface?
- What is the gravitational field strength at the altitude that the space station orbits the earth?

$g = \frac{GM_e}{r^2}$

$4.9 = \frac{1}{2} \cdot 9.8\,\frac{N}{kg}$

$g \propto r^{-2}$

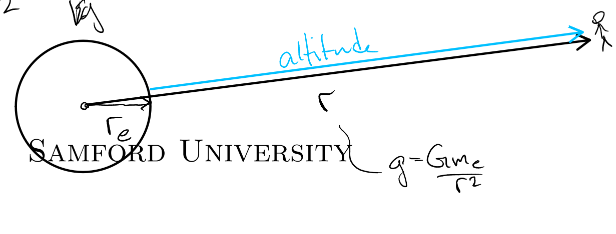
$g_2 = \frac{1}{2} g_1 \Rightarrow \frac{g_2}{g_1} = \frac{1}{2}$

$\frac{g_2}{g_1} = \left(\frac{r_2}{r_1}\right)^{-2}$ ← solve for r_2

$r_e = 6.37 \cdot 10^{6}\,m$

altitude → distance from the surface of earth

alt of space station $= 254\,mi \rightsquigarrow 4.08 \cdot 10^{5}\,m$

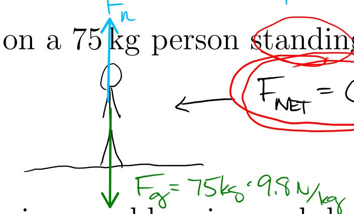


$g = \frac{GM_e}{(r_e + 4.08 \cdot 10^{5}\,m)^2}$

$g = \frac{6.67 \cdot 10^{-11} \cdot 5.97 \cdot 10^{24}}{(6.37 \cdot 10^{6} + 4.08 \cdot 10^{5})^2} = 8.67\,\frac{N}{kg}$

F_n ← don't know at first

7. What is the normal force on a 75 kg person standing on the floor? Where does Newton's first law come into play here?



$F_{NET} = 0$

$F_{NET} = F_n + F_g$ ← definition

$0 = F_n + (-750\,N)$ → solve $F_n = +750\,N$

8. If the person from the previous problem jumped, by exerting a 10 000 N force on the floor (in addition to their weight) then what is the normal force from the floor on the person?

$F_n = 10000\,N + 750\,N$

$F_n = 10{,}750\,N$ ←

on surface of earth → $g = 9.8\,\frac{N}{kg}$ ← gravitational field strength

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

$F_g = m \cdot g = -\left(5\,kg \cdot 9.8\,\frac{N}{kg}\right) = -49\,N$ | $-49\,N + F_n = 0 \Rightarrow F_n = +49\,N$

10. 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? $-49\,N + F_n = 0 \Rightarrow F_n = +49\,N$

from gravity

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

Newton's 2nd → $\boxed{F_{NET} = m \cdot a}$

$F_{NET} = 5\,kg \cdot (+1\,m/s^2) = +5\,kg\,m/s^2 = +5\,N$

$-49\,N + F_n = +5\,N$

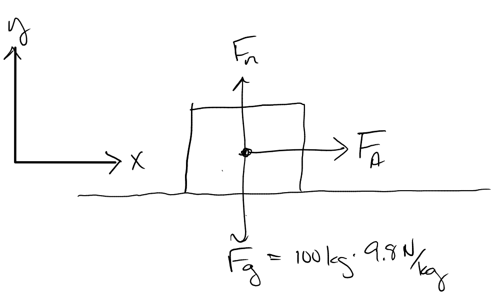
$F_n = 54\,N$

$\boxed{F_{NET} = F_1 + F_2 + F_3 + \ldots}$

12. If I accelerate the cup downwards with an acceleration of $-1\,m/s^2$, then what force does my hand need to provide to the cup? $F_{NET} = m \cdot a = 5\,kg(-1\,m/s^2) = -5\,N$

F_g → $-49\,N + F_n = -5\,N \rightarrow F_n = +44\,N$

13. 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.



	x	y
F_A	+700N	0N
F_n	0	$+F_n$
F_g	0	−980N
	+700N	0N

→ $-980\,N + F_n = 0$ ← $F_{NET,y} = F_{1y} + F_{2y}$

$F_n = +980\,N$

$F_{NET} = +700\,N$ x-direction

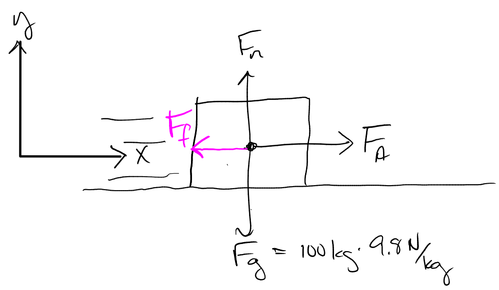
14. Take the same problem from above and now add friction. The coefficient of friction is $\mu = 0.5$ then what is the net force?

magnitudes

$|F_f| = \mu \cdot |F_n|$

$= 0.5(980N)$

$|F_f| = 490N$



	x	y
F_A	+700N	0N
F_n	0	$+F_n$
F_g	0	−980N
F_f	−490N	0N
	+210N	0N

$F_n = +980N$

$F_{NET,x} = +210N$

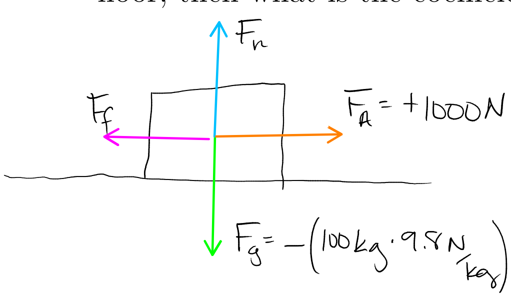
15. In order to keep a box moving *at constant speed* along a friction-less level surface, what pushing force is required?

$F_A = 0N$

16. If I have to exert a force to keep a box moving along a level surface at constant speed, then what other force is probably present? What is the net force on the box in this case?

17. 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?

$\to F_{NET,x} = 0$



	x	y
F_g	0	−980N
F_A	+1000N	0
	0	F_n
F_f	F_f	0
	0	0

y-dir

$-980N + F_n = 0$

$F_n = 980N$

x-dir

$+1000N + F_f = 0$

$F_f = -1000N$

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

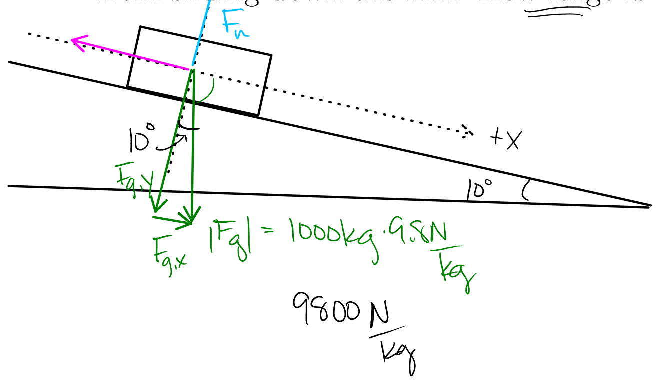
$\mu = \frac{1000N}{980N}$

$\mu = 1.02$

$F_f \leq \mu_s F_n$

18. 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?

what kind



x	y
9800 sin10°	−9800 N cos10°
0	F_n
$-F_f$	0
0	0

$\Sigma F_y = F_{NET,y}$

$-9800 \cos 10° + F_n = 0$

$F_n = 9800 \cos 10°$

$F_n = 9650 N$

$\Sigma F_x = F_{NET,x}$

$9800 \sin 10 - F_f = 0$

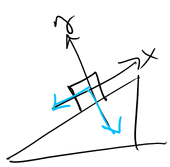
$F_f = 9800 \sin 10 = 1700N$

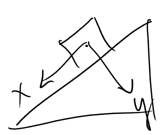
19. If the hill that the car is parked on from the previous problem is somehow made steeper to a 20° incline, what is the normal force and the frictional force on the car now? It is still motionless.

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

$$F_{f,max} = \mu_s F_n$$

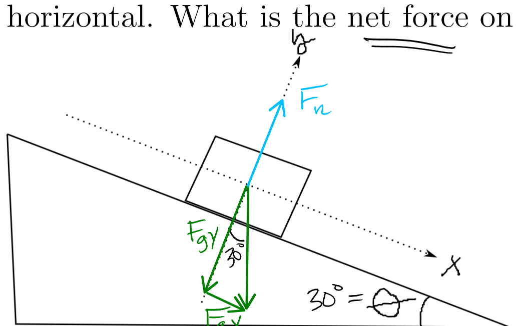
$$\mu_s = \frac{F_{f,max}}{F_n}$$





sign ±

21. 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?



$|F_g| = 100\,kg \cdot 9.8\,N/kg$
$= 980\,N$

	x	y
F_n	0	F_n
F_g	$+980\sin 30°$	$-980N\cos 30°$
	$+490N$	0

$F_n - 980\cos 30 = 0$

$F_n = 980\cos 30°$

$F_n = 849\,N$

$F_{NET,x} = +490N$ ← sum of all x-Forces

$F_{NET,x} = ma_x \Rightarrow \frac{490N}{100\,kg} = a = 4.9\,m/s^2$

22. 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?

	x	y
F_n	0	F_n
F_g	$+980\sin 30°$	$-980N\cos 30° = 849N$
F_f	$-F_f$	0
	$F_{NET,x}$	0 ← Newton's 1st

Know: • F_g • μ → F_f → Want: • $F_f = \mu F_n$ • F_{NET}

$F_n = ?$

$F_n - 849 + 0 = 0$

$F_n = 849N$

$0.1 = \frac{F_f}{849N}$

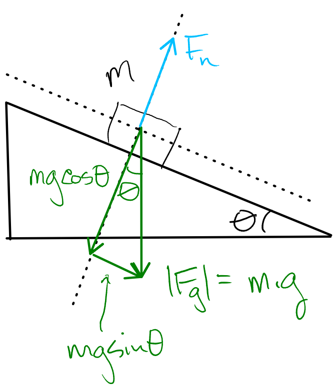
$F_f = 84.9N$

$490N - 84.9N = F_{NET,x} =$

$405.1N = F_{NET,x}$

$a_x = \frac{F_{NET,x}}{m} = \frac{405.1N}{100kg} = 4.05\ m/s^2$

23. 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.



x	y
$+mg\sin\theta$	$-mg\cos\theta$
0	$+F_n$
$+mg\sin\theta$	0 ← Newton's 1st →

$F_n - mg\cos\theta = 0$

$\boxed{F_n = mg\cos\theta}$

$\boxed{F_{NET,x} = mg\sin\theta}$

$F_{NET,x} = ma_x$

$mg\sin\theta = ma_x$

$\frac{\cancel{m}g\sin\theta}{\cancel{m}} = \frac{\cancel{m}a_x}{\cancel{m}}$

$\boxed{a_x = g\sin\theta}$

$N = \frac{kg\,m}{s^2}$

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

24. 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.

x	y
$+mg\sin\theta$	$-mg\cos\theta$
0	$+F_n$
$-F_f$	0
$mg\sin\theta - F_f$	0 ← Newton's 1st →

$F_n - mg\cos\theta + 0 = 0$

$\boxed{F_n = mg\cos\theta}$

$|F_f| = \mu|F_n|$

$\boxed{|F_f| = \mu mg\cos\theta}$

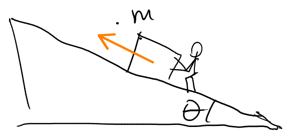
$F_{NET,x} = mg\sin\theta - F_f$

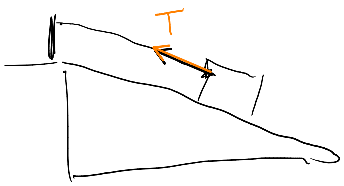
$\boxed{F_{NET,x} = mg\sin\theta - \mu mg\cos\theta}$

$a_x = \frac{F_{NET,x}}{m}$

$\boxed{a_x = g\sin\theta - \mu g\cos\theta}$

25. 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*?





motionless: $|F_A| = mg\sin\theta$

constant speed: $|F_A| = mg\sin\theta$

26. What is a displacement? What is velocity? What is acceleration? How do you know you have moved places or how do you know you are in motion? How do you know you are accelerating?

displacement → change in position $(x_f - x_i)$

velocity → rate of change in position $\left(\frac{x_f - x_i}{t}\right)$

acceleration → rate of change in velocity $\left(\frac{v_f - v_i}{t}\right)$

27. If I go from $x = 10\,\text{m}$ to $x = 28\,\text{m}$, then what is my displacement? If it takes 12 seconds to do that, then what is my average velocity over that interval. Does this mean that my velocity has this value at every instant along the path?

displacement → $\Delta x = x_f - x_i$

$\Delta x = 28\,\text{m} - 10\,\text{m}$

$\Delta x = 18\,\text{m}$

$v = \frac{\Delta x}{t}$

$v = \frac{18\,\text{m}}{12\,\text{s}} = 1.5\,\text{m/s}$

→ no, you could have gone many different speeds over that time but the average of them would be 1.5 m/s

28. If I am initially going $+10\,\text{m/s}$ and it takes me 15 seconds to speed up to $+25\,\text{m/s}$, then what is my acceleration?

$a = \frac{\Delta v}{t} = \frac{v_f - v_i}{t}$

$a = \frac{25\,\text{m/s} - 10\,\text{m/s}}{15\,\text{s}} = \frac{15\,\text{m/s}}{15\,\text{s}}$

$a = 1\,\text{m/s}^2$

29. If my acceleration is $+10\,\text{m/s}^2$, then if I started at rest, how long would it take me to speed up to $+45\,\text{m/s}$? How fast would I be going after 10 seconds?

$v_i = 0$

$a = 10\,\text{m/s}^2$

$a = \frac{\Delta v}{t} = \frac{v_f - v_i}{t}$

$10\,\text{m/s}^2 = \frac{45\,\text{m/s} - 0}{t}$

$t = \frac{45\,\text{m/s}}{10\,\text{m/s}^2} = \underline{\underline{4.5\,\text{s}}}$

$a = \frac{v_f - 0}{t}$ ← at rest

a: $10\,\text{m/s}^2$; t: $10\,\text{s}$

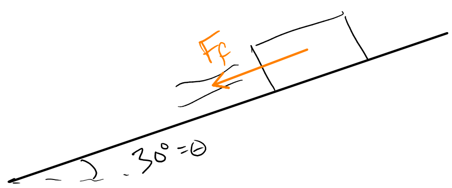
$10\,\text{m/s}^2 = \frac{v_f}{10\,\text{s}}$

$v_f = \underline{\underline{100\,\text{m/s}}}$

HW #8

A crate of potatoes of mass 20.0 kg is on a ramp with angle of incline 30.0° to the horizontal. The coefficients of friction are μ_s = 0.750 and μ_k = 0.400.

Find the frictional force on the crate if the crate is sliding up the ramp. If the direction of the frictional force is up the ramp, enter a positive value and if the direction is down the ramp, enter a negative value.



$$|F_f| = \mu |F_n|$$

$$F_n = mg\cos\theta$$

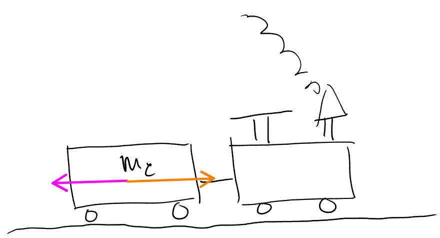
$$F_f = \mu \cdot mg\cos\theta$$

Find the frictional force on the crate, if the crate is being carried up the ramp at constant velocity by a conveyor belt (without sliding). If the direction of the frictional force is up the ramp, enter a positive value and if the direction is down the ramp, enter a negative value.

use → μ_s

F_f points <u>up</u> the plane

#14



given

$a = 2.7\ m/s^2$

$m_c = 1\ kg$

$m_e = 2\ kg$

$F_f = 0.5\ N$

$$F_{NET,C} = 1kg \cdot 2.7\ m/s^2$$

$$F_{NET,C} = 2.7\ N$$

$$F_{NET,C} = F_e - F_f$$

$$F_{NET,C} + F_f = F_e$$

$$2.7N + 0.5N = F_e$$