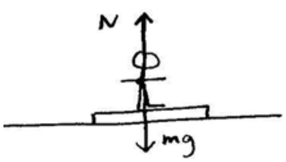
Problem 1. A 100 kg person stands on a scale.
a.) What would be the scale readout?
(How does this compare with the person's weight?)
b.) If the person stands on the scale in an elevator accelerating upwards at 5 m/s^2, what is the scale readout?
(How does this compare with the person's weight?)
c.) If the person stands on the scale in an elevator accelerating downwards at 5 m/s^2, what is the scale readout?
(How does this compare with the person's weight?)
d.) If the person stands on the scale in an elevator accelerating downwards at 9.8 m/s^2, what is the scale readout?
(How does this compare with the person's weight?)
e.) Explain why your result from part d makes sense. Is the actual weight of the person any different? What does the person perceive his weight to be?
f.) If the person stands on the scale in an elevator moving up at a constant speed of 100 m/s, what is the scale readout?
(How does this compare with the person's weight?)
Explain why during most of the time during an elevator ride, a person will perceive nothing unusual.

I'll use m = 100 kg, for parts b-c: accelerates upwards, downwards at 5 m/s^2

A) Scale reading is the same as person's weight (mg).



$F_{net\,y} = m\overset{0}{a_y}$ person at rest

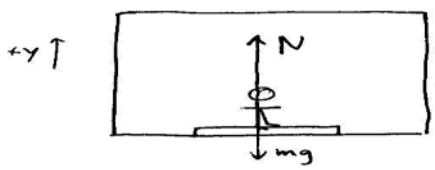
$(+N) + (-mg) = 0$ scale reads N

$N = mg$

$N = \text{scale reading} = (100\,kg)(9.8\,m/s^2)$

$\boxed{= 980\ N}$

B) Scale reading (1480 N) is larger than person's actual weight (980 N). Person will feel heavier (feel more support) than they really are (because the floor is pushing up on them with a force larger than their weight).



$a_y = +5\,m/s^2$

$F_{net\,y} = ma_y$

$(+N) + (-mg) = m(a_y)$

$N = mg + ma_y$

$N = m(g + a_y)$

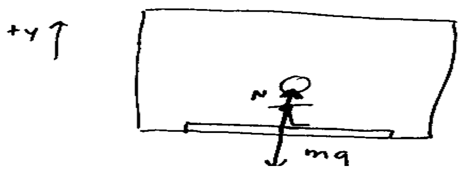
$= (100\,kg)(9.8\,m/s^2 + +5\,m/s^2)$

$\boxed{N = 1480\ N}$

scale reading $N > mg$

reading (1480 N) is larger
son's actual weight (980 N).
will feel heavier than they
are (because floor is pushing up
with a force larger than their
weight.)

C) Scale reading (480 N) is less than person's actual weight (980 N). Person will feel lighter than they really are (because floor is pushing up on them with a force smaller than their weight).



$a_y = -5\,m/s^2$

$F_{net\,y} = ma_y$

⋮ same steps as part b

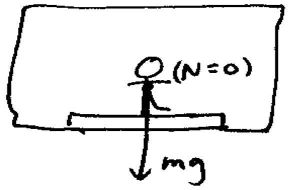
$N = m(g + a_y)$

$N = 100(9.8\,m/s^2 + -5\,m/s^2)$

$\boxed{N = 480\ N}$

scale reading $N < mg$

D) Scale reading (0 N) is less than person's actual weight (980 N).



$\downarrow a_y = -9.8\ m/s^2$

$F_{net_y} = ma_y$

⋮ see part b.

$N = m(g + a_y)$

$N = 100\ kg\,(9.8\ m/s^2 + -9.8\ m/s^2)$

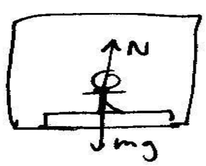
$\boxed{N = 0}$

scale reading

$N < mg$

E) The scale reads zero. Accordingly, the person will "feel" weightless. It's not that the actual weight (mg = 980 N) of the person is any different from normal. Gravity still exerts the same force on them. But now, since $a_y = -9.8\ m/s^2$, the person and elevator are in freefall. They will fall together, and there is no danger of the person smashing the surface. (Normal force is only as large as it needs to be, so it is zero here.) The floor falls out from underneath the person as fast as the person can fall towards it, so they maintain the same distance apart without actually pressing against each other. Then N can be 0.

F) Scale reading is same as person's weight. This looks identitcal to part A, since both at rest and constant velocity are equivalent states according to Newton's 1st Law. For both, $F_{net} = 0$. Person will "feel" their weight just as if standing at rest (not feel heavier or lighter). For most of an elevator ride the elevator is going at a constant velocity, so the person will not feel anything unusual. It is only during the short periods when the elevator is accelerating (getting up to speed from rest, and slowing to a stop) that the person feels lighter or heavier than normal.



$\vec{a} = 0$

$F_{net_y} = m\cancel{a_y}^{\,0}$

$(+N) + (-mg) = 0$

$N = mg = \boxed{980\,N}$

Problem 1. A 35 kg person stands on a scale.
a.) What would be the scale readout?
(How does this compare with the person's weight?)
b.) If the person stands on the scale in an elevator accelerating upwards at 7 m/s^2, what is the scale readout?
(How does this compare with the person's weight?)
c.) If the person stands on the scale in an elevator accelerating downwards at 7 m/s^2, what is the scale readout?
(How does this compare with the person's weight?)
d.) If the person stands on the scale in an elevator accelerating downwards at 9.8 m/s^2, what is the scale readout?
(How does this compare with the person's weight?)
e.) Explain why your result from part d makes sense. Is the actual weight of the person any different? What does the person perceive his weight to be?
f.) If the person stands on the scale in an elevator moving up at a constant speed of 100 m/s, what is the scale readout?
(How does this compare with the person's weight?)
Explain why during most of the time during an elevator ride, a person will perceive nothing unusual.

Solutions. **(a)** The person's weight is mass times *g*: W = (35 kg)(9.8 m/s^2) = 343 N. This is exactly the person's weight, though we usually measure our bulk in mass, in kg, rather than in force. (I am not sure where you find a scale that reads out in newtons.)
(b) The scale is actually measuring the normal force on the person, and we now have to add the acceleration of the elevator to *g*: N = m(g+a)=(35 kg)(9.8 m/s^2 + 7 m/s^2) = 588 N.
(c) Now the acceleration is negative: N = m(g+a)=(35 kg)(9.8 m/s^2 - 7 m/s^2) = 98 N.
(d) Here the elevator is in free fall; N = 0 N.
(e) Well - in free fall, you certainly would not expect to press downwards on the scale.
(f) If the elevator moves at *any* constant speed, the acceleration is equal to zero, and the weight is the same as if the elevator were at rest. N = W = 343 N.
(g) Most of the time in an elevator ride the elevator is moving at constant velocity, so there is no acceleration, and ones weight "feels" normal.

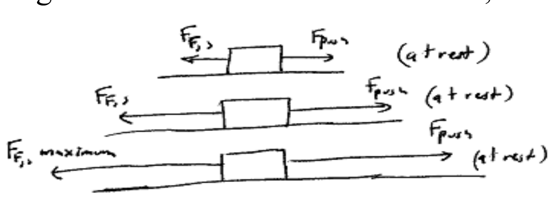
Problem 2. Static and Kinetic Friction:
A 10 kg crate is at rest on a horizontal table (μ_s =0.9, μ_k =0.2). Then various amounts of horizontal pushing force are applied to it.
a.) The largest pushing force that can be applied before the crate starts moving is of size:
b.)-d.) If the pushing force were instead the two amounts shown below, please fill in the rest of the values on the chart below:

horizontal pushing force:	**friction force:** (size only) (indicate static or kinetic):	**net force on crate:** (size only)	**acceleration of crate:** (size only)
11 N	11 N, static	0 N	0 m/s^2
115 N	19.6 N, kinetic	95.4 N	9.54 m/s^2

Solutions. **(a)** this is just equal to the maximum static frictional force,

$$f_{\text{static - max}} = \mu_s N = \mu_s mg = (0.9)(10\text{ kg})(9.8\text{ m/s}^2) = 88.2\text{ N}$$

Static friction will oppose the pushing force, keeping the object stationary, up until some maximum amount. (If the pushing force is greater than this maximum amount, the object will move.)

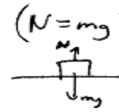


$F_{F,s} \le \mu_s N$
static friction can take on any value
$0 \to \mu_s N$
$F_{F,s}$ maximum

if F_{push} is equal to $F_{F,s}$ maximum, then object will remain stationary. If F_{push} is even slightly greater, object will move.

largest $F_{push} = F_{F,s}$ maximum $= \mu_s N$
$= \mu_s mg$

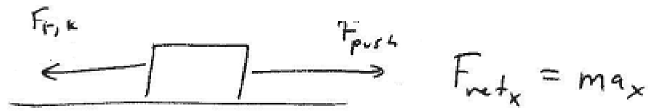
($N = mg$)



(b,). With a horizontal pushing force of only 11 N, less than the maximum static frictional force, the crate will not move, and all forces balance out, in horizontal and vertical directions. So, the frictional force just equals the pushing force (in magnitude); the net force is zero; and the acceleration is equal to zero. The object will stay stationary → static friction. Force of static friction can take on any value from 0 to 88.2 N. In this case, it only needs to be 11 N to prevent motion.
(c,d). With a horizontal pushing force of 115 N, greater than the maximum static frictional force, the crate will break loose and accelerate away. The object will move → use kinetic friction. The frictional force is kinetic friction now. There is no static friction now. Friction will be equal to

$$f_{\text{kinetic}} = \mu_k N = \mu_k mg = (0.2)(10\text{ kg})(9.8\text{ m/s}^2) = 19.6\text{ N}$$

The net force is the pushing force, minus this amount, 115 N - 19.6 N = 95.4 N, causing an acceleration of a = F/m = (95.4 N)/(10 kg) = 9.54 m/s^2.

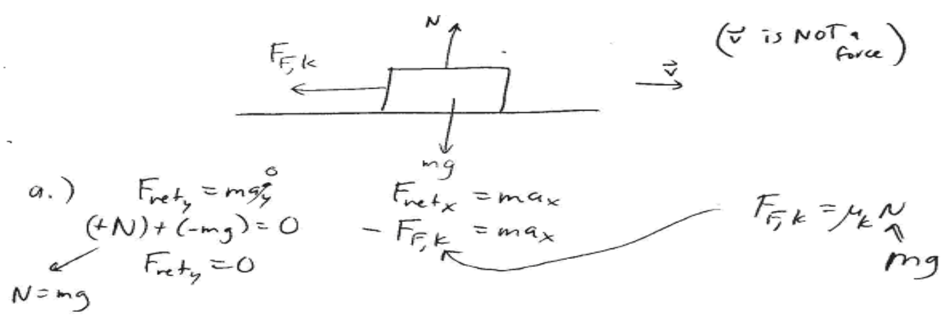


Problem 3. **Friction Patch:** A 10 kg crate is sliding at a constant speed of 13 m/s along a frictionless horizontal table, when it encounters a friction patch (μ_s =0.9, μ_k =0.3). Once the crate enters the friction patch,
a.) What are the sizes of the net force and acceleration of the crate?

size of net force: ______ N

size of acceleration: ______ m/s^2

b.) How fast will the crate be going, when it has traveled 5 m across the friction patch? ______ m/s



Solution. **(a)** The normal force throughout is equal to the weight of the crate, mg = (10 kg)(9.8 m/s^2) = 98 N. And since the crate is sliding, the friction is kinetic, not static. So, the frictional force is

$$f = \mu_k mg = (0.3)(10\text{ kg})(9.8\text{ m/s}^2) = 29.4\text{ N}$$

This is the net force, since the weight and the normal force cancel out in vertical direction and in horizontal direction there is only kinetic friction and no other forces. The resulting acceleration is

$$a = f / m = 2.94\text{ m/s}^2$$

(b) We can use equation (4) of the constant -acceleration equation set, (this equation doesn't need to know time, and it relates v, v0, a and Δx.

$$v^2 = v_0^2 + 2a\Delta x$$

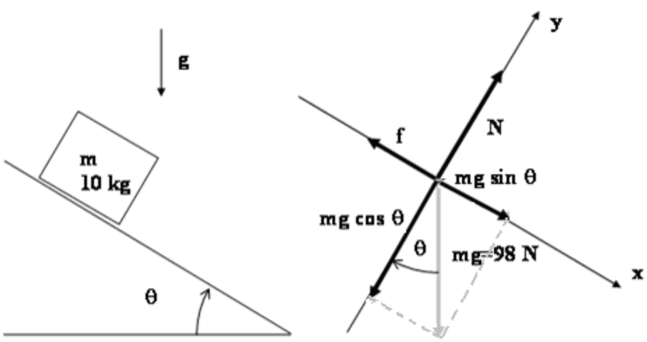
Here v_0 = 13 m/s, Δx = 5 m, and a (opposite to the direction of motion) = -2.94 m/s^2. So,

$$v = \sqrt{(13\text{ m/s})^2 - 2(2.94\text{ m/s}^2)(5\text{ m})} = 11.82\text{ m/s} = 11.8\text{ m/s}$$

Problem 4. Static and Kinetic Friction on an incline:
A 10 kg crate is placed at rest on an incline plane (μ_s =0.7, μ_k =0.5), whose angle can be adjusted.
a.) The maximum angle of the incline for which the crate will stay at rest is:
b.)-e.) If the angle of the incline were instead the two amounts shown below, please fill in the rest of the values on the chart below:

angle of incline:	**component of weight acting along incline:** (size only)	**friction force:** (size only) (indicate static or kinetic):	**net force on crate:** (size only)	**acceleration of crate:** (size only)
15°	N	N,	N	m/s^2
65°	N	N,	N	m/s^2

f.) For the 65° angle, find how long it would take the crate to slide down 5 m along the incline.
g.) Explain why it is NOT possible for an object which is placed at rest on an inclined plane to then start sliding down with constant speed.



Solution. First we need a diagram and a free-body diagram. We choose x direction to be along the incline and y direction to be perpendicular to the incline.
(a) When it is not moving, the friction is static friction. Total forces in all directions add to zero. From the free-body diagram we can see that, since the *x* and the *y* forces must cancel (body at rest, no acceleration!),

$$N = mg\cos\theta$$

$$f = mg\sin\theta$$

and, for the maximum angle without the mass sliding,

$$f = \mu_s N = \mu_s mg\cos\theta$$

This much will always be true if the object is at rest. (N = mg cos Θ is generally always true on an inclined plane). mg sin Θ tries to pull object down incline, but if the object is able to stay at rest, that means force of static friction must be the same size to cancel it off (hence the statement of: mg sin Θ= $F_{F,s}$). At the max angle, just before the object would slide f_s is as large as it possible can be, which is μ_sN.

Setting the two expressions for $f=f_{s,max}$ (at maximum angle) equal gives

$$mg\sin\theta = \mu_s mg\cos\theta$$

$$\mu_s = \frac{\sin\theta}{\cos\theta} = \tan\theta$$

For a static coefficient of friction of 0.7, this gives that the maximum angle will be:

$$\theta = \tan^{-1} \mu_s = \tan^{-1} 0.7 = 34.99° = 35 \text{ degree}$$

(b-e) Now fill in the table. If the angle is equal to 15 degrees, the crate will not slide. We still only have static friction. The component of the weight along the incline is (always, in fact) equal to mg sin θ, which in the fifteen-degree case is equal to mg*sin θ= 25.4 N.

The frictional force (static friction) just cancels it out. And all the forces cancel out in pairs, so the net force is zero and the acceleration is zero.

Do not use f =μ_s N to calculate static friction. Because μ_s N is the maximum of f_s, not f_s

You should note that, in this case, f_s is far less than its maximum amount. Remember $f_{,s} \le \mu_s N$. So f_s can be anywhere from 0 to $\mu_s N$. IN this case the force trying to get it moving (mg sin Θ) is only 25.4 N, so f_s only needs to be that much to stay at rest. $F_{net} = 0$, $a = 0$

Total force in the direction along the incline is mg*sin15 – f_s=0, so f_k = mg*sin15=25.4 N

In the 65-degree case, the maximum static force of friction has been exceeded. It moves. And there is only kinetic friction now. $f_k = \mu_k N$ **, always.**

Normal force is still N = mg cos 65. Because the acceleration in y direction is still zero.

The component of the weight along the incline is mg sin(65°)=88.8 N.

The frictional force is equal to

$$f = \mu_k N = \mu_k mg \cos\theta = (0.5)(98 \text{ N}) \cos 65° = 20.71 \text{ N}$$

The net force on the crate is equal to the component of the weight along the incline, minus the frictional force. (The forces perpendicular to the incline cancel out.) And this net force causes the acceleration. $F_{net} = mg \sin\theta - f_k = mg \sin\theta - \mu_k mg \cos\theta$

$$F_{net} = 88.82 \text{ N} - 20.71 \text{ N} = 68.11 \text{ N}$$

$$a = \frac{F_{net}}{m} = \frac{(68.11 \text{ N})}{(10 \text{ kg})} = 6.611 \text{ m/s}^2$$

Round off to 2 or 3 significant figures. a = 6.61 m/ s^2

(f) Now in the second case, with an acceleration (from rest) of 6.61 m/s^2, the crate goes a distance of 5 m. How long does it take?, v0=0. x0=0,

$$x = \tfrac{1}{2}at^2$$

$$t = \sqrt{\frac{2x}{a}} = \sqrt{\frac{2(5 \text{ m})}{(6.611 \text{ m/s}^2)}} = 1.230 \text{ s}$$

=1.23 s

(g) If an object is placed at rest on the incline, it will remain at rest unless the angle is great enough for the component of the weight down the incline to overcome static friction. From then on, the retarding force is due to *kinetic* friction.

The force needed to get object moving from rest is larger than the force needed to keep object at constant velocity. I mean the maximum static friction force is larger than the kinetic friction. The force needed to get object moving must overcome maximum static friction, whereas the force needed to keep an object at constant velocity must be equal to the kinetic friction. This is always true since $\mu_s > \mu_k$ for all materials. So, if the force trying to get object moving is large enough to get the object moving from rest, it is definitely larger than the forced needed to keep it moving at constant velocity. So there will be a net for, and acceleration, down incline. In other words, if mg sin Θ is enough to exceed $F_{F,s}$ maximum (=$\mu_s N$), so there will be net force, hence acceleration, down incline → constant velocity from rest impossible.

While the driving force is the component of gravity along the incline's direction mg sinθ. Once the angle is larger enough and mgsinθ is already more than the maximum static friction, mgsinθ is definitely larger than the kinetic friction force, so the object has to accelerate.