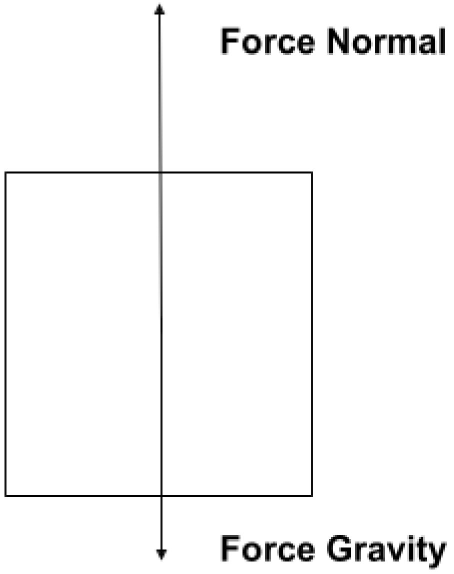
Ramp Simulation Lab
Jin Hyung Park

1. Move the ramp to an angle of zero (horizontal) and draw a free body diagram of the cabinet below.



2. On a horizontal plane, a normal force is equal to the amount of weight but directly opposite to the weight.

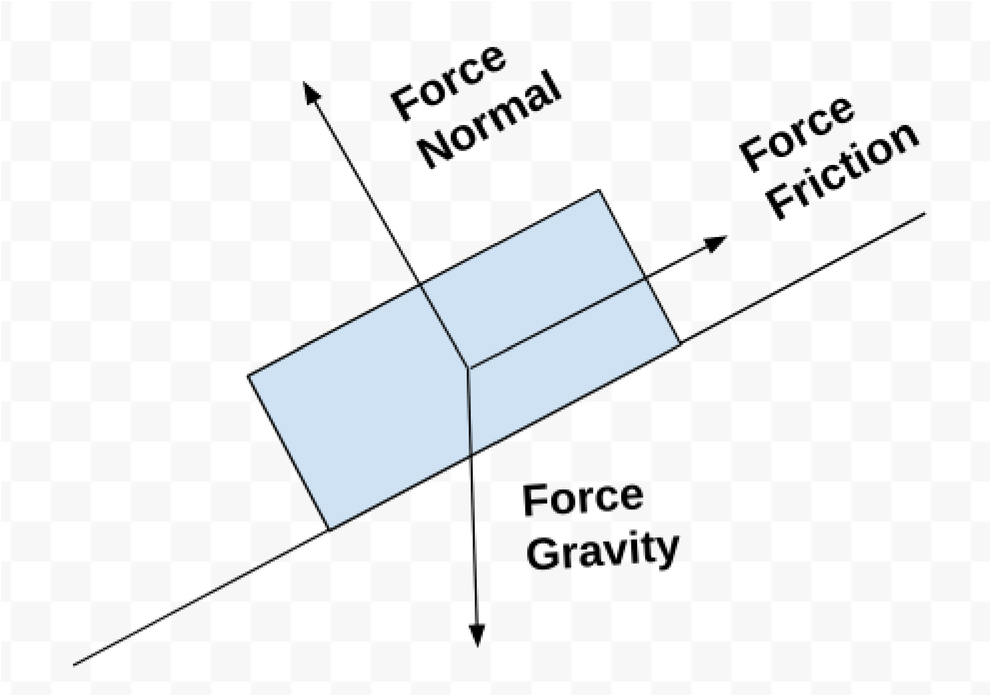
3. The cabinet has a mass of precisely 100kg.

   $Normal\ Force = 9.8 \times 10^2 N = 980N$

   $A\ frictional\ force\ (on\ the\ horizontal\ plane) = 290N = 2.9 \times 10^2 N\ (when\ \mu = 0.30)$

   - Normal Force is $F_N = mg$
   - Frictional Force is $F_f = \mu F_N$

Reset the ramp and draw a free body diagram of the cabinet in the box below.



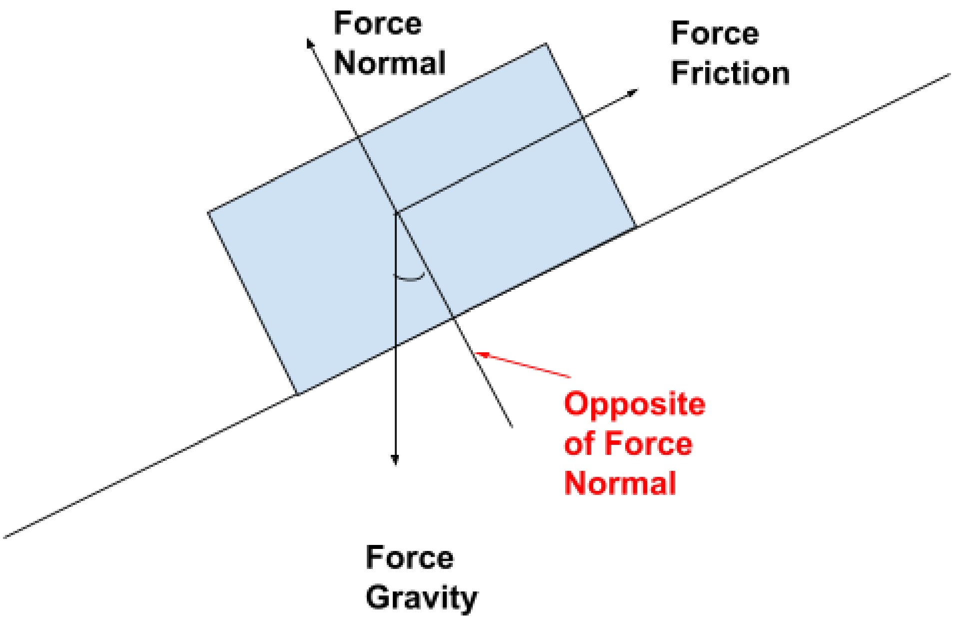
4. When we apply a force to get the cabinet moving, the friction force acts in the opposite direction as the movement of the cabinet.

5. Slowly increase the angle (0.1 degrees at a time) of the ramp until the cabinet starts to move on its own (note that you can control the angle of the ramp at the panel at the side. Remember to hit the “Go” green light button). What angle is this? About 16.9° = θ

6. At this point, the force down the plane is more than the force of friction.

7. Since the ramp is now at an angle, the normal force is less than the weight.

8. At the angle above, the normal force equals $cos\,\theta \times F_g N$. (hint: what trig function?) Show calculations below.



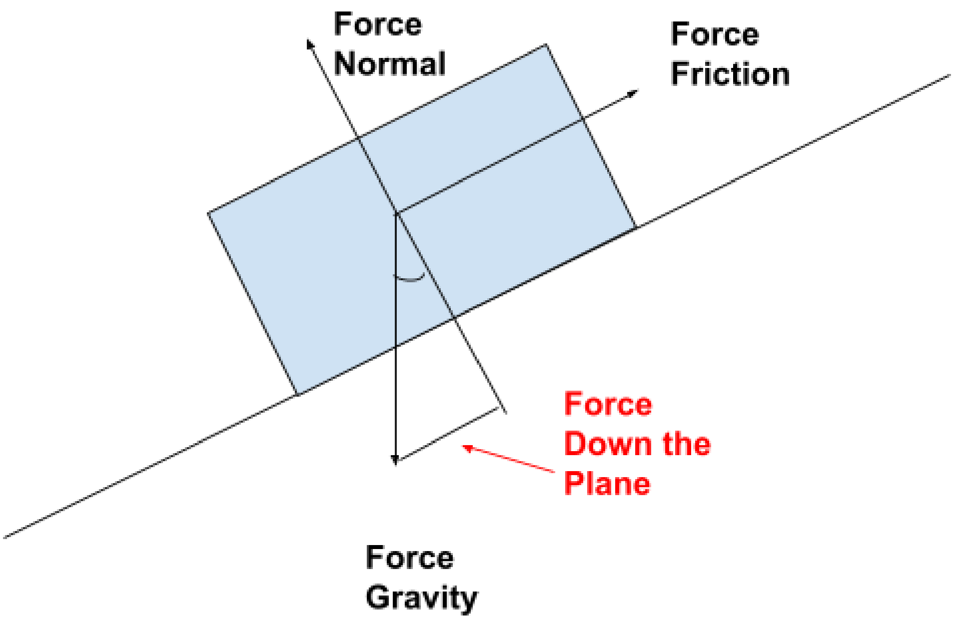
$F_N = F_g \times \cos\theta$

$F_N = (gravitational\,force) \times (mass) \times \cos\theta$

$= (9.8m/s^2) \times (100kg) \times \cos(16.9)$

$F_N = 937.677 = 9.4 \times 10^2 N$ $[normal\ to\ the\ plane]$

9. At the angle above, the force down the plane equals $\sin\theta \times F_g N$. (trig function?) Show calculations below.



$F = F_g \times \sin \theta$

$F = (gravitational\ force) \times (mass) \times (\sin \theta)$

$F = (9.8g) \times (100.0kg) \times \sin(16.9)$

$F \approx 284.888 = 2.8 \times 10^2 N\ [down\ to\ the\ plane]$

10. Using the formula for friction above, the force of friction is $2.8 \times 10^2 N$.

    $F_f = \mu F_N$

    $F_f = \mu(gravitational\ force) \times (mass) \times (\cos \theta)$

    $F_f = (0.30) \times (9.8m/s^2) \times (100.0kg) \times \cos(16.9)$

    $F_f \approx 281.3 \approx 2.8 \times 10^2 N$

11. If the plane-cabinet were frictionless, what angle would be required for the cabinet to move? Above 0°

12. Why?
    The cabinet will move if the plane becomes frictionless, as there will be no opposing forces of force down the plane. Any angle greater than 0° causes the cabinet to move due to the force down the plane and gravitational force.

13. Calculate first, and then test each object in the table below with the simulation on a horizontal plane.

    Because the horizontal plane means that the angle of inclination is 0°, we must determine how to overcome static friction. As a result, the normal force will be the same as the normal force.

Object...	Mass...	Weight...	Normal Force	Coefficient	Friction Force
Dog	$1.50 \times 10kg$	$1.47 \times 10^2 N$	$1.47 \times 10^2 N$	0.10	$1.47 \times 10N$
Crate	$3.00 \times 10^2 kg$	$2.94 \times 10^3 N$	$2.94 \times 10^3 N$	0.70	$2.058 \times 10^3 N$
Piano	$2.25 \times 10^2 kg$	$2.21 \times 10^3 N$	$2.21 \times 10^3 N$	0.40	$8.82 \times 10^2 N$
Refrigerator	$1.75 \times 10^2 kg$	$1.72 \times 10^2 kg$	$1.72 \times 10^2 kg$	0.50	$8.58 \times 10^2 N$

- Dog
    1) Weight

       $W = (mass) \times (gravitational\ force)$

       $= (15kg) \times (9.8m/s^2)$

       $= 1.47 \times 10^2 N$

2) Normal Force
$F_N = (gravitational\ force) \times (mass) \times (cos\ \theta)$
$= (9.8m/s^2) \times (15kg) \times (cos\ 0)$
$= 1.47 \times 10^2 N$
3) Friction Force to Overcome
$F_f = \mu(gravitational\ force) \times (mass) \times (cos\ \theta)$
$= (0.10) \times (9.8m/s^2) \times (15kg) \times cos(0)$
$= 1.47 \times 10$N

- Crate
  1) Weight
  $W = (mass) \times (gravitational\ force)$
  $= (300kg) \times (9.8m/s^2)$
  $= 2.94 \times 10^3 N$
  2) Normal Force
  $F_N = (gravitational\ force) \times (mass) \times (cos\ \theta)$
  $= (9.8m/s^2) \times (300kg) \times (cos\ 0)$
  $= 2.94 \times 10^3 N$
  3) Friction Force to Overcome
  $F_f = \mu(gravitational\ force) \times (mass) \times (cos\ \theta)$
  $= (0.70) \times (9.8m/s^2) \times (300kg) \times cos(0)$
  $= 2.058 \times 10^3$N
- Piano
  1) Weight
  $W = (mass) \times (gravitational\ force)$
  $= (225kg) \times (9.8m/s^2)$
  $= 2.21 \times 10^3 N$
  2) Normal Force
  $F_N = (gravitational\ force) \times (mass) \times (cos\ \theta)$
  $= (9.8m/s^2) \times (225kg) \times (cos\ 0)$
  $= 2.21 \times 10^3 N$
  3) Friction Force to Overcome
  $F_f = \mu(gravitational\ force) \times (mass) \times (cos\ \theta)$
  $= (0.40) \times (9.8m/s^2) \times (225kg) \times cos(0)$
  $= 8.82 \times 10^2$N

- Refrigerator
  1) Weight
  $W = (mass) \times (gravitational\ force)$
  $= (175kg) \times (9.8m/s^2)$

$= 1.72 \times 10^{3} N$

2) Normal Force

$F_N = (gravitational\ force) \times (mass) \times (\cos \theta)$

$= (9.8 m/s^{2}) \times (175 kg) \times (\cos 0)$

$= 1.72 \times 10^{3} N$

3) Friction Force to Overcome

$F_f = \mu(gravitational\ force) \times (mass) \times (\cos \theta)$

$= (0.50) \times (9.8 m/s^{2}) \times (175 kg) \times \cos(0)$

$= 8.58 \times 10^{2}$N

Conclusion Calculations:

Switch back to the cabinet (Reset). $\mu = 0.30$

Complete the table below. You may check your answers in the simulation.

- Force Normal: $F_N = (gravitational\ force)(mass) \cdot cos\theta$
- Force Parallel: $F_{//} = (gravitational\ force)(mass) \cdot sin\theta$
- Force Friction: $F_f = \mu F_N = \mu(gravitational\ force)(mass) \cdot cos\theta$
- Force Applied: $F_a = F_g sin\theta - F_f$
    - If the force parallel is smaller than the force friction, then the force applied equals to zero because there is not enough force down the plane to move the object downwards.

Angle θ	Mass	Weight ($g = 9.8m/s^2$)	Normal Force, F_n	Force Parallel, $F_{//}$	Friction Force, F_f	Force Applied, F_a
0.0°	100kg	980N	980N	0N	294N	$2.9 \times 10N$ [0.00 degree up to the ramp]
10.0°	100kg	980N	965.1N	170.2N	$2.9 \times 10^2 N$ [10.0 degree up to the ramp]	-294N
20.0°	100kg	980N	920.9N	$3.4 \times 10^2 N$ [parallel to the ramp]	276.3N	63.7N
30.0°	100kg	980N	$8.5\times10^2 N$ [up to the horizon]	490N	254.6N	235.4N
40.0°	100kg	980N	750.7N	6.3×10^2 N [parallel to the ramp]	225.2N	404.7N
50.0°	100kg	980N	629.9N	750.7N	1.9×10^2 N [50.0° down along the ramp]	561.7N
60.0°	100kg	980N	490N	848.7N	147N	7.0×10^2 N [0.00° up along the ramp]
70.0°	100. kg	980N	335.2N	920.9N	1.0×10^2 N [70.0° down along the ramp]	820.3N

80.0º	100. kg	980N	170. 2N	9. 7 × 10 N [parallel to the ramp]	51. 1N	914. 1N
90.0º	100. kg	980N	0N	980N	0. 0N [70.0° down along the ramp]	980N