SPH3U: 4.1 Gravitational Force near Earth

1. Air resistance and free fall

Which piece of paper will reach the ground first? Flat paper (Crumpled paper)

Free fall:	when a falling object only experiences gravity, no other forces (not common).
air resistance	a force that prevents falling objects from falling. depends on 2 factors: ① cross-sectional area of object. ② the speed of the object.
terminal speed	maximum speed of a falling object.

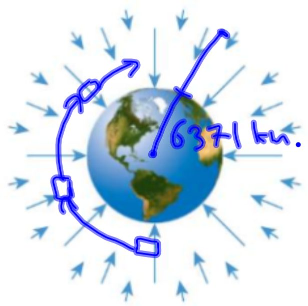
Skydiver:

First leaving the plane	Falling for a while	No longer accelerating
Fair, Fg	Fair, Fg	Terminal speed. Fair, Fg, Fnet =0.
Open parachute	**Slowed down a bit**	**Falling constant speed**
Slow down. Fair, Fg	Fair, Fg	Terminal speed (slower than above). Fair, Fg, Fnet =0

~~**Drag force:**~~ $F_D = \frac{1}{2}\rho v^2 C_D A$	F_D is the drag force, ρ is the density of the fluid, v is the speed of the object relative to the fluid, A is the cross sectional area, and C_D is the drag coefficient – a dimensionless number.

2. Gravitational field strength

Force field:	a region of space where objects experience a force.
gravitational field strength	the force per kilogram that an object experiences in a gravitational field. $g = \frac{F_g}{m}$. Units: N/kg.
g in Toronto	9.807 N/kg.
g 6,371 km above Earth's surface	2.45 N/kg.

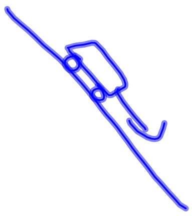


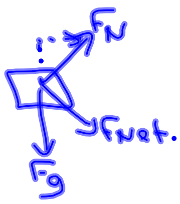
3. The difference between mass and weight

Mass:	quantity of matter in an object (particles).
Weight:	force of gravity acting on an object.
"weightlessness" or "microgravity"	when no normal force is holding you up. for instance Drop Zone (free fall).
International Space Station (ISS)	g = 8.69 N/kg. 400 km above Earth. they seem weightless because of freefall.

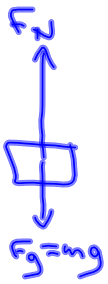
4. Normal force: not always equal to gravity

A cart rolls down an incline. Assume that friction is negligible. Draw an FBD for the cart. In which directions do the normal force and the force of gravity act on the cart?





A 50 kg person is standing on a bathroom scale inside an elevator. The scale is calibrated in newtons. What is the reading on the scale when the elevator is accelerating up at 2.2 m/s²?

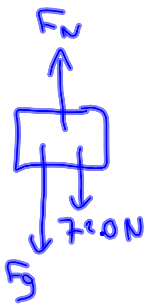


$F_{Net} = ma$
$= 50(2.2)$
$= 110N$

$F_{Net} = F_N - F_g$
$110N = F_N - 50(9.8)$

$F_N = 110 + 50(9.8)$
$= 600\ N.$

A 60.0 kg person is standing on a bathroom scale calibrated in newtons. A friend pushes down on the person with a force of 72.0 N. What is the reading on the scale?



$F_{Net} = 0$
$= F_N - F_g - 72.0N.$

$F_N = mg + 72.0N$
$= (60)(9.8) + 72.0N$
$= 660\ N.$

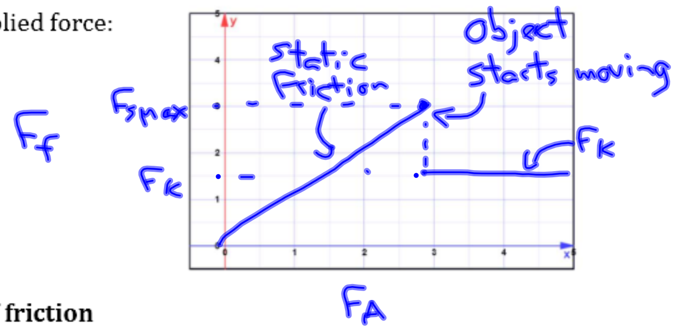
Homework: page 167: #1-3, 5-7

SPH3U: 4.2 Friction

1. Static vs. kinetic friction

Static friction:	friction that prevents an object from moving on a surface. there is a maximum, $F_{s max}$. Any force larger than $F_{s max}$ will make a stationary object move.
Kinetic friction:	friction that slows down an object moving on a surface. F_K.

Friction vs. the applied force:



2. Coefficients of friction

Frictional force depends on:	the mass of the object and the type of materials of the object and the surface.
coefficients of friction	μ (Greek letter "mu"). $\mu = \frac{F_f}{F_N}$ $\mu_s = \frac{F_{s max}}{F_N}$ $\mu_K = \frac{F_K}{F_N}$

Some approximate coefficients of kinetic and static friction:

Material	μ_s	μ_K
rubber on asphalt (dry)		0.5–0.80
rubber on asphalt (wet)		0.25–0.75
steel on steel (dry)	0.78	0.42
steel on steel (greasy)	0.05–0.11	0.029–0.12
ice on ice	0.1	0.03
steel on ice	0.1	0.01
Teflon on Teflon	0.04	0.04

near-frictionless carbon		0.001
synovial joints in humans	0.01	0.003

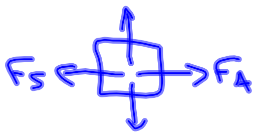
3. Determining the forces of friction

A 3.0 kg block of wood sits on a horizontal wooden floor. The largest horizontal force that can be applied to the block before it will start moving is 14.7 N. Once the block starts moving, it only takes 8.8 N to keep it moving at a constant velocity.

Calculate the coefficient of static friction for the block and the floor.

$$\mu_s = \frac{F_{smax}}{F_N} = \frac{14.7 N}{3.0(9.8)} = 0.50.$$

Determine the force of friction acting on the block if a horizontal force of 6.8 N [E] acts on the block.



$F_s = F_A$ because $6.8 N < F_{smax}$

$F_s = 6.8 N [W].$

Calculate the maximum magnitude of static friction acting on the block if a 2.1 kg object is placed on top of it.

$$\mu_s = \frac{F_{smax}}{F_N} \qquad m = 3 + 2.1 = 5.1 kg.$$

$$F_{smax} = \mu_s F_N = 0.50(5.1)(9.8)$$
$$= 25 N.$$

Determine the coefficient of kinetic friction.

$$\mu_K = \frac{F_K}{F_N} = \frac{8.8 N}{3.0(9.8)}$$
$$= 0.30$$

Homework: page 172: #1-2, 4-5, 9, 11

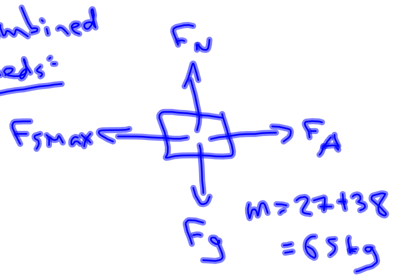
SPH3U 4.3 Solving Friction Problems

1. Static friction acting on several objects

Two sleds are tied together with a rope. The coefficient of static friction between each sled and the snow is 0.22. A small child is sitting on sled 1 (total mass of 27 kg) and a larger child sits on sled 2 (total mass of 38 kg). An adult pulls on the sleds.

a. What is the greatest horizontal force that the adult can exert on sled 1 without moving either sled?

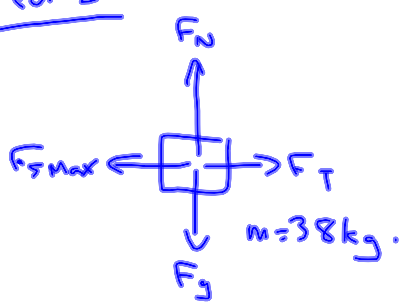
Combined Sleds:



$F_A = F_{Smax}$
$= \mu_s F_N$
$= \mu_s mg$
$= 0.22(65)(9.8)$
$= 140 N$.

b. Calculate the magnitude of the tension in the rope between sleds 1 and 2 when the adult exerts this greatest horizontal force.

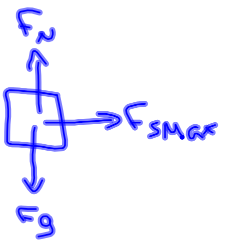
Sled 2:



$F_T = F_{Smax}$
$= \mu_s mg$
$= 0.22(38)(9.8)$
$= 82 N$.

2. Static friction can cause motion

The coefficient of static friction between a person's shoe and the ground is 0.70. Determine the maximum magnitude of acceleration of the 62 kg person, if he starts running on a horizontal surface from rest.



$F_{Net} = ma \quad a = \frac{F_{Net}}{m}.$

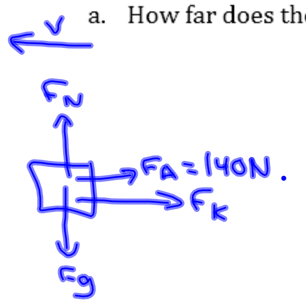
$F_{Net} = F_{Smax}$
$= \mu_s F_N$
$= \mu_s mg = 0.70(62)(9.8)$
$= 425.3 N.$

$a = \frac{F_{Net}}{m} = \frac{425.3}{62} = 6.9 \, m/s^2.$

3. Stopping a sliding box

A 250 kg box slides down a ramp and then across a level floor. The coefficient of kinetic friction along the floor is 0.20. A person sees the box moving at 1.0 m/s [left] and pushes on it with a horizontal force of 140 N [right].

a. How far does the box travel before coming to rest?



$F_{Net} = ma \quad a = \frac{F_{Net}}{m}.$

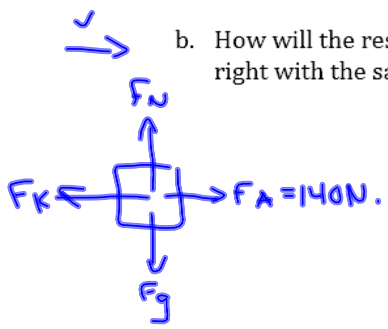
$F_{Net} = F_A + F_k. = F_A + \mu_k mg.$
$= 140 N + 0.20(250)(9.8)$
$= 630N.$

$a = \frac{F_{Net}}{m} = \frac{630}{250} = 2.52 \, m/s^2.$

$v_f^2 = v_i^2 + 2a\Delta d$

$\Delta d = \frac{v_f^2 - v_i^2}{2a} = \frac{0 - (-1.0)^2}{2(2.52)} = -0.20 \, m.$

b. How will the results change if the box is moving right and the person still pushes right with the same force?



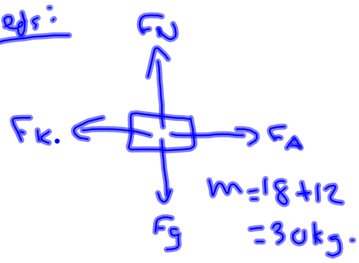
The person is fighting friction instead of helping it. ∴ the box will move further.

4. Kinetic friction and tension

Two sleds tied together are pulled across an icy surface with an applied force of 150 N [E]. The mass of sled 1 is 18.0 kg and the mass of sled 2 is 12.0 kg. The coefficient of kinetic friction for each sled is 0.20.

a. Calculate the acceleration of the sleds.

Combined Sleds:



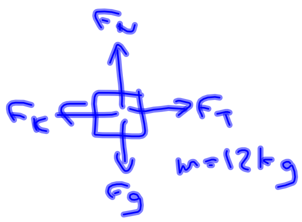
$\vec{a} = \frac{\vec{F}_{Net}}{m}$

$F_{Net} = F_A - F_K$
$= F_A - \mu_K F_N$
$= 150 - 0.20(30)(9.8)$
$= 91.2 \text{ N}$

$\vec{a} = \frac{\vec{F}_{Net}}{m} = \frac{91.2}{30} = 3.0 \text{ m/s}^2 \text{ [E]}$

b. Determine the magnitude of the tension in the rope between the sleds.

Sled 2:



$F_{Net} = ma$
$F_{Net} = F_T - F_K$
$F_T = F_{Net} + \mu_K mg$
$= ma + \mu_K mg$
$= (12)(3.0) + 0.20(12)(9.8)$
$= 60 \text{ N}$

Homework: page 178: #1, 3, 7, 8