PHY 115
Assignment 5 Solutions

1.

a. What is the magnitude of the weight of a 100-kg Japanese macaque on the moon? The magnitude of acceleration due to gravity on the moon is 1.6 m/s^2.

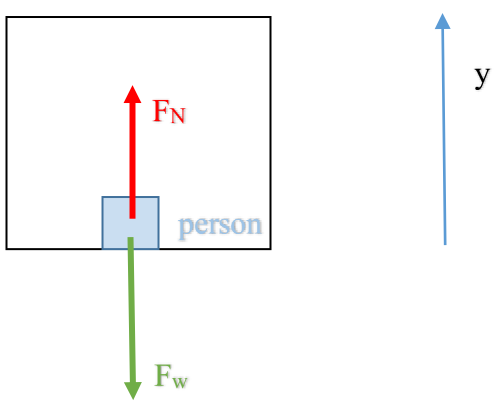
$$F_{w,moon} = mg_{moon} = 100\ kg * 1.6\frac{m}{s^2} = 160\ N = \boldsymbol{1.6\ x\ 10^2\ N}$$

Comparing this magnitude to the weight of the macaque on the earth:

$$F_{w,earth} = 100kg * 9.8\frac{m}{s^2} = 9.8\ x\ 10^2 N$$

b. What is the apparent weight of a 100-kg person inside an elevator that is accelerating downwards at 0.50 m/s^2?

Below is the free-body diagram for the person:



Note that only the forces on the person are represented.
The net force on the person is: $\sum \vec{F} = \vec{F}_N + \vec{F}_w = m\vec{a}$
Where m = 100 kg, $\vec{a} = -0.50\ m/s^2$ (according to the coord. system depicted above).
But the apparent weight is the normal force. So the question is: $\vec{F}_N = ?$

$$\vec{F}_N + \underbrace{100\ kg * \left(-9.8\frac{m}{s^2}\right)}_{-980\ N} = \underbrace{100\ kg * (-0.50\frac{m}{s^2})}_{-50\ N}$$

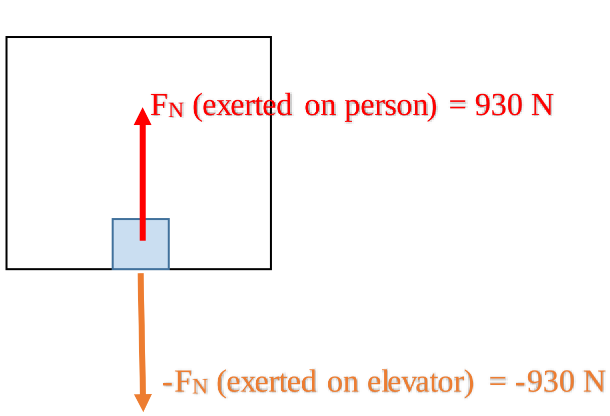
$\vec{F}_N = 980\ N\ \hat{y} - 50\ N\ \hat{y} = +930\ N\ \hat{y} = \mathbf{9.3\ x\ 10^2 N, up}$

Note that the magnitude of the normal force is smaller than the magnitude of the weight, since the elevator is accelerating downwards. Therefore, the person feels lighter.

c. What is the action/reaction pair to the force you calculated on b.? Please provide direction, magnitude and the object that this force is exerted on.

Newton's 3rd Law can be stated as: *when an object (object 1) exerts a force on another object (object 2), then object 2 simultaneously exerts a force on object 1, that is equal in magnitude and opposite in direction.* There forces are an action/reaction pair of forces.

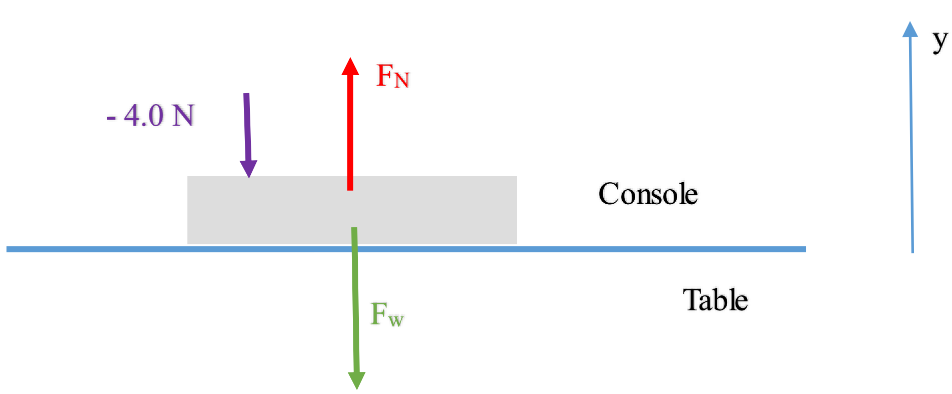
The force calculated on b is the normal force, exerted by the elevator on the person. The person exerts a force on the elevator that is directed downward, and has a magnitude of 930 N. This force is represented below.



Note that are other forces on the elevator: the elevator's weight and the tension force exerted by the cable. These forces are not represented here.

d. If you exert a downward force of 4.0 N on a 5.0-kg game console that is sitting on a table, what is the normal force (magnitude and direction) exerted by the table on the console?

Free-body diagram for the console:



$\vec{F}_N = ?$

$$\sum \vec{F} = \vec{F}_N + \vec{F}_w + (-4.0\ N) = m\vec{a} = 0\ (since\ the\ console\ is\ at\ rest)$$

Where $\vec{F}_w = m\vec{g} = 5.0\ kg * \left(-9.8\frac{m}{s^2}\right) = -49\ N$

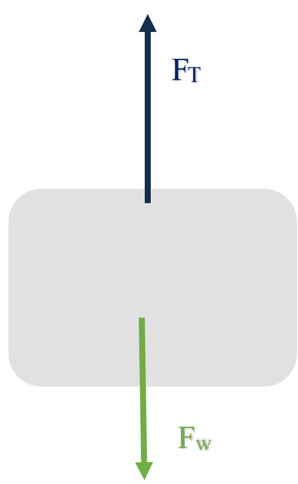
$\vec{F}_N = 0 - (-\ 490\ N) - (-4.0\ N) = \boldsymbol{+\ 53\ N}$

So here the normal force is larger (in magnitude) than the weight force.

2. Digipen Zee has plans to go home. Unfortunately, today she parked at an illegal spot and her car is being towed. However, it is being towed by a monster (the company is called Monster Towing Inc., and it takes its name literally).

The monster uses a cable to lift the car vertically. The mass of the car is 1.5×10^3 kg. The car accelerates upwards at a constant rate of $1.0\ m/s^2$.

a. Draw a free-body diagram for the car, identifying all the forces on the car.



Where $\vec{F}_T$ is the tension force exerted by the cable on the car.

b. Determine the tension force exerted by the cable on the car as the car accelerates upwards.

$\vec{F}_T = ?$

The net force on the car is:

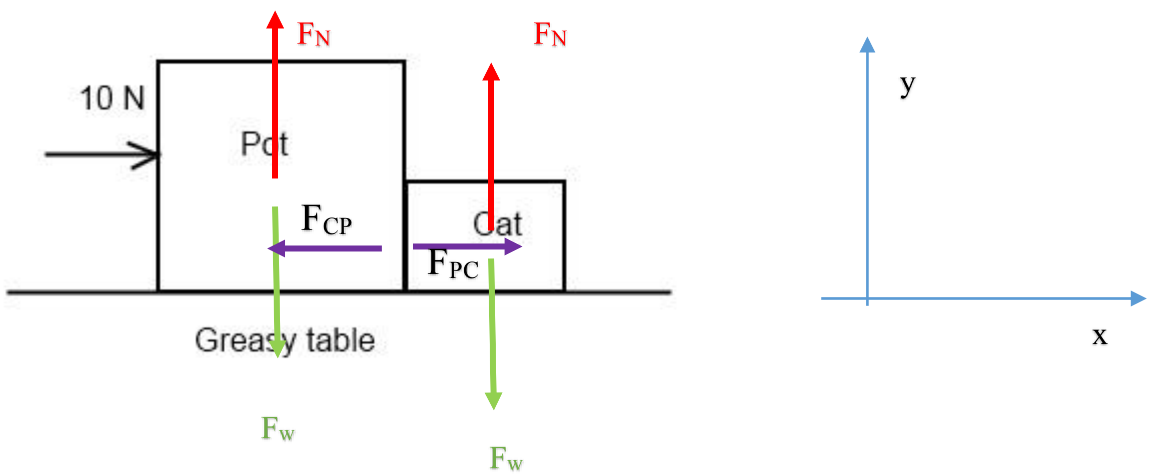
$$\sum \vec{F} = \vec{F}_T + \vec{F}_w = m\vec{a} = 1.5\ x\ 10^3 kg * 1.0\frac{m}{s^2} = 1.50\ x\ 10^3 N, up$$

In the equation above, $\vec{F}_w = m\vec{g} = 1.5\ x\ 10^3 kg * \left(-9.8\frac{m}{s^2}\right) = -1.47\ x\ 10^4 N\ (down)$

So the tension force on the car is $\vec{F}_T = 1.50\ x\ 10^3 N + 1.47\ x\ 10^4 N \approx \mathbf{1.6\ x\ 10^4 N\ (up)}$

3. Digipen Dee has a part-time job in a cafeteria. Late at night, she is still cleaning the kitchen, but everything seems to be covered in grease. To avoid exerting herself, Dee pushes a 9.0-kg pot on a horizontal table with a constant force of 10.0 N. However, she does not realize that behind the pot there is a 6.0 kg cat, who was after the food in the pot. The cat slides with the pot as Dee applies the force on the pot. The surface of the table is so greasy that friction can be neglected.

The force exerted by Dee is represented in the diagram below.



The vectors above represent all the forces, horizontal and vertical, on the post and the cat.

$\vec{F}_{CP}$ and $\vec{F}_{PC}$ are, respectively, the force of the cat on the pot and the force of the pot on the cat (see diagram).

In this situation, $a_y = 0$, since the acceleration is horizontal. This means the cat and the pot are at equilibrium in the y-direction, and, for both, the magnitude of the normal force is equal to the magnitude of the weight force.

However, $\vec{a}_x \neq 0$, and the horizontal motion is analyzed below.

a. Determine the acceleration of the cat and the pot, as they move together.

Since they are moving together, they have the same acceleration.
For the system cat + pot, $\vec{F}_{CP}$ and $\vec{F}_{PC}$ cancel each other force. Since friction can be neglected, the net force in the horizontal direction is 10 N.

$$\vec{F}_{net,x} = \sum \vec{F}_x = m_{total} * \overrightarrow{a_x}$$

$$10\ N = 15\ kg * \overrightarrow{a_x}$$

$\overrightarrow{a_x}$ **= 0.67 m/s² in the positive x-direction**.

b. Determine the horizontal force that the cat exerts on the pot as they accelerate together. Is that part of an action/reaction pair of forces? Why/why not?

$\vec{F}_{CP} = ?$

In this case, only the forces on the pot are used while applying Newton's Second Law. The horizontal forces on the pot are: the force exerted by Dee (10 N) and $\vec{F}_{CP}$ (see figure).

$$\vec{F}_{net,x,on\ the\ pot} = \sum \vec{F}_{x,pot} = \vec{F}_{CP} + 10\ N = m_{pot}\,\vec{a}_x = 9.0\ kg * 0.67\frac{m}{s^2} \approx 6.0\ N$$

$$\boldsymbol{\vec{F}_{CP} = 6.0\ N - 10\ N = -4.0\ N\ (to\ the\ left)}$$

Yes, $\vec{F}_{cp}$ and $\vec{F}_{PC}$ are a Newton's 3rd Law action/reaction pair of forces. There are only two objects interacting (cat and pot), and the forces arise from the contact between them (the forces are of the same kind); moreover, those two forces have the same magnitude and opposite directions.

c. Draw a free-body diagram for the cat and for the pot, determining all the vertical and horizontal forces on the cat and on the pot.

In the figure above,

The forces on the cat are:

Vertical forces: $\sum \vec{F}_{y,cat} = 0$

$$\vec{F}_{N,cat} + m_{cat}\vec{g} = 0 = \vec{F}_{N,cat} + 6.0\ kg * \left(-9.8\frac{m}{s^2}\right)$$

$$\boldsymbol{\vec{F}_{N,cat} \approx 59\ N\ (up)\ and\ \vec{F}_{w,cat} = m_{cat}\vec{g} \approx -59\ N\ (down)}$$

Horizontal forces: the only horizontal force on the cat is $\boldsymbol{\vec{F}_{PC}}$**, which is equal to + 4.0 N**.

The forces on the pot are:

Vertical forces:

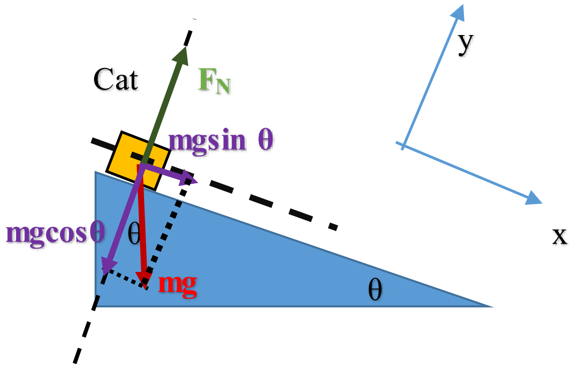
$$\vec{F}_{N,pot} + m_{pot}\vec{g} = 0 = \vec{F}_{N,pot} + 9.0\ kg * \left(-9.8\frac{m}{s^2}\right)$$

$$\boldsymbol{\vec{F}_{N,pot} \approx 88\ N\ (up)\ and\ \vec{F}_{w,pot} = m_{pot}\vec{g} \approx -88\ N\ (down)}$$

The horizontal forces on the pot are: 10 N and

$\boldsymbol{\vec{F}_{CP} = 6.0\ N - 10\ N = -4.0\ N}$ **as determined on b.**

4. The 6.0 kg-cat jumps from the table and falls on a frictionless (also covered in grease) ramp. The angle of the incline is θ = 23 degrees.



a. What is the acceleration of the cat down the ramp?

From the free-body diagram above,

$$\sum \vec{F}_x = m\vec{a}_x = mgsin\theta\ \hat{x}$$

Dividing by m,

$$\vec{a}_x = gsin\theta\ \hat{x} = 9.8\frac{m}{s^2} * \sin 23°\ \hat{x} = 3.83\frac{m}{s^2}\hat{x} \approx \mathbf{3.8\ m/s^2\ \hat{x}}$$

Note that this acceleration is smaller in magnitude than g.

b. What is the normal force on the cat as the feline accelerates down the ramp?

$$\sum \overrightarrow{F_y} = 0$$

$$\vec{F}_N + m\vec{g}\cos\theta = 0$$

$$\vec{F}_N = mgcos\theta\ = 6.0\ kg * 9.8\frac{m}{s^2} * (0.92)\hat{y} \approx \mathbf{54\ N\ \hat{y}}$$

Note that this force is smaller than the normal force on the cat calculated in the previous problem.

c. The cat moves 1.0 m down the ramp, as shown in the figure. How long does this motion last?

$\boldsymbol{t} = ?$

$$\vec{\boldsymbol{x}} = \overrightarrow{x_0} + \vec{v}_{0x} t + \frac{1}{2}\vec{a}_x t^2$$

Where

$\Delta\vec{x} = \vec{x} = \overrightarrow{x_0} = 1.0\ m\ \hat{x}$,
$\vec{v}_{0x} = 0$ (assuming all kinetic energy was transfered to the ramp)and $\vec{a}_x = 3.83\ m/s^2\hat{x}$

So

$t^2 = 2 * \frac{1.0\ m}{3.83\frac{m}{s^2}} \approx 0.52\ s$
$\boldsymbol{t \approx 0.72\ s}$