Forces

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Learning Outcome

I highly recommend you to finish this checklist to determine whether you've achieved the learning objectives.

- ☐ State Newton's First Law of Motion, and explain related phenomena
- ☐ State Newton's Second Law of Motion, grasp the relationship between mass, acceleration and resultant force
- ☐ State Newton's Third Law of Motion, and distinguish pairs of action force and reaction force
- ☐ Using $F = ma$ to solve kinematics problems
- ☐ Solving problems by resolving forces and utilize common models.

Leadin

After the full study of kinematics, and basis concept of forces, Sir Issac Newtonhas set up the rule for the fundation of *dynamics*, which has in turn elevated him to the summit of physics world.

Do you want to attend the same university/college[1] that Newton has acquired his bachelor? Actually, Newton does not major in physics at that time, it is called *natural philosophy*.

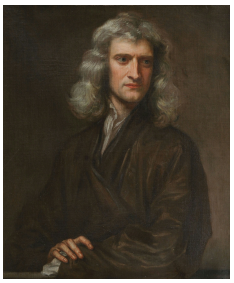


Figure 1: Sir Issac Newton 1643-1727

[1] surf the internet

NFL

Newton's First Law of motion is sometimes also refered to as the law of inertia. It states:

Definition 0.1 *An object will remain at rest or in a state of uniform motion unless it is acted on by an external force.*

This is the first time that kinematics has been given a clear definition. NFL is a qualitative law but it's a huge step in the method of studying mechanics.

Summary

If the resultant force acting on an object is **zero**, then the object must be at rest or in uniform motion. We call this state *Equilibrium*.

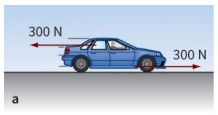
NSL

This is actually the most important law in the set of Newton's Law of Motion, and also a bridge that combines *kinematics* with *dynamics*[2].

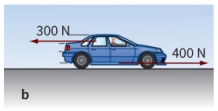
[2] def:

Resultant Force

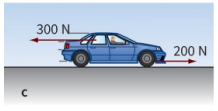
If several forces acting on the same object, due to the vector nature of forces, we can combine all the force into one single force which will have same motional effect on the object, this force is called *Resutlant Force*. The advantage of using resultant force is quite obvious, so it is the most important technique whenever analysing the forces is required.



Two equal forces acting in opposite directions cancel each other out. We say they are **balanced**. The car will continue to move at a steady velocity in a straight line.
resultant force = 0 N



These two forces are unequal, so they do not cancel out. They are **unbalanced**. The car will accelerate.
resultant force
= 400 N – 300
= 100 N to the **right**



Again the forces are unbalanced. This time, the car will slow down or decelerate.
resultant force
= 400 N – 300 N
= 100 N to the **left**

Free-body Diagram

In order to learn physics better, you have to develop ability to draw various kinds of figures and graphs. For example, sketch the path of motion, the *v-t* graph. Now a third type of graph is introduced - *Free Body Diagram*. Such graphs can show all the forces acting on the object.

NSL

After all this preparation work, the Newton's Second Law of motion is finally presented to you:

Definition 0.2 *For a body of constant mass, its acceleration is directly proportional to the resultant force applied to it.*

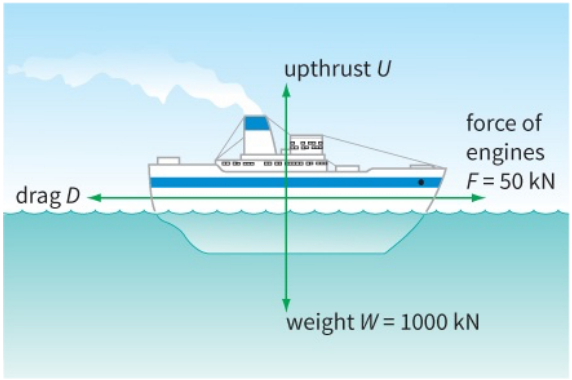


Figure 2: This is the FBD of a boat

This law links the acceleration of an object and the resultant force acting on the object, thus making it a bridge to connect two topics. And this relationship can be written as:

$$a \propto F$$

However, that's not the end of story, after carefully investigation, the measure of inertia would be a key factor when deciding the value of acceleration. And Newton found that, the mass is **inversely proportional** to the mass[3]. Expressed in mathmematic language, it is

[3] or it is directly proportional to the reciprocal of mass

$$a \propto 1/m$$

Finally, the complete quantitative NSL can be written in the form of

$$F = ma \tag{1}$$
$$a = F/m \tag{2}$$

Either form is correct. But one thing to mention is that because both acceleration and force are vectors, thus this formula also implied that, the direction of acceleration is the same as the resultant force.

NTL

Netwon's Third Law is the last law, it is about interacting objects It states:

Definition 0.3 *When two bodies interact, the forces they exert on each other are equal and opposite.*

Unlike the first and second law, Newton's Third Law does not focus on single object but on the interacting objects. The two forces that make up a 'Newton's third law pair' have the following characteristics:

- They act on **different** objects
- They are **equal** in magnitude
- They are **opposite** in direction
- They are forces of the same type.[4]

[4] this is not hard to understand, but easy to dismiss

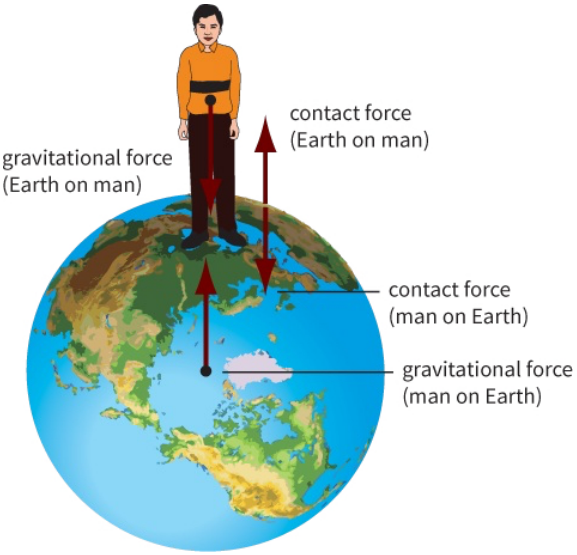


Figure 3: Weight and Normal Contact Force are not 'pairs of action and reaction force'

Task

In figure 3, point out which two forces are a pair.

Common Models

In this section, we are going to apply newton's law of motion to determine the dynamics or kinematics of objects.

Process of Anaylsing Forces

Usually, there exist a standard process when analyse the states of forces on the object.

1. Any object with mass and is placed on Earth (or other celestial bodies) will subject to the gravity or weight, the formula is $W =$ _____. Direction of weight is
2. Determine, whether the object is in *contact* with other objects, if so _____ contact forces may exist, the direction of such forces is always .
3. Check whether the object is partially or fully immersed in fluids, if so, upthrust[5] should be considered. The formula for upthrust is

$$F = \rho\_\_\_\_ \cdot \_\_\_\_$$

4. If resistance or friction can not be ignored, and the object has a tendency to move, or just in the state of moving, *frcition, drag, resistance* should be taken into account.
5. If spring or rope is mentioned, *Tension* might be considered. The direction of tension is alway
6. Check any other clear articulation about pull or push from other objects like human hand or engine.

[5] sometimes bouyance is used

Incline Model

This model involves an object placed on an sloped incline, which makes an angle of θ with the horizontal. As shown in the following figure

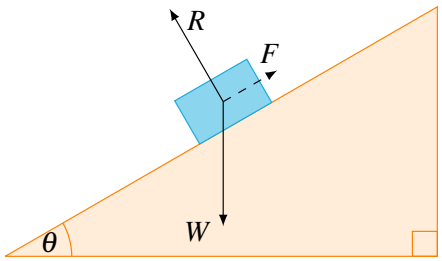


Figure 4: an incline with an object and its forces

Task

State what forces are acting on the object, and their origins.

Resolve the Weight W into the direction parallel to the plane and the direction perpendicular to the plane. State quantitatively the magnitude relationship between R and F.