A free body diagram mechanics essay

A free body diagram consists primarily of a sketch of the body in question and arrows representing the forces applied to it. The selection of the body to sketch may be the first important decision in the problem solving process. For example, to find the forces on the pivot joint of a simple pair ofpliers, it is helpful to draw a free body diagram of just one of the two pieces, not the entire system, replacing the second half with the forces it would apply to the first half.

What is included

The sketch of the free body need include only as much detail as necessary. Often a simple outline is sufficient. Depending on the analysis to be performed and the model being employed, just a single point may be the most appropriate.

All external contacts, constraints, and body forces are indicated byvectorarrows labeled with appropriate descriptions. The arrows show the direction andmagnitudeof the various forces. To the extent possible or practical, the arrows should indicate the point of application of the force they represent.

Only the forces acting on the object are included. These may include forces such asfriction, gravity, normal force, drag, or simply contact force due to pushing. When in anon-inertial reference frame, fictitious forces, such ascentrifugal forcemay be appropriate.

Acoordinate systemis usually included, according to convenience. This may make defining the vectors simpler when writing the equations of motion. The x direction might be chosen to point down the ramp in aninclined planeproblem, for example. In that case the friction force only has an x component, and the normal force only has a y component. The force of gravity will still have components in both the x and y direction: mgsin(Î¸) in the x and mgcos(Î¸) in the y, where Î¸ is the angle between the ramp and the horizontal.

What is excluded

All external contacts and constraints are left out and replaced with force arrows as described above.

Forces which the free body applies to other objects are not included. For example, if a ball rests on a table, the ball applies a force to the table, and the table applies an equal and opposite force to the ball. The FBD of the ball only includes the force that the table causes on the ball.

Internal forces, forces between various parts that make up the system that is being treated as a single body, are omitted. For example, if an entiretrussis being analyzed to find the reaction forces at the supports, the forces between the individual truss members are not included.

Any velocity or acceleration is left out. These may be indicated instead on a companion diagram, called “ Kinetic diagrams”, “ Inertial response diagrams”, or the equivalent, depending on the author.

Assumptions

The free body diagram reflects the assumption and simplifications made in order to analyze the system. If the body in question is a satellite in orbit for example, and all that is required is to find its velocity, then a single point may be the best representation. On the other hand, thebrake diveof a motorcycle cannot be found from a single point, and a sketch with finite dimensions is required.

Force vectors must be carefully located and labeled to avoid assumptions that presuppose a result. For example, in the accompanying diagram of a block on a ramp, the exact location of the resulting normal force of the ramp on the block can only be found after analyzing the motion or by assuming equilibrium.

Other simplifying assumptions that may be considered include two-force members and three-force members.

Drawing Free-Body Diagrams

Free-body diagrams are diagrams used to show the relative magnitude and direction of all forces acting upon an object in a given situation. A free-body diagram is a special example of the vector diagrams which were discussedin an earlier unit. These diagrams will be used throughout our study of physics. The size of the arrow in a free-body diagram is reflects the magnitude of the force. The direction of the arrow shows the direction which the force is acting. Each force arrow in the diagram is labeled to indicate the exact type of force. It is generally customary in a free-body diagram to represent the object by a box and to draw the force arrow from the center of the box outward in the direction which the force is acting. An example of a free-body diagram is shown at the right.

The free-body diagram above depicts four forces acting upon the object. Objects do not necessarily always have four forces acting upon them. There will be cases in which the number of forces depicted by a free-body diagram will be one, two, or three. There is no hard and fast rule about the number of forces which must be drawn in a free-body diagram. The only rule for drawing free-body diagrams is to depict all the forces which exist for that object in the given situation. Thus, to construct free-body diagrams, it is extremely important to know thevarious types of forces. If given a description of a physical situation, begin by using your understanding of the force types to identify which forces are present. Then determine the direction in which each force is acting. Finally, draw a box and add arrows for each existing force in the appropriate direction; label each force arrow according to its type. If necessary, refer tothe list of forces and their descriptionin order to understand the various force types and their appropriate symbols.

EXAMPLES

No doubt you are aware of free body diagrams (otherwise known as FBD's). These are simplified representations of an object (thebody) in a problem, and includes force vectors acting on the object. This body isfreebecause the diagram will show it without its surroundings

Let's take Figure 1 to be a pictoral representation of our problem: a boat on the floor, with a rope pulling it. First we will represent the boat — the ' body' in our problem — as a (really) simplified figure, a square

Gravity

The first force we will investigate is that due to gravity, and we'll call it thegravitational force. We know that the acceleration due to gravity (if on Earth) is approximatelyg= 9. 8 m/s . The force, by Newton's Second Law is

F= mg

wheregis the acceleration due to gravity. Let's add this to our diagram . Note that the force vector, labelledFmg, points downward, as this is the direction in which the gravitation force acts.

Note that this force is commonly calledweight. This ' weight' (mg) is different from our everyday use of the word ' weight' (which is known in physics as ' mass').

Normal

Thenormal forceone which prevents objects from ' falling' into whatever it is they are sitting upon. It is alwaysperpendicularto the surface with which an object is in contact. For example, if there is a crate on the floor, then we say that the crate experiences a normal forcebythe floor; and because of this force, the crate does not fall into the floor. The normal force on the crate points upward, perpendicular to the floor.

It is called the normal force becausenormalandperpendicularmean the same thing. The normal force is always perpendicular to the surface with which a body is in constact. For a body on a sloped surface (say a ramp), the normal force acting on that body is still perpendicular to the slope.

In the case of our problem, the ship, we will pretend the ship is being pulled on a floor. (This is because on water there is the complication with another force, buoyancy. For simplicity's sake, we will ignore buoancy by putting the ship on the floor.) Let's add the normal force to our FBD (Figure), and represent the normal force with the script ' N', .

Friction

Related to the normal force is thefrictional force. The two are related because they are both due to the surface in contact with the body. Whereas the normal force was perpendicular to the surface, the frictional force is parallel. Furthermore, friction opposes motion, and so its vector always points away from the direction of movement.

Friction is divided into two categories, static and kinetic. These are represented by the script ‘ F’, with a subscript ‘ s’ for static friction:, and a subscript ‘ k’ for kinetic friction,. As its name suggests, static frictionoccurs when the body is not moving (i. e. “ static”). It is the force which makes it difficult to start something moving. On the other hand, kinetic frictionoccurs when the body is in motion. This is the force which causes objects to slow down and eventually stop.

Friction is usually approximated as being proportional to the normal force. The proportionality constant is called the coefficient of (static or kinetic) friction. The constant is represented asfor static friction, andfor kinetic friction; it depends on the actual surface with which the body is in contact.

To summarize,

We’ve added (kinetic) friction to our free body diagram, Figure .

Push and Pull

Another force which may act on an object could be any physical push or pull. This could be caused by a person pushing a crate on the floor, a child pulling on a wagon, or in the case of our example, the wind pushing on the ship.

We will label the push force caused by the wind withFpush

Tension

Tension in an object results if pulling force act on its ends, such as in a rope used to pull a boulder. If no forces are acting on the rope, say, except at its ends, and the rope itself is in equilibrium, then the tension is the same throughout the rope.

We will use the letterTto represent tension in a free body diagram.

If we say that our ship is being pulled by a rope at its front end, then we can add this force to our FBD (Figure).

- And there we have it: all the forces acting on our ship has been labelled in Figure . This is the complete FBD for our problem of a ship being pulled along a floor by a rope

Steering Wheel and Pedals of a Bicycle

Two examples of the turning effect of two equal and opposite forces not acting in the same straight line are the steering wheel and the pedals of a bicycle. In the figure (a) below, the left hand is pulling with force F on the steering wheel while the right hand is pushing with the same force F. The two forces make the wheel turn in an anticlockwise direction.

In figure (b) shown above, one pedal is being pushed forward while the other is being pushed back. This rotates the sprocket wheel and the attached chain anticlockwise. Can you think of other everyday examples in which a turning effect or rotation takes place?

Examples of Couple

In our day-to-day life, we come across many objects which work on the principle of couple. Winding up the spring of a toy car, opening and closing the cap of a bottle, turning of a water tap, cork screws, door key etc. are some of the common examples of couples.

A beam balance

The physical balance used in the school laboratory is pivoted in the middle with equal arms. The two scale pans of equal weights are hung from the upper edge of wedge shaped supports at either end of the beam. When the beam is raised for weighing, it swings freely about the lower edge of a wedge shaped support in the center. In this position the balance is in equilibrium.

Beam balance

Because $l1= l2$and $m1= m2$, according to the principle of moments,

$m1x\ l1= m2x\ l2$

Now if you place a mass of 1 kg in one pan and an unknown mass ‘ x’ on the other pan so that the balance is in equilibrium.

then, $(m1+ x)\ l1= (m2+ 1)\ l2$

As $m_1 = m_2$ and $l_1 = l_2$

- x = 1 kg

Let us calculate what part of the load each boy carries.

To find the upward force exerted by the boy at A, we shall consider the hand of the boy at B as the pivot.

Now, the clockwise moment = F_1x 5 m and the anticlockwise moment due to the load 900 N = 900 x 3.

If the bar is in equilibrium, then

F_1x 5 = 900 x 3

F_1= 900 x= 540 N

Hence, the force exerted by the boy = 540 N.

But F_1+ F_2= 900 N (sum of the downward forces equal to the sum of upward forces).

Therefore, F_2= 900 – F_1

= 900 – 540

= 360 N

The force exerted by the boy at B can also be calculated by using A as a pivot.

Therefore, F_2x 5 = 900 x 2

or, F1= 900 x

= 360 N

REFERENCE

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DIFFERENT BOOKS

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G. K. LAL