SPH4U UNIVERSITY PHYSICS

DYNAMICS

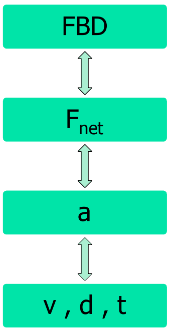
☞ Forces & Free-Body Diagrams (FBDs) (P.62-69)

Analyzing Motion

When analyzing motion, the solution will typically require more than one step. You might have information about the forces acting on an object, which you would use to find the acceleration. In the next step, you would use that acceleration to calculate some other property of the motion (such as the object's velocity, displacement, ...). In other cases, you might analyze the motion to find the acceleration and then use the acceleration to calculate the force applied to a mass.

RECALL!

$F_{net} = ma$



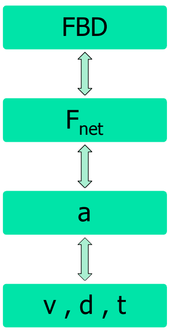
Analyzing Motion

PRACTICE

1. An object with a mass of 15 kg rests on a frictionless horizontal plane and is acted upon by a horizontal force of 30 N. What will be its velocity after 10 s?

   ① calculate the acceleration ($F_{net} = ma$)
   $a = 2.0$ m/s^2

   ② calculate the final velocity ($v_2 = v_1 + at$)
   $v_2 = 20$ m/s



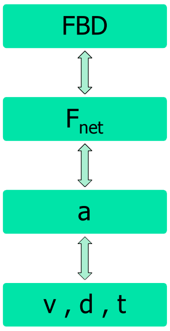
Analyzing Motion

PRACTICE

2. A car with a mass of 1000 kg is moving in a straight line at a constant speed of 30 m/s when the driver applies the brakes and brings the car to rest in 25 s. What constant force is acting to stop the car?

   ① calculate the acceleration ($v_2 = v_1 + at$)
   $a = -1.2\ m/s^2$[fwd]

   ② calculate the net force ($F_{net} = ma$)
   $F_{net} = -2000$ N[fwd]



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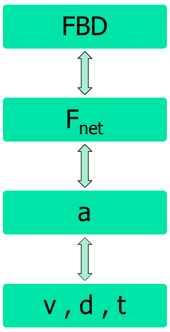
Forces & Free-Body Diagrams (FBDs)

However, in almost every instance of motion, more than one force is acting on the object of interest. To apply Newton's second law, you need to find the resultant force (F_{net}). A FBD (free-body diagram) is an excellent tool that will help to ensure that you have correctly identified and combined the forces.

RECALL!

$\Sigma F \quad F_{net} = F_1 + F_2 + \ldots$

math term meaning "summation"



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Forces & Free-Body Diagrams (FBDs)

PRACTICE

3. Two children are playing with a wagon. One child pulls forward on a rope tied to the front, while the other child pushes on the wagon from behind. Draw a FBD showing all the forces acting on the wagon? Be sure to label the forces accordingly. (Hint: there are five forces in total.)

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Forces & Free-Body Diagrams (FBDs)

RECALL!

- *Examples of common forces that you encounter every day are Earth's gravity, the normal force, tension, friction, applied forces, and air resistance.*
- *One type of friction, called **static friction (F_S)**, is the force that tends to prevent a stationary object from starting to move.*
- *Once the object is moving, **kinetic friction (F_K)** is the force that acts against an object's motion in a direction opposite to the direction of motion.*
- *For horizontal motion, if the applied force has the same magnitude as the friction, the moving object will maintain uniform motion. In other words, if the object is at rest it will remain at rest and if it is in motion, it will remain in motion (constant velocity).*

Forces & Free-Body Diagrams (FBDs)

PRACTICE

4. A 0.17 kg hockey puck slides along the ice at 19 m/s[E] when it hits a rough patch of ice that is 5.1 m across. Assume the coefficient of kinetic friction (μ_K) between the puck and the rough ice is 0.47.
   (a) Draw a FBD of the puck moving on the rough ice.

Forces & Free-Body Diagrams (FBDs)

PRACTICE

4. A 0.17 kg hockey puck slides along the ice at 19 m/s[E] when it hits a rough patch of ice that is 5.1 m across. Assume the coefficient of kinetic friction (μ_K) between the puck and the rough ice is 0.47.
   (b) Calculate the kinetic friction acting on the puck.

   (b) F_k = 0.78 N[W]

Forces & Free-Body Diagrams (FBDs)

PRACTICE

4. A 0.17 kg hockey puck slides along the ice at 19 m/s[E] when it hits a rough patch of ice that is 5.1 m across. Assume the coefficient of kinetic friction (μ_K) between the puck and the rough ice is 0.47.
   (c) Determine the puck's average acceleration while on the rough ice.

   (c) $a = 4.6$ m/s²[W]

Forces & Free-Body Diagrams (FBDs)

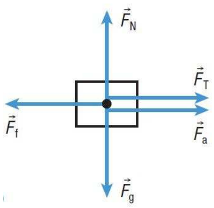
PRACTICE

4. A 0.17 kg hockey puck slides along the ice at 19 m/s[E] when it hits a rough patch of ice that is 5.1 m across. Assume the coefficient of kinetic friction (μ_K) between the puck and the rough ice is 0.47.
   (d) Calculate the puck's velocity as it leaves the rough ice and returns to the smooth ice.

   (d) $v_f = 18$ m/s[E]

Forces & Free-Body Diagrams (FBDs)

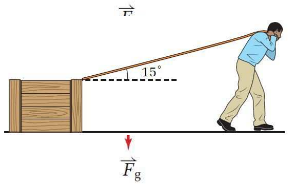
Determining the sum of all the forces acting on an object is straightforward if all the forces are linear or perpendicular to each other, but the task is more complex if some of the forces are at angles other than 90°. In this case $F_N = F_g$ but there are instances where $F_N \neq F_g$.



Forces & Free-Body Diagrams (FBDs)

One of these situations occurs when a force is applied at an angle to the horizontal surface.

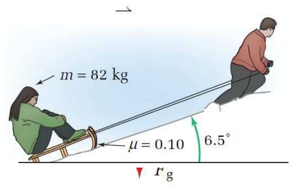
NOTE!
In this case, a component of the applied force causes the crate to move horizontally.



Forces & Free-Body Diagrams (FBDs)

Another of these situations occurs when an object is sliding up or down an incline.

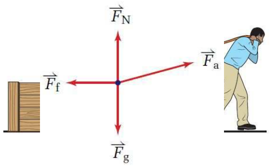
NOTE!
In order to analyze this motion, a different frame of reference is used and the force of gravity is resolved into its component forces.



Forces & Free-Body Diagrams (FBDs)

PRACTICE

5. To move a 45 kg wooden crate across a wooden floor (μ = 0.20), a worker ties a rope onto the crate and pulls on the rope with a force of 115 N as shown.
   (a) Draw FBD of the situation.

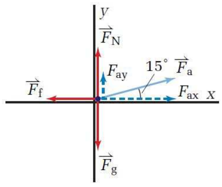


Forces & Free-Body Diagrams (FBDs)

PRACTICE

5. To move a 45 kg wooden crate across a wooden floor (μ = 0.20), a worker ties a rope onto the crate and pulls on the rope with a force of 115 N as shown.
   (b) Resolve F_a into its component forces and determine their values.

(b) $F_{ay} = F_a \sin 15 = 29.8$ N
$F_{ax} = F_a \cos 15 = 14.5$ N



Forces & Free-Body Diagrams (FBDs)

PRACTICE

5. To move a 45 kg wooden crate across a wooden floor (μ = 0.20), a worker ties a rope onto the crate and pulls on the rope with a force of 115 N as shown.
   (c) How much time elapses before the crate is moving at 1.4 m/s? (Recall: FBD → Fnet → a → t)

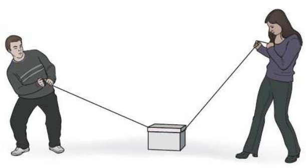
(c) t = 2.2 s

Forces & Free-Body Diagrams (FBDs)

PRACTICE

6. Two people pull on an object at different angles but with equal force.
   (a) Which person applies the greater horizontal force to the load? (Hint: if no measurements are given in a problem you may want to assume some. In this case, assume a force of 100 N and angles of 30° and 60° respectively.)

(a) F_{boy} = 100 cos30 = 87 N
F_{girl} = 100 cos60 = 50 N

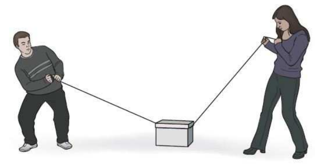


Forces & Free-Body Diagrams (FBDs)

PRACTICE

6. Two people pull on an object at different angles but with equal force.
   (b) What effect does this have on the horizontal motion of the load?

   (b) object moves toward the boy

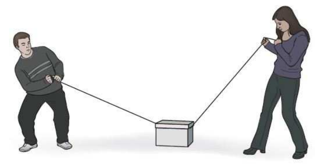


Forces & Free-Body Diagrams (FBDs)

PRACTICE

6. Two people pull on an object at different angles but with equal force.
   (c) Which person applies the greater vertical force to the load?

   (c) F_{boy} = 100 sin30 = 50 N
   F_{girl} = 100 sin60 = 87 N

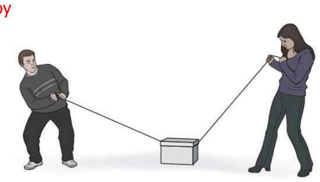


Forces & Free-Body Diagrams (FBDs)

PRACTICE

6. Two people pull on an object at different angles but with equal force.
   (d) What effect does this have on frictional forces? On the vertical motion of the load?

   (d) reduces friction ($F_N < F_g$) – the object may lift off the floor but it still moves towards the boy



✔ Check Your Learning

TEXTBOOK

P.69 Q.2,4,7,9 (Review)
P.76 Q.3 (Review)
P.83 Q.5 (Review)

WIKI (DYNAMICS)

- 4U1 - QUIZ#2 (Forces - Part 1)