Step-by-step Process of Solving

Dynamics Problems

[Chapter 4](https://openstax.org/books/college-physics/pages/4-problems-exercises)

**This handout contains selected problems with**

* **step-by-step solutions**

**and**

* **the demonstration of the thinking process involved in problem-solving.**

**For extra support watch Khan Academy:** [**Forces and Newton’s Laws**](https://www.khanacademy.org/science/physics/forces-newtons-laws)

**# 1**

*A 63.0-kg sprinter starts a race with an acceleration of* *. What is the net external force on him?*

# Step 1

Read the problem again and highlight main information: what is known and what is unknown.

Check that all quantities have SI units of measurements.

If not, convert to SI units before calculations.

*A 63.0-kg sprinter starts a race with an acceleration of* *. What is the net external force on him?*

Known: mass = 65 kg and acceleration 4.20 m/s2. All are in SI units of measurements.

Needs to find: net external force.

SI units of force are Newtons (N).

# Step 2

Think about what formula to use.

This problem is about force, mass, and acceleration. The second Newton’s law is the right formula to use.

$$F = m x a$$

Notes:

Force F and acceleration a are vector quantities.

Mass m is scalar quantity.

# Step 3

Substitute numbers into formula and calculate.



**# 3**

*A cleaner pushes a 4.50-kg laundry cart in such a way that the net external force on it is 60.0 N. Calculate its acceleration.*

# Step 1

Read the problem again and highlight main information: what is known and what is unknown.

Check that all quantities have SI units of measurements.

If not, convert to SI units before calculations.

*A cleaner pushes a 4.50-kg laundry cart in such a way that the net external force on it is 60.0 N. Calculate its acceleration.*

Known: mass = 4.50 kg and net external force = 60.0 N. All are in SI units of measurements.

Needs to find: acceleration.

SI units of acceleration are m/s2 or N/kg.

# Step 2

Think about what formula to use.

This problem is about force, mass, and acceleration. The second Newton’s law is the right formula to use.

$$F = m x a$$

Or

$$a= \frac{F}{m}$$

In this problem we will use the second formula because we need to find acceleration.

Notes:

Force F and acceleration a are vector quantities.

Mass m is scalar quantity.

# Step 3

Substitute numbers into formula and calculate.

of the cart.

**# 9**

*Suppose two children push horizontally, but in exactly opposite directions, on a third child in a wagon. The first child exerts a force of 75.0 N, the second a force of 90.0 N, friction is 12.0 N, and the mass of the third child plus wagon is 23.0 kg.*

*(a) What is the system of interest if the acceleration of the child in the wagon is to be calculated?*

*(b) Draw a free-body diagram, including all forces acting on the system.*

*(c) Calculate the acceleration.*

*(d) What would the acceleration be if friction were 15.0 N?*

# Step 1

Read the problem again and highlight main information: what is known and what is unknown.

Check that all quantities have SI units of measurements.

If not, convert to SI units before calculations.

*Suppose two children push horizontally, but in exactly opposite directions, on a third child in a wagon. The first child exerts a force of 75.0 N, the second a force of 90.0 N, friction is 12.0 N, and the mass of the third child plus wagon is 23.0 kg.*

*(a) What is the system of interest if the acceleration of the child in the wagon is to be calculated?*

*(b) Draw a free-body diagram, including all forces acting on the system.*

*(c) Calculate the acceleration.*

*(d) What would the acceleration be if friction were 15.0 N?*

Known: two external horizontal forces, and force of friction; mass of a system.

Unknown: acceleration.

# Step 2

Solution *(a):*

The system is the child in the wagon plus the wagon.

Solution *(b):*

Free-body diagram includes a system of mass *m* (a child and wagon) and all the external forces acting on this system:

* force of gravity $w=mg$, $g=9.8$ m/s2 is acceleration due to gravity – downward;
* normal force from the support – upward;
* force of one child $F\_{r}$ – to the right;
* force of another child $F\_{l}$ – to the left;
* force of friction – in the direction opposite to motion of the system.

In this case, force of friction is to the left because one of the children pushes with greater force that the other. In our case we chose $F\_{r}>F\_{l}$ , so the system is moving to the right.

So, we have two vertical forces and three horizontal forces.

Vertical forces cancel each other according to 3rd Newton’s law (there is no vertical motion of the system).

We will now work with horizontal forces only.

**Free-body Diagram**



Solution *(c):*

Think about what formula to use.

This problem is about force, mass, and acceleration. The second Newton’s law is the right formula to use.

$$F = m x a$$

Or

$$a= \frac{F}{m}$$

In this problem we will use the second formula because we need to find acceleration.

Notes:

Force F and acceleration a are vector quantities.

Mass m is scalar quantity.

Net force in this case consists of three horizontal forces.

We need to rewrite the formula’s numerator so that directions of forces are included:

Positive – to the right.

Negative – to the left.

# Step 3

Substitute numbers into formula and calculate.

 so that



To the right.

Solution *(d):*



**# 10**

|  |
| --- |
| *A powerful motorcycle can produce an acceleration of*  *while traveling at 90.0 km/h. At that speed the forces resisting motion, including friction and air resistance, total 400 N. (Air resistance is analogous to air friction. It always opposes the motion of an object.) What force does the motorcycle exert backward on the ground to produce its acceleration if the mass of the motorcycle with rider is 245 kg?*  |

# Step 1

Read the problem again and highlight main information: what is known and what is unknown.

Check that all quantities have SI units of measurements.

If not, convert to SI units before calculations.

|  |
| --- |
| *A powerful motorcycle can produce an acceleration of*  *while traveling at 90.0 km/h. At that speed the forces resisting motion, including friction and air resistance, total 400 N. (Air resistance is analogous to air friction. It always opposes the motion of an object.) What force does the motorcycle exert backward on the ground to produce its acceleration if the mass of the motorcycle with rider is 245 kg?*  |
|  |

In this problem all quantities are in SI units.

# Step 2

Think about what formula to use.

This problem is about force, mass, and acceleration. The second Newton’s law is the right formula to use.

$$F = m x a$$

Notes:

Force F and acceleration a are vector quantities.

Mass m is scalar quantity.

# Step 3

Substitute numbers into formula and calculate.



**# 23**

*A*  *rocket is accelerating straight up. Its engines produce  of thrust, and air resistance is . What is the rocket’s acceleration? Explicitly show how you follow the steps in the Problem-Solving Strategy for Newton’s laws of motion.*

# Step 1

Read the problem again and highlight main information: what is known and what is unknown.

Check that all quantities have SI units of measurements.

If not, convert to SI units before calculations.

*A*  *rocket is accelerating straight up. Its engines produce  of thrust, and air resistance is . What is the rocket’s acceleration? Explicitly show how you follow the steps in the Problem-Solving Strategy for Newton’s laws of motion.*

In this problem all quantities are in SI units already.

# Step 2

Think about what formula to use.

$$a= \frac{F}{m}$$

In this problem we will use the second formula because we need to find acceleration.

Notes:

Force F and acceleration a are vector quantities.

Mass m is scalar quantity.

Net force in this case consists of three vertical forces:

* gravity ($mg$, $g$=9.8 m/s2 is acceleration due to gravity) – downward.
* air resistance ($f$) – downward.
* thrust ($T$) - upward.

The object moves upward.

**Free-body Diagram**




# Step 3

Substitute numbers into formula and calculate.

We choose positive direction as upward, that is why thrust $T$ is positive, $mg$ is negative and $f$ is negative.

Using the free body diagram: so that



**# 24**

*The wheels of a midsize car exert a force of 2100 N backward on the road to accelerate the car in the forward direction. If the force of friction including air resistance is 250 N and the acceleration of the car is , what is the mass of the car plus its occupants? Explicitly show how you follow the steps in the Problem-Solving Strategy for Newton’s laws of motion. For this situation, draw a free-body diagram and write the net force equation.*

# Step 1

Read the problem again and highlight main information: what is known and what is unknown.

Check that all quantities have SI units of measurements.

If not, convert to SI units before calculations.

*The wheels of a midsize car exert a force of 2100 N backward on the road to accelerate the car in the forward direction. If the force of friction including air resistance is 250 N and the acceleration of the car is , what is the mass of the car plus its occupants? Explicitly show how you follow the steps in the Problem-Solving Strategy for Newton’s laws of motion. For this situation, draw a free-body diagram and write the net force equation.*

In this problem all quantities are in SI units already.

# Step 2

Think about what formula to use.

$$m= \frac{F}{a}$$

In this problem we will use the second formula because we need to find acceleration.

Notes:

Force F and acceleration a are vector quantities.

Mass m is scalar quantity.

Net force in this case consists of two horizontal forces:

* air resistance - to the left;
* force on a car – to the right.

The car is moving to the right.

The car exerts a force on the road to the left, and the road exerts the force on the car in opposite direction (according to the 3rd law of Newton).

On the free-body diagram we draw only forces that act on the car.

**Free-body Diagram**



# Step 3

Substitute numbers into formula and calculate.

We chose to have positive direction to the right. That is why force $F$ is positive and $f $is negative.

