

F=ma

Teacher's Guide

1.0 Summary

"F=ma" is the fourth activity in the Dynamica sequence. This activity should be done after Motion Graphs and it should take students approximately 30 minutes. This activity has been entirely rewritten for the 2004-2005 school year. It includes a four-question quiz at the end of the activity.

2.0 Learning Goals

Driving Question: How do forces affect the motion of objects with different masses?

This activity explores the relationships between force, mass, and acceleration. The model allows students to apply a force to an object and predict how its velocity will change.

Step One: **Force and Mass** demonstrates the difference in the magnitude of the force needed to move a more massive object than a less massive object.

Step Two: **Force in Newtons** explains the F component of the F=ma equation. Students will calculate the force needed to accelerate an object.

Step Three: **Mission 1: Flying** is a game that uses the arrow keys on the keyboard to represent force boosters applied to a space ship.

Step Four: **Mission 2: Target Practice** asks students to predict the force needed for a space ship to hit a target at a certain velocity. Students calculate the required force and adjust the force boosters as needed.

Step Five: **Mission 3: Landing Zone** requires that students apply forces in the opposite direction of the ship's motion in order to slow down or stop a ship.

Step Six: **Mission 4: Flight Commander** requires students to understand the F=ma equation. Students use the equation to complete various tasks, such as calculating acceleration.

Step Seven: **Quiz** is a four-question assessment. Students will receive a score and can review their answers at the end of the quiz.

Additional Teacher Background

The change in velocity depends on three simultaneous variables: the force, the length of time it is applied, and the mass. Force and duration are directly proportional to velocity change, and mass is inversely proportional. These relationships make sense intuitively, but working with all three at once can be challenging.

The common algebraic expression of Newton's Second Law, $F = ma$, is presented here in a slightly different but equivalent form:

Impulse = change in momentum

Since *impulse* is equal to the *force applied over a specified time*, you can rearrange this to be equivalent to Newton's Second Law because change in velocity divided by time equals acceleration.

$$\text{Force} \times \text{time applied} = \text{mass} \times \text{velocity}$$

$$\text{Force} = \text{mass} \times (\text{change in velocity} / \text{time applied})$$

Force = mass x acceleration

Additional Activities

Air carts: low friction carts with motor-driven propellers provide a constant force. Measure the force by letting the cart push against a force probe as it runs. Then add different masses to the cart and measure its acceleration with a Sonar Ranger. Since the force is constant, students can test the inverse relationship between mass and acceleration.

3.0 Standards Alignment

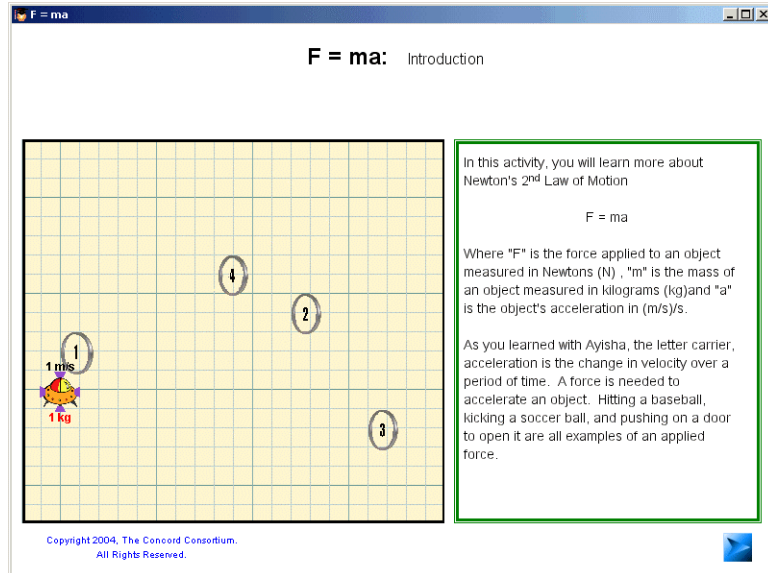
Alignment to National Math and Science Standards (NCTM or NSES)

Objective	Standards
<p>Students will understand that change in velocity is proportional to the strength of the force and the length of time it is applied.</p>	<ul style="list-style-type: none"> • Laws of motion are used to precisely calculate the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship $F = ma$, which is independent of the nature of the force.
<p>Students will understand that change in velocity is inversely proportional to mass.</p>	<ul style="list-style-type: none"> • Students will interpret representations of functions of two variables.
<p>Students will calculate the unknown quantity in an equation with three variables ($F = ma$).</p>	<ul style="list-style-type: none"> • Students will use the language of mathematics to express mathematical ideas precisely. • Students will write equivalent forms of equations and solve them with fluency -- mentally or with paper and pencil in simple cases and using technology in all cases.
<p>Students will learn the definitions of impulse and momentum.</p>	<ul style="list-style-type: none"> • Students will recognize and apply mathematics in contexts outside of mathematics.
<p>Students will predict the outcome of an event and compare it with data from a simulation.</p>	<ul style="list-style-type: none"> • Students will use the language of mathematics to express mathematical ideas precisely. • Students will draw reasonable conclusions about a situation being modeled.
<p>Students will understand the equivalency of the two statements of Newton's Second Law: ($F=ma$) and (impulse = change in momentum).</p>	<ul style="list-style-type: none"> • Students will write equivalent forms of equations and solve them with fluency -- mentally or with paper and pencil in simple cases and using technology in all cases • Students will recognize and apply mathematics in contexts outside of mathematics.

4.0 Activity Sections

4.1 Table of Contents

This activity has 7 sections. The last section is a 4 question quiz to assess student understanding of the material. Students will receive a score after completing the quiz. They will also be able to review their answers.



Opening screen

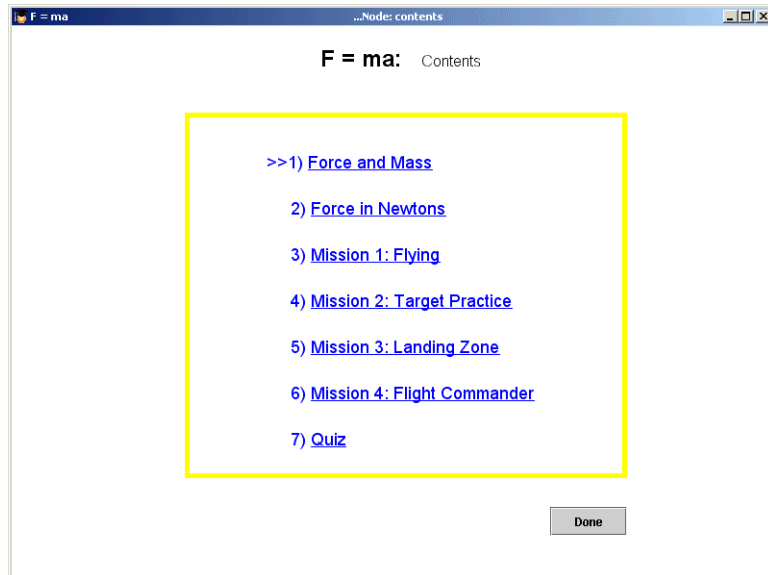
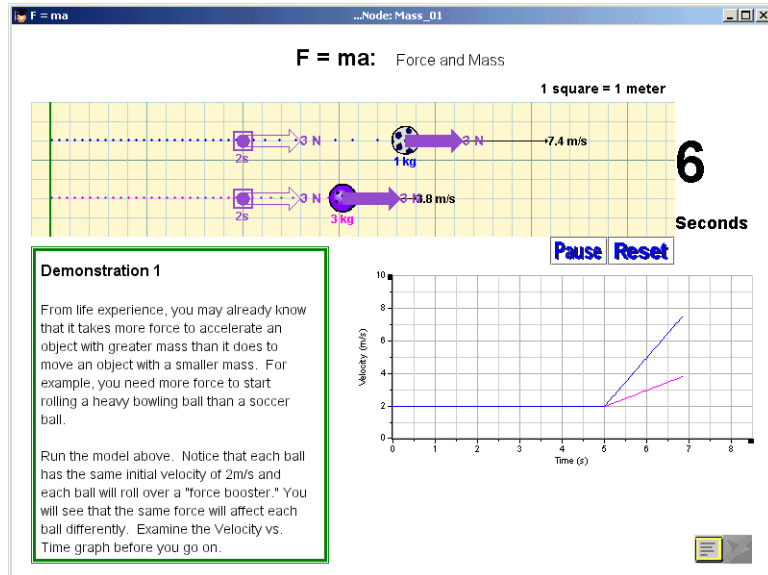


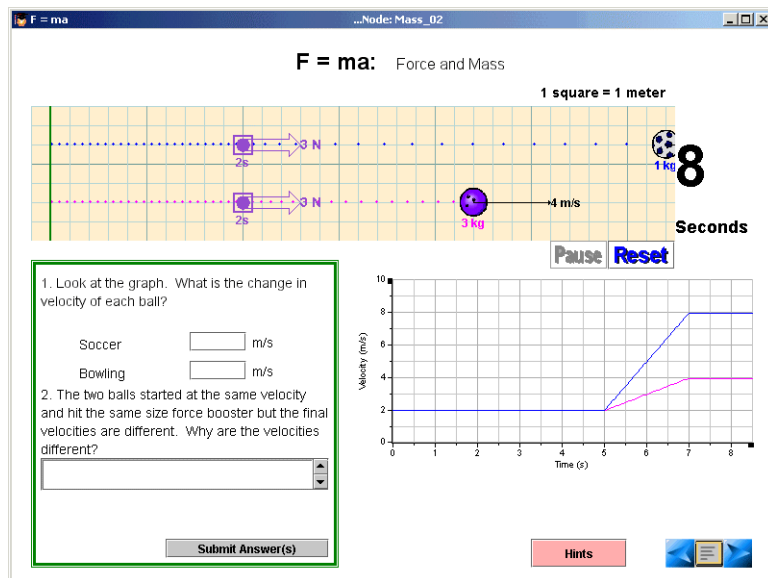
Table of Contents

4.2 1) Force and Mass

To understand the equation $F=ma$, students must understand the components of force, mass and acceleration. In this section, students are introduced to the relationship between a model showing the difference in the force needed to roll a soccer ball and a bowling ball.



Equal force is applied to objects with two different masses



Using the graph, find the velocity of each object.

F = ma: Force and Mass

1 square = 1 meter

0 Seconds

Run Reset

Demonstration 2

In this model, we have increased the magnitude of the bowling ball's force booster. The soccer ball's force booster has not changed.

3. Make a prediction. What do you think the final velocity of each ball will be?

Soccer m/s

Bowling m/s

Go on.

Submit Answer(s)

Predict the final velocity of each ball (8m/s).

4.3 2) Force in Newtons

In this section, students run models of collisions with two balls of different mass. First, they are asked to predict what will happen after the collision. Then, they are guided through various scenarios.

F = ma: Force in Newtons

1 square = 1 meter

8 Seconds

Pause Reset

Force in Newtons

The unit that measures the magnitude of a force is called a Newton (N). The strength of one 1N is the force needed to change the velocity of a 1kg object by 1m/sec in one second.

6. What is the magnitude of force booster that each ball encounters?

Soccer N Check it!

Bowling N Check it!

Correct! Go on.

Run the model and examine the graphs.

F = ma: Force in Newtons

How to Calculate the Change in Velocity

You can also calculate the change in velocity of an object that encounters a force booster using a mathematical formula. The change in velocity depends on the magnitude of the force, the number of seconds that the force will act on the object and the object's mass.

The soccer ball has a mass of 1kg and its initial velocity is 6m/s. It hit a force booster that applied a force of 2N for 1s. Use the formula below to calculate the change in velocity. To better understand how to cancel out the units in this equation, check the Hint.

Change in Velocity = $\frac{\text{Force (Newtons)} * \text{Time (Seconds)}}{\text{Mass (kilograms)}}$

$2\text{m/s} = \frac{2\text{N} * 1\text{s}}{1\text{kg}}$

7. Assume the bowling ball has a mass of 4kg and an initial velocity of 6m/s. It hit a force booster which applied a force of 2N for 6s. Calculate the change in velocity of the bowling ball.

m/s = $\frac{\text{[] N} * \text{[] s}}{\text{[] kg}}$

Example of formula for calculating the change in velocity

F = ma: Force in Newtons

1 square = 1 meter

-2 m/s
10kg

-2 m/s
10kg

6s → 6 N

2s → 10 N

0
Seconds

Challenge Problem

Now you will have the chance to practice calculating the change in velocity. Run the model and answer the following questions. Note the mass of each car is 10kg.

8. Calculate the change in velocity of the **blue** car.

m/s

=

$\frac{\text{[] N} * \text{[] s}}{\text{[] kg}}$

✓

9. What is the final velocity of the **blue** car? To calculate the final velocity, add the change in velocity that you calculated below to the initial velocity of 2m/s.

m/s

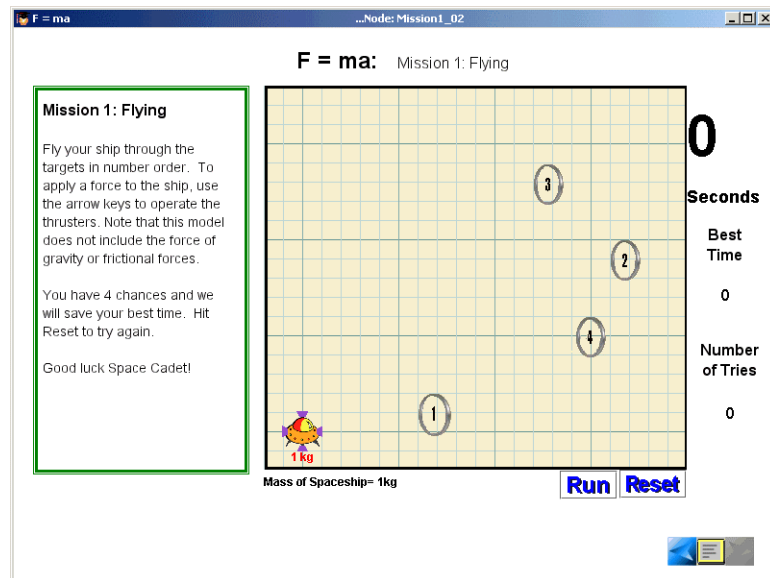
✓

Correct! Go on.

Final velocity = change in velocity * initial velocity

4.4 3) Mission 1: Flying

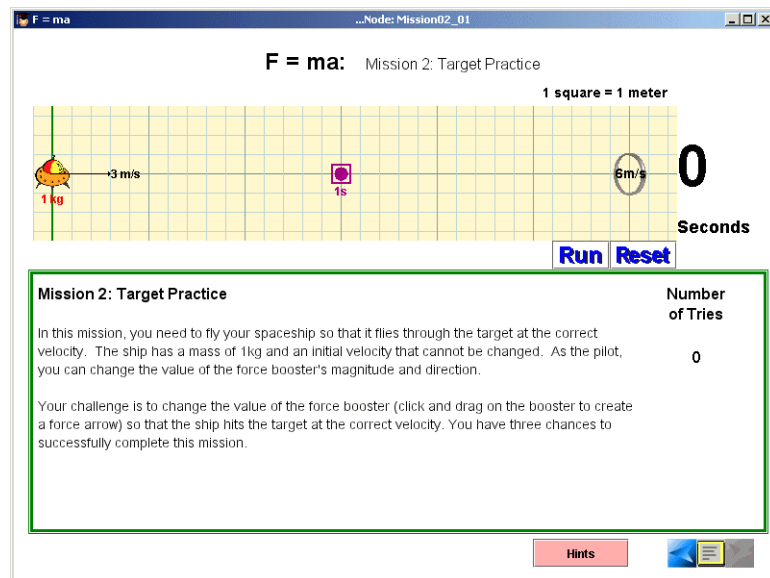
The student will be led through a series of short "missions" with the goal of becoming a Flight Commander on planet Erehwon. In the first mission, students are introduced to their space ship and the targets that they will need to fly through in subsequent missions. Students use the arrow keys on the keyboard to fly their ship through the targets in numerical order. Every time an arrow key is hit, a force of 1N in that direction is added to the ship.



The law as applied to objects of the same mass

4.5 4) Mission 2: Target Practice

In this mission, students must fly the ship through the target at the velocity indicated within the target. To do this, students must adjust the force on the force booster by clicking and dragging on the force booster.



Students have three chances to adjust the booster to 3N.

F = ma: Mission 2: Target Practice

1 square = 1 meter

3 kg 3 m/s 3 N 0 m/s 0 Seconds

Run Reset

Mission 2: Target Practice

As a Space Cadet on planet Erehwon, you need to learn to fly a variety of ships. Now, you are given the larger, Space Craft Deluxe. The Deluxe has a mass of 3kg. Before you run the model, answer the following questions.

12. Notice that the only thing that has changed in this model is the mass of the ship. The force booster is the same. What will the ships velocity be when it hits the target?

m/s

13. Explain your answer. Submit your answers and then run the model.

Submit Answer(s)

Hints

Students predict the final velocity of the Space Craft Deluxe (4m/s).

4.6 5) Mission 3: Landing Zone

Up to this point, students have used force boosters to increase the velocity of a ship. Now, students will need to apply an opposing force in order to slow a ship down. In the last part of this section, students will need to apply a force in the opposite direction of the ship's motion in order to stop the ship on the landing zone.

Note that in the following screen the answer is -25N , meaning that the force needed is 25N ; the negative sign indicates that the force is in the opposite direction.

F = ma: Mission 3: Landing Zone

How to Calculate the Force Needed to Stop a Ship

Step 1 - To stop an object, you must apply a force that will decrease the object's velocity to 0m/s . So, if a ship's initial velocity is 10m/s , you must apply a force such that the change in velocity will equal -10m/s . Here is the formula:

$$\text{Change in Velocity} = \text{Final Velocity} - \text{Initial Velocity}$$

$$-10\text{m/s} = 0\text{m/s} - 10\text{m/s}$$

Step 2 - To calculate the amount of force you will need, you must first calculate the change in velocity as above.

15. If a ship of mass 5kg has an initial velocity of 10m/s , what force is needed to stop the ship in 2 seconds?

Force (N) = Mass (kg) * $\frac{\text{Change in Velocity (m/s)}}{\text{Change in Time (s)}}$ This quantity is known as Acceleration

$$-25 \text{ N} = 5 \text{ kg} * \frac{-10 \text{ m/s}}{2 \text{ s}}$$

You are correct! Notice that -25N really means that you need to apply a force of 25N in the opposite direction of motion. You will need to use this formula to complete this mission.

Submit Answer(s)

Calculating the force needed to stop a ship

F = ma: Mission 3: Landing Zone

1 square = 1 meter

12 N

1s

2m/s

10

Seconds

Pause Reset

Mission 3: Landing Zone

16. Before you run the model, calculate the force needed to hit the target at 2m/s.

Number of Tries: 2

$$\text{Force (N)} = \text{Mass (kg)} * \frac{\text{Change in Velocity (m/s)}}{\text{Change in Time (s)}}$$

-12 N = 3 kg * $\frac{.4 \text{ m/s}}{1 \text{ s}}$

Submit Answer(s)

Great job, you did it in only 2 tries!

Student must complete the equation before running the model.

F = ma: Mission 3: Landing Zone

1 square = 1 meter

9 N

1s

LANDING ZONE

9

Seconds

Pause Reset

Mission 3: Landing Zone

The final challenge of this mission is to land your ship on the landing zone. Your task is to change the force booster so that the ship slows down and stops on the landing platform. Your ship has a mass of 3kg and its initial velocity is 3m/s. To adjust the force booster, click on the booster and drag the force arrow.

You have five chances to land your ship successfully.

Number of Tries: 6

Great job, you did it in only 6 tries!

Hints

Set the booster to 9N to reduce the ships velocity to 0m/s.

4.7 6) Mission 4: Flight Commander

This is the final mission in the space cadet sequence. In this mission, the force booster arrow is hidden. Students must use the $F=ma$ equation to calculate the magnitude of the force.

F = ma: Mission 4: Flight Commander

1 square = 1 meter

3 m/s 7 kg 2s 6 m/s 0 Seconds

Run Reset

Mission 4: Pilot Certification

To find the force (F), you must first know the mass of the ship and calculate its acceleration. Acceleration is calculated by dividing the change in velocity by the duration of the change. To complete this mission, and receive your Pilot Certification, you must show that you understand the parts of the $F = m \cdot a$ equation. (The arrow on the force booster is hidden. Your job will be to calculate the force in this challenge.)

The equation can be broken down like this:

- $F = m \cdot a$
- $F = m \cdot (m/s)/s$
- $F = m \cdot (\text{change in velocity})/(\text{duration of time})$

Think about this equation when you run the model. Click the Next arrow button to complete your challenge.

Breakdown of the $F=ma$ equation

F = ma: Mission 4: Flight Commander

1 square = 1 meter

12 m/s 7 kg 2s 6 m/s 0 Seconds

Run Reset

Mission 4: Pilot Certification

This is the most challenging problem yet! Calculate the acceleration (a) and then the force (F), needed for your ship to reach the target at the correct velocity.

18. For a ship of 7kg, enter the force needed to hit the target at 6m/s (the final velocity). The initial velocity is 12m/s and the force will be applied for 2s.

$F = m \cdot a$

$F = 7\text{kg} \cdot$ (m/s)/s

N = $7\text{kg} \cdot -3$ (m/s)/s

Great job, Space Cadet! Go on.

Hints

Calculate the acceleration and then the force.

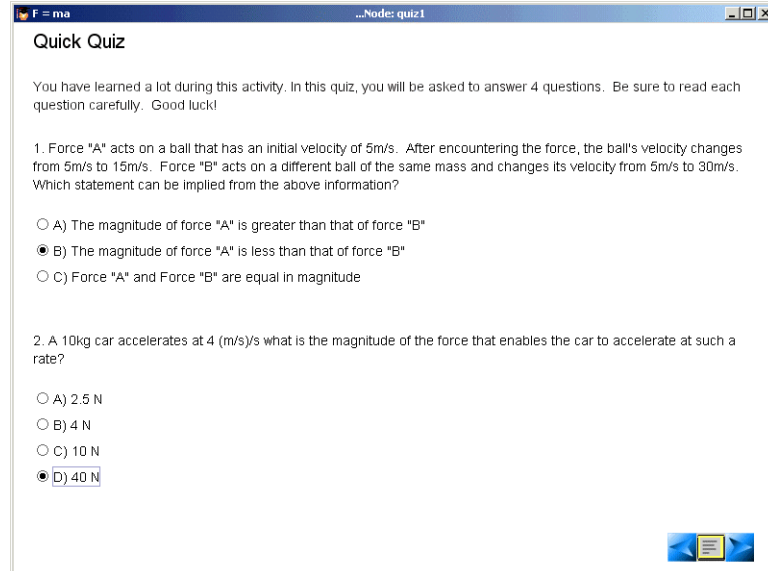


Flight Commander Certificate

4.8 7) Quiz

This quiz has four questions. Students will be able to review their answers at the end of the quiz.

Answers: 1-B, 2-C, 3-A, 4-C



F = ma ...Node: quiz2

3. An object is moving at 6m/s. If a force of 2N acts upon the object for 3 seconds, its velocity changes to 12m/s, what is the mass of the object?

A) 1 kg
 B) 4 kg
 C) 6 kg
 D) 12 kg

4. If the force on an object increases from 4N to 8N how will the acceleration of that object change?


A) The acceleration will decrease by 1/2.
 B) The acceleration will remain the same.
 C) The acceleration will double in magnitude.
 D) The acceleration will increase by 1/4.

F = ma ...Node: quiz6

Congratulations! You have completed the quiz at the end of the F = m*a activity.

Your score:
4/4

Excellent work!



Click on the question number below to see the correct answer for each question.

#	Answer	Correct
1	B	✓
2	C	✓
3	A	✓
4	C	✓

Done

To review the quiz questions and answers, click on the question number links.

5.0 Student Reports

Your students' work with the F=m*a activity is logged and viewable on the MAC Project Web Portal at <http://mac.concord.org>. For each student, you can view a report containing questions and student answers.

Students should now attempt the Forces in 2D activity.