

# Understanding Runaway Stars Using Newton's Laws

## Introduction

Newton's three laws (summarized in the flowchart below) can help us explain a lot of the phenomena we observe in the universe. This includes the observations scientists have made about stars and their location in the universe.

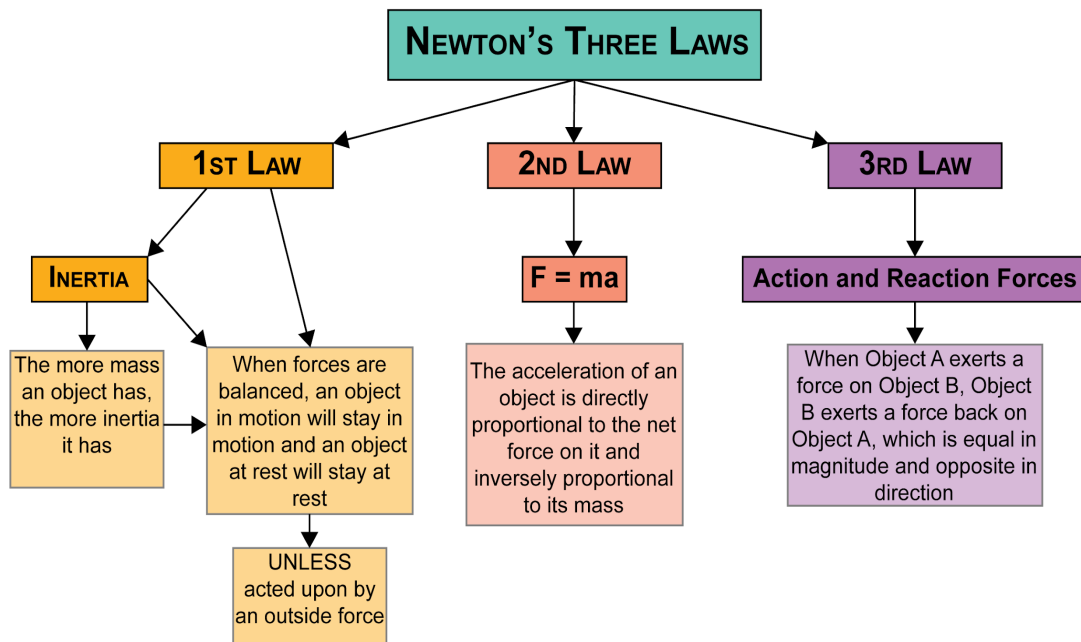
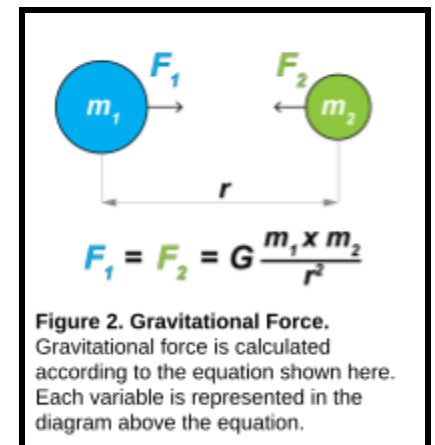


Figure 1. A Flowchart of Newton's Three Laws of Motion.

The Law of Universal Gravitation, which is an extension of Newton's Third Law of Motion, states that there is a gravitational force that attracts any two objects to each other. Both  $m_1$  and  $m_2$  in the diagram below experience an equal magnitude of this force, which depends on both of their masses and the distance between them. In this activity, you will use Newton's Laws of Motion and Newton's Law of Universal Gravitation to explore a fascinating phenomenon: runaway stars.



## What To Do

Watch the demo of two students rotating around each other and answer the analysis questions, reading the Bite when instructed.

## Analysis Questions

1. Answer the following questions about the demonstration.
  - a. What keeps the two students orbiting around each other?
  - b. According to Newton's Third Law of Motion, what can you say about the magnitudes of the forces that each of the two students experiences? Are they equal or not? Explain.
  - c. What happens to the second student when one of the students lets go of the rope all of a sudden?

 & read  : Where Do Runaway Stars Come From?  
(Read the first three paragraphs only.)

2. Answer the following questions about binary star systems.
  - a. What is a binary star system?
  - b. Thinking about the student model and what you read about binary stars, draw a model of what a binary star system might look like. In your model include labeled arrows that represent the force on each star from the other star and the instantaneous velocity vectors of each star.
  - c. Use the orbiting student demo as an analogy of binary stars. What does the rope represent for binary star systems? Cite specific information from the Bite to support your connection.
  - d. What do you think might happen if one of these massive, fast moving stars in a binary system were to suddenly disappear? Explain using the Law of Universal Gravitation and your observations from the demonstration.

**STOP** & read Science Bite: Where Do Runaway Stars Come From?

(Read the rest of the Bite.)

3. Answer the following questions about supernovae in binary star systems.
- What happens to the mass of a star during a supernova explosion?
  - Look at the Law of Universal Gravitation in the Introduction section above. What is the relationship between the gravitational force between two objects and the masses of those objects?
  - What would happen to the amount of gravitational force between the two stars in a binary system after a supernova explosion of one of them? Use the Law of Universal Gravitation to explain your answer.
  - Multiple Choice: Because the two stars in the binary system were so close in proximity, they were orbiting each other at a very high speed. What do you expect would happen to the motion of the second star after one of the stars explodes? Choose one of the options below and explain your answer.
    - It would keep moving around in its orbit at the same speed as before
    - It would keep moving around in its orbit at a slower speed than before
    - It would come to a crashing halt
    - It would be propelled out of its orbit at a very high velocity

Explain your choice.

4. Once the runaway star makes it out into empty space, it will continue in a straight line indefinitely, since there are no other external forces to change its velocity. Explain why this is true using Newton's First Law of Motion.
  
5. **Connect to the Big Question.** Making observations in astronomy has many unique challenges and interesting opportunities.
  - a. In the Science Bite you read, the researcher, Dr. Catherine McEvoy, wasn't able to come to a specific conclusion about what causes runaway stars. What information would help scientists better understand the causes of runaway stars? Do you think we will ever be able to obtain that information? What does that say about the limits of our observations?
  
  - b. In astronomy, researchers are often looking at light that is billions of years old. What unique advantages does that give researchers when they are trying to use observations to develop an understanding of the universe? What limitations does that create?