# INTERSTELLAR

NOVEMBER 7

## DEAR EDUCATORS AND YOUTH ORGANIZATION FACILITATORS,

Welcome to the world of *Interstellar*, the fascinating new movie by director Christopher Nolan. *Interstellar* is based on the scientific theories of renowned physicist Kip Thorne. The movie depicts a heroic voyage to the farthest borders of our scientific understanding.

"The film *Interstellar* takes us to the stars with imagination and encourages us to look into the future, and the *Interstellar* study guide can help make that future a reality. It's an engaging teaching tool to inspire a new generation of students to value science and seek careers in science, technology, engineering, and even space exploration. These careers can introduce them to a universe of exciting possibilities."

— *Dr. June Scobee Rodgers*
*Ph.D., Founding Director of Challenger Center for Space Science Education; Educator; Author and Speaker*

This program offers activities and resources for high school science students, out-of-school high school **STEM** programs, and college science students, using the movie and its concepts as a basis for in and out-of-school classes and programs to explore and investigate scientific, mathematic, and humanitarian concepts of a changing world that will challenge students' understandings and beliefs and encourage them to think deeply about things they may never have thought of until this point.

The movie features an all-star cast, including **Matthew McConaughey**, **Anne Hathaway**, **Jessica Chastain**, and **Michael Caine**.

The activities in this program challenge students to learn about one of the many mind-expanding concepts explored in the movie—relativity—and offer flexibility to teachers and youth group facilitators as they introduce the concept to students. Activities are aligned to **NSTA Next Generation Science Standards** and **Common Core Math Standards** where applicable for ease of implementation in existing curricula. The activities can be done individually or in groups, and for maximum impact, should be completed prior to viewing the movie.

The website offers extensions of the program experience with links to resources to reinforce the lessons, along with a digital trivia game to test and stretch student understanding.

The movie opens in theaters on **November 7, 2014**, and we encourage you and your students to see it after completing these activities in order to fully explore the rich and dynamic world of *Interstellar.*

STEM Science, Technology, Engineering, Mathematics

**Target Audience**

- High school science students and STEM programs
- Out-of-school high school science and STEM groups, classes, and programs
- College natural and physical science students
- Science centers, museums, and camps
- High school PTAs

**Group Sales**
**Experience Interstellar—Plan Your Movie Event Today**
Private advance screening events available for educators and student groups starting **Monday, November 3, 2014**.

**For pricing and additional details: 877-GRP-7878**
**or Interstellar_GroupSales@PARAMOUNT.COM**
**Visit www.interstellarmovie.com/groupsales**

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## PROGRAM OBJECTIVE

The goal of this program is to introduce students to accepted and proposed theories and concepts of relativity in the context of a movie that will bring the content to life and engage students with multiple scientific, mathematic, and humanitarian concepts that will challenge their existing understandings.

### COMPONENTS

- Program website, including:
  - » This teacher/facilitator guide
  - » Sections for teachers/facilitators, parents/PTAs, and students in grades 9–12 and college
  - » Link to movie trailer
  - » Movie field trip guide for parents/PTAs/ administrators
  - » 3 educational activities aligned to NSTA Next Generation Science Standards and related Common Core State Standards
    - All activities are available in downloadable PDF format
    - A resource section on the website encourages further exploration of activity concepts
  - » An interactive digital trivial game, at www.interstellar-education.com, ideal for use on interactive whiteboards and computers
- Movie ticket sweepstakes for teens/students
- Poster, with movie information on one side and reproducible print versions of three educational activities on the other

NEXT GENERATION SCIENCE STANDARDS

COMMON CORE STATE STANDARDS INITIATIVE
PREPARING AMERICA'S STUDENTS FOR COLLEGE & CAREER

### STANDARDS USED FOR ALIGNMENT

The activities in this program have been based on and aligned to NSTA Next Generation Science Standards and Common Core State Standards in Mathematics for high school students.

### HOW TO USE THE PROGRAM

The program is designed to be flexible, so these guidelines are merely suggestions—feel free to adjust them to meet your needs.

1. Have teens register for a chance to win free movie tickets!
2. Then, have teens complete the activities and discuss the questions they raise. It's okay if kids don't have all the answers—the program and movie are as much about raising questions as they are about answering them. These activities will lay the groundwork for concepts that the movie will further explore.
3. **Go see the movie!** After watching the movie, ask kids the following:
   - **What scientific, mathematic, and humanitarian questions did the movie raise?**
   - **What did you learn about relativity, or what questions do you have?**
   - **What was the importance of gravity in the movie?**
   - **What are your thoughts on time travel and wormholes after seeing the movie?**
   - **Do you think it's possible to sustain life on planets other than Earth? Why?**
   - **What challenges are presented in the movie that you can relate to? Explain.**
   - **What challenges are presented in the movie that you find hard to relate to? Discuss.**
   - **How has the movie changed your understanding of science, space-time, and what's important in our day-to-day lives?**
4. Encourage kids to play the digital trivia game to test their Earth and space-science mettle in a fun way.

Each activity in this program will enhance students' understanding of the concepts fleshed out in the movie, and the activities are arranged in order to build from a basic to a more complex understanding. Watching the movie will raise questions and in many cases provide answers that can lead to meaningful discussions and explorations of student understandings of space science, time, mathematical concepts, and humanitarian issues.

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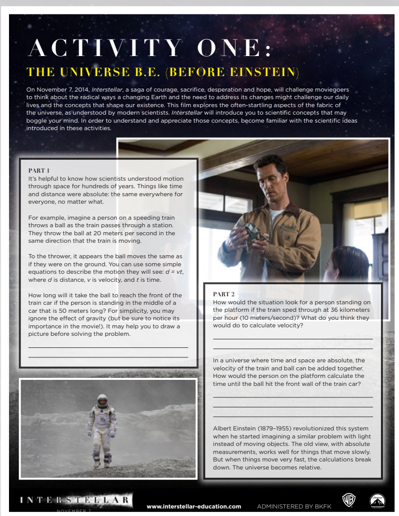
## ACTIVITY OVERVIEW: ACTIVITY GUIDELINES

These thought-provoking supplemental activities are designed to introduce the concept of relativity, and to give students a broader and deeper understanding of some of the fascinating science behind *Interstellar*. Use these activities as an introduction to the movie and its concepts, and then see the movie together (talk to your PTA!) or have students see the movie with their families and friends before embarking on post-movie discussions about the intriguing concepts and questions the movie raises.

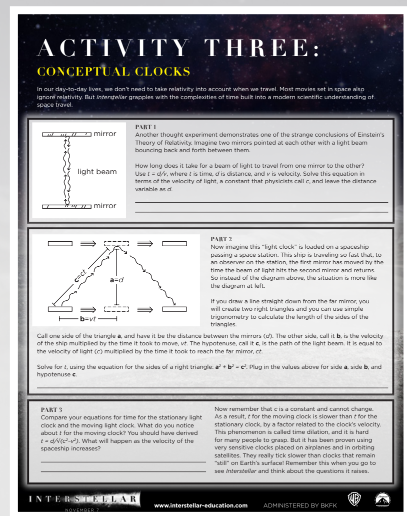



### ACTIVITY 1:
### THE UNIVERSE B.E. (BEFORE EINSTEIN)

*Interstellar* explores a number of fascinating science, math, and humanitarian concepts. One of these concepts is relativity. Use this activity as an introduction to the paradigm shift that was relativity in terms of concepts of absolute space and time, and to help students understand some basic ways scientists have thought about motion, time, and frames of reference for measurement. Students will be asked to do some simple calculations.


### ACTIVITY 2:
### IT'S ALL RELATIVE

This activity continues to lay the groundwork for more advanced concepts related to the movie that will be explored in activity 3. Use this activity to help students begin to see how Albert Einstein's ideas about relativity radically changed our picture of the universe. Students will be introduced to a thought experiment that demonstrates how the speed of light is related to relativity. They will then be asked to perform a few basic calculations about distance, velocity, and time.



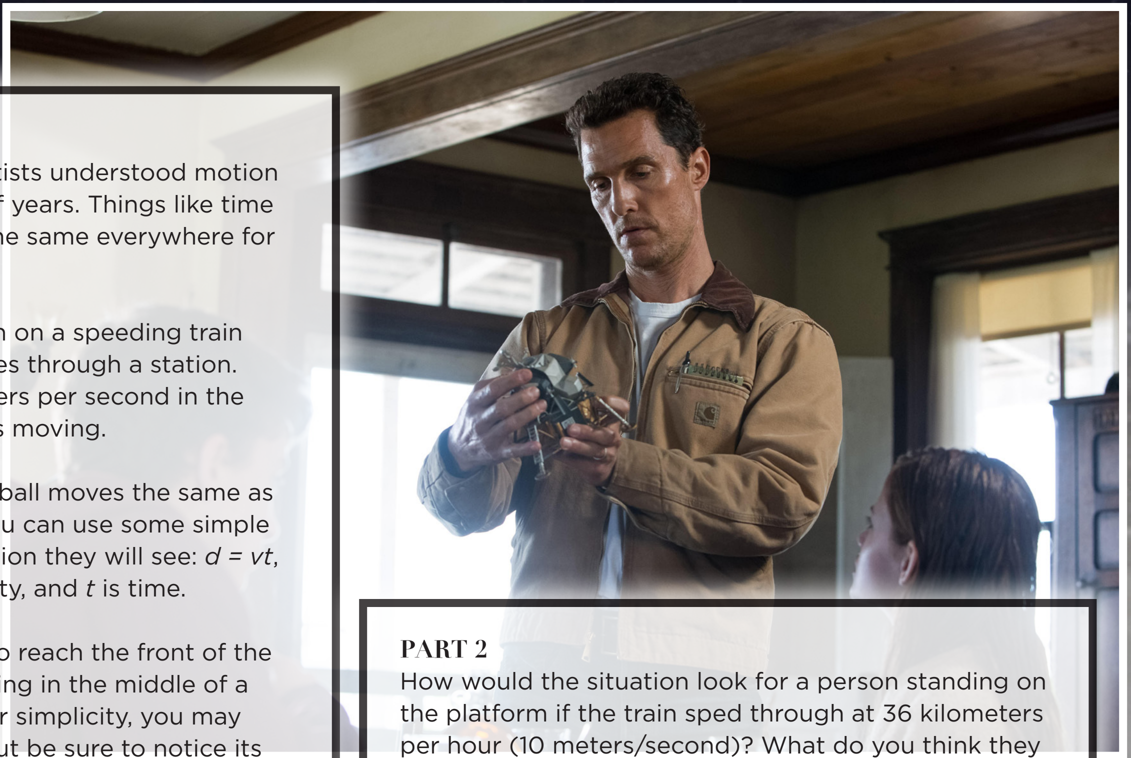

### ACTIVITY 3:
### CONCEPTUAL CLOCKS

Use this activity to show how relativity alters the passage of time. Students will be asked to perform thought experiments related to Einstein's Special Theory of Relativity. They will also be asked to perform some basic calculations related to distance, velocity, and time, as well as some geometry.

# ACTIVITY ONE:

## THE UNIVERSE B.E. (BEFORE EINSTEIN)

On November 7, 2014, *Interstellar*, a saga of courage, sacrifice, desperation and hope, will challenge moviegoers to think about the radical ways a changing Earth and the need to address its changes might challenge our daily lives and the concepts that shape our existence. This film explores the often-startling aspects of the fabric of the universe, as understood by modern scientists. *Interstellar* will introduce you to scientific concepts that may boggle your mind. In order to understand and appreciate those concepts, become familiar with the scientific ideas introduced in these activities.



### PART 1

It's helpful to know how scientists understood motion through space for hundreds of years. Things like time and distance were absolute: the same everywhere for everyone, no matter what.

For example, imagine a person on a speeding train throws a ball as the train passes through a station. They throw the ball at 20 meters per second in the same direction that the train is moving.

To the thrower, it appears the ball moves the same as if they were on the ground. You can use some simple equations to describe the motion they will see: $d = vt$, where $d$ is distance, $v$ is velocity, and $t$ is time.

How long will it take the ball to reach the front of the train car if the person is standing in the middle of a car that is 50 meters long? For simplicity, you may ignore the effect of gravity (but be sure to notice its importance in the movie!). It may help you to draw a picture before solving the problem.

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### PART 2

How would the situation look for a person standing on the platform if the train sped through at 36 kilometers per hour (10 meters/second)? What do you think they would do to calculate velocity?

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In a universe where time and space are absolute, the velocity of the train and ball can be added together. How would the person on the platform calculate the time until the ball hit the front wall of the train car?

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Albert Einstein (1879–1955) revolutionized this system when he started imagining a similar problem with light instead of moving objects. The old view, with absolute measurements, works well for things that move slowly. But when things move very fast, the calculations break down. The universe becomes relative.

# ACTIVITY TWO:

## IT'S ALL RELATIVE

The universe we know and as depicted in *Interstellar* has a history of changed and challenging scientific understandings. For example: by the early 1900s, scientists had discovered a lot about light. It moved incredibly fast, roughly 300,000,000 meters per second in a vacuum. And the velocity was predicted to be constant. Recognizing the nature of light was a critical change in human understanding that helped reveal the universe as we understand it today and as explored in *Interstellar*.

### PART 1

Even as a young man, Albert Einstein knew there was something special and unusual about light. He imagined what he would see if he were able to run at light speed. What would a light ray look like? Would it be standing still next to him? What do you think you would see?

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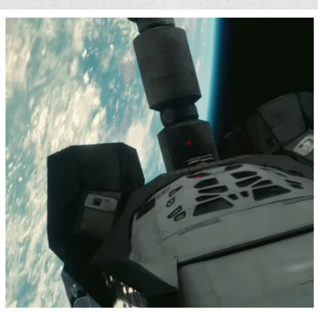
### PART 2

Einstein proposed a thought experiment in 1917 to show how new understandings of light speed changed our picture of the universe. Imagine a person sitting in the middle of the train and one sitting in the middle of the station. The train is moving through the station very quickly when lightning strikes the front and back.

The observer in the station sees the lightning strike the front and back of the train at the same time. You can use $v = d/t$ to depict the situation, where $v$ is velocity, $d$ is distance, and $t$ is time.

Try calculating $t$ if the observer is 1000 meters from the train to get a sense of how fast light moves. Use 300,000,000 meters per second for $v$. How long did it take to reach the observer?



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### PART 3

Now imagine what the person on the train would see. Remember, the person on the platform says the lightning struck the front and back at the same time. That is, $t$ is the same for them from both ends.

How do you think you would calculate the velocity of light from the front and the velocity of light from the back for the person on the train?

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Remember: the speed of light is constant for a given medium, which is air in this case; you cannot add to it or subtract from it. So as the light races from the front and back of the train, the person is also racing forward. But the light from the back is not going faster because the train is in motion. What do you think the person on the train will see?

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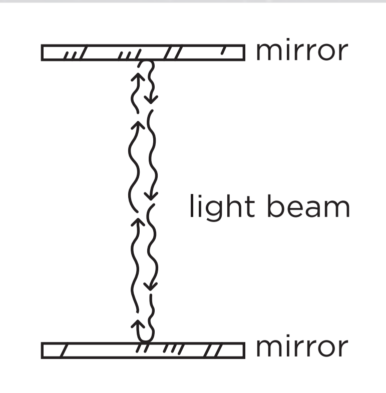
Einstein realized that the person on the train would see the front flash first, and then the back flash. Unlike the ball, we cannot just add the velocity of the train to the velocity of light, because the velocity of light is constant. The observers do not agree on when the lightning struck. Who's right? The answer is, it is relative to their frame of reference.

# ACTIVITY THREE:

## CONCEPTUAL CLOCKS

In our day-to-day lives, we don't need to take relativity into account when we travel. Most movies set in space also ignore relativity. But *Interstellar* grapples with the complexities of time built into a modern scientific understanding of space travel.




### PART 1

Another thought experiment demonstrates one of the strange conclusions of Einstein's Theory of Relativity. Imagine two mirrors pointed at each other with a light beam bouncing back and forth between them.

How long does it take for a beam of light to travel from one mirror to the other? Use $t = d/v$, where $t$ is time, $d$ is distance, and $v$ is velocity. Solve this equation in terms of the velocity of light, a constant that physicists call $c$, and leave the distance variable as $d$.

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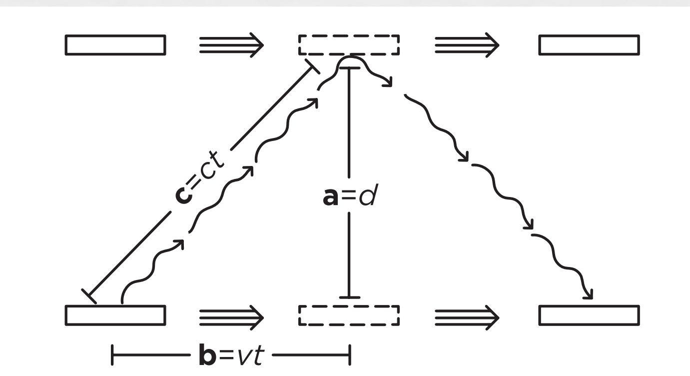


### PART 2

Now imagine this "light clock" is loaded on a spaceship passing a space station. This ship is traveling so fast that, to an observer on the station, the first mirror has moved by the time the beam of light hits the second mirror and returns. So instead of the diagram above, the situation is more like the diagram at left.

If you draw a line straight down from the far mirror, you will create two right triangles and you can use simple trigonometry to calculate the length of the sides of the triangles.

Call one side of the triangle **a**, and have it be the distance between the mirrors (*d*). The other side, call it **b**, is the velocity of the ship multiplied by the time it took to move, *vt*. The hypotenuse, call it **c**, is the path of the light beam. It is equal to the velocity of light (*c*) multiplied by the time it took to reach the far mirror, *ct*.

Solve for $t$, using the equation for the sides of a right triangle: $\mathbf{a}^2 + \mathbf{b}^2 = \mathbf{c}^2$. Plug in the values above for side **a**, side **b**, and hypotenuse **c**.

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### PART 3

Compare your equations for time for the stationary light clock and the moving light clock. What do you notice about $t$ for the moving clock? You should have derived $t = d/\sqrt{(c^2 - v^2)}$. What will happen as the velocity of the spaceship increases?

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Now remember that $c$ is a constant and cannot change. As a result, $t$ for the moving clock is slower than $t$ for the stationary clock, by a factor related to the clock's velocity. This phenomenon is called time dilation, and it is hard for many people to grasp. But it has been proven using very sensitive clocks placed on airplanes and in orbiting satellites. They really tick slower than clocks that remain "still" on Earth's surface! Remember this when you go to see *Interstellar* and think about the questions it raises.

# ANSWER KEY:

## ACTIVITY 1

Part 1: 1.25 seconds

Part 2: Add train velocity to velocity of throw.

Students would need to add the velocity of the train to the ball, but also add the velocity of the wall. Since the velocity of the wall is the same as the velocity of the train, those factors essentially cancel out, and the result is the same as part 1.

## ACTIVITY 2

Part 1: Answers will vary

Part 2: 0.000003 seconds

Part 3: Answers will vary. Students may suggest adding velocity of light to velocity of train. They may also indicate that the observer on the train will also see both flashes at the same time.

## ACTIVITY 3

Part 1: $t=d/c$

Part 2: $t=d/\sqrt{(c^2-v^2)}$

Part 3: The time for the moving clock is dependent on the velocity of the system. More specifically, the time for the moving system slows down as the velocity increases.