

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble's Law to determine the age of the universe.

**Materials:** 2.0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the "Big Bang" theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be "red-shifted" (this is the Doppler effect). If this is true then something must have happened to start things moving. A "Big Bang" is one possibility. In this activity you will create your own one dimensional universe. Then you will "expand" it and compare the final state to the initial state. After analyzing your data you will be able to determine the "age" of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2. 0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2. 0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble's Law to determine the age of the universe.

**Materials:** 2.0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the "Big Bang" theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be "red-shifted" (this is the Doppler effect). If this is true then something must have happened to start things moving. A "Big Bang" is one possibility. In this activity you will create your own one dimensional universe. Then you will "expand" it and compare the final state to the initial state. After analyzing your data you will be able to determine the "age" of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2. 0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2. 0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2.0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2. 0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble's Law to determine the age of the universe.

**Materials:** 2.0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the "Big Bang" theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be "red-shifted" (this is the Doppler effect). If this is true then something must have happened to start things moving. A "Big Bang" is one possibility. In this activity you will create your own one dimensional universe. Then you will "expand" it and compare the final state to the initial state. After analyzing your data you will be able to determine the "age" of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2. 0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2. 0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble's Law to determine the age of the universe.

**Materials:** 2.0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the "Big Bang" theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be "red-shifted" (this is the Doppler effect). If this is true then something must have happened to start things moving. A "Big Bang" is one possibility. In this activity you will create your own one dimensional universe. Then you will "expand" it and compare the final state to the initial state. After analyzing your data you will be able to determine the "age" of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble's Law to determine the age of the universe.

**Materials:** 2.0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the "Big Bang" theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be "red-shifted" (this is the Doppler effect). If this is true then something must have happened to start things moving. A "Big Bang" is one possibility. In this activity you will create your own one dimensional universe. Then you will "expand" it and compare the final state to the initial state. After analyzing your data you will be able to determine the "age" of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2. 0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble's Law to determine the age of the universe.

**Materials:** 2.0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the "Big Bang" theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be "red-shifted" (this is the Doppler effect). If this is true then something must have happened to start things moving. A "Big Bang" is one possibility. In this activity you will create your own one dimensional universe. Then you will "expand" it and compare the final state to the initial state. After analyzing your data you will be able to determine the "age" of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble's Law to determine the age of the universe.

**Materials:** 2.0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the "Big Bang" theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be "red-shifted" (this is the Doppler effect). If this is true then something must have happened to start things moving. A "Big Bang" is one possibility. In this activity you will create your own one dimensional universe. Then you will "expand" it and compare the final state to the initial state. After analyzing your data you will be able to determine the "age" of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble's Law to determine the age of the universe.

**Materials:** 2.0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the "Big Bang" theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be "red-shifted" (this is the Doppler effect). If this is true then something must have happened to start things moving. A "Big Bang" is one possibility. In this activity you will create your own one dimensional universe. Then you will "expand" it and compare the final state to the initial state. After analyzing your data you will be able to determine the "age" of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2. 0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2. 0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2.0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2. 0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble's Law to determine the age of the universe.

**Materials:** 2.0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the "Big Bang" theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be "red-shifted" (this is the Doppler effect). If this is true then something must have happened to start things moving. A "Big Bang" is one possibility. In this activity you will create your own one dimensional universe. Then you will "expand" it and compare the final state to the initial state. After analyzing your data you will be able to determine the "age" of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2. 0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2. 0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???

**Lab - How Old is the Universe?**

**Purpose:** To make a model of an expanding one dimensional universe and to apply Hubble’s Law to determine the age of the universe.

**Materials:** 2. 0m elastic cord  
6 safety pins or paper clips  
meter stick or measuring taper

**Discussion:** The universe in which we live has been around for a long, long time. Many theories exist regarding the formation of the universe. Some scientists believe that the universe began with an event similar to a large explosion. This hypothesis is called the “Big Bang” theory. Data to support a beginning such as this exists. For instance, scientists believe that the objects in the universe are moving away from each other at great speeds because objects out in space seem to be “red-shifted” (this is the Doppler effect). If this is true then something must have happened to start things moving. A “Big Bang” is one possibility. In this activity you will create your own one dimensional universe. Then you will “expand” it and compare the final state to the initial state. After analyzing your data you will be able to determine the “age” of your universe. Using the same analysis and some data supplied by modern astronomers you will determine the age of our universe!

**Procedure:** **Building Your Universe**

- cut a piece of elastic cord to exactly 2.0m long.
- randomly six galaxies (safety pins) along the length of the elastic cord
- select one of the galaxies as your home galaxy.
- measure and record the initial distances of each of the other five galaxies to your home galaxy to the nearest 0.1 millimeter.

**Expanding Your Universe**

- stretch your galaxy to a distance of about twice as long as it started. This will model the expansion of your 2D universe.
- measure and record the new distances of each galaxy from your home galaxy to the nearest tenth of a millimeter.

**Data:**

Galaxy	Initial Dist. (cm)	Final Dist. (cm)	Recession Vel. (cm/s)
1			
2			
3			
4			
5			
6			

## Analysis:

### Finding the Age of Your Universe

- assuming the time of expansion to be one second, you can calculate the velocity at which the galaxies are moving away from your home galaxy using  $v = d \div t$  ( $d$  is the difference in the distances from home galaxy before and after the expansion and  $t$  is one second).
- use the graph provided (*Graph Grid to Accompany Hubble Law Activity*) or MS Excel to plot the recessional velocities vs. original distance from home galaxy. \*\*If you use MS Excel, make the scale the same as that on the graph grid provided.
- make a best fit line and determine the slope of that line.
- compare your results to those of other lab groups.

## Questions:

1. How is recessional velocity related to original distance in your universe?
2. What does the reciprocal of the slope of the graph of rec. vel. vs.  $d$  represent (Hint: use dimensional analysis).
3. How do your results compare with other groups who chose different home galaxies? How does your answer relate to the first postulate of Relativity? Is there a center of the Universe?
4. What can you deduce about the speeds of the farther galaxies in the Sandage Data compared to the speeds of the closer galaxies? Does this support your findings with your universe?
5. Use your graph to find the age of your universe.
6. Using the method from this lab plot the **Sandage Redshift Data** and determine the age of our universe.

- Notes:
- $pc$  stands for *parsec*,  $1 pc = 3.28 ly$
  - $M$  stands for *Mega* ( $\times 10^6$ )

## Error Analysis:

Discuss any sources of error in this lab and describe ways that you could improve the accuracy. Discuss whether or not you see this as an accurate way to find the age of the Universe.

## Conclusion:

What did you do in this lab? What did you find? What generalizations can you make???