**Hubble’s Law and the Big Bang Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

1. Astronomy measures really big objects at large distances and they often measure distance in light-years. Watch **Minute Physics: How far is a second?** <http://www.youtube.com/watch?v=Wp20Sc8qPeo> Describe how far is it from your home to school using units like bus-minutes.

**Teacher Information**: This video helps make the idea of a light-year reasonable by showing how we do this already when we are asked how far some place is and we say it is 5 hours away. If we were talking about the distance from Toronto to Ottawa, then what we meant was 5 car-hours. It would be less in airplane-hours and would involve a couple of bicycle-days.

**Student Answer**: 20 bus-minutes or 25 skateboard-minutes.

1. A hundred years ago Edwin Hubble and other scientists looked at galaxies and measured how far away they were and how fast they were moving. Some modern sample data is shown below.

|  |  |  |
| --- | --- | --- |
| Name of galactic cluster | Distance in billions of light-years | Speed in millions of metres per second |
| Virgo | 0.78 | 12 |
| Ursa Major | 1.0 | 15 |
| Corona Borealis | 1.4 | 22 |
| Bootes | 2.5 | 39 |
| Hydra | 3.96 | 61 |

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1. Make a large, neatly labelled graph of the data with velocity on the vertical axis

**v (106m/s)**

**60**

**50**

**40**

**30**

**20**

**10**

**0**

**0 1 2 3 4 d (109 light-year)**

1. There is a very clear pattern here. Describe how speed and distance are related.   
   The farther away a galaxy is, the faster it appears to be moving away from us.
2. A galaxy is moving at 30 million m/s. How far away is it? Label this on the graph 1.8 billion l-year
3. A galaxy is moving at 70 million m/s. How far away is it? Label this on the graph. 4.2 billion l-year
4. A galaxy is 2 billion light-years away. How fast is it moving? Label this on the graph. 32 million m/s
5. A galaxy is 5 billion light-years away. How fast is it moving? Label this on the graph. 82 million m/s

**Teacher Information**: This question is here to support what they are learning in their math classes; potting data, interpreting graphs, extrapolating and interpolating. It could be reduced or it could be extended to include calculating the slope and finding and using the equation of the line.

1. The space between the galaxies is growing larger and larger. This suggests that at one time they were all together in one place and then moved apart in a ‘**Big Bang’**. You will calculate how long ago this occurred was by using the data for one of the galaxies above. The name of my assigned galaxy is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

a) How far away is your galaxy in metres? Hint: A light-year is how far light travels in one year and that is 9,500,000,000,000,000 m or 9.5 x 1015 m. A billion is 1,000,000,000 or 109.

**Teacher Information**: This question is designed to give students a sense of how physicists can say when the universe started. It is also designed to make them appreciate that using powers of ten can actually make problems easier.

0.78 x 109 light-years x 9.5 x 1015 m/light-year = 7.4 x 1024 m.  
  
b) How long ago was the Big Bang? The time can be calculated by dividing the distance in metres by the velocity in metres per second, t = d/v. Hint: A million is 1,000,000 or 106.

(7.4 x 1024 m)/(12 x 106 m/s) = 6.2 x 1017 s

c) How old is the universe in years? Hint: There are about 32,000,000 or 3.2 x 107s in a year.

(6.2 x 1017s)/(3.2 x 107s/year) = 19 x 109 years or 19 billion years.

Teacher Information: The present accepted value is 13.8 billion and the difference between the answers is due to the fact that the rate of expansion has not been constant.

1. Go to **Alice & Bob in Wonderland:** “**Is that star really there?”** <http://www.q2cfestival.com/play.php?lecture_id=8245&talk=alice\> Explain why looking far away in space is like looking back in time.

Light is very fast but it is not infinitely fast. It takes time for the light to get to us. The farther away, the more time it takes.

1. **Watch Minute Physics:** **The Oldest Light in the Universe**   
   <http://www.youtube.com/watch?NR=1&feature=endscreen&v=_mZQ-5-KYHw>

What is the cosmic background radiation and what does it have to do with the big bang?

**Student Answer**: The universe used to be very hot and emitting light for that temperature. Shortly after the Big Bang, the universe became transparent to this light and it freely and in all directions. As time went on space expanded, stretching the light waves until they became microwaves. This stretching of the light waves cooled the universe, until it is now just a few degrees above absolute zero. These microwaves are shining on the Earth and everywhere else, from all directions.

**Teacher Information:** The apparent motion of the galaxies was interpreted as evidence for the expansion of space the Big Bang theory. This theory led to the prediction of the cosmic background radiation. This successful prediction gave astrophysicists confidence that the theory was correct.