Name: ___________________________ Period: _______ Date: __________

Space Time – Ted ED

Astronomy

Directions: Using the links below, watch the videos on space time and answer the questions that go with it. These do a great job of explaining how this last dimension works and that will help us wrap up all that we need to know about gravity! Be sure to use complete sentences in your answers for the open ended!

Fundamentals of Space Time: Part One

https://www.youtube.com/watch?v=ScdLqAA_64E

1. We showed the worldlines of objects moving at a constant speed. What would a worldline look like for someone who starts out sitting down, walks across the room, then sits down again? What would a worldline look like for a smoothly accelerating car? Try thinking of other objects that you could draw worldlines for, and draw them. Have your partner at your table try to guess what it is you've drawn. (Write their name beside the picture.)

2. We showed worldlines for single objects moving at constant speeds. What about the worldlines of two objects colliding with each other? How would you represent these on a spacetime diagram? What happens at the end of a worldline?

3. The spacetime diagrams we've drawn show only one spatial dimension. How would you represent an object that moved forward, backward, up and down?

4. We showed how spacetime diagrams are like the edge of a flipbook, and so can be created by stacking up a series of animation panels. A single panel tells us:
   A. The location of the drawn objects at a single moment in time
   B. The speed at which the drawn objects are moving
   C. The direction in which the drawn objects are moving

5. Things that happen later will therefore appear:
   A. Further to the right on the screen, in a different stack
   B. Further down the screen. at the bottom of the stack
   C. Further up the screen, at the top of the stack

6. In a spacetime diagram, a "worldline" is ________.
   A. A line that shows where the ground is relative to something that moves
   B. A straight line that has no physical meaning
   C. A line representing where an object is at different times

7. When drawn a spacetime diagram, something that is not moving looks like
   A. A horizontal line
   B. A tilted line
   C. A vertical line

8. To create a flipbook from a stack of panels such that the camera follows a moving object we must:
   A. shift the panels
   B. reorder the panels in the stack
   C. redraw the panels from scratch and make a new stack

9. It is useful to do this and examine how the world looks to objects moving at different steady speeds because:
   A. We can work out which perspective is the correct one according to the laws of physics
   B. The laws of physics should be the same from any of these perspectives
   C. It helps to avoid unravelling the fabric of the spacetime continuum

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Fundamentals of Space Time: Part Two
https://www.youtube.com/watch?v=aeCsS6PjhK8

1. Why does light have to appear at the same angle when drawn on a space-time diagram?
   A. It's because light always travels in straight lines
   B. It means light worldlines will never touch the worldlines of other objects
   C. The angle of a worldline represents speed, and the speed of light is a constant

2. Why doesn't sliding the panels to change perspective work when we have light in the picture?
   A. Light has to be drawn parallel to the edge of the panels, and so only appears on one panel at a time
   B. Sliding the panels tilts the light worldlines, which suggests the speed of light has changed
   C. Light moves so quickly that we can't draw enough panels to measure the correct speed

3. Why do we need to glue the panels together?
   A. Gluing the panels holds them in place when they move very quickly
   B. The glue slows down light to the correct, fixed speed
   C. A continuous block of space-time can be stretched and squashed in a way that lets us change perspectives while keeping light at the same speed

4. Why does Andrew appear thinner to Tom when Tom is driving in his car?
   A. In order to make Tom's worldline vertical, we have had to stretch and squash space-time
   B. Andrew prefers running to driving, and so he has lost weight
   C. The light travels to Tom's eyes at a greater speed when he is driving towards Andrew

5. Why do we have to redraw the animation as seen from Andrew's perspective?
   A. Shifting to the perspective of another person changes the laws of physics
   B. Tom is moving relative to Andrew, and so he should have been drawn Lorentz contracted to look thinner from the start
   C. The speed of light has changed - it should be moving more slowly so that it hits Tom at the right time

6. We have chosen to draw the angle of light worldlines at 45 degrees. Given the speed of light is 299,792,458 metres per second, what duration does a space-time diagram 20cm wide and 20cm tall represent? Scientists often like to set the speed of light, c, to 1 in what are called "Natural Units." What do you think this means? Do the units matter? Why do you think the angle of 45 degrees is important? (Hint - think about the stretch-and-squash trick.)

7. All of the space-time diagrams we have drawn so far feature straight worldlines. What does this mean? What would a curved worldline on a space-time diagram represent?

Fundamentals of Space Time: Part Three
https://www.youtube.com/watch?v=NAXHHBUY9_E

1. You may have learned about gravity as a force that acts instantly between two objects, pulling them together. Looking back over lessons 1, 2 and 3, why do you think this idea doesn't work in Einstein's space-time?

2. Most forces apply only to certain types of particles, and not to others. The electric force, for instance, is only felt by charged particles (like electrons or protons), and is not felt by neutral particles (like neutrons or neutrinos). Experiments show that gravity is special: it applies equally to all matter and energy. Why is this experimental result crucial to Einstein's description of gravity?

3. The expansion of the Universe fits perfectly into Einstein's equations of gravity. But the expansion is speeding up, which is more surprising, because everything ought to be pulled back together. How can accelerated expansion be reconciled with Einstein's theory of gravity? Why do some people think it points to a new, better theory beyond Einstein's?

4. What is different about curved worldlines from straight ones?
    A. They represent objects that are accelerating, i.e. changing their speed over time
    B. They represent objects which can travel faster than the speed of light
    C. They represent objects that are subject to the laws of quantum mechanics, i.e. their speed is uncertain

5. Why does sewing different patches of spacetime together lead to worldlines that looked curved?
    A. Because the worldlines are repelled from the edges of panels, so end up bending
    B. Because the patches can be stretched and squashed before sewing, so that even straight worldlines in the individual small patches look curved overall
    C. Because every patch of space-time is made of a different material from any other

6. A gravity wave is________.
    A. A ripple in space time
    B. A slight alternate squashing and stretching of space, varying over time
    C. Both of the above; they are equivalent

7. The precise orbit of Mercury around the Sun is significant because ________.
    A. It was some of the first evidence that Einstein's theory of gravity is superior to Newton's
    B. It shows that Newton's theory of gravity is better than Einstein's, unless gravitational waves are taken into account
    C. It remains unexplained

8. Quantum gravity – the union of quantum mechanics and Einstein's theory of gravity – has so far proved impossibly hard to construct. If we could work it out, it would be significant because:
    A. It would describe how each patch of space-time is stretched and squashed before being stitched together into an overall space-time
    B. It would help us find dangerous asteroids before they are pulled towards the Earth
    C. It would help us better understand black holes