Name: ______________________

Class: ______________________

Due Date: ______________________

Physics Topic 19C - Orbital Speed and Escape Speed

Answer the following questions. The solutions to this worksheet can be found on the YouTube channel Go Physics Go.

1. C: The following problem refers to *escape speed*.

   a. Define *escape speed*. This is also called *escape velocity*.

   b. What are some assumptions made when defining *escape speed*?

   c. For which objects does *escape speed* apply to?

   d. For which objects does *escape speed* not apply to?

   e. Use the law of conservation of energy $E_{\text{initial}} = E_{\text{final}}$ to solve for the equation of the *escape speed* of an object leaving the gravitational pull of a planet. What is the minimum speed needed for an object to escape the gravitational pull of the Earth?

2. C: You might want to derive this equation with your teacher: A planet is orbiting in a circular motion with a constant speed around a star (like the Sun).

   a. Use Newton's Law of Gravitation $F_{\text{g}} = m_{\text{planet}} a_{\text{planet}} = \frac{G m_{\text{star}} m_{\text{planet}}}{r^2}$ and the equation for centripetal acceleration $a_{\text{planet}} = \frac{{v_{\text{planet}}}^2}{r}$ to solve for the speed squared ${v_{\text{planet}}}^2$ of a planet moving around a star. Place a box around your answer. In both equations r is the distance from the planet to the star.

   b. Take your solution from part a and multiply both sides by $\frac{m_{\text{planet}}}{2}$. This new equation is equal to the kinetic energy of the planet. Place a box around your answer.

   c. Substitute your answer from part b to the total energy of the orbiting planet $E_{\text{T}} = E_{\text{k}} + E_{\text{g}} = \frac{1}{2} m_{\text{planet}} {v_{\text{planet}}}^2 - \frac{G m_{\text{planet}} m_{\text{star}}}{r}$. Place a box around your answer. Your answer should have only one fraction.

   d. Is the total energy positive, negative, or zero? Why?

   e. Draw an *energy vs. distance* graph. On this graph draw the *kinetic energy vs. distance*, *potential energy vs. distance*, and *total energy vs. distance* graphs.

3. C: An object is orbiting a planet. It encounters a small viscous drag due to the atmosphere. Describe the subsequent motion of the object.

4. E: A rocket with a mass of 6.40×10^4 kg is orbiting Jupiter's moon Callisto. Callisto has a radius of 2.40×10^6 m and a mass of 7.35×10^{22} kg.

   a. What would the velocity of the rocket have to be in order for it to orbit Callisto at an altitude of 4.60×10^3 km?

   b. What would be the gravitational force between this rocket and Callisto while orbiting at this altitude?

   c. What would be the kinetic energy of this rocket while orbiting Callisto at this altitude?

   d. What would be the gravitational potential energy of this rocket while orbiting Callisto at this altitude?

   e. What would be the total energy of this rocket while orbiting Callisto at an altitude of 4.60×10^3 km?

f. What would be the total energy of this rocket while sitting at rest on the surface of Callisto?

g. How much kinetic energy would you have to give to this rocket while sitting on the surface of Callisto in order to put the rocket into orbit around Callisto at an altitude of 4.60×10^3 km?

h. With what velocity would this rocket have to be launched from the surface of Callisto in order to go into orbit around Callisto at an altitude of 4.60×10^3 km?

i. With what velocity would this rocket have to be launched from the surface of Callisto in order for the rocket to escape the gravitational effects of Callisto?

5. E: A rocket, which has a mass of 3.80×10^4 kg, is initially sitting at rest on the surface of the planet Venus. Venus has a radius of 6.05×10^6 m and a mass of 4.87×10^{24} kg.

   a. What is the total energy content of this rocket while sitting at rest on the surface of Venus?

   b. What velocity would be required for this rocket to orbit Venus at an altitude of 550. km?

   c. What total energy is required if this rocket is to orbit Venus at an altitude of 550. km?

   d. With what velocity should this rocket be launched from the surface of Venus in order to go into orbit around Venus at an altitude of 550. km?

      Use the law of conservation of energy:

e. With what minimum velocity should this rocket be launched from the surface of Venus in order to escape the gravitational effects of Venus?

f. What will be the velocity of this rocket when it is very far from Venus if the rocket is launched from the surface of Venus with a velocity of $1.40 \times 10^4\ \frac{\mathrm{m}}{\mathrm{s}}$?

6. E: A rocket, which has a mass of 6.40×10^4 kg, is sitting on the surface of Neptune. Neptune has a mass of approximately 1.03×10^{26} kg and a radius of approximately 2.43×10^7 m. This rocket is to be launched from Neptune's surface with the intention of going into orbit around the planet Neptune at an altitude of 1.00×10^4 km.

   a. With what minimum velocity should this rocket be launched from Neptune's surface in order to go into orbit around Neptune at the given altitude?

b. What will be the total energy content of this rocket while orbiting Neptune at the given altitude?

c. How much kinetic energy must be added to this orbiting rocket if it is to escape the gravitational effects of Neptune?

d. What velocity must this orbiting rocket attain in order for it to escape the gravitational effects of Neptune?

e. Suppose that somehow the planet Neptune were to change into a black hole. What would the maximum radius of Neptune have to be in order for it to become a black hole?

7. E: A 3.20×10^4 kg rocket is orbiting the planet Jupiter at an altitude of 2.00×10^4 km. Jupiter has a mass of approximately 1.90×10^{27} kg and a radius of approximately 7.14×10^7 m.

   a. What is the velocity of this rocket while orbiting Jupiter at this altitude?

   b. What is the total energy content of this rocket while orbiting at this altitude?

   c. How much additional energy must this rocket acquire in order to leave orbit and escape the gravity of Jupiter?

   d. Suppose that this orbiting rocket is given an additional 3.20×10^{13} J of energy. What will be the resulting velocity of this rocket when it is very far from Jupiter?

   e. What would the maximum radius of Jupiter have to be if it was to become a black hole?

8. E: A rocket, which has a mass of 1.80×10^4 kg, is moving through space with a velocity of $1.25 \times 10^4\ \frac{\mathrm{m}}{\mathrm{s}}$ when it begins its approach to Saturn. This rocket would like to go into orbit around Saturn at an altitude of 8.20×10^3 km. Saturn has a mass of approximately 5.68×10^{26} kg and a radius of approximately 6.00×10^7 m.

   a. What is the initial total energy of this rocket before it approaches Saturn?

   b. What total energy is required in order for the rocket to go into orbit around Saturn at the given altitude?