

ANSWERS - AP Physics Multiple Choice Practice – Gravitation

<u>Solution</u>	<u>Answer</u>
1. Orbital speed is found from setting $\frac{GMm}{r^2} = \frac{mv^2}{r}$ which gives $v = \sqrt{\frac{GM}{r}}$ where M is the object being orbited. Notice that satellite mass does not affect orbital speed. The smallest radius of orbit will be the fastest satellite.	B
2. As a satellite moves farther away, it slows down, also decreasing its angular momentum and kinetic energy. The total energy remains the same in the absence of resistive or thrust forces. The potential energy becomes less negative, which is an increase.	E
3. With different masses, g would have a different value, but the physical characteristics of the objects would not be affected.	D
4. $g = \frac{GM}{r^2}$ so the acceleration due to gravity (and the weight of an object) is proportional to the mass of the planet and inversely proportional to the distance from the center of the planet squared. $M \times 2 = g \times 2$ and $r \times 2 = g \div 4$ , so the net effect is the person's weight is divided by 2	A
5. $g = \frac{GM}{r^2}$ so the acceleration due to gravity (and the weight of an object) is proportional to the mass of the planet and inversely proportional to the distance from the center of the planet squared. $M \div 10 = g \div 10$ and $r \div 2 = g \times 4$ , so the net effect is $g \times 4/10$	D
6. Circular orbit = constant r, combined with constant speed gives constant angular momentum (mvr). As it is a circular orbit, the force is centripetal, points toward the center and is always perpendicular to the displacement of the satellite therefore does no work.	E
7. The gravitational force on an object is the weight, and is proportional to the mass. In the same circular orbit, it is only the mass of the body being orbited and the radius of the orbit that contributes to the orbital speed and acceleration.	C
8. Newton's third law	E
9. $g = \frac{GM}{r^2}$	D
10. Force is inversely proportional to distance between the centers squared. $R \times 4 = F \div 16$	E
11. $g = \frac{GM}{r^2}$ so the acceleration due to gravity (and the weight of an object) is proportional to the mass of the planet and inversely proportional to the distance from the center of the planet squared. $M \times 2 = g \times 2$ and $r \times 2 = g \div 4$ , so the net effect is the person's weight is divided by 2	B
12. A planet of the same size and twice the mass of Earth will have twice the acceleration due to gravity. The period of a mass on a spring has no dependence on g, while the period of a pendulum is inversely proportional to g.	E
13. Orbital speed is found from setting $\frac{GMm}{r^2} = \frac{mv^2}{r}$ which gives $v = \sqrt{\frac{GM}{r}}$	C

14.  $g = \frac{GM}{r^2}$  so the acceleration due to gravity (and the weight of an object) is proportional to the mass of the planet and inversely proportional to the distance from the center of the planet squared.  $M \div 10 = g \div 10$  and  $r \div 2 = g \times 4$ , so the net effect is  $g \times 4/10$  B
15. Kepler's second law (Law of areas) is based on conservation of angular momentum, which remains constant. In order for angular momentum to remain constant, as the satellite approaches the sun, its speed increases. D
16.  $g = \frac{GM}{r^2}$  so the acceleration due to gravity (and the weight of an object) is proportional to the mass of the planet and inversely proportional to the distance from the center of the planet squared.  $M \times 4 = g \times 4$  and if the net effect is  $g = g_{\text{Earth}}$  then  $r$  must be twice that of Earth. C
17.  $g = \frac{GM}{r^2}$ . 300 km above the surface of the Earth is only a 5% increase in the distance (1.05 times the distance). This will produce only a small effect on  $g$  ( $\div 1.05^2$ ) D
18.  $a = g = \frac{GM}{r^2}$ , if  $R_2 = 2R_1$  then  $a_2 = \frac{1}{4} a_1$  E
19. Orbital speed is found from setting  $\frac{GMm}{r^2} = \frac{mv^2}{r}$  which gives  $v = \sqrt{\frac{GM}{r}}$  where  $M$  is the object being orbited. If  $r$  is doubled,  $v$  decreases by  $\sqrt{2}$  B
20. Newton's third law C
21.  $g = \frac{GM}{r^2}$  so the acceleration due to gravity (and the weight of an object) is proportional to the mass of the planet and inversely proportional to the distance from the center of the planet squared.  $M \times 2 = g \times 2$  and if the net effect is  $g = g_{\text{Earth}}$  then  $r$  must be  $\sqrt{2}$  times that of Earth C
22. From conservation of angular momentum  $v_1 r_1 = v_2 r_2$  A
23. As the ball moves away, the force of gravity decreases due to the increasing distance. A
24.  $g = \frac{GM}{r^2}$  At the top of its path, it has doubled its original distance from the center of the asteroid. D
25. Angular speed (in radians per second) is  $v/R$ . Since the satellite is not changing speed, there is no tangential acceleration and  $v^2/r$  is constant. E
26. The radius of each orbit is  $\frac{1}{2} D$ , while the distance between them is  $D$ . This gives B
- $$\frac{GMM}{D^2} = \frac{Mv^2}{D/2}$$
27. An burst of the ship's engine produces an increase in the satellite's energy. Now the satellite is moving at too large a speed for a circular orbit. The point at which the burst occurs must remain part of the ship's orbit, eliminating choices A and B. The Earth is no longer at the focus of the ellipse in choice E. D

28. Escape speed with the speed at which the kinetic energy of the satellite is exactly equal to the negative amount of potential energy within the satellite/mass system. That is B
- $$\frac{1}{2}mv^2 = \left| -\frac{GMm}{r} \right| \text{ which gives the escape speed } v_e = \sqrt{\frac{2GM}{r}}$$
29. Orbital speed is found from setting  $\frac{GMm}{r^2} = \frac{mv^2}{r}$  which gives  $v = \sqrt{\frac{GM}{r}}$  where M is the D
- object being orbited. Also,  $T = \frac{2\pi}{v}$ . Since the mass is divided by 2, v is divided by  $\sqrt{2}$
30.  $g = \frac{GM}{r^2}$  so the acceleration due to gravity (and the weight of an object) is proportional to the C
- mass of the planet and inversely proportional to the distance from the center of the planet squared.  $M \times 7 = g \times 7$  and  $r \times 2 = g \div 4$ , so the net effect is  $g \times 7/4$
31. Orbital speed is found from setting  $\frac{GMm}{r^2} = \frac{mv^2}{r}$  which gives  $v = \sqrt{\frac{GM}{r}}$  where M is the C
- object being orbited. Notice that satellite mass does not affect orbital speed or period.
32.  $g = \frac{GM}{r^2}$  so the acceleration due to gravity (and the weight of an object) is proportional to the B
- mass of the planet and inversely proportional to the distance from the center of the planet squared.  $M \div 5 = g \div 5$  and  $r \div 2 = g \times 4$ , so the net effect is  $g \times 4/5$
33. Part of the gravitational force acting on an object at the equator is providing the necessary centripetal force to move the object in a circle. If the rotation of the earth were to stop, this part of the gravitational force is no longer required and the “full” value of this force will hold the object to the Earth. A
34. Standard orbital altitudes are not a large percentage of the radius of the Earth. The acceleration due to gravity is only slightly smaller in orbit compared to the surface of the Earth. A
35.  $F = \frac{GMm}{r^2}$ . F is proportional to each mass and inversely proportional to the distance between E
- their centers squared. If each mass is doubled, F is quadrupled. If r is doubled F is quartered.
36. Since the acceleration due to gravity is less on the surface of the moon, to have the same B
- gravitational force as a second object on the Earth requires the object on the Moon to have a larger mass.
37. Satellites in orbit are freely falling objects with enough horizontal speed to keep from falling E
- closer to the planet.
38. The mass of an object will not change based on its location. As one digs into a sphere of uniform D
- density, the acceleration due to gravity (and the weight of the object) varies directly with distance from the center of the sphere.
39. Combining  $\frac{GMm}{r^2} = \frac{mv^2}{r}$  with  $T = \frac{2\pi}{v}$  gives the equation corresponding to Kepler’s second A
- law. The mass of the satellite cancels in these equations.

40.  $F = \frac{GMm}{r^2}$  so F is proportional to  $1/r^2$ . Standard orbital altitudes are not a large percentage of

the radius of the Earth. The acceleration due to gravity is only slightly smaller in orbit compared to the surface of the Earth.

41. NO, this is not part of the curriculum, but interesting to know (and a bit of common sense if you follow the changing of the theories) A

42. Gravitational force is also the weight.  $mg$ . E

43.  $g$  is the same for all bodies in the absence of air resistance E

44. Satellites in orbit are freely falling objects with enough horizontal speed to keep from falling closer to the planet. C

45. The energy of a circular orbit is E

$$K + U = \frac{1}{2}mv^2 + \left(-\frac{Gmm}{r}\right) = \frac{1}{2}m\left(\sqrt{\frac{GM}{r}}\right)^2 + \left(-\frac{GMm}{r}\right) = -\frac{GMm}{2r}$$

The energy of an elliptical orbit is  $-\frac{GMm}{2a}$  where  $a$  is the semimajor axis. If the speed is cut in

$$\text{half we have } K + U = \frac{1}{2}m\left(\frac{v}{2}\right)^2 + \left(-\frac{Gmm}{r}\right) = \frac{1}{2}m\left(\frac{1}{2}\sqrt{\frac{GM}{r}}\right)^2 + \left(-\frac{GMm}{r}\right) = -\frac{7GMm}{8r}$$

Setting  $-\frac{7GMm}{8r} = -\frac{GMm}{2a}$  gives  $a = (4/7)r$

46. Sweeping out equal areas is based on the satellite moving faster as it moves closer to the body it is orbiting. This is a result of conservation of angular momentum. C

47. The angular momentum of each satellite is conserved independently so we can compare the orbits at any location. Looking at the common point between orbit A and B shows that satellite A is moving faster at that point than satellite B, showing  $L_A > L_B$ . A similar analysis at the common point between B and C shows  $L_B > L_C$  A

48.  $U = -\frac{GMm}{r}$  D

49. Since they are orbiting their center of mass, the larger mass has a radius of orbit of  $\frac{1}{4}d$ . The A

$$\text{speed can be found from } \frac{G(3M)M}{d^2} = \frac{(3M)v^2}{d/4} \text{ which gives } v = \sqrt{\frac{GM}{4d}} = \frac{2\pi(d/4)}{T}$$

50. The energy of a circular orbit is E

$$K + U = \frac{1}{2}mv^2 + \left(-\frac{Gmm}{r}\right) = \frac{1}{2}m\left(\sqrt{\frac{GM}{r}}\right)^2 + \left(-\frac{GMm}{r}\right) = -\frac{GMm}{2r}$$

The energy of an elliptical orbit is  $-\frac{GMm}{2a}$  where  $a$  is the semimajor axis. If the speed is cut in

half we have  $K + U = \frac{1}{2}m\left(\frac{v}{2}\right)^2 + \left(-\frac{Gmm}{r}\right) = \frac{1}{2}m\left(\frac{1}{2}\sqrt{\frac{GM}{r}}\right)^2 + \left(-\frac{GMm}{r}\right) = -\frac{7GMm}{8r}$

Setting  $-\frac{7GMm}{8r} = -\frac{GMm}{2a}$  gives  $a = (4/7)r$

The distance to the planet from this point is  $r$  (the radius of the circular orbit and aphelion for the elliptical orbit). The opposite side of the ellipse is  $2a$  away, or  $8r/7$ , making the distance to the planet at perihelion  $8r/7 - r = r/7$

51.  $U = -\frac{GMm}{r}$  B

52. The top of Pikes Peak is a very small fraction of the radius of the Earth. Moving to twice this elevation will barely change the value of  $g$ . D

53. Orbital speed is found from setting  $\frac{GMm}{r^2} = \frac{mv^2}{r}$  which gives  $v = \sqrt{\frac{GM}{r}}$  where  $M$  is the object being orbited. A

54.  $F = \frac{GMm}{r^2}$ . The masses of the proton and electron can be found in the table of constants (these masses do not need to be memorized) B

55.  $F = \frac{GMm}{r^2}$ ; If  $r \div 2$ ,  $F \times 4$ . If each mass is multiplied by 1.41,  $F$  is doubled ( $1.41 \times 1.41$ ) D

56.  $g = \Delta v/t = (31 \text{ m/s} - 50 \text{ m/s})/(5 \text{ s}) = -3.8 \text{ m/s}^2$  B

57. mass is unchanged, weight is changed due to a change in the acceleration due to gravity A

58. Orbital speed is found from setting  $\frac{GMm}{r^2} = \frac{mv^2}{r}$  which gives  $v = \sqrt{\frac{GM}{r}}$  where  $M$  is the object being orbited. B

59.  $g = v^2/r$  and  $v = 2\pi r/T$  B

