Physics 200 **Name:** Answers

2019-2020 Test: Circular Motion, Gravity, and Kepler's Laws

I. Multiple Choice (1pt each)

1. A tennis ball is swung in a vertical circle (horizontal axis) at a constant velocity. Where in the swing is the tension in the string the weakest?
   - A. At the bottom of the swing
   - [✓ B.] At the top of the swing
   - C. Half-way between the top and the bottom, on the way up
   - D. Half-way between the top and the bottom, on the way down

2. If car goes around a curve of radius r at a constant speed v, the car's acceleration is...
   - [✓ A.] directed towards the curve's center.
   - B. directed away from the curve's center.
   - C. directed toward the back of the car.
   - D. directed toward the front of the car.
   - E. zero.

3. A ball of mass m attached to a string is moving in a horizontal circle of radius r with a uniform speed of v. The tension in the string (i.e. the force needed to keep the ball moving in a circle) is F_T. If the velocity of the ball triples to 3v (i.e. 3 times its original velocity), what is the new tension in the string?

   A. $F_T/9$ B. $F_T/3$ C. F_T D. $3F_T$ [✓ E.] $9F_T$

4. A ball of mass **M** attached to a string is moving in a horizontal circle of radius r with a uniform speed of v. The tension in the string (i.e. the force needed to keep the ball moving in a circle) is F_T. If the mass of the ball increases to 5**M**(i.e. 5 times its original mass), what is the new tension in the string?

   A. $F_T/25$ B. $F_T/5$ C. F_T [✓ D.] $5F_T$ E. $25F_T$

5. Which is <u>not</u> one of Kepler's 3 Laws?
   - A. Planets orbit the Sun in ellipses
   - B. An imaginary segment drawn between the Sun and the planet sweeps out equal areas in equal times
   - [✓ C.] A planet's centripetal acceleration is proportional to its velocity squared.
   - D. The square of a planet's period is proportional to the cube of its orbital radius

6. A satellite orbits the Earth with a period of 2 hours. If the mass of the satellite were suddenly doubled, its orbital period would be ...

   A. 30 minutes b. 1 hour c. $\sqrt{2}$ hours [✓ d.] 2 hours e. 4 hours

7. The speed of a comet, while traveling in its elliptical orbit around the Sun,
   - A. is constant.
   - B. slows to zero at its furthest distance from the Sun.
   - [✓ C.] increases as it nears the Sun.
   - D. decreases as it nears the Sun.

8. The gravitational force between two masses separated by a distance r is 400 N. If the distance between the two masses (measured from center to the center) is now cut in half, the gravitational forces becomes

[✓ A. 1600 N] B. 800 N C. 400 N D. 200 N E. 100 N

9. The table below presents four planets whose masses and radii are expressed in terms of Earth's mass (M_E) and Earth's radius (R_E). On each planet, a ball of a different mass is dropped from a height of 10m. Neglecting air resistance, in which case will the ball fall fastest?

	Mass of Planet (Earth masses)	Radius of Planet (Earth radii)	Ball Mass (kg)
A.	1 M_E	1 R_E	1kg
B.	4 M_E	2 R_E	6kg
C.	5 M_E	1 R_E	8kg
[✓ D.]	2 M_E	0.5 R_E	2kg

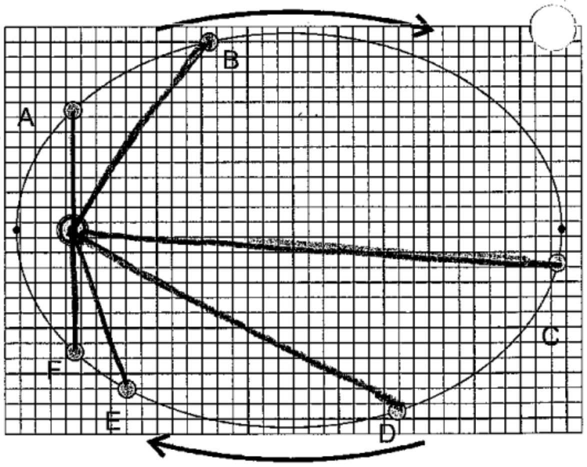
10. A car of mass **m** is traveling at a constant speed through a circular loop-the-loop of radius **r**. What <u>normal force</u> does the car experience at the top of the loop? [assume down = negative]

a. mv^2/r b. mg [✓ c. mv^2/r -mg] d. 0 e. -mg - F_N

11. In order to properly simulate Earth's gravity, approximately how fast must the outer edge of a cylindrical space station rotate, if the radius of the space station is 5 m?

a. 1m/s b. 3m/s c. 5m/s [✓ d. 7m/s] e. 9m/s

12-13. The ellipse on the right represents the path of an orbiting planet. The small black dots represent perihelion (closest to the Sun) and aphelion (farthest).



12. The planet spends the same amount of time traveling from point A to point B as it does traveling from ___________

B to C C to D D to E

E to F [✓ F to A]

13. At which point in the planet's orbit do the vector representing the planet's velocity and the vector representing the Sun's gravitational pull make the largest acute angle with one another?

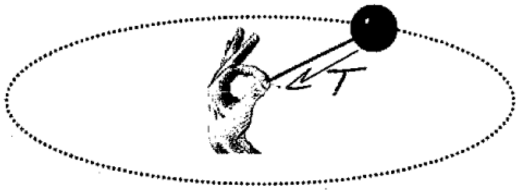
A B [✓ C] D E F

II. **Problems (4pts each):** For at least one of the problems, you will need at least one bit of this information. For partial credit, show your work. Box your starting formula(s) and your final answer. All answers must include correct units.

1.00 AU = 1.50×10^{11} m
$M_{Sun} = 1.99 \times 10^{30}$ kg
$M_{Moon} = 7.35 \times 10^{22}$ kg

1.00 y = 3.16×10^{7} s
$M_{Earth} = 5.97 \times 10^{24}$ kg
$R_{Earth} = 6.378 \times 10^{6}$ m

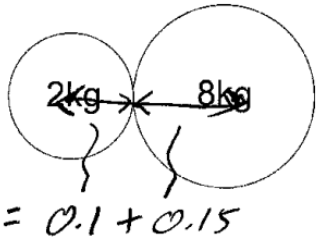
1. A 0.058kg tennis ball on a string travels in a horizontal circle at a constant speed of 6.30 m/s. If the string is 1.15 m long, what is the tension in the string? [Assume that this happens in a gravity-free environment.]



$$\boxed{\begin{array}{l} \Sigma F = \frac{mv^2}{r} \\ \Sigma F = T \end{array}} \Rightarrow \frac{mv^2}{r} = T$$

$$\frac{(0.058\,kg)(6.3\,m/s)^2}{1.15\,m} = \boxed{2\,N}$$

2. The radii of the spheres on the right are 0.1m and 0.15m, respectively. What is the force of gravitational attraction between the two spheres?



$$\boxed{F_g = G\frac{M_1 M_2}{r^2}} = 6.67\times10^{-11}\frac{N m^2}{kg^2}\left(\frac{(2kg)(8kg)}{0.25m^2}\right)$$

$$\boxed{= 1.73\times10^{-8} N}$$

$r = 0.1 + 0.15$
$= 0.25m$

3. A 1,500kg car traverses a loop-the-loop with a radius of 5m, maintaining a constant speed the whole time. If, at the top of the loop, the car is being pushed downward by a normal force of 5,000N, what is the car's speed?

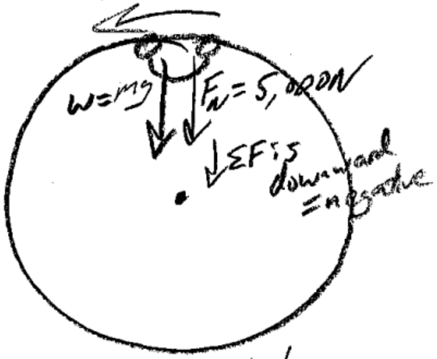
Down, so negative

$$\boxed{\begin{array}{l} \Sigma F = -\frac{mv^2}{r} \\ \Sigma F = -mg - F_N \end{array}} \Rightarrow \frac{-mv^2}{r} = -mg - F_N$$

$$v^2 = \frac{r}{m}(mg + F_N)$$

$$v = \sqrt{\frac{r}{m}(mg + F_N)}$$

$$v = \sqrt{\frac{5m}{1500kg}\left[1500kg(9.8m/s^2) + 5000N\right]} = \boxed{8.1 m/s}$$



4. A 60kg student is on a ride called the *Ring of Fire*, which travels in vertical circles. At the bottom of one of the circles, the student is traveling at a speed of 11 m/s. Furthermore, the bathroom scale that is supporting her suggests that her weight is three times its normal value. Assuming that her speed is constant, what is the radius of the circle in which the student is traveling?

$$\boxed{\Sigma F = \frac{mv^2}{r} \qquad \Sigma F = F_N - mg}$$

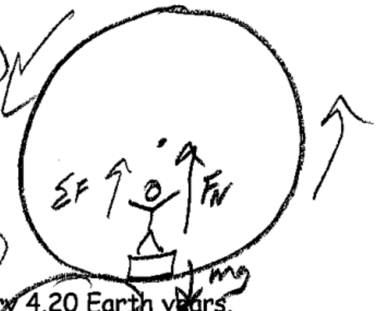
up, so positive

$F_N = 3mg$

$$\frac{Mv^2}{r} = F_N - mg$$

$$\frac{\cancel{M}v^2}{r} = 3\cancel{m}g - \cancel{m}g \Rightarrow \frac{v^2}{r} = 2g$$

$$\boxed{r = 6.17\,m} \Leftarrow \frac{(11\,m/s)^2}{r} = 2(9.8\,m/s^2)$$



5. An asteroid traveling in a circular orbit circles the Sun once every 4.20 Earth years.

a. What is the radius of the asteroid's orbit in AU (1AU = 1 astronomical unit = Earth's orbital radius)? A = Earth B = Asteroid

$$\boxed{\frac{T_a^2}{T_b^2} = \frac{r_a^2}{r_b^2}} \qquad \frac{(1\,yr)^2}{(4.2\,yr)^2} = \frac{(1\,Au)^3}{(r_B)^3}$$

$$\boxed{= 2.6\,Au}$$

b. What is the asteroid's speed, in AU per year (much e an m/s, in this case)?

$$\boxed{v = \frac{d}{t}}$$

one orbit (circumference)

42yrs

$$v = \frac{2\pi r}{T} = \frac{2\pi(2.6\,Au)}{4.2\text{ years}}$$

$$\boxed{v = 3.89\,\frac{Au}{yr}}$$

6. A satellite is launched into a circular orbit that is 4.22×10^7 m from the center of Earth. What is its speed?

$$\boxed{v = \sqrt{\frac{GM}{r}}} \Rightarrow v = \sqrt{\frac{6.67\times10^{-11}\frac{Nm^2}{kg^2}\left(5.97\times10^{24}\,kg\right)}{4.22\times10^{7}\,m}}$$

$$\boxed{v = 3{,}072\,m/s}$$

7. To what altitude would you have to shoot a cannonball so that, at its highest point, it would begin to free-fall back to Earth with an acceleration of -5m/s²? [In other words, so that g would equal 5m/s at that point]

$g = 5\,m/s^2$

$$\boxed{g = \frac{GM}{r^2}}$$

$$5\,m/s^2 = \frac{6.67\times10^{-11}\frac{Nm^2}{kg^2}\left(5.97\times10^{24}\,kg\right)}{r^2}$$

$$\boxed{r = 8.92\times10^{6}\,m}$$