Use $g=10m/s^2$. Ignore drag and use standard MKS units unless indicated otherwise.

1. Uniform sphere X with mass 1kg and radius 1m is dropped from rest in a vacuum near Earth's surface and free falls 5m. How many more seconds would it take to fall 20m?

   A. 1 B. 2 C. 3 D. 4 E. NOTA

2. Uniform sphere X with mass 1kg and radius 1m is dropped from rest in a vacuum near Earth's surface and free falls 5m. To the nearest 1J what is the net work done on the sphere?

   A. 0 B. 5 C. 25 D. 50 E. NOTA

3. Uniform sphere X with mass 1kg and radius 1m is released from rest in a vacuum near Earth's surface and rolls 10m, no slipping, down a long incline that meets the horizon at a 30° angle. In $kg \cdot m^2/s$, what is the final angular momentum of the sphere about an axis through its center?

   A. 10 B. $\frac{4\sqrt{15}}{3}$ C. $\frac{4\sqrt{35}}{7}$ D. $2\sqrt{10}$ E. NOTA

4. Uniform sphere X with mass 1kg and radius 1m is released from rest in a vacuum near Earth's surface and rolls 10m without slipping down a long incline that makes a 30° angle with the horizon. What is the magnitude of the force of friction on the sphere in Newtons?

   A. $10\sqrt{3}$ B. $5\sqrt{3}$ C. $\frac{10}{7}$ D. 0 E. NOTA

5. Uniform sphere X with mass 1kg and radius 1m is released from rest in a vacuum near Earth's surface and rolls 10m without slipping down a long incline that makes a 30° angle with the horizon. What is the energy dissipated due to friction in Joules?

   A. $50\sqrt{3}$ B. 25 C. $25\sqrt{3}$ D. 0 E. NOTA

6. What is the total energy of a satellite of mass m in the satellite-Earth system in a circular orbit around Earth when it is at an altitude of R (the radius of Earth)? The mass of Earth is M.

A. $-\sqrt{\frac{GMm}{2R}}$ B. $-\frac{GMm}{4R}$ C. $-\frac{GMm}{2R}$ D. $\frac{GMm}{2R}$ E. NOTA

7. Starting at the origin and time $t = 0$, a small particle with mass 100g and a negative charge of magnitude .1C is moving 2m/s in the positive *x* direction. The particle is moving through a uniform time-varying electric field $E(t) = -0.2t\hat{\imath}$ V/m and experiences no other forces. Which of the following is the closest to the kinetic energy of the particle at $t = 2$ in Joules?

A. 0.008 B. 0.16 C. 0.288 D. 2.88 E. 5.76

8. Starting at the origin and time $t = 0$, a small particle with mass 100g and a negative charge of magnitude .1C is moving 2m/s in the positive *x* direction. The particle is moving through a uniform time-varying electric field $E(t) = -0.2t\hat{\imath}$ V/m and experiences no other forces. What is the position of the particle at time $t = 2$ in meters?

A. $\frac{64}{15}$ B. $3\sqrt{2}$ C. 4.4 D. 4.8 E. NOTA

9. Starting at the origin and time $t = 0$, a small particle with mass 100g and a negative charge of magnitude .1C is moving 2m/s in the positive *x* direction. The particle is moving through a uniform time-varying electric field $E(t) = -0.2t\hat{\imath}$ V/m and experiences no other forces. What is the momentum of the particle at time $t = 3$ in $kg \cdot m/s$?

A. 0.29 B. 0.24 C. 0.09 D. 0.04 E. NOTA

10. Starting at the origin and time $t = 0$, a small particle with mass 100g and a negative charge of magnitude .1C is moving 2m/s in the positive *x* direction. The particle is moving through a uniform time-varying electric field $E(t) = -0.2t\hat{\imath}$ V/m and experiences no other forces. What is the magnitude of the derivative of the momentum of the particle at time t = 2 in standard units?

A. 0.02 B. 0.04 C. 0.22 D. 0.24 E. NOTA

11. The coefficient of restitution is the negative of the final difference in the velocities of the two objects in a collision divided by their initial difference. Given that two rubber balls have a 1-dimensional head on collision, ball A has mass 1kg and initial velocity -8m/s, ball B has mass 2kg and initial velocity 4m/s. Given ball A has a post collision velocity of 6m/s, what is the coefficient of restitution for these two balls?

A. $-\frac{4}{3}$ B. $-\frac{3}{4}$ C. $-\frac{1}{4}$ D. $\frac{1}{4}$ E. NOTA

12. Two small spheres of mass M and 2M hang from equal strings connected to the ceiling at the same point. The less massive sphere is pulled to the side until it is a height H above the larger sphere and then released from rest. The smaller sphere collides with the larger and they stick together and swing to what maximum height above their lowest point?

A. $\frac{H}{9}$ B. $\frac{H}{4}$ C. $\frac{H}{3}$ D. $\frac{H}{2}$ E. NOTA

13. A certain satellite, at a distance R away from the center of a planet, has an orbital period of 80 minutes. Which of the ranges below contains the orbital radius it would have with a period of 24 hours?

A. $(2R, 4R)$ B. $(5R, 9R)$ C. $(10R, 20R)$ D. $(100R, 400R)$ E. NOTA

14. A uniform disk is at rest and mounted on a frictionless axle through its center and parallel to its axis of rotational symmetry. A thin hoop with $\frac{1}{6}$ of the mass, the same radius as the disk, and with angular speed 2π revolutions per second about the same axle through its center and parallel to its axis of rotational symmetry, slides down the axle and sticks to the disk. Which is closest to the angular speed of the combined system after the collision in rad/s?

A. $\frac{\pi}{2}$ B. $\frac{4\pi}{3}$ C. 10 D. 4π E. $\frac{8\pi^2}{3}$

15. Which of these is the moment of inertia of a uniform rectangular sheet of mass M, length L and width $\frac{L}{2}$ about an axis perpendicular to the plane of the sheet and passing through its center?

A. $\frac{5ML^2}{48}$ B. $\frac{ML^2}{12}$ C. $\frac{ML^2}{3}$ D. $\frac{ML^2}{8}$ E. NOTA

16. An unstretched at rest .5kg Hookean spring, with spring constant 9×10^{16}N/m and length 2m, is floating in deep space when an 80kg astronaut, at rest, pushes it in a way that does not stretch or compress it. The spring moves in the direction it was pushed at 20m/s and the astronaut moves the opposite way at .125m/s. Next, the spring and astronaut are returned to their initial positions and are restored to rest. Finally, the spring is compressed to a new length of 1m, locked at that length by someone else, and the astronaut pushes it in the same way but harder so that the astronaut recoils at .25m/s. What will be the speed of the spring this time in m/s?

A. 10 B. $10\sqrt{2}$ C. 20 D. 40 E. NOTA

17. A 1kg point-like particle experiences a force in the direction of its motion that starts at 100N and decreases linearly to 0N over the course of 1m. Given the particle starts at 5m/s, then what is its final speed in m/s?

A. $5\sqrt{5}$ B. 10 C. $5\sqrt{3}$ D. $5\sqrt{2}$ E. NOTA

18. What minimum coefficient of static friction does a uniform square's interface with an incline need so that if it rests on the incline, it will always topple without sliding as the angle the incline makes with the horizon is increased?

A. $\frac{\sqrt{2}}{2}$ B. $\frac{\sqrt{3}}{2}$ C. 1 D. 2 E. NOTA

19. A 9V battery, a 3Ω resistor and an initially uncharged 1F capacitor are connected in series. Which of the following is the closest to the current (in A) through the resistor when the capacitor is at half of the maximum charge?

A. 0.5 B. 1.0 C. 1.5 D. 2.0 E. 3.0

20. The period of a physical pendulum is $T_p = 2\pi\sqrt{\frac{I}{mgr}}$, where I is the rotational inertia of the pendulum about its pivot, m is its mass, and r is the distance from the pivot to the center of mass. This is approximately true when the amplitude of the oscillation is sufficiently small. If the amplitude is such that the pendulum sweeps out an arc angle of nearly π radians then which of these is true of the period T_L?

A. $T_L > T_p$ B. $T_L = T_p$ C. $T_L < T_p$ D. Need more information E. NOTA

21. Given a uniform sphere of aluminum with radius 3R, then what would be the equilibrium electric field at a distance of 2.5R from its center after a charge of Q is deposited on it?

A. $\frac{2kQ}{15R^2}$ B. $\frac{4kQ}{25R^2}$ C. 0 D. $\frac{kQ}{9R^2}$ E. NOTA

22. Two long parallel conducting rails are fixed in place to a table and 1m apart from each other. They are connected at one end by a 1-ohm resistor. They are straddled by another conducting rail that is 1kg, is perpendicular to the long rails, is free to move and is initially 2m away from the resistor. There is a 1T magnetic field directed up from the bottom of the table so that it is perpendicular to the plane of the long rails. The 1kg rail is pulled away from the resistor along the rails by an external force so that its acceleration described as $a(t) = 2t$, with t measured in seconds. Given the rails have no resistance and the 1kg rail starts at rest at $t = 0$, then what is the current in amps in the resistor at time $t = .5$?

A. 0 B. 0.125 C. 0.25 D. 0.5 E. NOTA

23. For the same situation from question 22: What is the force (in N) on the 1kg rail by the external force that is moving it away from the resistor at $t = .5$?

A. 0.75 B. 1 C. 1.25 D. 1.5 E. NOTA

24. An object is thrown straight down with an initial velocity of 12m/s from the top of a ladder that is 17m tall. Which of the following is the closest to the time (in s) it takes for the object to hit the ground?

A. 0.6 B. 1.0 C. 1.4 D. 1.8 E. 2.2

25. A simple pendulum on earth has a period of 1 second. What would be its period if it were on a rocket, away from measurable gravitational fields, accelerating in a line at constant 40m/s^2?

A. $\frac{1}{4}$ B. $\frac{1}{2}$ C. $\frac{\sqrt{2}}{2}$ D. $\sqrt{2}$ E. NOTA

26. One end of an ideal spring has mass 2M attached and is held fixed. The other end has mass M attached and is initially free to oscillate vertically, with period T_1. Then the end with mass 2M is released and the system is allowed to free fall. Assume it continues to oscillate, but with period T_2. Which of the following is the closest to T_2/T_1?

A. $\sqrt{\frac{1}{3}}$ B. $\sqrt{\frac{2}{3}}$ C. 1 D. $\sqrt{3}$ E. NOTA

27. Take α Cen to be a point 4.5 light years from earth as measured from earth. Now suppose ship A leaves Earth traveling at a constant 0.6c headed for α Cen. Which of the following is closest to the number of years it would take to reach α Cen, as measured by a clock on the ship?

A. 4.5 B. 6 C. 7.5 D. 9 E. 10.5

28. Take one of the wheels on a car to have mass m. The angular acceleration of the wheel can be described with $\alpha(t) = 2\pi t$ on the interval from t = 0 to t = 5. Given a radius of $1.5^{2/3}$m, it doesn't slip, and the car is at rest at t=0, then which of these is closest to the total acceleration (in m/s^2) of a point on the wheel touching the ground when $t = (1.5)^{1/3}$?

A. $\frac{3\pi\sqrt{2}}{10}$ B. π C. 1.5π D. π^2 E. $2.25\pi^2$

29. A ball is hanging in equilibrium from a vertical spring. Mr. Grumpy then pulls the ball .2m down. At time t=0 Mr. Grumpy releases the ball. The period of the oscillation that follows is 1 second. Given up as positive and choosing the release point to be $y = 0$, then what is the position of the ball (treated as a point and measured in meters) 1/6 of a second after it is released?

A. 0 B. $\frac{1}{15}$ C. $\frac{1}{10}$ D. $\frac{1}{5}$ E. NOTA

30. For the ball spring oscillator described in question 29 what would be the total distance (in meters) traveled by the ball 1.5 seconds after it is released?

A. 0.1 B. 0.3 C. 0.6 D. 1.2 E. NOTA