General assumptions, unless otherwise indicated:

- Air resistance is negligible.
- Racers start at the same time.
- Wires and batteries are ideal.
- Lenses and mirrors are ideal.
- Gravity is 10 m/s^2

Choose NOTA if none of the provided answers are correct.

1. A ball is fired at a velocity V and angle Θ to the horizontal from the ground. Derive an expression for the horizontal range of the fired ball. Express your answer in terms of V, Θ, and any fundamental constants, assume the starting and ending vertical positions are the same, and the gravitational field is constant.

   A. $\frac{V^2 \sin 2\theta}{2g}$ B. $\frac{V^2 \sin \theta}{2g}$ C. $\frac{V^2 \sin \theta}{g}$ D. $\frac{V^2 \sin 2\theta}{g}$ E. NOTA

2. During a thermodynamic cycle, a heat engine discards 600J of energy to a cold source and absorbs 1000J of energy from the heat source. Calculate the efficiency for the engine.

   A. 2/5 B. 5/8 C. 2/3 D. 5/16 E. NOTA

3. The potential energy of a particle can be modeled by the following expression: $U(x, y) = 400x^2 + 441y^2$. The particle can perform several types of periodic motion. What is the ratio of the maximum to minimum periods of oscillation the particle could experience?

   A. 29 B. 21 C. 20 D. $\sqrt{21/20}$ E. NOTA

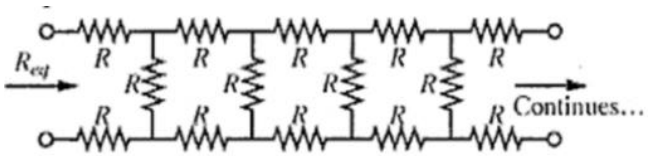
4. A circuit is created that contains a battery with voltage V and a capacitor with capacitance C in series. The battery charges the capacitor for a long period of time. The battery is then disconnected from the circuit and the plates of the capacitor are separated such that the separation between the plates doubles. If the potential energy before the plates were separated was U, what is the new potential energy between the plates in terms of U? Assume the plate separation is small enough so the capacitor can be treated as ideal in both cases.

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

5. Zach's Chell company produces a special type of device called a Chell. The machines build the Chell as it travels along the conveyor belt, which travels east at 5 m/s. When the Chell is complete, the Chell transitions smoothly onto another conveyor belt, traveling at 10 m/s north, which takes it to the boxing room. As the Chell makes the transition from the eastward belt to the northward belt, what is the minimum speed of the Chell?

A. 5 m/s B. $2\sqrt{5}$ m/s C. $\sqrt{5}$ m/s D. 2.5 m/s E. NOTA

6. One day, Dan Dub was hanging with Mr. Lu asking for high IQ problems. Mr. Lu draws the following diagram and tells Dan Dub to calculate the effective resistance between the two nodes to the left of the picture (2 white circles) assuming the chain goes on infinitely to the right. What is the correct answer?



A. $R + R\sqrt{3}$ B. $R\sqrt{3} - R$ C. $2R$ D. $R + R\sqrt{2}$ E. NOTA

7. An adiabatic process is defined as a process without the transfer of heat into or out of the system. Which expression involving the pressure, P, and volume, V, for an adiabatic process performed on an ideal gas is constant? (Hint: the energy for an ideal gas can be modeled as fPV/2, where f represents the number of degrees of freedom for a gas. The adiabatic index, a, is equal to (f+2)/f).

A. $P^{1-a}V^{a}$ B. PV^{a} C. $P^{a}V^{1-a}$ D. $P^{1-a}V^{-a}$ E. NOTA

8. Xiya carries around a round object with a moment of inertia I=βmr^2. Xiya's favorite activity is to take said round object and roll it down a slope with an incline of Θ. Solve for the linear acceleration of this object down the slope. The object rolls without slipping.

A. gsinΘ B. $\frac{g\sin\theta}{\beta}$ C. $\frac{g\sin\theta}{1+\beta}$ D. $\frac{g\sin\theta}{|1-\beta|}$ E. NOTA

9. The coefficient of thermal expansion for brass is .000188 per degree Celsius. A brass washer of diameter of 400 cm has a hole of radius 100 cm. If the washer's temperature is increased by 100 degrees Celsius, then the circumference of the hole of the washer is Xπ cm. Solve for X. Round the answer to the nearest integer.

A. 204 B. 196 C. 408 D. 392 E. NOTA

10. A wooden rectangular prism with density of ρ and a height of h floats partially submerged in a zero viscosity liquid with a density ρ_o where $\rho < \rho_o$. The block is pushed further into the liquid by a small amount Δh. Calculate the period of the oscillation in terms of some or all of the given variables and fundamental constants.

A. $2\pi\sqrt{\frac{h\rho_0}{g\rho}}$ B. $2\pi\sqrt{\frac{h\rho}{g\rho_0}}$ C. $2\pi\sqrt{\frac{h}{g}(1-\frac{\rho}{\rho_0})}$ D. $2\pi\sqrt{\frac{h}{g}(1-\frac{\rho_0}{\rho})}$ E. NOTA

11. Calculate the units of the derivative of crackle with respect to time in terms of meters and seconds.

A. m B. m/s^3 C. m/s^4 D. m/s^5 E. NOTA

12. Kejin really loves tennis balls. His favorite activity is to launch the ball so that while traveling up, it hits a target that is 105 meters above the ground on the side of a building. The ball elastically collides with the vertical face of the target and bounces back towards Kejin. He is really strong and can hit the ball so it leaves his racket at $50\sqrt{2}$ meters per second at an angle of 45 degrees. How far away from Kejin does the ball land? Assume Kejin's height is negligible and that he stands still after launching the ball.

A. 200 B. 300 C. 350 D. 150 E. NOTA

13. Coley is driving to a football game. He is running late, so he is driving at 20 m/s until he comes across a cop with an inefficient speed monitor that measures the length of the car and how long it takes for the car to travel its length in order to calculate the average velocity. If the length of Coley's car is 10 meters, how much should Coley constantly decelerate so that the speed the detector measures is the speed limit of 50/3 m/s?

A. $240{,}000 km/hr^2$ B. $200/3 km/s^2$ C. $100/9\ m/s^2$ D. $1/54\ m/s^2$ E. NOTA

14. Wow, Coley gets to punt for this game! Coley punts a football at a 15-degree angle to a person that is 20 meters away. Assuming Coley and his fellow players' heights are negligible, calculate the velocity at which Coley punted the ball.

A. $20\sqrt{2}$ m/s B. 10 m/s C. $10\sqrt{2}$ m/s D. 20 m/s E. NOTA

15. In a separate universe, Earth has the same mass and the same radius, but is shaped as a hemispherical bowl with negligible thickness. Calculate the magnitude of the gravitational acceleration at the center of the Great circle of the hemisphere. Assume the shell has a uniform mass density per area (you can call it d).

A. $G\pi$d/3 B. $G\pi$d C. $2G\pi$d/3 D. $3G\pi$d/4 E. NOTA

16. In a parallel universe, Earth has the same mass and the same radius, but is shaped as a thin spherical shell. Calculate the magnitude of the gravitational acceleration at a radius of 500 km from the center of the shell.

A. $5\sqrt{2}$ m/s^2 B. 5 m/s^2 C. 2.5 m/s^2 D. 0 m/s^2 E. NOTA

17. In a final parallel universe, Earth has the same mass (M) and the same radius (R), but the density of earth is directly proportional to the distance from the center. Produce an expression to represent the magnitude of the gravitational acceleration with respect to the distance from the center (variable r) for an r < R. (hint: the G constant from Newton's law of gravity already considers the coefficients gained from the integration, similar to how k represents the permeability of space divided by the coefficients of integration for the closed integral of EdA)

A. $\frac{GMR^2}{r^4}$ B. $\frac{GM}{r^2}$ C. $\frac{GM}{R^2}$ D. $\frac{GMr^2}{R^4}$ E. NOTA

18. Rishi is in a race and he has just passed Mr. Payne. Mr. Payne runs at an astonishing 10 meters per second while Rishi races at 30 meters per second on his super bike. Rishi planted a noise maker on Mr. Payne so he could tell how far away he was. If the frequency of the noise maker is 525 hertz when both are at rest, what is the perceived frequency from Rishi's point of view after he has passed Mr. Payne. Round your answer to the nearest integer. (The speed of sound is 340 m/s)

A. 493 hz B. 559 hz C. 497 hz D. 555 hz E. NOTA

19. Mr. Frazer tells his AP Statistics class to spin pennies on a table for a project. Model the penny as a thin uniform disk with a mass of M and a radius of R. Calculate the moment of inertia for the penny within the experiment (The axis of rotation should be the diameter of the circle).

A. $\frac{3MR^2}{2}$ B. $\frac{MR^2}{2}$ C. $\frac{MR^2}{4}$ D. $\frac{3MR^2}{4}$ E. NOTA

20. A special circuit is created using a battery with voltage V connected to 2 parallel branches with a capacitor with capacitance C and an inductor with inductance L, respectively. The capacitor is then charged over a long period of time before the battery is disconnected from the loop. This LC circuit can be modeled as a simple harmonic oscillation with respect to the electrical energy stored in each of the structures. Calculate the period of oscillation for this LC circuit.

A. $2\pi\sqrt{\frac{L}{C}}$ B. $2\pi\sqrt{\frac{C}{L}}$ C. $2\pi\sqrt{\frac{1}{LC}}$ D. $2\pi\sqrt{LC}$ E. NOTA

21. A car has constant power output on its engine. The car starts out at rest at time t=0 and travels for 10 seconds, by which time it has kinetic energy K. If the instantaneous acceleration at time t=10 seconds is a, what is the instantaneous acceleration at time t=60 seconds?

A. $a/6$ B. $a/3$ C. $a/\sqrt{3}$ D. $a/\sqrt{6}$ E. NOTA

22. A beetle is moving along a rubber band at 5 cm/s. The rubber band is attached to a wall at one end and is stretched at 3 m/s on the other end. If the rubber band is 1 meter long and the beetle starts at the wall, how long does it take for the beetle to travel from one end of the rubber band to the other (Hint: it is smart to consider the relative distance the beetle has traveled rather than the actual distance)?

A. 100 sec. B. $\frac{e^{60}-1}{3}$ sec C. 20 sec D. $\frac{e^{30}-1}{6}$ sec E. NOTA

23. Oh No! Jake forgot to do his Physics homework. The problem is: A circuit is made of a 120 V battery connected to parallel branches. One branch has a resistor of resistance 6 ohms while the other branch has 2 resistors, one with resistance 9 ohms and the other with 15 ohms. If the 9 ohm resistor is replaced with ideal wire, what is the difference between the power dissipated at the 6 ohm resistor before and after the 9 ohm resistor is replaced?

A. 585 watts B. 375 watts C. 0 watts D. 960 watts E. NOTA

24. 14 perfectly elastic identical beads are sliding along a frictionless horizontal axis. Calculate maximum amount of collisions that could happen between the beads on the axis. Assume that the beads have negligible size, no more than 2 beads collide at the same time, and that the beads can initially be travelling in any direction along the axis with some finite velocity.

A. 91 B. 14! C. 287483 D. 1827 E. NOTA

25. A block of mass m moves at a velocity of v along a frictionless track. It 1^{st} collides perfectly inelastically with a block of mass 2m at rest. 2^{nd} the 2 block system collides perfectly inelastically with a block of mass m at rest. 3^{rd}, the 3 block system collides perfectly elastically with a block of mass 4m at rest. Rank the magnitude of the impulses provided to the blocks at rest for the 3 collisions from greatest to least.

A. 2^{nd}, 1^{st}, 3^{rd} B. 1^{st}, 3^{rd}, 2^{nd} C. 2^{nd}, 3^{rd}, 1^{st} D. 3^{rd}, 1^{st}, 2^{nd} E. NOTA

26. Slik Rik was messing with 1 kg of Mystery Metal. He heats it up to 100 degrees Celsius and drops it into 6 kg of a non-viscous form of Mu Goo at 50 degrees Celsius. If the specific heat of Mystery Metal is 4.32 J/g°C and the specific heat of Mu Goo is 2.16 J/g°C, find the equilibrium temperature between the Mystery Metal dropped into the Mu Goo. (Assume that no heat escapes into the environment)

A. 62.5 °C B. 65 °C C. 54°C D. 50°C E. NOTA

27. Helena goes to her favorite restaurant, Jeezcake Factory, in order to eat their world famous Jeezcake. When going to the restaurant, Helena travels at an astonishing 80 mph in a delirious state of Jeezcake craving. After somehow not getting arrested for going exactly 30 mph over the speed limit, she enjoys a 60 dollar Jeezcake before returning home at the speed limit. What is her average driving speed for this Jeezcake trip (ignore time spent eating cake)?

A. 65 mph B. 67.6 mph C. 800/13mph D. 900/13mph E. NOTA

28. In a cross country race, Jake finishes the race while Jae and Jack have covered 4/5, and 5/6 of the distance, respectively. How much of the race has Jae finished when Jack finishes the race?

A. 24/25 B. 5/6 C. 25/36 D. All of it E. NOTA

29. Buffy decides to go to BF Phangs for lunch. Driving in the new 2022 Boing! Car, he is driving at 18 m/s when he suddenly collides with Candy Hu driving on the wrong side of the road at 16 m/s, also driving the new 2022 Boing! Car. If they collide in a perfectly elastic head on collision, what is Buffy's final speed after the collision. (The masses of the two cars and drivers are equal).

A. 17 m/s B. 18 m/s C. 19 m/s D. 16 m/s E. NOTA

30. 2 blocks are attached to by rope, hung over a massless pulley, and allowed to move under the influence of gravity. The blocks have mass m and bm. Calculate the tension in the rope while they are accelerating. Assume b is greater than or equal to 1.

A. m(b+1)g B. m(b-1)g C. $\frac{m(b-1)}{b+1}g$ D. $\frac{2mgb}{b+1}$ E. NOTA