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.

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

2. 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 capacitor is then disconnected from the circuit and replaced with a capacitor with double the separation between plates. If the potential energy of the first capacitor was U, what is the ratio of the potential of the second to first capacitor.

   A. 4   B. 2   C. ½   D. 1/4   E. NOTA

3. In a cross country race, Ahan finishes the race while Jimmy and Jack have covered 2/3, and 4/5 of the distance, respectively. How much of the race has Jimmy finished when Jack finishes the race? Assume they maintain a constant velocity throughout the race due to their numerous hours of intense training.

   A. 8/9   B. 5/6   C. 35/36   D. All of it.   E. NOTA

4. 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 removed, what is the positive difference between the power dissipated at the 6 ohm resistor before and after the 9 ohm resistor is removed?

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

5.   Anjana Ballerchandar is practicing her shooting skills. She is holding a 500-gram basketball and shoots it at a 30-degree angle with an initial speed of 100 m/s at a target that is $75\sqrt{3}$ m away horizontally and 75 meters high attached to a wall. By what height does Anjana miss the target? Assume her height and the dimensions of the basketball are negligible.

   A.   5 m   B.   2.5 m   C.   11.25m   D.   7.5 m   E.   NOTA

6.   Andrew's Ama-xing Factory produces a special type of phone. The machines build the phone as it travels along the conveyor belt, which travels east at 25 m/s. When the phone is complete, the phone drops onto another conveyor belt, traveling at 50 m/s north, which takes it to the boxing room. As the phone makes the transition from the eastward belt to the northward belt, what is the minimum speed of the phone? Assume the drop from the conveyor belt is so small that the addition of the vertical velocity is negligible.

   A.   25   B. $10\sqrt{5}$ C. $\sqrt{5}$ D.   2.5   E.   NOTA

7.   In Himal's Epic Theme Park, visitors can ride the "Wheely Whirl" where they stand in a tube that is 10m in radius. The tube then starts to spin faster and faster until it is spinning at 3 radians per second. It is at this point that the platform they are standing on opens and they are stuck to the wall. If the maximum weight of a person riding the Whirly Wheel is 800N, what is the minimum coefficient of static friction needed for the riders to not slide down after the platform goes away?

   A.   1   B.   2/9   C.   9/2   D.   5/9   E.   NOTA

8.   Calculate the effective resistance between the two nodes on the left side of the following diagram (2 white circles) assuming the chain goes on infinitely to the right.
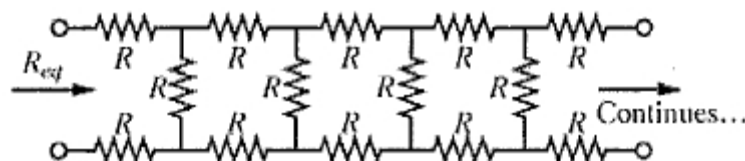
   A.   2R   B. $R\sqrt{3} - R$ C. $R + R\sqrt{2}$ D. $R + R\sqrt{3}$ E.   NOTA

9. Calculate the effective spring constant of an infinite line of springs connected in series, each with a spring constant of 1N/m.

    A. 0   B. $1 + \sqrt{3}$ C.   1   D. $\sqrt{3} - 1$ E. NOTA

10. 23 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. 253   B. 508   C. 73823   D. 10626   E. NOTA

11. A car has constant power output on its engine. The car starts out at rest at time $t = 0$ and travels for 5 seconds, by which time it has kinetic energy K. If the instantaneous acceleration at time $t = 5$ seconds is a, what is the instantaneous acceleration at time $t = 60$ seconds?

    A. $a/\sqrt{3}$ B. $a/2\sqrt{3}$ C. $a/12$ D. $a/6$ E. NOTA

12. Nathan has a candle of length 15 cm. He places the candle 30 cm away from a converging lens. The lens has a focal length of 10 cm. How far away from the lens is the image and is it virtual or real?

    A. 15 real   B. 15 virtual   C. 30 real   D. 30 virutal   E. NOTA

13. 2 blocks are attached to a rope over a massless pulley. The blocks have mass m and bm with $b > 1$. Calculate the magnitude of acceleration of the block with mass bm.

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

14. A rope with linear mass density μ experiences the maximum tension T. If a new rope had 5 times the radius and the same density μ, then what would be the ratio of the fundamental frequency between the new rope and the original rope?

    A. 1/5   B. 5   C. $\frac{1}{\sqrt{5}}$ D. 1   E. NOTA

15. The electric potential at the apex of a square pyramid with a height of s/2 and a base side length of s with a uniform charge distribution ρ is approximately equal to $\frac{0.03\rho s^2}{\varepsilon_0}$. Calculate the electric potential at the corner of a cube with a side length of s. Round the coefficient to the nearest thousandth.

   A. $\frac{0.18\rho s^2}{\varepsilon_0}$ B. $\frac{0.9\rho s^2}{\varepsilon_0}$ C. $\frac{0.24\rho s^2}{\varepsilon_0}$ D. $\frac{0.225\rho s^2}{\varepsilon_0}$ E. NOTA

16. Olivia Lee has come out with the revolutionary Olee Guacamolee. In the commercial, Olivia shoots a 1 meter thick layer of Olee Guacamolee with a bullet of mass 50 grams at a velocity of 1000 m/s. If the Guacamolee provides a constant force on the bullet as it goes through, calculate how long it takes for the bullet to stop if the bullet comes to a rest after going through the entire layer of Guacamolee.

   A. 2 s   B. 1s   C. 1/1000s   D. 1/500s   E. NOTA

17. Melissa and her twin Timmy are playing on a See Saw. Melissa sits on one end of a See Saw which is a total length of 10 meters and has a pivot at the direct center of the See Saw. Timmy starts out directly in front of Melissa and walks forward until the See Saw moves and Melissa's side is in the air. If Timmy is 80 kg while Melissa is 50 kg, how far away from Melissa does Timmy have to walk along the See Saw for Melissa's side to be put in the air.

   A. 65/8 m   B. 25/8 m   C. 25/4 m   D. 57/4 m   E. NOTA

18. A block of mass m moves at a velocity of v along a frictionless track. It first collides perfectly inelastically with a block of mass 2m at rest. Then the 2 block system collides perfectly inelastically with a block of mass m at rest. Finally, 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. 2,1,3   B. 2,3,1   C. 1,3,2   D. 3,1,2   E. NOTA

19. Buffy decides to go to BF Phangs for lunch. Driving in the new 2022 Boing! Car, he is driving at 9 m/s when he suddenly collides with Candy Hu driving on the wrong side of the road at 33 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 are equal and that the drivers are also the same mass).

   A. 9m/s   B. 33 m/s   C. 21 m/s   D. 15m/s   E. NOTA

20. 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 70 mph in a delirious state of Jeezcake craving. After somehow not getting arrested for going exactly 40 mph over the speed limit, she enjoys a 60 dollar Jeezcake before returning home at the speed limit. What is her average speed for this Jeezcake trip? Ignore the time she stopped.

    A. 55 mph   B. 45 mph   C. 42 mph   D. 52 mph   E. NOTA

21. A special oscillation set up is created that involves 3 springs with spring constant k and 2 blocks of mass M. 2 of the springs are attached to opposite walls on one end and to one of the blocks on the other end. Between the blocks is the final spring, which is attached to both blocks. If friction is negligible, calculate the ratio (that is greater than 1) of the angular frequencies between when the blocks oscillate in phase and out of phase with each other.

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

22. A equilateral triangular prism is placed on a ramp with a coefficient of friction μ at an angle of Θ. At some critical angle, the block will topple over instead of sliding off the ramp. What is the minimum value of μ will the prism topple over instead of sliding down.

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

23. Kejin's favorite activity is to hit tennis balls while they are traveling up, against a target that is 420 meters above the ground. The ball elastically collides head on with the target and bounces back towards Kejin. He is really strong and can hit the ball so it leaves his racket at $100\sqrt{2}$ meters per second at an angle of 45 degrees. How far away from Kejin does the ball land? Assume Kejin's height is negligible.

    A. 800   B. 600   C. 200   D. 400   E. NOTA

24. The coefficient of thermal expansion for brass is .000188 per degree Celsius. A brass washer of diameter of 200 cm has a hole of radius 50 cm. Calculate the circumference of the hole of the washer if the washer's temperature is increased by 200 degrees Celsius.

    A. 103.76π B. 96.24π C. 207.52π D. 192.48π E. NOTA

25. During a thermodynamic cycle, a heat engine discards 400J of energy to a cold source and absorbs 1000J of energy from the heat source. Calculate the efficiency for the engine.

    A. 3/5   B. 2/5   C. 4/25   D. 16/25   E. NOTA

26. A ball is launched upward from the ground at an initial vertical speed of v_0 and begins bouncing vertically. Every time it rebounds, it loses a proportion of the magnitude of its velocity due to the inelastic nature of the collision, such that if the speed just before hitting the ground on a bounce is v, then the speed just after the bounce is rv, where r < 1 is a constant. Calculate the total length of time that the ball remains bouncing, assuming that any time associated with the actual contact of the ball with the ground is negligible.

    A. $\dfrac{2v_0}{g(1-r^2)}$ B. $\dfrac{v_0}{g(1-r)}$ C. $\dfrac{rv_0}{g(1-r)}$ D. $\dfrac{2v_0}{g(1-r)}$ E. NOTA

27. Coley 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 pass the cop in order to calculate the average velocity. If the length of Coley's car is 10 meters long, how much should Coley constantly decelerate so that the speed the detector measures is the speed limit of 50/3 m/s.

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

28. Coley shoots an arrow at a 15-degree angle and hits a target that is 180 meters away. Assuming Coley and the target's heights are negligible, calculate the velocity at which Coley shot the arrow.

    A. $60\sqrt{2}$ m/s   B. $30\sqrt{2}$ m/s   C. 30 m/s   D. 60 m/s   E. NOTA

29. Jimmy Timmy was messing with 2 kg of Mystery Metal. He heats it up to 100 degrees Celsius and drops it into 12 kg of a non-viscous form of Mu Goo at 50 degrees Celsius. If the specific heat of Mystery Metal is 8.64 J/g°C and the specific heat of Mu Goo is 4.32 J/g°C, find the equilibrium temperature between the Mystery Metal dropped into the Mu Goo.

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

30. Daniel chases his dog at 10 meters per second while his dog flees at 30 meters per second. Daniel is blowing his whistle which has a frequency of 525 hertz when at rest. What of the following is the closest to the perceived frequency of Daniel's whistle from the dog's point of view. (The speed of sound is 340 m/s)

    A. 493 Hz   B. 509 Hz   C. 525 Hz   D. 541 Hz   E. 557 Hz