IPhR 2023: 1st Round

STEM October Physics Club

August 18, 2023

§1 Questions

1. Calculate the following while considering significant figures.

$$(0.48 + 0.084) \times (2.2 \times 10^4)$$

   a) 1848
   b) 12000
   c) 12320
   d) 12408

   Solution: b
   Since the smallest available significant figure is 2, our answer should only contain 2 significant figures. The answer to the above equation is 12408, which is 12000 when rounded to 2 significant figures.

2. The current lags the applied voltage in an RLC circuit when

   a) $X_L > X_C$
   b) $X_L < X_C$
   c) $X_L = X_C$
   d) $X_L = R$

   Solution: a
   When $X_L > X_C$, the phase angle is positive, which means that the current lags behind the applied voltage.

3. A painter wanted to paint four walls with a total area of 430.0 ft^2. The painter used one gallon of paint to finish this task. What is the thickness of the paint layer? Note that 1 gallon = 231 in^3 and 1 ft = 12 in.

   a) 0.0037 in
   b) 0.0450 in
   c) 0.0540 in
   d) 0.0090 in

   Solution: a
   First, we know from the givens that 430 ft^2 is equal to 61920 in^2. We can now easily find the thickness t of the layer:

$$t = \frac{V}{A} = \frac{231}{61920} = 0.0037 \text{ in}$$

4. The current drawn by a DC motor is proportional to
   a) Speed
   b) Torque
   c) Potential difference across the terminals
   d) All of the above

   Solution: b
   The current drawn depends on the torque needed.

5. The area under a torque-time graph represents
   a) Change in energy
   b) Change in angular momentum
   c) Change in velocity
   d) Change in linear momentum

   Solution: b
   The area under a torque-time graph represents the change in the angular momentum of the sought object.

6. An ideal gas with 10^{26} particles is in a container. It has a temperature of 0°C and a volume of 1.0 m^3. What is the pressure in atm?
   a) 2.6
   b) 3.8
   c) 260000
   d) 380000

   Solution: b

$$P = \frac{Nk_BT}{V} = \frac{10^{26} \times 1.38 \times 10^{-23} \times 273}{1} = 3.8 \text{ atm}$$

7. A ball of mass 2.00 kg is spun in a vertical circle with a wire of length 0.500 m at a constant speed of 3.00 m/s. What is the net force acting on the ball when it's at the lowest point of its trajectory?
   a) 16.4 N
   b) 19.6 N
   c) 36.0 N
   d) 55.6 N

   Solution: c
   At the lowest point, the net force acting on the ball is $\frac{mv^2}{r}$. Therefore,

$$F_{net} = 36.0 \text{ N}$$

8. In order for a machine to double its loudness, by what factor should the intensity of the sound increase? Assume that doubling the loudness is equivalent to an increase of 10 dB.
   a) 2
   b) 5
   c) 10
   d) 20

   Solution: c
   For the loudness to double, it has to increase by approximately 10 decibels. Therefore,
   $$10\log\frac{I_2}{I_0} - 10\log\frac{I_1}{I_0} = 10$$
   $$\implies \frac{I_2}{I_1} = 10$$

9. The work needed to move a charge q from the center of a hollow, charged spherical conductor to the surface of the conductor is
   a) equal to 0 since the sphere has an equipotential volume.
   b) equal to the dot product of the electrostatic force on charge q and the radius of the sphere.
   c) equal to the charge q multiplied by the potential difference ΔV between the center and the surface of the sphere.
   d) All answers are correct.

   Solution: d
   Since the electric field inside a spherical conductor is 0, the electrostatic force acting on it is 0. Furthermore, since there is no electric field, the electric potential is constant, meaning that the potential difference between the surface and the center is zero. Thus, we conclude that all answers provide the same interpretation and provide the same answer.

10. Astronauts want to build a pendulum with a period of half a minute on an exoplanet. How long do they need to make it if the exoplanet's gravitational acceleration is ten times weaker than that of Earth?
    a) 20.0 m
    b) 22.3 m
    c) 45.0 m
    d) 880 m

    Solution: b
    $$T = 2\pi\sqrt{\frac{L}{g}} \implies L = \frac{T^2\frac{1}{10}g_E}{4\pi^2} = 22.3\text{ m}$$

11. A rope is oscillating, transferring an energy E each second. To double its power output, someone only changes the tension in the rope. Find the ratio between the new tension and the old tension.
    a) $\sqrt[3]{2}$
    b) $\sqrt{2}$

c) 2

d) 4

Solution: d
The power carried by the rope varies with the square root of the tension of the rod. Therefore,

$$\frac{P_{new}}{P_{old}} = \sqrt{\frac{T_{new}}{T_{old}}}$$

Substituting with the given values, we get that

$$\frac{T_{new}}{T_{old}} = 4$$

12. In a system consisting of a positive charge and an electric field, the electric potential energy of the system ... when the charge moves in the direction of the field.

a) decreases

b) increases

c) remains constant

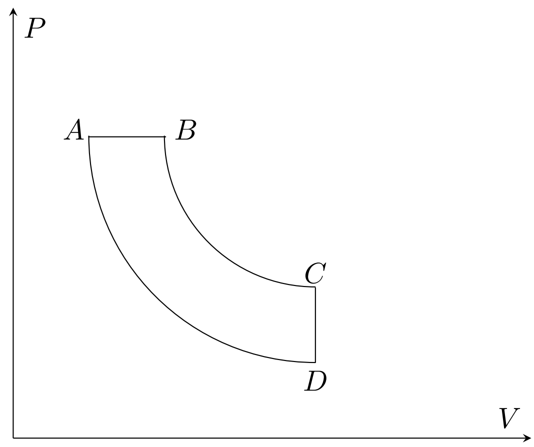
d) depends on the strength of the field

Solution: a

$$\Delta U_E = qV = -qEd$$

Therefore, the electric potential energy decreases as a positive charge moves away from the system.

The three following questions (Questions 13, 14, and 15) ask about this figure. Unless given, do not assume a single value for either pressure or volume on the graph.



13. The work done on a gas that goes quasi-statically from state C to state B is

a) Negative and equals the area under the curve.

b) Positive and equals the negative of the area under the curve.

c) Negative and equals the negative of the initial pressure multiplied by the change in volume.

d) Positive and equals the change in pressure multiplied by the change in volume.

Solution: b
The work done on a gas equals negative the area under the PV curve. Since the gas decreases in volume, outside positive work must be done on it.

14. The work done by the gas going from A to B is simply
    a) $P(V_A - V_B)$
    b) $-P(V_A - V_B)$
    c) $P(V_B - V_A)$
    d) $-P(V_B - V_A)$

    Solution: c
    The work done **by** a gas is negative that is done on the gas. Additionally, the process is isobaric. Hence, the work done by the gas is $P(V_B - V_A)$.

15. Provided that $T_B > T_D$, a process from state B to state D is
    a) Isothermal.
    b) Isobaric.
    c) Isovolumetric.
    d) Adiabatic.

    Solution: d
    Since there is a change in temperature, it couldn't be isothermal. Also, the pressure and volume change. Hence, it is an adiabatic process where the temperature of a gas decreases during expansion.

16. In 1973, Egyptian soldiers projected many mortar bombs on the Bar Lev Line, which was about 300 m from the mortar. If you know that the mortar gives about 2 kJ of kinetic energy for each 500-gram bomb, then at which angle with the horizontal were the bombs projected?
    a) 11° or 79°
    b) 21° or 69°
    c) 42° or 48°
    d) 18° or 72°

    Solution: a
    Using the kinetic energy K formula, we find that

    $$v = \sqrt{\frac{2K}{m}} = 40\sqrt{5} \text{ m/s}$$

    Using the equation for the range R, we get that

    $$300 = \frac{v^2 \sin(2\theta)}{g} \Rightarrow \theta = 11^\circ \text{ or } 79^\circ$$

17. A block attached to a spring is extended by 1.00 m from its equilibrium position ($x = 0$) and, therefore, experiences simple harmonic motion. How far away from the equilibrium position must the block be in order to be moving with half its maximum speed?
    a) 25.0 cm

b) 50.0 cm

c) 70.7 cm

d) 86.6 cm

Solution: d

$$v(x) = \omega\sqrt{A^2 - x^2} \implies v(fA) = \omega A\sqrt{1 - f^2} = \frac{1}{2}\omega A \implies f = \sqrt{1 - \left(\frac{1}{2}\right)^2} = 0.866$$

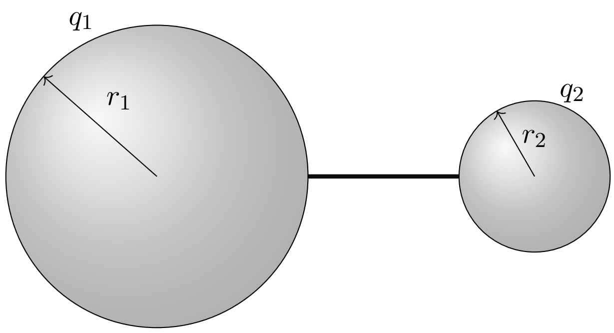
18. Consider the two conducting spheres in the following figure connected by a conducting wire of infinite length. If the ratio between their radii is $\frac{r_1}{r_2} = \frac{25}{16}$. Then the ratio between the electric fields at the surfaces of the two spheres $\frac{E_1}{E_2}$ is:

a) $\frac{25}{16}$

b) $\frac{16}{25}$

c) $\frac{5}{4}$

d) $\frac{4}{5}$



Solution: b

Since the two conducting spheres are infinite distance apart, their electric fields cannot affect each other. Additionally, since they are connected by a conducting wire, they have equipotential surfaces. Hence,

$$\frac{E_1}{E_2} = \frac{kq_1/r_1^2}{kq_2/r_2^2} = \frac{\frac{1}{r_1}V}{\frac{1}{r_2}V} = \frac{r_2}{r_1} = \frac{16}{25}$$

19. If a resistor's resistance increased by a factor of 2 when its temperature increased by 50°C, then what is its temperature coefficient of resistivity α?

a) 0.02 /°C

b) 0.04 /°C

c) 0.02 Ω/°C

d) 0.04 Ω/°C

Solution: a

$$\frac{R_f}{R_i} = 1 + \alpha\Delta T \implies \alpha = \frac{\frac{R_f}{R_i} - 1}{\Delta T} = \frac{2-1}{50} = 0.02\ /°\mathrm{C}$$

20. A light wave's wavelength decreased by 100 nm when it traveled from a vacuum to a medium with refractive capabilities. What is the medium refractive index n if the wave's frequency is 5×10^{14} Hz?

a) 1.10
b) 1.20
c) 1.30
d) 1.40

Solution: b

$$n = \frac{c}{v} = \frac{c}{\gamma_{\text{final}} f} = \frac{c}{(\frac{c}{f} - 100 \times 10^{-9})f} = 1.20$$

21. If $\vec{F_1} = 4.00$ N makes an angle of 55° with the negative direction of x-axis, while $\vec{F_2} = 9.00$ N makes an angle of 20° with the positive direction of x-axis, the resultant of the two forces will be

a) 7.53 N with an angle of 46° with the positive direction of the x-axis
b) 8.85 N with an angle of 45.9° with the positive direction of the x-axis
c) 9.81 N with an angle of 24° with the positive direction of the x-axis
d) 10.1 N with an angle of 15.4° with the positive direction of the x-axis

Solution: b
The net vector's magnitude F is calculated using vector addition and the Pythagorean theorem. Consequently, we get that

$$\sqrt{(9\cos(20) - 4\cos(55))^2 + (4\sin(55) + 9\sin(20))^2} = 8.85 \text{ N}$$

The angle made with the positive x-axis θ is

$$\theta = \arctan\left(\frac{9\sin(20) + 4\sin(55)}{9\cos(20) - 4\cos(55)}\right) = 45.9°$$

22. Two waves are traveling in opposite directions and combine, forming a standing wave. Their separate wave functions are

$$y_1 = 2\sin(x - 3t)$$

$$y_2 = 2\sin(x + 3t)$$

where x and y are measured in meters. What is the amplitude of the resulting wave at $x = 10$ cm?

a) 0.4 m
b) 0.5 m
c) 0.6 m
d) 0.7 m

Solution: a
The amplitude y of the resulting wave is

$$y = 2A\sin kx = 2 \cdot 2 \cdot \sin(0.1 \text{ rad}) = 0.4 \text{ m}$$

23. A racing car of mass 900 kg, including the driver but not fuel, decelerates from a speed of 50.0 m/s to 30.0 m/s. The brakes exert a fixed retarding force of 5000 N. The time for the car to decelerate when it is out of fuel is t_1. The time for it to decelerate when it has a full load of 130 kg of fuel is t_2. What is the absolute difference between two the times (i.e., $|t_2 - t_1|$)?

a) 0.37 s
b) 0.52 s
c) 0.62 s
d) 1.43 s

Solution: b
From the kinematic equations, one could get that

$$v - u = at \Rightarrow 20 = at$$

By making the substitution of $F = ma$, we get that

$$t = \frac{20m}{F}$$

Therefore,

$$|t_2 - t_1| = \frac{20 \times 130}{5000} = 0.52 \text{ s}$$

24. The coefficient of static friction between the shoes of a man standing on an incline and the ground is 0.60. Then, he sits down, resulting in 40% of his weight being mounted on his trousers, which has a coefficient of static fraction of 0.50 with the ground. What is the ratio between the coefficient of static friction before and after sitting?

a) 0.90
b) 0.91
c) 0.92
d) 0.93

Solution: d
The effective coefficient of static friction μ_e is equal to

$$\mu_e = \mu_1(1 - w) + \mu_2 w$$

where μ_1 and μ_2 are the coefficients of friction before and after sitting and w is his weight. Therefore,

$$\mu_e = 0.6 \times 0.6 + 0.4 \times 0.5 = 0.56$$

Therefore, the ratio between them is

$$\frac{0.56}{0.6} = 0.93$$

25. The band gap of $GaAs$ is 1.52 eV. The wavelength of light emitted when an electron near the bottom of the conduction band of $GaAs$ makes a direct transition to a state near the top of the valence band equals

a) 0.130 ym.
b) 8.17 nm.
c) 0.130 zm.
d) 817 nm.

Solution: d

$$1.52 \times 1.6 \times 10^{-19} = \frac{hc}{\lambda}$$

$$\lambda = \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{1.52 \times 1.6 \times 10^{-19}} = 8.17 \times 10^{-7} = 817 \text{ nm}$$

26. A 60-W bulb currently lights this webpage from a distance of 0.100 m. If the bulb has an efficiency of 10%, what is the maximum value of the magnetic field incident on the webpage given that the intensity of the bulb is equal to $\frac{E_{max}^2}{2\mu_0 c}$?

    a) 4.32×10^{-7} T

    b) 5.32×10^{-7} T

    c) 6.32×10^{-7} T

    d) 7.32×10^{-7} T

    Solution: c

$$I = \frac{P_{avg}}{4\pi r^2} = \frac{E_{\max}^2}{2\mu_0 c} \Rightarrow E_{\max} = \sqrt{\frac{\mu_0 c P_{avg}}{2\pi r^2}}$$

$$E_{\max} = 1.90 \times 10^2 \text{ V/m}$$

$$B_{max} = \frac{E_{max}}{c} = 6.32 \times 10^{-7} \text{ T}$$

27. A concave mirror forms an image of an object situated far away from the mirror (You can assume that the incident rays are parallel). What is the radius of curvature of the mirror if the image is formed at a distance of 2 cm from the center of the mirror?

    a) 2 cm

    b) 4 cm

    c) 6 cm

    d) 8 cm

    Solution: b
    In this case, the image is formed at the focal point. From the mirror equation, we get that

$$f = \frac{R}{2} \Rightarrow R = 4 \text{ cm}$$

28. The volume flow rate of a hose with a b cm^2 nozzle is Q. The hose is held horizontally at a height h and is suddenly opened to fill a bucket. How far is the bucket from the Hose?

    a) $\frac{2Qh}{gb}$

    b) $\sqrt{\frac{2Q}{gbh}}$

    c) $\frac{2Q}{gh}$

    d) $\sqrt{\frac{2hQ^2}{b^2 g}}$

Solution: d
The velocity v of the water is

$$v = \frac{Q}{b}$$

Using the kinematic equation, we can find that the horizontal distance covered R is

$$R = v\sqrt{\frac{2h}{g}} = \sqrt{\frac{2hQ^2}{b^2 g}}$$

29. An object was projected with an initial velocity of 45.0 m/s at an angle of 65° with the horizontal. After 3 seconds, what will be the angle between the velocity vector and the horizontal?
    a) 14.3°
    b) 30.9°
    c) 36.8°
    d) 53.2°

    Solution: b
    The x-component of the velocity vector stays the same. The y-component is equal to

    $$v_y = 45\sin(65) - 9.8 \cdot 3 = 11.38 \text{ m/s}$$

    Therefore, the angle θ is equal to

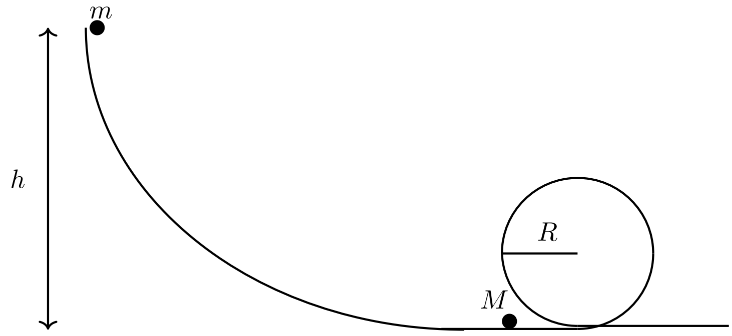
    $$\theta = \arctan\left(\frac{11.38}{45\cos(65^\circ)}\right) = 30.9^\circ$$

30. A capacitor, with two parallel metal plates that are shaped as squares, stores energy. If the plates' sides are doubled while the distance is halved, by what factor will the stored energy increase? Assume $\Delta V_{\text{final}} = \Delta V_{\text{initial}}$.
    a) 2
    b) 4
    c) 8
    d) 16

    Solution: c

    $$\frac{E_f}{E_i} = \frac{\cancel{\frac{1}{2}(\Delta V_f)^2} C_f}{\cancel{\frac{1}{2}(\Delta V_i)^2} C_i} = \frac{\cancel{\epsilon_0}\frac{A_f}{d_f}}{\cancel{\epsilon_0}\frac{A_i}{d_i}} = \frac{(2s_i)^2 d_i}{(s_i)^2 \frac{1}{2} d_i} = 8$$

31. A frictionless track contains a loop of radius $R = 1.00$ m. A ball of mass $m = 1.00$ kg is situated on top of the track at height h. Another ball of mass $M = 2.00$ kg stands at the end of the track. Find the minimum height h needed so that the ball of mass M can barely go through the ring. Neglect the sizes of the balls and rotational effects, and assume that the collision is perfectly elastic.
    a) 4.35 m
    b) 5.63 m
    c) 6.36 m
    d) 7.55 m



Solution: b
The ball of mass m reaches the bottom of the track with velocity $v_b = \sqrt{2gh}$. Using conservation of momentum, we have that

$$mv_b = mv_m + Mv_M$$

Since the collision is perfectly elastic, we get that

$$v_M - v_m = v_b$$

Making the substitution for v_M in equation 1, we get that

$$v_M = \frac{2mv_b}{m+M}$$

For the ball to barely complete the loop, its acceleration at the highest point must equal g. Therefore,

$$\frac{v_t^2}{R} = g \Rightarrow v_t = \sqrt{gR}$$

Applying the conservation of energy, we get that

$$\frac{1}{2}v_M^2 = \frac{1}{2}v_t^2 + 2gR$$

Substituting for v_t, v_b, and v_M, we get an equation in one variable for h. Solving the equation, we get that $h = 5.63$ m

32. A stationary observer notices that rain is falling at 10.0 m/s. A car going 10° below the horizontal notices that rain makes an angle of 30° with the vertical, which is the same vertical in the observer's frame of reference. What would be the speed of the car relative to the stationary observer?

    a) 5.32 m/s
    b) 10.5 m/s
    c) 18.8 m/s
    d) 23.9 m/s

    Solution: a
    We can construct a diagram for the involved vectors and use the sine law to find the car's speed. By doing so, we can easily find that

$$\frac{\sin 70^\circ}{10} = \frac{\sin 30^\circ}{v_{car}} \Rightarrow v_{car} = 5.32 \text{ m/s}$$

33. In a men's 100-m race, accelerating uniformly, Ahmed takes 1.00 s and Loay takes 2.00 s to attain their maximum speeds, which they each maintain for the rest of the race. They cross the finish line simultaneously after 20 s. What is the acceleration (measured in m/s^2) of Ahmed and Loay, respectively, to three significant figures?

    (a) 4.88, and 4.55

    (b) 5.13, and 2.63

    (c) 5.13, and 5.00

    (d) 5.26, and 5.13

    Solution: b
    Total distance = distance during accelerating period + distance during constant velocity

$$100 = \Delta x_a + \Delta x_{\text{const } v}$$

$$100 = \frac{1}{2}at^2 + v(T - t)$$

where t is the time required to reach maximum velocity and T is the time they finished the race in.

$$100 = \frac{1}{2}at^2 + at(T - t)$$

$$a = \frac{100}{\frac{1}{2}t^2 + t(T - t)}$$

Ahmed's acceleration = 5.13
Loay's acceleration = 2.63

34. Two objects, x and y, are placed on an adjustable inclined plane. Object x starts to slide at twice the angle with the horizontal that y starts sliding at. The coefficients for static friction for x and y are c_x and c_y respectively. Which of the following relations must be correct?

    a) $c_y < c_x < 2c_y$

    b) $c_x < c_y$

    c) $c_x > 2c_y$

    d) $c_y = 2c_x$

    Solution: c
    By adding forces, we get that

$$c_x = \tan(2\theta)$$

$$c_y = \tan(\theta)$$

Therefore,

$$\frac{c_x}{c_y} = \frac{\tan(2\theta)}{\tan(\theta)} = \frac{2}{1 - \tan^2(\theta)}$$

Since θ has to be greater than 0, we get that

$$\frac{2}{1 - \tan^2(\theta)} > 2 \text{ for all } \theta \text{ greater than } 0$$

35. A proton with a kinetic energy of 1 MeV moving in the positive x direction passes through a magnetic field $\vec{B} = 0.01\hat{k}$ T directed out of the page and extends between $x = 0$ m and $x = 1$ m. Find the angle between its velocity vector before entering the magnetic field region and after leaving the magnetic field. Ignore relativistic effects.

    a) 2.53°

    b) 3.15°

    c) 3.98°

    d) 4.33°

    Solution: c
    The velocity of the proton can be calculated using the kinetic energy of the proton

    $$K = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2K}{m}} \Rightarrow v = 1.38 \times 10^7$$

    The radius of curvature of the path can be calculated using the formula

    $$r = \frac{mv}{qB} \Rightarrow r = 14.4 \text{ m}$$

    Using trigonometry, we can deduce that the angle θ deviated by the proton is related to the radius as

    $$\sin\theta = \frac{1}{r} \Rightarrow \theta = 3.98^\circ$$

36. We can model the motion of an electron around its nucleus as a particle in a uniform circular motion. The electron moves with a constant speed v and radius r. What is the ratio between the magnitudes of the magnetic moment developed by the electron and the angular momentum of the electron? The charge of the electron is q, and the mass of the electron is m.

    a) $\frac{qr}{m}$

    b) $\frac{qr}{2m}$

    c) $\frac{q}{m}$

    d) $\frac{q}{2m}$

    Solution: d
    The current I developed by the electron is

    $$I = \frac{q}{T} \Rightarrow I = \frac{qv}{2\pi r}$$

    The magnetic moment μ developed by the electron is

    $$\mu = IA \Rightarrow \frac{qv}{2\pi r} \times \pi r^2 \Rightarrow \mu = \frac{qvr}{2}$$

    Since the angular momentum L of the electron is equal to mvr, we can deduce that

    $$\mu = \frac{q}{2m}L$$

37. A wire of uniform circular cross-section has diameter d and length L. A potential difference V between the ends of the wire gives rise to a current I in the wire.
    If the resistivity ρ of the material is given by

    $$\rho = \frac{\pi d^2 V}{4LI}$$

then what is the calculated (with consideration to uncertainty) resistivity ρ when

$$d = 1.2 \pm 0.1 \text{ m}$$

$$I = 1.5 \pm 0.1 \text{ A}$$

$$L = 1.1 \pm 0.2 \text{ m}$$

$$V = 5.0 \pm 0.3 \text{ V}$$

a) 3.43 ± 0.90

b) 3.43 ± 0.70

c) 2.54 ± 0.24

d) 1.20 ± 0.81

Solution: a

The error propagation for multiplication and division is

$$\frac{\Delta z}{z} = \sqrt{\left(\frac{m\Delta x}{x}\right)^2 + \left(\frac{n\Delta y}{y}\right)^2 + ...} \text{ for any } z = x^m y^n ...$$

By applying this formula, we get that

$$\rho = 3.43 \pm 0.90$$

38. Ahmed, who was standing near a firework festival, heard a firework from 300 m away and noticed that the acoustic pressure reached a maximum of 5.00 Pa. What is the sound level heard by someone who is 2.00 km away? Assume there is an intensity loss of 5 dB/km.

a) 79.8 dB

b) 88.1 dB

c) 91.1 dB

d) 96.6 dB

Solution: a

The intensity heard by the first person I_1 is

$$I_1 = \frac{P_{max}^2}{2\rho v} \Rightarrow I_1 = 0.0304 \text{ W/m}^2$$

If there is no power loss, the intensity would vary with the inverse of the distance squared. Therefore, the intensity heard by the second person I_2 is

$$I_2 = I_1 \times \left(\frac{d_1}{d_2}\right)^2 \Rightarrow I_2 = 6.83 \times 10^{-4} \text{ W/m}^2$$

Consequently, the sound level heard by the second person is

$$10 \log\left(\frac{I_2}{10^{-12}}\right) - 5 \times (2 - 0.3) = 79.8 \text{ dB}$$

39. A tuning fork vibrating at a frequency of 500.0 Hz falls from rest under the influence of gravity. At $d = 10.40$ m, the sound frequency is 480.0 Hz. What is the speed of sound in this case? Neglect any rotational motion and resistive forces.

a) 342.3 m/s
b) 342.5 m/s
c) 342.7 m/s
d) 342.9 m/s

Solution: c
The time taken to fall the distance d is

$$d = \frac{1}{2}gt^2 \implies t = \sqrt{\frac{2d}{g}}$$

We also have that

$$t = \frac{v}{g}$$

To know the velocity v at which the sound has a frequency of 480 Hz, we can use the Doppler shift experienced as follows

$$v = v_s\left(\frac{f}{f'} - 1\right)$$

where v_s is the speed of sound. From the equations above, we get that

$$\sqrt{\frac{2d}{g}} = \frac{v_s\left(\frac{f}{f'} - 1\right)}{g} \Rightarrow v_s = \frac{\sqrt{2dg}}{(\frac{f}{f'} - 1)}$$

Substituting with the given values, we get that

$$v_s \approx 342.7 \text{ m/s}$$

40. The power reaching the Earth's surface from the sun is 1000 W/m^2 for all regions. Calculate the entropy change of the universe in 1 second if only half the surface of the Earth is exposed to and exchanges energy with the Sun.
a) 4.19×10^{13} J/K
b) 4.19×10^{14} J/K
c) 4.19×10^{15} J/K
d) 4.19×10^{16} J/K

Solution: b
The energy reaching half the surface of the earth per second Q is

$$Q = 1000 \times \pi R^2 = 1.28 \times 10^{17}\text{J}$$

The change in entropy ΔS is

$$\Delta S = \frac{Q}{T_E} - \frac{Q}{T_S} \Rightarrow \Delta S = 4.19 \times 10^{14} \text{ J/K}$$