IPhR 2024: Trial Round

STEM October Physics Club

August 6, 2024

§1 Questions

1. A planet orbiting a star has a period of 4 days and the length of the semi-major axis between them is $8000Km$. If the period suddenly increased to 8 days, what is the new semi-major axis length in km?

   Solution: $12699Km$

$$\frac{T_1^2}{a_1^3} = \frac{T_2^2}{a_2^3}$$

$$\frac{(4 \times 24 \times 60 \times 60)^2}{(8,000,000)^3} = \frac{(8 \times 24 \times 60 \times 60)^2}{(X)^3}$$

2. Two identical blocks of the same mass are released simultaneously: one is thrown horizontally from the top of a mountain, and the other is dropped vertically. Which object is traveling faster when it hits the ground below?

   a) The first block

   b) The second block

   c) They have the same speed when hitting the ground

   d) It is impossible to determine from the given information

   Solution: a

3. Vector A = (2.0i + 2.0j) and B = (2.0i - 4.0j). What is the angle, in degrees, that the vector sum of the two vectors makes with the origin?

   Solution: 333°

4. In one-dimensional motion, what properties does the average speed of an object exhibit if it travels from one location to another and then returns to its original position?

   a) It is positive

   b) It is negative

   c) It is zero

d) It can be negative, positive, or zero

Solution: a

5. A particle at $x_i = 3m$ is moving with velocity $v_i = 10m/s$ and is under uniform acceleration. If after some time $t = 2s$ the velocity of the particle becomes $v_f = -7m/s$. What is the final position of the particle?

   Solution: $6m$

$$a = \frac{v_f - v_i}{t} = -8.5$$

$$x_f = x_i + vt + \frac{1}{2}at^2$$

6. Which of the following is equivalent to Joule (J):

   a) $\frac{Kg.m}{s^2}$

   b) $\frac{Kg.m^2}{s}$

   c) $\frac{Kg.m^2}{s^2}$

   d) $\frac{Kg^2.m^2}{s^2}$

   Solution: c

7. A small object of mass 300 g was released from a 7 m height, what's its velocity at a height of 0.5 m?

   Solution: $11.3m/s$

$$mgh_{top} = mgh_{bottom} + \frac{1}{2}mv^2$$

$$0.3 \times 9.8 \times 7 = 0.3 \times 9.8 \times 0.5 + \frac{1}{2} \times 0.3 \times v^2$$

8. Consider six variables a, b, c, d, etc, and f which are related by the equation $ab + c = \frac{d}{e} - f$. If the units of a, b, and e are Pa, J, and N respectively, what are the units of c,d, and f?

   a) $N^2/m \mid N^3/m \mid N^2/m$

   b) $N/m \mid N^2/m \mid N/m$

   c) $N^2/m^2 \mid N^3/m^2 \mid N^2/m^2$

   d) $N/m^2 \mid N^2/m^2 \mid N/m^2$

   Solution: a

9. If a rotating object with an angular velocity (ω = 40rad/s) produces 50J of energy every second, what is the applied torque on this object?

   Solution: $1.25N \cdot m$

$$P = \omega \times \tau$$

$$50 = 40 \times \tau$$

10. Which of the following is true about torque (τ) ?

    a) torque is a vector quantity whose direction is tangent to the trajectory of the rotation.

    b) torque is a vector quantity whose direction is towards the axis of rotation.

    c) torque is a vector quantity whose direction is perpendicular on the plane of the trajectory.

    d) torque is a scalar quantity which has no direction.

    Solution: c

11. 50 Newtons of force are needed to compress a spring with an initial length of 50 cm to a final length of 48 cm. What is the spring constant, k, of this spring?

    a) $250N/m$

    b) $250kg \cdot s^2$

    c) $2500N \cdot meter$

    d) $2500kg/s^2$

    Solution: d

    According to Hooke's law:

    $$F = k\Delta x$$

    Solving for k:

    $$k = \frac{F}{\Delta x}$$

    $\Delta x = 0.50m - 0.48m = 0.02m$

    $$k = \frac{50N}{0.02m} = 2500N/m = 2500kg/s^2$$

12. What determines the speed of a wave travelling through a medium?

    a) The wave's frequency

    b) The wave's amplitude

    c) The properties of the medium

    d) The properties of the observer

    Solution: c

    Wave's speed is related to the properties of the mediums it is travelling through. More specifically, the elastic and the inertial properties of the medium

13. What is the restoring force and the energy of a spring? If the spring's position was at $2m$, then it compressed to $-3m$. $[k = 2.85N/m]$

    a) $-14.25N$, $35.63J$

    b) $14.25N$, $35.63J$

    c) $-14.25N$, $36.63J$

    d) $14.25N$, $36.63J$

    Solution: b

    we use Hooke's law to calculate the force. [the law is in the negative form as we calculate the **restoring** force]

$$F_s = -k\Delta x$$

$$F_s = -2.85 \times (-3 - 2) = 14.25N \tag{1}$$

$$E = \frac{1}{2}k\Delta x^2 = \frac{1}{2} \times 2.85 \times (-5)^2 = 35.63j$$

14. What is the angular frequency of a simple pendulum?

    ℓ: the length of the pendulum

    g: the acceleration due to gravity

    m: mass of the pendulum

    k: the young's modulus of the string

    a) $\sqrt{\frac{k}{m}}$

    b) $\frac{k}{m}$

    c) $\frac{g}{\ell}$

    d) $\sqrt{\frac{g}{\ell}}$

    Solution: d

15. The power of a wave increased the most in which of the following

    a) amplitude is doubled

    b) velocity is doubled

    c) angular frequency decreased to half

    d) mass per unit length triples

    Solution: a

16. if a system is considered adiapatic and the work is done on the system then:

    a) $\Delta U = W$

b) $\Delta U = -W$

c) $\Delta U = Q$

d) $\Delta U = -Q$

Solution: b

17. Which of the following processes occurs with constant entropy?

(a) Isentropic process

(b) Isenthalpic process

(c) All of the above

(d) None of the above

Solution: c

18. If a Carnot engine has a heat reservoir of $225°c$ and a cold reservoir at a temperature of $40°c$, Its operating efficiency to the nearest percent will be:

a) 52%

b) 68%

c) 37%

d) 98%

Solution: c

A Carnot engine's efficiency is given by:

$$\eta = 1 - \frac{T_c}{T_h} = 1 - \frac{40 + 273.15}{225 + 273.15} \approx 0.37$$

19. The length of a sheet of aluminum is $L = 40m$ at 10 °C, so what is the increase of its length, ΔL, at 50 °C? (Linear expansion coefficient (α) of aluminum = 24×10^{-6})

a) 6.84 cm

b) 5.84 cm

c) 4.84 cm

d) 3.84 cm

Solution: d

From the law of thermal expansion in one dimension:

$$\Delta L = L_i \alpha \Delta T$$

By substituting with the provided data, ΔL is found to be = 3.84 cm.

20. if three electric lines are coming out from q_1 and only two entering q_2 then:

    a) q_1 is +, q_2 -, $3q_2 = 2q_1$

    b) q_1 is -, q_2 -, $3q_2 = 2q_1$

    c) q_1 is +, q_2 +, $2q_2 = 3q_1$

    d) q_1 is -, q_2 +, $2q_2 = 3q_1$

    Solution: a

21. a volt is:

    a) the amount of work done to transfer a charge

    b) the amount of work done to create a current

    c) a vector quantity

    d) a and b

    Solution: d

22. A charge of 10 coulombs is represented by 20 electric field lines. How many lines will represent a 5-coulomb charge?

    a) 20

    b) 10

    c) 5

    d) 2.5

    Solution: b

    The field lines are linear with the charge.

    $$\frac{10}{5} = \frac{20}{X}$$

23. Which of the following statements describe the potential difference across a parallel combination of resistors correctly?

    a) They all have the same potential difference.

    b) The closest resistor to the battery has the largest potential difference.

    c) The farthest resistor from the battery has the largest potential difference.

    d) Depends on the resistance of each resistor.

    Solution: a

    Resistors in parallel combinations have the same potential difference regardless of their ohmic resistance.

24. What is the acceleration of an electron moving through an electric field of $E = 1 \times 10^5 N/C$?

    a) $1.76 \times 10^{16} m/s^2$

    b) $1.67 \times 10^{16} m/s^2$

    c) $1.67 \times 10^{6} m/s^2$

    d) $1.76 \times 10^{6} m/s^2$

    Solution: a

    According to the particle in an electric field model:

$$F_e = qE$$

$$m_e a = qE$$

$$a = \frac{qE}{m_e} = 1.76 \times 10^{16}$$

25. if a wire is 5 meters long carries 5 mA with no internal resistance. Calculate the force exerted on that conductor when it is placed in a uniform magnetic field equals 6×10^{-3} Tesla

    a) 1.4×10^{-4}

    b) 1.4×10^{-6}

    c) 1.5×10^{-4}

    d) 1.5×10^{-6}

    Solution: c

$$\text{Force on a current-carrying wire} = ILB$$

$$F = 0.005 \times 5 \times 6 \times 10^3$$

26. With the beginning of the alien invasion of Earth, an Unidentified flying Object, of cylindrical shape of height $3m$ and its diameter is $10m$, is flying horizontally in a vertical uniform electric field of magnitude 2×10^4. Determine the electric flux through the bottom of the strange aircraft.

    a) 1.885×10^7

    b) 1.571×10^6

    c) 4.712×10^6

    d) 6.283×10^6

Solution: b

The electric flux ($\Phi_E = E \cdot A \cdot \cos\theta$) through the bottom surface with $E = 2 \times 10^4$ N/C, $A = 25\pi\,\mathrm{m}^2$, and $\cos 0^\circ = 1$:

$$\Phi_E = 2 \times 10^4 \cdot 25\pi \approx 1.571 \times 10^6\,\mathrm{N \cdot m^2/C}$$

27. The resistance of a wire of 0.01 cm radius is 10 Ω. If the resistivity of the material of the wire is 50×10^{-8} Ωm, find the length of the wire.

    a) $0.628cm$

    b) $6.28cm$

    c) $0.628m$

    d) $62.8m$

    Solution: c

$$R = \rho\frac{l}{A}$$
$$l = \frac{RA}{\rho}$$
$$l = \frac{R \times \pi r^2}{\rho}$$
$$l = \frac{10 \times \pi(10^{-4})^2}{50 \times 10^{-8}} = 0.628m$$

28. If a person is diagnosed with nearsightedness, he should wear a lens with an angular magnification factor equal to . . .

    a) equal to 1

    b) slightly more than 1

    c) less than 0

    d) more than 0

    Solution: b

29. If the radius of the first curvature in a thin lens = -35cm, the radius of the second curvature = 25cm, and n of the lens = 1.5 what is the focal length of this lens?

    a) 29

    b) 28

    c) 27

    d) 26

Solution: a

By substitution in the lens makers' formula

$$\frac{1}{f} = (n-1) \cdot (\frac{1}{R_1} - \frac{1}{R_2})$$

we find that $f = 29$.

30. After nearly 3 months of preparation, an IPhR organizer wanted to regain his fitness, so he decided to exercise by speeding from rest to $0.95c$. Calculate the energy he used in this process if his mass is $m\ Kg$.

a) $1.1mc^2$

b) $2.2mc^2$

c) $3mc^2$

d) $3.1mc^2$

Solution: b

$$E = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

The energy of IPhR's Organizer before starting the run was $E_0 = mc^2$. Hence, the energy he used to accelerate from rest to $0.95C$ is

$$E - E_0 = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}} - mc^2 = 2.2mc^2$$