IPhR 2023 Problems

STEM October Physics Club

September 1, 2023

1. The restoring force F in harmonic motion is directly proportional to
   a) displacement x
   b) velocity v
   c) acceleration a
   d) time t

   Solution: a
   For any motion to be considered simple harmonic, the following relation must be true
   $$a = -\omega^2 x$$
   where ω is the angular frequency. Thus, the force must be proportional to the displacement.

2. $\vec{F} = 120$ N was applied to a 50-kg block in the direction of motion for a distance of 4.0 m and was increased to 150 N for the next 8.0 m. Ignoring friction, how much work was done by the varying force?
   a) 1230 J
   b) 1550 J
   c) 1680 J
   d) 2420 J

   Solution: c
   $$W_1 + W_2 = 120 \times 4 + 150 \times 8 = 1680 \text{ J}$$

3. In harmonic motion, the maximum displacement from the equilibrium position is called the
   a) amplitude A
   b) frequency f
   c) wavelength γ
   d) velocity v

   Solution: a
   The amplitude A of a wave is defined as the maximum displacement or vibration from the equilibrium position $y = 0$.

4. Engineers want to calculate the drag force acting on the car. Drag force can be calculated through the formula

$$F = \frac{1}{2}\rho v^2 C_d A$$

where F is the drag force, v is velocity of the car, C_d is the drag coefficient, ρ is the density of air, and A is the cross-sectional area. Find the measuring unit of the drag coefficient in SI units.

   a) Dimensionless
   b) kg/m s
   c) kg/m^2 s^2
   d) kg m/s^2

Solution: a
Using the dimensions of the given parameters, we get that

$$MLT^{-2} = ML^{-3} \times L^2T^{-2} \times L^2 \times C_d$$

We can see that the equation is already dimensionally correct, meaning that the drag coefficient is dimensionless.

5. Which of the following are the correct energy conversions in induction furnaces?

   a) Magnetic → Electrical → Thermal
   b) Electrical → Thermal → Magnetic
   c) Magnetic → Thermal → Electrical
   d) Electrical → Magnetic → Thermal

Solution: a
In an induction furnace, a magnetic field creates eddy currents which dissipate heat.

6. How can a train driver use a pendulum to measure acceleration?

   a) He only needs to measure its deflection angle to calculate the train's acceleration.
   b) He only needs to measure the tension in the pendulum's wire to calculate the train's acceleration.
   c) He only needs to measure the pendulum's weight to calculate the train's acceleration.
   d) Using a pendulum as an accelerometer isn't physically possible.

Solution: a
By doing a force analysis for the pendulum from the inertial frame of reference, we get that

$$T \sin\theta = ma$$

$$T \cos\theta = mg$$

By solving these equations, we get

$$a = g \tan\theta$$

This means that the driver can measure the train's acceleration by just measuring the deflection angle of the pendulum.

7. A capacitor with 25 μF is attached to a 50-V battery. The net charge on the capacitor is
   a) 1.00 mC
   b) 1.25 mC
   c) 1.50 mC
   d) 2.00 mC

   Solution: b

$$C = \frac{Q}{V}$$

$$Q = C \times V = 25 \cdot 10^{-6} \cdot 50 = 1.25\ mC$$

8. What is 10 °F on the Kelvin scale?
   a) 150 K
   b) 200 K
   c) 261 K
   d) 283 K

   Solution: c
   We can easily use the following formula to convert Fahrenheit to Kelvin:

$$(^\circ\mathrm{F} - 32) \times \frac{5}{9} + 273.15 = \mathrm{K}$$

   By substituting with the given value, we get that

$$10\ ^\circ\mathrm{F} = 261\ \mathrm{K}$$

9. If elements with the principal quantum number $n \geq 4$ were not allowed in nature, then the number of possible elements would be
   a) 30.
   b) 28.
   c) 20.
   d) 18.

   Solution: d
   The first 18 elements in the periodic are the only ones with a principal quantum number $n \geq 4$.

10. Compute the power output of a machine that lifted 2.3 tons at a height of 60 meters in a time of 2 minutes.
    a) 5070 W
    b) 8450 W
    c) 11270 W
    d) 15000 W

    Solution: c

$$\text{Power} = \frac{\text{Energy}}{\text{Time}} = \frac{mgh}{t} = \frac{2.3 \times 1000 \times 9.8 \times 60}{2 \times 60} = 11270\,\mathrm{W}$$

11. Which of the following statements accurately describes entropy in a closed system?
    a) Entropy always decreases over time
    b) Entropy remains constant in all processes
    c) Entropy tends to increase in natural processes
    d) Entropy is a measure of total energy content

    Solution: c
    The entropy of a closed system is always increasing according to the second law of thermodynamics.

12. A hollow conducting sphere of radius 5 cm is charged with 5 V. The potential at the center of the sphere is
    a) -5 V
    b) 0 V
    c) 1.44×10^{-7} V
    d) 5 V

    Solution: d
    Since $\Delta V = 0$ inside any charged hollow sphere, the potential at the center will equal the potential at the surface.

13. A 1,500-kg elevator is rising and its speed is constant at 3 m/s. The tension force of the cable on the elevator is
    a) 14.7×10^3 N
    b) 14.7×10^4 N
    c) 29.4×10^3 N
    d) 29.4×10^4 N

    Solution: a
    Moving at a constant velocity implies the net force being equal to 0. Therefore, the tension must equal the force of gravity:

    $$F = m \times g = 14.7 \times 10^3 \text{ N}$$

14. What is the angular speed of an engine revolving at a rate of 5000 rpm?
    a) 274 rad/s
    b) 353 rad/s
    c) 424 rad/s
    d) 524 rad/s

    Solution: d
    One round per minute is equal to

    $$1 \text{ rpm} = \frac{2\pi}{60} \text{ rad/s}$$

    Therefore,

    $$5000 \text{ rpm} = \frac{5000 \times 2\pi}{60} \approx 524 \text{ rad/s}$$

15. The period P of a simple pendulum depends on the

a) amplitude A

b) mass m of the pendulum bob

c) length L of the pendulum

d) angle θ of release

Solution: c
The period of a pendulum is given by

$$P = 2\pi\sqrt{\frac{L}{g}}$$

Thus, the period P depends on the length of the pendulum only.

16. What is the distance a car travels before stopping, given that it weighs 2,000 kg and is moving at 65 m/s before coming to a halt by applying its brakes and skidding (i.e., the tires losing their grip on the road and sliding without rotating), with a friction force of 7,000 N between its tires and the road?

a) 105 m

b) 200 m

c) 550 m

d) 604 m

Solution: d

$$W = \Delta K = 0 - \frac{1}{2}mv^2 = -\frac{1}{2}(2000\,\text{kg})(65\,\text{m/s})^2 = -4225\,\text{kJ}$$
$$W = -fx = -(7000\,\text{N})x \Rightarrow x \approx 604\text{ m}$$

17. An object is situated at a distance $d = 7.5$ cm from a converging lens of focal length $f = 5$ cm. What is the magnification of this lens?

a) -0.5

b) 0.5

c) -2

d) 2

Solution: c
We can use the mirror equation

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

where p is the principal distance, q is the image distance, and f is the focal distance. Also, we can use the equation for the magnification m

$$m = -\frac{q}{p}$$

From these two equations, we get that

$$m = \frac{1}{1 - \frac{p}{f}}$$

Plugging in the values, we get that $m = -2$. Also, we can manually calculate q and plug it in to get the same answer.

18. What is the amount of torque produced by an electric motor operating at 1500 revolutions per minute and generating 0.5 horsepower? Note that 1 horsepower is equal to 746 W.

    a) 2.37 Nm

    b) 4.50 Nm

    c) 7.30 Nm

    d) 13.0 Nm

    Solution: a

$$P = \tau\omega \Longrightarrow \tau = \frac{P}{\omega} = \frac{0.5 \times 746}{2 \times \pi \times \frac{1500}{60}} = 2.37 \text{ Nm}$$

19. A rectangular solar panel with dimensions 2 and 4 meters delivers 10 A and 25 V. Assuming that the solar power output reaching the Earth is 1000 W/m^2, what is the energy conversion efficiency of the solar panel?

    a) 3.13 %

    b) 4.05 %

    c) 5.80 %

    d) 8.63 %

    Solution: a
    The efficiency of the solar panel is equal to

$$\frac{P_f}{P_i} = \frac{25 \times 10}{1000 \times 2 \times 4} = 3.13\%$$

20. Two moles of a rigid diatomic gas are heated at constant pressure from 300 K to 440 K. What is the work done on the gas?

    a) 2.33 kJ

    b) -2.33 kJ

    c) 14 kJ

    d) -14 kJ

    Solution: b
    The first law of thermodynamics states that

$$\Delta E_{int} = W + Q \implies W = \Delta E_{int} - Q$$

We also have that

$$\Delta E_{int} = nC_V\Delta T$$
$$Q = nC_P\Delta T$$

Therefore, we get that

$$W = n\Delta T(C_V - C_P)$$

Substituting with the given values, we get that

$$W = -2.33 \text{ kJ}$$

21. Resonance occurs when

a) two waves destructively interfere

b) a wave reflects off a surface

c) a system is driven at its natural frequency

d) the amplitude of a wave decreases over distance

Solution: c
If a system has a frequency that is equal to its fundamental frequency or any integer multiple of it, the system is said to be at resonance.

22. Let $Z = X^a Y^b$, where Z has the dimensions of L/T^2, X has dimensions of L^4/T, and Y has the dimensions LT^3. What are the numerical values of a and b?

a) $a = \frac{4}{13}$ and $b = -\frac{3}{13}$

b) $a = -\frac{4}{13}$ and $b = \frac{3}{13}$

c) $a = \frac{5}{13}$ and $b = -\frac{7}{13}$

d) $a = -\frac{5}{13}$ and $b = \frac{7}{13}$

Solution: c
We can construct a system of equations to find the values of a and b. Since both sides of the given equation must have the same dimensions, we get that

$$4a + b = 1$$

$$3b - a = -2$$

Solving this system of equations, we get that

$$a = \frac{5}{13} \text{ and } b = \frac{-7}{13}$$

23. The core of any transformer is laminated to

a) reduce the energy loss due to eddy currents

b) increase the intensity

c) make it robust

d) increase the secondary voltage

Solution: a
A laminated core provides less area of cross-section for the current to flow. Because of this, the resistance of the core increases, and the current decreases, hence decreasing the eddy currents.

24. Three capacitors are connected in parallel, each with a capacitance of 14 μF, and with an AC source of frequency 50 Hz. The total capacitive reactance X_C equals

a) 76 Ω

b) 152 Ω

c) 341 Ω

d) 682 Ω

Solution: a

$$X_C = \frac{1}{2\pi f C_{\text{equivalent}}} = \frac{1}{2\pi f \sum_i C_i} \approx 76\Omega$$

25. A current of magnitude I flows in coil A of radius R, while a current of magnitude $2I$ flows in coil B of radius $2R$. The ratio between the magnetic fields produced by them $B_A : B_B$ is
    a) 1
    b) 2
    c) 4
    d) $\frac{1}{2}$

    Solution: a
    The magnetic field produced by a current carrying circular coil of radius R at its center
    $$B = \frac{u_0}{4\pi}\frac{I}{R}\cdot 2\pi$$
    $$B_A = \frac{u_0}{4\pi}\frac{I}{R}\cdot 2\pi$$
    $$B_B = \frac{u_0}{4\pi}\frac{2I}{2R}\cdot 2\pi = \frac{u_0}{4\pi}\frac{I}{R}\cdot 2\pi$$
    Then, the ratio is 1.

26. Which of the following phenomena is NOT an example of resonance?
    a) Breaking a glass with a high-pitched voice
    b) Swinging on a playground swing
    c) Tuning a guitar string
    d) Echo from a wall

    Solution: d
    An echo is just a reflection of sound waves from some surface and doesn't represent a case of resonance.

27. A circle of radius a is cut from a circle of radius $2a$. Given that both circles are concentric (i.e, have the same geometrical center) at $(0, 0)$, what is the coordinate of the center of mass of this hollow-circle system?
    a) $(a, 0)$
    b) $(0, 0)$
    c) (a, a)
    d) $(2a, a)$

    Solution: b
    From the symmetry of the problem, it can be guessed that the answer is $(0, 0)$. However, to calculate it, we can use the negative mass method. The y-coordinate of the center of mass is 0 and the x-coordinate of the center of mass is
    $$x_{\mathrm{CM}} = \frac{A_1x_1 + A_2x_2}{A_1 + A_2}$$
    Given that $A_1 = 4\pi a^2$, $x_1 = 0$, $A_2 = \pi a^2$, and $x_2 = 0$, we get that
    $$x_{\mathrm{CM}} = 0$$

28. A gun contains a spring whose spring constant is 20.0 N/m. The spring is compressed 8.00 cm and then used to propel an 8.00 g cork. The cork, however, sticks to the spring for 2.00 cm beyond its unstretched length before separation occurs. The velocity of this cork is

    a) 2.64 m/s
    b) 3.87 m/s
    c) 4.02 m/s
    d) 5.21 m/s

    Solution: b

    $$K = P_i - P_f = \frac{1}{2}k \times (0.08^2 - 0.02^2) = \frac{1}{2}mv^2 \implies v = 3.87 \text{ m/s}$$

29. Given that the temperature of space is 2.7 K, and the sun is a perfect black body, what is the power output of the sun?

    a) 3.91×10^{23} W
    b) 3.91×10^{24} W
    c) 3.91×10^{25} W
    d) 3.91×10^{26} W

    Solution: d
    The power emitted by a black body follows the Stefan-Boltzmann law. Therefore, we find that the power emitted by the sun P is equal to

    $$P = A\sigma\epsilon(T^4 - T_o^4)$$

    where T_o is the temperature of the surrounding space. However, we can neglect the T_o^4 since it's insignificant when compared to the T^4 term. Using the given values, we get that

    $$P = 3.91 \times 10^{26} \text{ W}$$

30. Which of the following represents the optical equivalent of sonic booms?

    a) Coronal mass ejections
    b) Cherenkov radiation
    c) Cosmic radiation
    d) Gamma radiation

    Solution: b
    Cherenkov radiation occurs when a charged particle's speed exceeds the speed of light in the same medium. This results in the emission of photons in a similar manner to sonic booms.

31. A sphere is moving in a pure rolling motion. What is the ratio between the velocities of its top point and its center of mass?

    a) $\frac{1}{2}$
    b) 1
    c) 2
    d) 4

Solution: c
For pure rolling motion, the relative velocity at the contact point is 0. Therefore, $v_{\text{CM}} = \omega R$, where R is the radius of the sphere and ω is its angular velocity. The top point's velocity v_{Top} is $2R\omega = 2v_{\text{CM}}$. Therefore, the sought ratio is

$$\frac{v_{\text{Top}}}{v_{\text{CM}}} = 2$$

32. When a source of sound moves towards a stationary observer, what happens to the perceived frequency of the sound?
   a) It increases
   b) It decreases
   c) It remains the same
   d) It becomes silent

   Solution: a
   The frequency perceived by the stationary observer will increase when the source starts moving towards them. This is because the wavelength γ gets shorter and

$$f \propto \frac{1}{\gamma}$$

33. Which of the following is true for any cyclic thermodynamic process?
   a) The change in internal energy is zero.
   b) The change in internal energy is equal to the energy added to the gas.
   c) The Change in the internal energy is equal to the work done by the system.
   d) Cyclic thermodynamic processes don't exist.

   Solution: a
   A cyclic thermodynamic process is basically any process in which the system undergoes some change and returns to its initial state. Thus, the change in internal energy is zero (i.e., $Q = -W$).

34. An ion with a charge of $+5e$ moves into a magnetic field with a flux density of $2.5\,\text{Wb/m}^2$ while traveling at a speed of $3.2 \times 10^4\,\text{m/s}$ perpendicular to the field direction. Calculate the force experienced by the ion.
   a) $2.0 \times 10^{-14}\,\text{N}$
   b) $6.4 \times 10^{-14}\,\text{N}$
   c) $1.6 \times 10^{-13}\,\text{N}$
   d) $3.2 \times 10^{-13}\,\text{N}$

   Solution: b

$$F = qvB = 5 \times (1.6 \times 10^{-19}\,\text{C}) \times (3.2 \times 10^4\,\text{m/s}) \times (2.5\,\text{Wb/m}^2) = 6.4 \times 10^{-14}\,\text{N}$$

35. At what speed will the kinetic energy of an electron equal its rest energy?
   a) $\frac{1}{2}c$
   b) $\frac{\sqrt{3}}{2}c$
   c) $\frac{2}{3}c$

d) The mentioned situation is impossible.

Solution: b
The relativistic kinetic energy K of an electron is equal to

$$K = (\gamma - 1)m_o c^2$$

For the mentioned situation to occur, $K = m_o c^2$. Therefore,

$$m_o c^2 = (\gamma - 1)m_o c^2 \Rightarrow \gamma = 2$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = 2 \Rightarrow v = \frac{\sqrt{3}}{2}c$$

36. When light rays go through a different medium, they emerge at the same angle but are shifted by a distance d. Given that these light rays travel from air ($n = 1.00$) to an ice slab ($n = 1.31$) of thickness $t = 1$ cm and are incident at an angle $\theta = 30°$, what distance d are these light rays shifted by?
   a) 1.38 mm
   b) 1.40 mm
   c) 1.42 mm
   d) 1.44 mm

Solution: c
By simple geometrical construction, we get that the length of the ray going through the slab l is

$$l = \frac{t}{\cos\theta_2}$$

where θ_2 is the refraction angle, which can be obtained from Snell's law. Considering $\alpha = \theta_1 - \theta_2$, we get that

$$d = l\sin\alpha \Rightarrow d = \frac{t}{\cos\theta_2}\sin\alpha$$

Substituting with the given values, we get that

$$d = 1.42 \text{ mm}$$

37. A 0.125-kg plastic ball dropped from a certain height. The ball's speed just before impact is 8.2 m/s. The ball bounces with speed of 4.3 m/s. If the ball is in contact with the floor for 0.057 s, what is the magnitude of the average force by the floor on the ball?
   a) 4.40 N
   b) 8.50 N
   c) 27.4 N
   d) 85.5 N

Solution: c
The average force exerted by the floor is equal to

$$F = \frac{\Delta p}{\Delta t} \Rightarrow F = \frac{0.125(8.2 + 4.3)}{0.057} = 27.4 \text{ N}$$

38. Determine the peak voltage across a 45-ohm resistor when an AC current with an RMS value of 5 A flows through it.
    a) 265.6 V
    b) 318.2 V
    c) 358.5 V
    d) 423.7 V

    Solution: b

$$V_{\text{peak}} = \sqrt{2} \times R \cdot I_{\text{rms}} = \sqrt{2} \times 45\,\Omega \times 5\,\text{A} = 318.2\,\text{V}$$

39. The total capacitance of a set of capacitors in an electric circuit is 48 μF. In order to decrease it to 30 μF, an additional capacitor is added. What is its capacitance and circuit connection?
    a) 64 μF, in series
    b) 64 μF, in parallel
    c) 80 μF, in series
    d) 80 μF, in parallel

    Solution: c
    The total capacitance cannot be decreased by adding a capacitor in parallel because $C_{\text{Parallel}} = \sum_i C_i$, so it must be connected in series.

$$\left(\frac{1}{C_1} + \frac{1}{C_2}\right)^{-1} = 30\,\mu\text{F} \implies C_2 = \left(\frac{1}{30} - \frac{1}{48}\right)^{-1} = 80\,\mu\text{F}$$

40. A man suffering from nearsightedness can't see well because light rays reflected by an object converge before reaching the retina. What should he do to correct his eyesight?
    a) Wear glasses with converging mirrors.
    b) Wear glasses with diverging mirrors.
    c) Wear glasses with converging lenses.
    d) Wear glasses with diverging lenses.

    Solution: d
    To correct his eyesight, he needs to force the light rays to converge later. This can be achieved by using a diverging lens that can delay the rays' convergence.

41. A 200-kg disc is rotating with an angular velocity ω. A 50-kg girl jumps on the disc's rim while rotating. What is the ratio between the disc's final angular velocity and initial angular velocity? The moment of inertia of a circular disc of mass M and radius R is $\frac{1}{2}MR^2$. Ignore friction and treat the girl as a point particle.
    a) 0.200
    b) 0.333
    c) 0.667
    d) 1.50

Solution: c
We will simply use the conservation of angular momentum. We have that

$$I_i\omega_i = I_f\omega_f \Rightarrow \frac{\omega_f}{\omega_i} = \frac{I_i}{I_f}$$

Since the girl stands at the rim and has a moment of inertia of mR^2, we get that

$$\frac{I_i}{I_f} = \frac{\frac{1}{2}MR^2}{\frac{1}{2}MR^2 + mR^2} = \frac{\frac{1}{2}M}{\frac{1}{2}M + m} = 0.667$$

42. A wave represented by $y = a\cos(kx - \omega t)$ is superposed with another wave, forming a stationary wave such that point $x = 0$ is a node. The equation of the other wave is

    a) $-a\cos(kx - \omega t)$
    b) $a\sin(kx + \omega t)$
    c) $-a\cos(kx + \omega t)$
    d) $-a\sin(kx - \omega t)$

    Solution: c
    The other wave should be in the opposite direction with a negative amplitude, taking into consideration a phase difference of π. Then, the other's wave equation is $y = -a\cos(kx + \omega t)$

43. An engineer wants to design a banked road of radius 40 m. The road is banked at an angle of 15°. What is the maximum speed a car can enter the curve without slipping? Do not consider friction.

    a) 10.2 m/s
    b) 14.7 m/s
    c) 15.6 m/s
    d) 30.5 m/s

    Solution: a
    The maximum velocity v for a frictionless banked road is

$$v = \sqrt{rg\tan\theta} \implies v = 10.2 \text{ m/s}$$

44. The emission resulting from the transition from $n = 4$ to $n = 3$ produces the shortest wavelength in

    a) triple ionized Beryllium.
    b) doubly ionized Lithium.
    c) singly ionized Helium.
    d) hydrogen atom.

    Solution: a
    Since all choices are hydrogen-like atoms, $E = -13.6 \text{ eV}\frac{Z^2}{n^2}$, where Z is the atomic number. Furthermore, $E = \frac{hc}{\lambda}$. Hence, $\lambda \propto \frac{1}{Z^2}$, which means the atom with the largest atomic number has the shortest emitted wavelength.

45. A pendulum is said to be isochronous when

a) its period is independent of amplitude

b) its period is constant

c) its amplitude is large

d) its length is short

Solution: a

An isochronous pendulum is a pendulum whose period is constant while its length remains the same, meaning that its amplitude doesn't affect its period.

46. Determine the approximate radius of a solid spherical planet, characterized by a density of 17 g/cm^3, such that standing on the planet's surface, you could launch a golf ball at a velocity of 75 m/s, causing it to escape the planet's gravitational influence permanently.

a) 5.50 km

b) 23.5 km

c) 24.3 km

d) 31.1 km

Solution: c

The escape velocity is given by:

$$v_e = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2G\left(\frac{4}{3}\pi\rho R^3\right)}{R}}$$

Solving for R,

$$R = v_e\sqrt{\frac{3}{8\pi G\rho}} = 24326\,\text{m} \approx 24.3\,\text{km}$$

47. A 1-m rod is held between two surfaces of temperatures 70° and 40°. The rod is split into two parts: aluminum and iron, where the aluminum is connected to the 40° surface, and the iron is connected to the 70° surface. What is the temperature at the boundary between the aluminum and the iron after attaining equilibrium? The thermal conductivity of aluminum and iron are 238 W/m °C and 79.5 W/m °C respectively.

a) 42.5 °C

b) 47.5 °C

c) 62.5 °C

d) 68.9 °C

Solution: b

At equilibrium, the power transfer from both ends is equal. Therefore, we have that

$$\frac{k_1 A_1 \Delta T_1}{L_1} = \frac{k_2 A_2 \Delta T_2}{L_2}$$

Since both rods have the same length and cross-sectional area, we find that

$$k_1 \Delta T_1 = k_2 \Delta T_2 \implies k_1(40 - T_3) = k_2(70 - T_3)$$

By solving the equation for T_3, we find that

$$T_3 = \frac{40k_1 + 70k_2}{k_1 + k_2}$$

Substituting with the given values, we get that

$$T_3 = 47.5°\text{C}$$

48. The resistance coefficient of a wire is 0.00125 /°C. At 300 K, the resistance is 1 Ω. The resistance is 2 Ω when the temperature is

    a) 1,127

    b) 1,100

    c) 1,400

    d) 1,154

    Solution: a

$$R = R_0(1 + \alpha T)$$
$$1 = R_0(1 + 0.00125 \cdot 27)$$
$$2 = R_0(1 + 0.00125 \cdot T)$$
$$T = 854°C = 1127\ K$$

49. An electric transformer of efficiency 96 % is connected to 10 electric ovens that are in parallel with each other. Each oven works on a potential difference of 220 V and draws an electric current of intensity 15 A. Therefore, the consumed electric power in the primary coil of the transformer equals

    a) 3.44×10^4 W

    b) 3.64×10^4 W

    c) 3.83×10^4 W

    d) 3.92×10^4 W

    Solution: a
    The power P consumed by each oven is equal to

$$P = VI = 15 \times 220 = 3300 \text{ W}$$

The power consumed by all 10 furnaces will be $10 \times 3300 = 33$ kW. Since the transformer has a 96 % efficiency, the power in the primary coil is

$$\frac{33 \text{ kW}}{0.96} = 34.4 \text{ kW}$$

50. A 500-kg satellite, released by NASA, moves from a circular orbit of radius 1,300 km to another circular orbit of radius 2,000 km. Ignoring the change in mass due to fuel burning, what energy change is needed for this process?

    a) 1.09 GJ

    b) -1.09 GJ

    c) 26.8 GJ

    d) -26.8 GJ

Solution: a

The total energy of the satellite E is equal to

$$E = \frac{-GMm}{2r}$$

Thus, the change in energy of the satellite is

$$\Delta E = \frac{-GMm}{2}\left(\frac{1}{r_f} - \frac{1}{r_i}\right)$$

Substituting with $r_i = 6371 + 1300 = 7671$ km and $r_f = 6371 + 2000 = 8371$ km, we get that

$$\Delta E = 1.09 \times 10^9 \text{ J} = 1.09 \text{ GJ}$$