PHYSICS

SECTION - A

Multiple Choice Questions: This section contains 20 multiple choice questions. Each question has 4 choices (1), (2), (3) and (4), out of which **ONLY ONE** is correct.

Choose the correct answer:

1. If a radioactive element having half-life of 30 min. is undergoing beta decay, the fraction of radioactive element remains undecayed after 90 min. will be

(1) $\frac{1}{8}$ (2) $\frac{1}{4}$

(3) $\frac{1}{16}$ (4) $\frac{1}{2}$

Answer (1)

Sol. t_{half} = 30 min.

In 90 min. there will be 3 half lives

Number of remaining $= \left(\frac{N_0}{2^3}\right)$

$= \frac{N_0}{8}$

$\therefore$ Fraction will be $\frac{1}{8}$

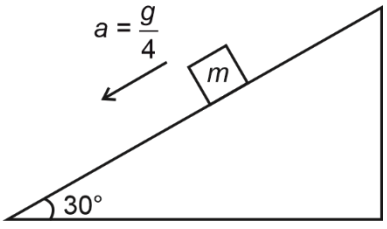
2. A block of mass m slides down the plane inclined at angle 30° with an acceleration $\frac{g}{4}$. The value of coefficient of kinetic friction will be:

(1) $\frac{2\sqrt{3}-1}{2}$ (2) $\frac{1}{2\sqrt{3}}$

(3) $\frac{2\sqrt{3}+1}{2}$ (4) $\frac{\sqrt{3}}{2}$

Answer (2)

Sol.



$\because$ $mg\sin\theta - \mu mg\cos\theta = ma$

Also $a = \frac{g}{4}$

$\therefore$ $\frac{mg}{2} - \mu mg\frac{\sqrt{3}}{2} = \frac{mg}{4}$

$\frac{mg}{4} = \mu mg\frac{\sqrt{3}}{2}$

$\mu = \frac{1}{2\sqrt{3}}$

3. Surface tension of a soap bubble is 2.0×10^{-2} Nm^{-1}. Work done to increase the radius of soap bubble from 3.5 cm to 7 cm will be:

Take $\left[\pi = \frac{22}{7}\right]$

(1) 5.76×10^{-4} J (2) 0.72×10^{-4} J

(3) 9.24×10^{-4} J (4) 18.48×10^{-4} J

Answer (4)

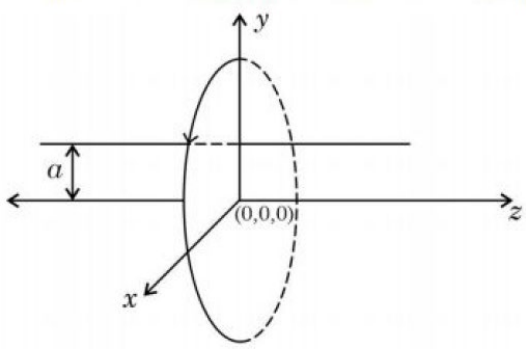
Sol. $T = 2 \times 10^{-2}$ N/m^2

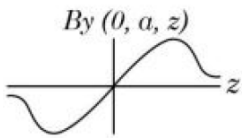
$W = T(\Delta A)$

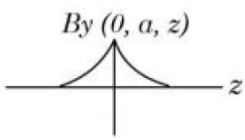
$= 2\times10^{-2}\left[2\times4\pi\left\{\left(\frac{7}{100}\right)^2 - \left(\frac{3.5}{100}\right)^2\right\}\right]$

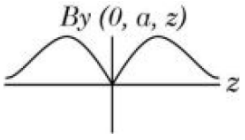
$= 18.48 \times 10^{-4}$ J

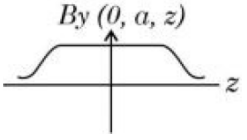
4. A single current carrying loop of wire carrying current I flowing in anticlockwise direction seen from +ve z direction and lying in xy plane is shown in figure. The plot of $\hat{j}$ component of magnetic field (By) at a distance 'a' (less than radius of the coil) and on yz plane vs z coordinate look like



(1) 

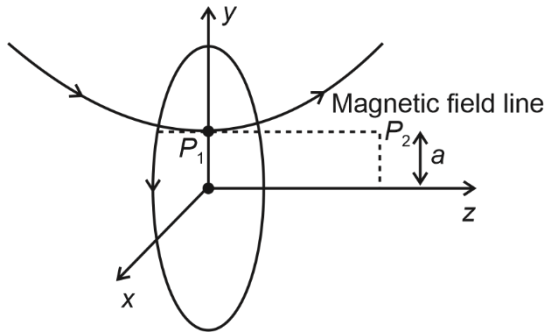
(2) 

(3) 

(4) 

Answer (1)

Sol.



$\because$ By at $P_1 = 0$ [option 2 and 4 are incorrect]

By has the opposite direction for the +ve and –ve z axis

5. A car is moving on a horizontal curved road with radius 50 m. The approximate maximum speed of car will be, if friction between tyres and road is 0.34. [take g = 10 ms^{-2}]

(1) 22.4 ms^{-1}

(2) 13 ms^{-1}

(3) 17 ms^{-1}

(4) 3.4 ms^{-1}

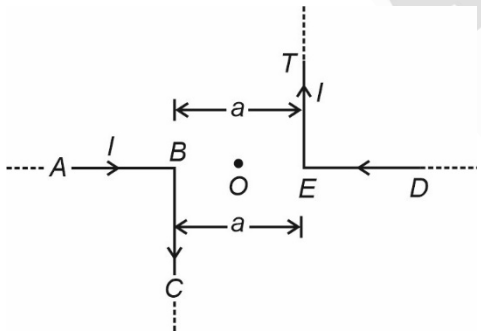
Answer (2)

Sol. $v_{max} = \sqrt{\mu gR}$

$= \sqrt{0.34 \times 10 \times 50}$

≈ 13 m/s

6. The magnitude of magnetic induction at mid point O due to current arrangement as shown in Fig. will be



(1) 0

(2) $\frac{\mu_0 I}{4\pi a}$

(3) $\frac{\mu_0 I}{\pi a}$

(4) $\frac{\mu_0 I}{2\pi a}$

Answer (3)

Sol. $B_0 = 2\left[\frac{\mu_0 I}{4\pi\left(\frac{a}{2}\right)}[\sin 0° + \sin 90°]\right]$

$= \frac{\mu_0 I}{\pi a}$

7. A stone is projected at angle 30º to the horizontal. The ratio of kinetic energy of the stone at point of projection to its kinetic energy at the highest point of flight will be -

(1) 4 : 3

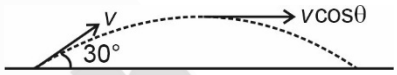
(2) 4 : 1

(3) 1 : 2

(4) 1 : 4

Answer (1)

Sol.



$KE_{in} = \frac{1}{2}mv^2$

$KE_{final} = \frac{1}{2}mv^2\cos^2 30° = \frac{1}{2}mv^2\left(\frac{\sqrt{3}}{2}\right)^2$

$\frac{KE_{in}}{KE_f} = \frac{\frac{1}{2}mv^2}{\frac{1}{2}mv^2\left(\frac{3}{4}\right)} = \frac{4}{3}$

8. Two particles of equal mass 'm' move in a circle of radius 'r' under the action of their mutual gravitational attraction. The speed of each particle will be :

(1) $\sqrt{\frac{Gm}{2r}}$

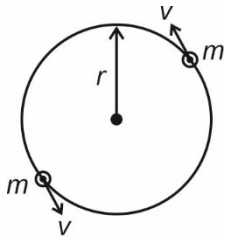
(2) $\sqrt{\frac{Gm}{4r}}$

(3) $\sqrt{\frac{4Gm}{r}}$

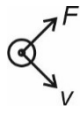
(4) $\sqrt{\frac{Gm}{r}}$

Answer (2)

Sol.



From one of the masses FBD



$$\frac{Gm^2}{(2r)^2} = \frac{mv^2}{r}$$

$$v = \sqrt{\frac{Gm}{4r}}$$

9. A bicycle tyre is filled with air having pressure of 270 kPa at 27°C. The approximate pressure of the air in the tyre when the temperature increases to 36°C is

(1) 270 kPa

(2) 278 kPa

(3) 360 kPa

(4) 262 kPa

Answer (2)

Sol. P_{in} = 270 kPa, T_{in} = 27°C

= 300 K

T_{final} = 36°C = 309 K

Hence we can consider process to be isochoric volume constant

$\therefore \quad P \propto T$

$$\frac{P_{in}}{P_f} = \frac{T_{in}}{T_f} \Rightarrow P_f = 278 \text{ kPa}$$

10. Given below are two statements: One is labelled as **Assertion A** and the other is labelled as **Reason R**.

Assertion A : If dQ and dW represent the heat supplied to the system and the work done on the system respectively. Then according to the first law of thermodynamics $dQ = dU - dW$.

Reason R : First law of thermodynamics is based on law of conservation of energy.

In the light of the above statements, choose the correct answer from the options given below :

(1) Both A and R are correct and R is the correct explanation of A

(2) A is correct but R is not correct

(3) A is not correct but R is correct

(4) Both A and R are correct but R is not the correct explanation of A

Answer (1)

Sol. ΔQ = heat supplied to system

ΔW = work done on the system

$\therefore \quad \Delta U = \Delta Q - \Delta W$

This comes from conservation of energy.

11. In a cuboid of dimension 2L × 2L × L, a charge q is placed at the center of the surface 'S' having area of 4 L^2. The flux through the opposite surface to 'S' is given by

(1) $\frac{q}{2\epsilon_0}$

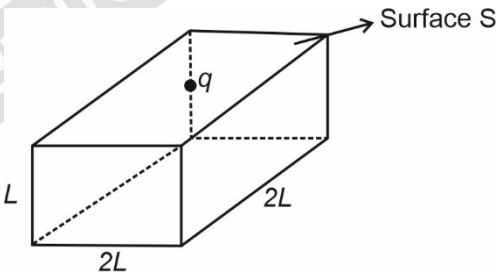
(2) $\frac{q}{6\epsilon_0}$

(3) $\frac{q}{12\epsilon_0}$

(4) $\frac{q}{3\epsilon_0}$

Answer (2)

Sol.



If we consider a similar box above this box then it becomes cube of side length 2L

ϕ through a surface $= \frac{q}{6\varepsilon_0}$

12. Which one of the following statement is not correct in the case of light emitting diodes?

A. It is a heavily doped p-n junction.

B. It emits light only when it is forward biased.

C. It emits light only when it is reverse biased.

D. The energy of the light emitted is equal to or slightly less then the energy gap of the semiconductor used.

Choose the correct answer from the options given below:

(1) C and D (2) C

(3) B (4) A

Answer (2)

Sol. ⇒ LED is a heavily doped, forward biased *p-n*-junction diode

⇒ It will not emit light in reverse bias

⇒ Energy of emitted photon is equal to or slightly less the band gap energy of forbidden band.

13. Match List I with List II:

	List I (Physical Quantity)		**List II (Dimensional Formula)**
A.	Pressure gradient	I.	$[M^0L^2T^{-2}]$
B.	Energy density	II.	$[M^1L^{-1}T^{-2}]$
C.	Electric field	III.	$[M^1L^{-2}T^{-2}]$
D.	Latent heat	IV.	$[M^1L^1T^{-3}A^{-1}]$

Choose the ***correct*** answer from the options given below:

(1) A-III, B-II, C-IV, D-I (2) A-II, B-III, C-I, D-IV

(3) A-III, B-II, C-I, D-IV (4) A-II, B-III, C-IV, D-I

Answer (1)

Sol. A. $\frac{\Delta P}{\Delta x} = \left[\frac{MLT^{-2}}{L^3}\right] = [ML^{-2}T^{-2}]$ ...(III)

B. $\frac{E}{v} = \left[\frac{ML^2T^{-2}}{L^3}\right] = [ML^{-1}T^{-2}]$ ...(II)

C. $\frac{F}{Q} = \left[\frac{MLT^{-2}}{AT}\right] = [MLT^{-3}A^{-1}]$ ...(IV)

D. Latent heat $= \left[\frac{ML^2T^{-2}}{M}\right] = [M^0L^2T^{-2}]$ ...(I)

14. Which of the following are true?

A. Speed of light in vacuum is dependent on the direction of propagation.

B. Speed of light in a medium is independent of the wavelength of light.

C. The speed of light is independent of the motion of the source.

D. The speed of light in a medium is independent of intensity.

Choose the correct answer from the options given below:

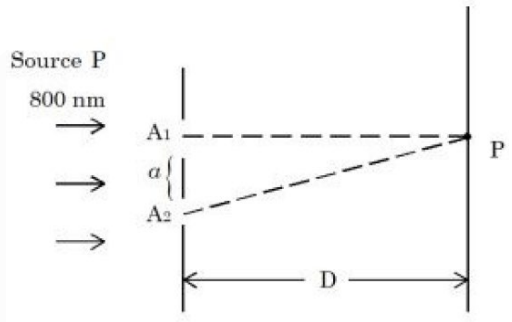
(1) C and D only (2) B and D only

(3) B and C only (4) A and C only

Answer (1)

Sol. Speed of light is independent of motion of source and Intensity.

15. In a Young's double slit experiment, two slits are illuminated with a light of wavelength 800 nm. The line joining A_1P is perpendicular to A_1A_2 as shown in the figure. If the first minimum is detected at P, the value of slits separation 'a' will be:



The distance of screen from slits D = 5 cm

(1) 0.4 mm

(2) 0.1 mm

(3) 0.2 mm

(4) 0.5 mm

Answer (3)

Sol. $y = \frac{(2n-1)\lambda D}{2a} = \frac{a}{2}$ for $n = 1$

$\Rightarrow \frac{\lambda D}{2a} = \left(\frac{a}{2}\right)$

$\Rightarrow \frac{800\times10^{-9}\times5\times10^{-2}}{2} = \frac{a^2}{2}$

$\Rightarrow a^2 = 4000 \times 10^{-11}$

$a = \sqrt{4\times10^{-8}} = 2 \times 10^{-4} = 0.2$ mm

16. If the height of transmitting and receiving antennas are 80 m each, the maximum line of sight distance will be:

Given: Earth's radius = 6.4×10^6 m

(1) 64 km (2) 36 km

(3) 28 km (4) 32 km

Answer (1)

Sol.

Maximum line of sight = $2\sqrt{2Rh}$

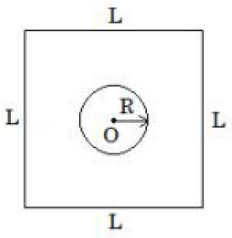
$= 2\sqrt{2 \times 6.4 \times 10^6 \times 80}$

$= 2 \times 4 \times 8 \times 10^3$

$= 64 \times 10^3$

$= 64$ km

17. Find the mutual inductance in the arrangement, when a small circular loop of wire of radius '*R*' is placed inside a large square loop of wire of side L (*L* >> *R*). The loops are coplanar and their centres coincide:

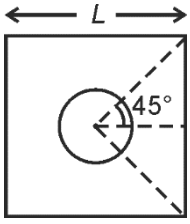


(1) $M = \dfrac{2\sqrt{2}\mu_0 R}{L^2}$ (2) $M = \dfrac{\sqrt{2}\mu_0 R}{L^2}$

(3) $M = \dfrac{2\sqrt{2}\mu_0 R^2}{L}$ (4) $M = \dfrac{\sqrt{2}\mu_0 R^2}{L}$

Answer (3)

Sol.



B at centre = $\dfrac{\mu_0 i}{4\pi\left(\frac{L}{2}\right)}\left(\dfrac{2}{\sqrt{2}}\right) \times 4$

$= \dfrac{\sqrt{2}\mu_0 i}{2\pi L} \times 4$

$= \left(\dfrac{2\sqrt{2}\mu_0 i}{\pi L}\right)$

Mutual inductance = $\dfrac{B \cdot A}{i}$

$= \dfrac{2\sqrt{2}\mu_0 i}{\pi L} \times \dfrac{\pi R^2}{i}$

$= \left(\dfrac{2\sqrt{2}\mu_0 R^2}{L}\right)$

18. Ratio of thermal energy released in two resistors R and 3R connected in parallel in an electric circuit is:

(1) 1 : 1 (2) 1 : 3

(3) 1 : 27 (4) 3 : 1

Answer (4)

Sol. For parallel connection, potential difference is same (ν)

$P_1 = \left(\dfrac{\nu^2}{R_1}\right)$

$P_2 = \left(\dfrac{\nu^2}{R_2}\right)$

$\dfrac{P_1}{P_2} = \dfrac{H_1}{H_2} = \left(\dfrac{R_2}{R_1}\right) = \dfrac{3R}{R} = (3:1)$

19. The threshold wavelength for photoelectric emission from a material is 5500 Å. Photoelectrons will be emitted, when this material is illuminated with monochromatic radiation from a

A. 75 W infra-red lamp

B. 10 W infra-red lamp

C. 75 W ultra-violet lamp

D. 10 W ultra-violet lamp

Choose the correct answer from the options given below:

(1) A and D only (2) C only

(3) C and D only (4) B and C only

Answer (3)

Sol. Wavelength of infra-red = 700 nm (minimum)

Wavelength of UV = 100 – 400 nm

Since we need λ < 5000 Å

$\Rightarrow$ Only UV would be able to emit photoelectrons.

20. A person observes two moving trains, 'A' reaching the station and 'B' leaving the station with equal speed of 30 m/s. If both trains emit sounds with frequency 300 Hz, (Speed of sound: 330 m/s) approximate difference of frequencies heard by the person will be:

(1) 33 Hz (2) 10 Hz

(3) 55 Hz (4) 80 Hz

Answer (3)

Sol. By doppler effect : $f' = f_0\left[\frac{v - v_0}{v - v_s}\right]$

$\Rightarrow \quad f_A' = 300\left[\frac{330}{330 - 30}\right]$ Hz

$= 330$ Hz

And $f_B' = 300\left[\frac{330}{330 + 30}\right]$ Hz

$= \frac{5}{6} \times 330$ Hz $= 275$ Hz

SECTION - B

Numerical Value Type Questions: This section contains 10 questions. In Section B, attempt any five questions out of 10. The answer to each question is a **NUMERICAL VALUE.** For each question, enter the correct numerical value (in decimal notation, truncated/rounded-off to the second decimal place; e.g. 06.25, 07.00, –00.33, –00.30, 30.27, –27.30) using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.

21. A certain elastic conducting material is stretched into a circular loop. It is placed with its plane perpendicular to a uniform magnetic field B = 0.8 T. When released the radius of the loop starts shrinking at a constant rate of 2 cms^{-1}. The induced emf in the loop at an instant when the radius of the loop is 10 cm will be _____ mV.

Answer (10)

Sol. $\varepsilon = \frac{-d\phi}{dt}$

$= -\frac{d}{dt}[B \cdot \pi r^2]$

$= -\pi B\left[2r\frac{dr}{dt}\right]$

$= 2 \times \pi \times 0.8 \times \frac{10}{100} \times \left(\frac{-2}{100}\right)$ Volts

$\Rightarrow \quad \varepsilon \simeq -10.048$ mV

22. A 0.4 kg mass takes 8 s to reach ground when dropped from a certain height 'P' above surface of earth. The loss of potential energy in the last second of fall is ____ J.

(Take g = 10 m/s^2)

Answer (300)

Sol. $8 = \sqrt{\frac{2h}{g}}$

$\Rightarrow \quad h = 320$ m

Distance covered in last second

$= \frac{1}{2}g \times 8^2 - \frac{1}{2}g \times 7^2$

$h' = 75$ m

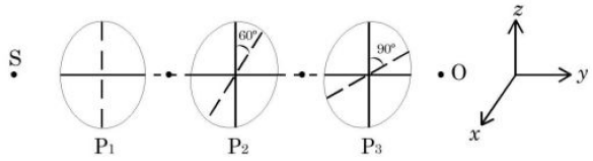
$\Rightarrow$ Loss of potential energy = mgh'

$= 0.4 \times 10 \times 75$ J

$= 300$ J

23. As shown in the figure, three identical polaroids P_1, P_2 and P_3 are placed one after another. The pass axis of P_2 and P_3 are inclined at angle of 60° and 90° with respect to axis of P_1. The source S has an intensity of $256\ \frac{W}{m^2}$.

The intensity of light at point O is _____ $\frac{W}{m^2}$.



Answer (24)

Sol. Using Malus' law, intensity would be

$I = I_0 \times \frac{1}{2} \times \cos^2 60° \times \cos^2(90° - 60°)$

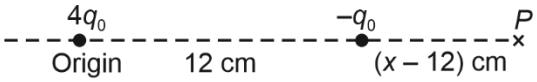
$= 256 \times \frac{1}{2} \times \frac{1}{4} \times \frac{3}{4}$ W/m^2

$\Rightarrow \quad I = 24$ W/m^2

24. A point charge $q_1 = 4q_0$ is placed at origin. Another point charge $q_2 = -q_0$ is placed at $x = 12$ cm. Charge of proton is q_0. The proton is placed on x axis so that the electrostatic force on the proton is zero. In this situation, the position of the proton from the origin is _____ cm.

Answer (24)

Sol.



Field at point $P = 0$

$\Rightarrow \quad \frac{1}{4\pi\varepsilon_0}\frac{4q_0}{x^2} = \frac{1}{4\pi\varepsilon_0}\frac{q_0}{(x-12)^2}$

$\Rightarrow \quad x = 2(x - 12) \Rightarrow x = 24$ cm

25. A solid sphere of mass 2 kg is making pure rolling on a horizontal surface with kinetic energy 2240 J. The velocity of centre of mass of the sphere will be _____ ms^{-1}.

Answer (40)

Sol. $\frac{1}{2}mv_{cm}^2+\frac{1}{2}\times\frac{2}{5}mR^2\times\frac{v_{cm}^2}{R^2}=2240\text{ J}$

$$\frac{7}{10}mv_{cm}^2=2240$$

$$v_{cm}=\sqrt{\frac{2240\times10}{7\times2}}=40\text{ m/sec}$$

26. Two simple harmonic waves having equal amplitudes of 8 cm and equal frequency of 10 Hz are moving along the same direction. The resultant amplitude is also 8 cm. The phase difference between the individual waves is _____ degree.

Answer (120)

Sol. $A_R=\sqrt{A_1^2+A_2^2+2A_1A_2\cos\phi}$

$$8=\sqrt{8^2+8^2+2\times8\times8\cos\phi}$$

$$\Rightarrow\quad\cos\phi=-\frac{1}{2}$$

$$\Rightarrow\quad\phi=120°$$

27. In a metre bridge experiment the balance point is obtained if the gaps are closed by 2 Ω and 3 Ω. A shunt of X Ω is added to 3 Ω resistor to shift the balancing point by 22.5 cm. The value of X is _____.

Answer (2)

Sol. Case 1:

$$\frac{l}{100-l}=\frac{2}{3}$$

$$\Rightarrow\quad l=40\text{ cm}$$

as 3 Ω is shunted the balance point will shift towards 3 Ω. So, new length $l'=22.5+l=62.5$

So, $\frac{62.5}{37.5}=\frac{2}{3x}(3+x)$

$$\Rightarrow\quad x=2\ \Omega$$

28. A radioactive element $^{242}_{92}X$ emits two α-particles, one electron and two positrons. The product nucleus is represented by $^{234}_{P}Y$. The value of P is _____.

Answer (87)

Sol. $^{242}_{92}X\xrightarrow{2\alpha}{}^{234}_{88}A\xrightarrow{e^-}{}^{234}_{89}B\xrightarrow{2e^+}{}^{234}_{87}Y$

So, P = 87

29. A tennis ball is dropped on to the floor from a height of 9.8 m. It rebounds to a height 5.0 m. Ball comes in contact with the floor for 0.2 s. The average acceleration during contact is_____ ms^{-2}.

(Given g =10 ms^{-2})

Answer (120)

Sol. The speed of ball just before collision with ground is $u=\sqrt{2\times gH}=\sqrt{2\times10\times9.8}=14\text{ m/sec}$ (Downwards)

The speed of ball just after collision is

$v=\sqrt{2gh}=\sqrt{2\times10\times5}=10\text{ m/sec}$ (Upwards)

So, $\vec{a}=\frac{\Delta\vec{v}}{\Delta t}$

$$=\frac{10+14}{0.2}=120\text{ m/s}^2$$

30. A body cools from 60°C to 40°C in 6 minutes. If, temperature of surroundings is 10°C. Then, after the next 6 minutes, its temperature will be _____°C.

Answer (28)

Sol. $\frac{\Delta T}{\Delta t}=-k\left(T_{av}-T_0\right)$

Case 1:

$$\frac{-20}{6}=-k(50-10)$$

$$\frac{10}{3}=40k$$

$$k=\frac{1}{12}$$

Case 2:

$$\frac{40-T}{6}=\frac{1}{12}\left(\frac{40+T}{2}-10\right)$$

$$80-2T=\frac{20+T}{2}$$

$$160-4T=20-T$$

$$\Rightarrow\quad T=\frac{140}{5}°\text{C}=28°\text{C}$$