___ 1 A scuba tank of volume 40 L is filled with 250 mol of compressed air at a pressure of 150 atm. What is the van der Waals correction to the pressure due to O_2? (For O_2 the van der Waals constants are $a = 1.382\,\mathrm{L^2\,atm/\,mol^2}$ and $b = 31.86\,\mathrm{m}L/\,\mathrm{mol}$; 21% of air consists of O_2; $R = 8.314\,\mathrm{J/\,K\,mol}$.)

A) 28.6 atm B) 1.79 atm C) 35.7 atm D) 2.38 atm E) 4.17 atm

Solution:

The number of moles of O_2 is $n_{O_2} = 0.210 \times 250\,\mathrm{mol} = 52.5\,\mathrm{mol}$. The cohesive pressure is $an_{O_2}/V^2 = 1.38\,\mathrm{L^2\,atm\,mol^{-2}} \times 52.5^2\,\mathrm{mol^2}/(40^2\,\mathrm{L^2}) = 2.38\,\mathrm{atm}$

The correct answer is: D

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___ 2 The dew point is the temperature at which the water vapor in the air would be at phase coexistence at the same partial pressure. Relative humidity is defined as the ratio of actual partial pressure of water vapor and the vapor pressure at gas-liquid phase coexistence at the same temerature. If the temperature is 30 °C and the dew point is 10 °C, what is the relative humidity? Use Table 1.

Table 1: Vapor pressure of water *vs* temperature

T (°C)	P (mmHg)	P (kPa)
0	4.581	0.611
10	9.209	1.23
15	12.653	1.69
20	17.535	2.34
30	31.827	4.24
40	55.335	7.38
50	92.55	12.3
60	149	19.9
70	233.8	31.2
80	355	47.4
90	526	70.1
100	760	101.3
110	1074	143.3
120	1489	198.5
130	2026	270.1

A) 53% B) 33% C) 3.4% D) 71% E) 29%

The relative humidity is $P(10\,°\mathrm{C})/P(30\,°\mathrm{C}) = 1.23\,\mathrm{kPa}/4.24\,\mathrm{kPa} = 29\%$.

The correct answer is: E

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___ 3 A certain blackbody radiates 200 W at a temperature of 3000 K. How much power would this body radiate at 3500 K?

A) 408 W B) 482 W C) 445 W D) 371 W E) 108 W

The power at 3500 K is $200\,\mathrm{W} \times (3500\,\mathrm{K}/3000\,\mathrm{K})^4 \approx 371\,\mathrm{W}$.

The correct answer is: D

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___ 4 An object at temperature 227 °C radiates energy at a net rate of R J/s. By what factor would the net rate of energy loss increase if the same object were at a temperature of 427 °C? Assume the surrounding temperature is 18 °C.

A) 0.238 B) 2.95 C) 4.21 D) 8.00 E) 3.79

Solution:

The rate of energy loss at 227 °C is proportional to $(227+273)^4$ and the rate of loss at 427 °C is proportional to $(427+273)^4$. The rate of gain is the same in each case and proportional to $(18+273)^4$.

The ratio is $\dfrac{700^4 - 291^4}{500^4 - 291^4} = 4.21$, because the proportionality constant is the Stefan-Boltzmann constant in each case.

The correct answer is: C

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___ 5 You are testing thermal conduction through two different materials, A and B, of the same cross-sectional area. Material A is 4 times as thick as material B, and the thermal conductivity of material A is 3 times that of material B. What is the thermal resistance of A divided by the thermal resistance of B?

A) 0.75 B) 4.0 C) 0.083 D) 12. E) 1.3

Solution:

Let the thickness of material X be d_X and let k_X be its thermal conductivity. Then we have $d_A = 4d_B$ and $k_A = 3k_B$. If S is the ocross-sectiona area of the materials, the thermal resistivities are $r_A = 4d_B/3Sk_B$ and $r_b = d_B/Sk_B$. It follows that $r_A/r_B = 4/3 = 1.3$.

The correct answer is: E

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___ 6 Calculate the rate of heat transfer from a 1.50 m × 1.00 m window frame made of aluminum. The thickness of the frame is 1.00 mm and it measures 3.00 cm the from inside of the house to outside. The inside room temperature is 25 °C and outside temperature is −20 °C. The thermal conductivity of aluminum is 205 W m^{-1} K^{-1}.

A) 0.692 W B) 1.38 W C) 1540. W D) 769. W E) 3080. W

Solution:

The heat transferred by conduction per unit time is $kA\Delta Tt^{-1}$ where k is the thermal conductivity, A is the surface area of the conducting material, $\Delta T = 45$ K is the temperature difference from one side to the other and t is the thickness of the material. The area of the frame is approximately $2\times(1.50+1.00)\,\text{m}\times 1.00\,\text{mm} = 0.00500\,\text{m}^2$. The heat loss per unit time is $205\,\text{W m}^{-1}\,\text{K}^{-1} \times 0.00500\,\text{m}^2 \times 45\,\text{K}/0.0300\,\text{m} = 1540.\,\text{W}$.

The correct answer is: C

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1. D
2. E
3. D
4. C
5. E
6. C