Physics Challenge for Teachers and Students

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Solution to January 2016 *Challenge*

Gas is ideal and U R 2!*

One mole of helium is heated in a process for which the molar heat capacity equals $2R$. During the process, the volume of the gas quadruples. How does the absolute temperature of the gas change?

* *(Adapted from Olimpiadnye Zadachi po Fizike by M. Bakunov and S. Biragov, R&C Dynamics, Moscow-Izhevsk, 2006)*

Solution:

The ideal gas equation for one mole of gas is:

$$PV = RT,$$

where P is the gas pressure, V is the volume, T is the absolute temperature, and R is the universal gas constant.

Following the definition of molar heat capacity, we have:

$$C = \frac{\delta Q}{\Delta T} \quad \text{or} \quad \delta Q = C\Delta T,$$

where $C = 2R$.

Looking at the conservation of energy law (or first law of thermodynamics) we can write:

$$\delta Q = \Delta U + p\Delta V,$$

where U is the internal energy of the gas.

Since helium is a monoatomic gas, we have

$$U = \frac{3}{2}RT \quad \text{and} \quad \Delta U = \frac{3}{2}R\Delta T.$$

Combining all of the above, we get:

$$2R\Delta T = \frac{3}{2}R\Delta T + P\Delta V, \text{ or } \frac{1}{2}R\Delta T = P\Delta V.$$

Using the ideal gas law, we can eliminate P and obtain:

$$\frac{1}{2}\frac{\Delta T}{T} = \frac{\Delta V}{V}.$$

Making the increments infinitesimal and integrating, we arrive at the following:

$$T = \alpha V^2 \quad \text{where } \alpha \text{ is a constant.}$$

Therefore, if the volume quadruples, the temperature gets **16 times bigger.**

(Submitted by Dan Cornea, Tian Yi High School, Wuxi, Jiangsu province, China)

We also recognize the following successful contributors:

R.R. Bukrey (retired, Loyola University, Evanston, IL)
Phil Cahill (The SI Organization, Inc., Rosemont, PA)
Don Easton (Lacombe, Alberta, Canada)
Supriyo Ghosh (KolKata, India)
José Ignacio Íñiguez de la Torre (Universidad de Salamanca, Salamanca, Spain)
Daniel Mixson (Naval Academy Preparatory School, Newport, RI)
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Pascal Renault (John Tyler Community College, Midlothian, VA)
Joseph Rizcallah (School of Education, Lebanese University, Beirut, Lebanon)
Jason L. Smith (Richland Community College, Decatur, IL)

Guidelines for contributors:

– We ask that all solutions, preferably in Word format, be submitted to the dedicated email address *challenges@aapt.org*. Each message will receive an automatic acknowledgment.

– The subject line of each message should be the same as the name of the solution file (see the instructions below).

– The deadline for submitting the solutions is the last day of the corresponding month.

– We can no longer guarantee that we'll publish every successful solver's name; each month, a representative selection of names will be published, both in print and on the web.

– If your name is—for instance—Lisa Randall, please name the file "**Randall16March**" (do not include your first initial) when submitting the March 2016 solution.

– If you have a message for the Column Editor, you may contact him at korsunbo@post.harvard.edu; however, please do not send your solutions to this address.

We look forward to your contributions and hope that they will include not only solutions but also your own *Challenges* that you wish to submit for the column.

Many thanks to all contributors and we hope to hear from many more of you in the future! –*Boris Korsunsky*