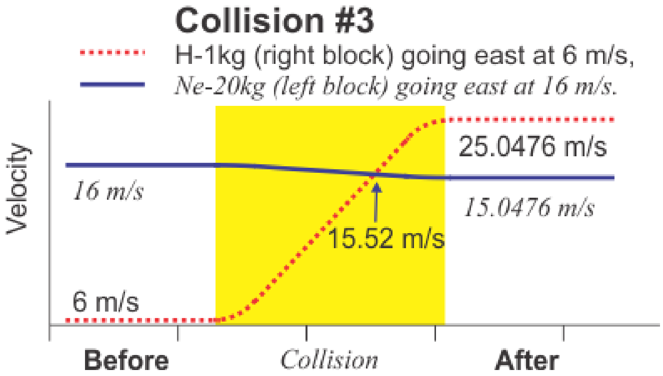
The Space-sci Sherlocks Deduce



Atomic Momentum Produces Graham's Law

Professor Du-Ane Du

www.Wacky1301SCI.com, *"Looking at serious science, sideways!"*

Three sisters, Pico, Hectii, and Tera, the "Space-sci Sherlocks," are traveling through the Asteroid Belt. Grandpa Proge shows them how statistical models can be used to compare momentum-based atomic collisions to Graham's Law of gas behavior.

—Excerpted from *Murdered Energy Mysteries*, Part 3, Chapter 14, by Du-Ane Du, (Amazon, Kindle, ebook 2018, paperback 2021).

"I've been reading about your experiments with heat," Proge said enthusiastically. "Have the Space-sci Sherlocks made any interesting discoveries?"

"We learned that collisions have a lot to do with trapped impulse and speed-based momentum," Pico said. "T-impulse and momentum-transfer both obey Newton's third law of action-reaction."

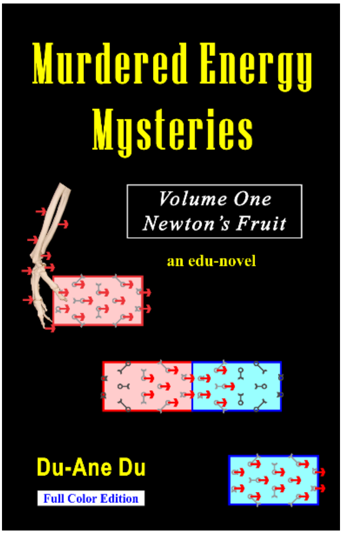
"Grandpa," Pico inquired. "All this stuff about collisions, why's this important?"

"Atoms and molecules are constantly in motion," Proge said. "And they collide with one another thousands of times a second."

"Which means, collisions tell us about solids, liquids, and gases?" Pico said.

"And collisions have a lot to do with heat and temperature?" Hectii said rhetorically.

Excerpted from:



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"Precisely," Proge confirmed. "Molecular collisions tell us a lot about both temperature and heat."

"Is there a way to study actual molecular collisions?" Pico said. "We want to know if our model accurately predicts molecular behavior!"

"The best way is to use statistical models," Proge said.

"Explo! I love math," Hectii declared. "Can you show us a statistical model of some ideal collisions?"

"Certainly," Proge acquiesced. "First you need to understand a statistical concept called a root-mean-square."

"I know that a mean is an average," Hectii said. "Is a root-mean also a type of average?"

"Yes, in fact it's sometimes called an rms-average," Proge explained. "When scientists talk about the velocity of a molecule, they're usually talking about the root-mean-square, or rms-average velocity."

"How's that work?" Pico said.

"Suppose we examined a bottle of hydrogen gas," Proge proposed as a text-box opened on the right side of the living-room display. "The molecules are flying around randomly at a wide variety of velocities. We measure the forward velocity of eight molecules…I'm typing some sample velocities into a table, can you see it?"

A: Sample Hydrogen Molecule Velocities

1010 m/s	989 m/s	1048 m/s	950 m/s
1100 m/s	889 m/s	1025 m/s	975 m/s

"Yes," Pico verified, as she pointed to the text-box on their display.

"I listed only positive velocities," Proge clarified. "Because we don't care if the molecules are flying backwards, and we don't care if they are flying at angles. Now, how would you calculate the mean, or average, of these velocities?"

"Add them up and divide by eight," Hectii said. "How do you take the root-mean-square?"

"Square the numbers, average them, then take a square-root of the average," Proge delineated. "It's the square root, of the average, of the squares, of the numbers."

"Like this?" Hectii said, as she slipped her fingers into a pink data-input ball and keyed the following into their computer:

rms-average velocity =

$$\sqrt[2]{\frac{1010^2 + 989^2 + 1048^2 + 950^2 + 1100^2 + 889^2 + 1025^2 + 975^2}{8}}$$

appeared on their display screens.

"Perfect," Proge said supportively.

"What's the result, Chip?" Hectii said, crossing her fingers hopefully.

"The rms-average velocity is 1 000 m/s," Chip wrote in a separate text-box.

"That's amazing, Grandpa," Pico said. "But how do we use that to create a model of an ideal gas?"

"There's an important law," Proge said kindly, as he placed more information into his text-box. "Commonly referred to as Graham's Law, the law can be written in several forms. Here are just a few:"

B: Graham's Law

At a stable temperature and pressure, the speed of effusion of a gas [escaping through a tiny hole], is inversely proportional to the square root of the molecular mass of the individual gases:

$$v_A = \frac{1}{\sqrt{m_{A-amu}}}$$

or: $$v_A\sqrt{m_{A-amu}} = v_B\sqrt{m_{B-amu}}$$

or: $$v_B = \frac{v_A\sqrt{m_{A-amu}}}{\sqrt{m_{B-amu}}}$$

"We've seen those equations before," Pico divulged. "Hectii was able to develop them when she derived the equations for enclosed momentum."

"But how does it relate to ideal collisions?" Hectii wondered.

"Several ways," Proge responded. "We can use it to create a model of an ideal gas, and we can use it to prove that your collision equations can correctly predict molecular behavior."

"Explo," Pico said, "let's do it!"

"First," Proge enumerated. "We'll start with a tiny imaginary jar containing 8 molecules of hydrogen, and 8 atoms each of helium-4, neon-20, argon-40, and krypton-84."

Pico nodded, "Eight each, for a total of 40 molecules."

"Most of those gases have only one atom in a molecule," Hectii said. "Does that matter?"

"No, but it does make the math easier," Proge emphasized. "Now we imagine the tiny jar is at a temperature that makes the hydrogen molecules fly at an rms-average velocity of 1 000 m/s."

"Will the other atoms fly the same velocity?" Pico said.

"No," Proge said. "We use Graham's law to calculate the rms-average velocity of the other molecules."

"What mass do we use?" Hectii said.

"Atomic mass units," Proge said, "like on the periodic table."

"So it'll look like this?" Hectii reckoned, as she keyed in the following:

$$\textit{Neon-20, rms-velocity} = \frac{v_{Hydrogen}\sqrt{m_{Hydrogen}}}{\sqrt{m_{Neon}}}$$

$$\textit{Neon-20, rms-velocity} = \frac{(1\,000\ m/s)_H\sqrt{(2\ amu)_H}}{\sqrt{(20\ amu)_{Ne}}}$$

$$\textbf{\textit{Neon-20, rms-velocity}} = \mathbf{707.11\ m/s}$$

appeared on their display screens.

"Beautiful," Proge approved. "I just placed a table of the rms-average velocities of our ideal gas mixture on the screen."

C: Ideal Gas RMS-Average Velocities

H-2	1000 m/s	Ar-40	223.61 m/s
He-4	707.11 m/s	Kr-84	154.3 m/s
Ne-20	316.23 m/s		

"The heavier the molecule, the slower it flies," Pico determined, after examining the velocities.

"But, why are there eight of each type of molecule?" Hectii said.

"We're doing a statistical test of your two-force collision equation," Proge said patiently. "And we want to test every type of collision in our ideal gas."

"What would that look like?" Pico said.

"The hydrogen molecules have the highest velocity," Proge said, as he added another table to the screen [below]. "If the hydrogen molecule is on the lavender-left, going east at 1 000 m/s, it can hit the helium-4 molecules either from the front or from the back. Those two options are in the green-right column, on Lines 1 and 2 of this table:"

D: Starting Velocities for Hydrogen Collisions

	Mass	V-L1 (Left)	Mass	V-R1 (Right)	
#1:	H-2	1000 m/s	He-4	707.11 m/s	(back)
#2:	H-2	1000 m/s	He-4	–707.11 m/s	(front)
#3:	H-2	1000 m/s	Ne-20	316.23 m/s	(back)
#4:	H-2	1000 m/s	Ne-20	–316.23 m/s	(front)
#5:	H-2	1000 m/s	Ar-40	223.61 m/s	(back)
#6:	H-2	1000 m/s	Ar-40	–223.61 m/s	(front)
#7:	H-2	1000 m/s	Kr-84	154.3 m/s	(back)
#8:	H-2	1000 m/s	Kr-84	–154.3 m/s	(front)

"A hydrogen molecule could also hit the neon-20 atom from either the front or back," Pico said. "That's Lines 3 and 4 of the green-right column.

"The same is true for hydrogen colliding with argon, and with krypton," Hectii added. "Which means, hydrogen can be involved in eight different types of collisions—not to mention hitting at funny angles."

"Exactly," Proge said, as he activated another table. "There are at least six more types of helium-4 collisions, four more types of neon-20 collisions, and two more types of argon-40 collisions. The starting data for the remaining collisions looks like this:"

E: Starting Velocities for Other Atoms

	Mass	V-L1 (Left)	Mass	V-R1 (Right)	
#9:	He-4	707.11 m/s	Ne-20	316.23 m/s	(back)
#10:	He-4	707.11 m/s	Ne-20	–316.23 m/s	(front)
#11:	He-4	707.11 m/s	Ar-40	223.61 m/s	(back)
#12:	He-4	707.11 m/s	Ar-40	–223.61 m/s	(front)
#13:	He-4	707.11 m/s	Kr-84	154.30 m/s	(back)
#14:	He-4	707.11 m/s	Kr-84	–154.30 m/s	(front)

	Mass	V-L1 (Left)	Mass	V-R1 (Right)	
#15:	Ne-20	316.23 m/s	Ar-40	223.61 m/s	(back)
#16:	Ne-20	316.23 m/s	Ar-40	–223.61 m/s	(front)
#17:	Ne-20	316.23 m/s	Kr-84	154.30 m/s	(back)
#18:	Ne-20	316.23 m/s	Kr-84	–154.30 m/s	(front)
#19:	Ar-40	223.61 m/s	Kr-84	154.30 m/s	(back)
#20:	Ar-40	223.61 m/s	Kr-84	–154.30 m/s	(front)

"I count 40 molecules, and a total of 20 collisions," Pico said admiringly, "now what?"

"Remember, the goal is to see if your two-force collision equations will work for molecular collisions," Proge reiterated. "Now, what were your equations for predicting the final velocities?"

"There were two," Pico said, as she thumb-scrolled through the notes on her handheld touchscreen. "The equation to predict the final velocity of the left object was:"

$$v_{2L} = 2\left[\frac{(m_L v_{1L} + m_R v_{1R})}{(m_L + m_R)}\right] - v_{1L}$$

was written on their screens.

"And if I put in the numbers for our first hydrogen-helium collision they look like this:"

$$= 2\left[\frac{(2\ amu_L \times 1000\ m/s_{1L} +\ 4\ amu_R \times\ 707.11\ m/s_{1R})}{(2\ amu_L +\ 4\ amu)}\right] - 1000\ m/s_{1L}$$

Hydrogen: $\boldsymbol{v_{2L} = 609.48\ m/s}$

was written on their screens.

"And the equation for the right side of the collision, the helium atom, will look like this:

$$v_{2R} = 2\left[\frac{(m_L v_{1L} + m_R v_{1R})}{(m_L + m_R)}\right] - v_{1R}$$

$$= 2\left[\frac{(2\ amu_L \times 1000\ m/s_{1L} +\ 4\ amu_R \times\ 707.11\ m/s_{1R})}{(2\ amu_L +\ 4\ amu)}\right] - 707.11\ m/s_{1R}$$

Helium: $\boldsymbol{v_{2R} = 902.37\ m/s}$

was written on their displays.

"Fabulous," Proge complemented. "Give me a moment, and I'll program your equations into the computer."

"Hi, Grandpa, great to see you again," Tera sang out, as she entered the living room, looked over Pico's shoulder, and waved at the computer camera. "I received Hectii's text and came as quick as I could. How's Grandma?"

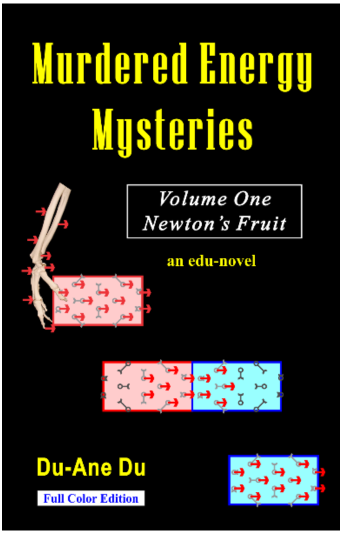
"Wonderful! We've had a lot of rain this week, and Aaret is tending to the flowers," Proge jovially replied, as he reached up and rotated the camera. The image on the display panned to show a series of blossoming bushes and trees—a colorful cloth hat bobbed above a rose bush.

"Those flowers are gorgeous," Pico said.

"I bet the fragrances are amazing," Tera said longingly.

"Look girls," Proge said expressively, as a data table appeared on one side of the screen. "the computer has finished making a table of the final velocities."

Excerpted from:



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F: Final Velocities After Collisions:

	Mass	V-L2 (Left)	Mass	V-R2 (Right)
#1:	H-2	609.48 m/s	He-4	902.37 m/s
#2:	H-2	–1276.15 m/s	He-4	430.96 m/s
#3:	H-2	–243.22 m/s	Ne-20	440.55 m/s
#4:	H-2	–1393.15 m/s	Ne-20	–76.92 m/s
#5:	H-2	–478.84 m/s	Ar-40	297.55 m/s
#6:	H-2	–1330.69 m/s	Ar-40	–107.08 m/s

#7:	H-2	–652.07 m/s	Kr-84	193.63 m/s
#8:	H-2	–1254.91 m/s	Kr-84	–100.61 m/s
#19:	Ar-40	129.71 m/s	Kr-84	199.02 m/s
#20:	Ar-40	–288.4 m/s	Kr-84	89.51 m/s

	Mass	**V-L2 (Left)**	**Mass**	**V-R2 (Right)**
#9:	He-4	55.64 m/s	Ne-20	446.52 m/s
#10:	He-4	–998.46 m/s	Ne-20	24.88 m/s
#11:	He-4	–171.98 m/s	Ar-40	311.52 m/s
#12:	He-4	–985.11 m/s	Ar-40	–54.39 m/s
#13:	He-4	–348.25 m/s	Kr-84	204.56 m/s
#14:	He-4	–937.4 m/s	Kr-84	–75.99 m/s
#15:	Ne-20	192.74 m/s	Ar-40	285.36 m/s
#16:	Ne-20	–403.56 m/s	Ar-40	136.28 m/s
#17:	Ne-20	–54.65 m/s	Kr-84	216.58 m/s
#18:	Ne-20	–443.86 m/s	Kr-84	26.67 m/s

"Awesome," Tera said, "that's a huge data table. What's it for?"

"Grandpa was showing us how to use an ideal gas to test if Pico's two-force collision equations are valid for atoms and molecules," Hectii revealed. "That'll help us comprehend what temperature and heat are."

"The velocities are all different," Pico bemoaned. "What does that tell us, Grandpa?"

"Remember Graham's law?" Proge hinted encouragingly.

"You mean the root-mean-square part?" Pico said. "Should the root-mean-square of the velocities still be proportional to the masses?"

"Precisely," Proge affirmed. "Examine the eight hydrogen molecules first."

"Will do," Pico said, as she began keying. "The rms-average velocity of hydrogen was originally 1 000 m/s. Then the molecules collided with other molecules. Now the rms-average velocity is:" ("Because of the squares, I can leave the negative signs off," she muttered to herself.)

$$\sqrt[2]{\frac{609.48^2 + 1276.15^2 + 243.22^2 + 1393.15^2 + 478.84^2 + 1330.69^2 + 652.07^2 + 1254.91^2}{8}}$$

Hydrogen rms-average velocity: 1 000.00 m/s.
appeared on their displays.

"It's the same as the original, both are 1 000 m/s!" Hectii loudly asserted. "That means Pico's equation was 100% accurate."

"Let's look at the helium data."

"Before the collisions," Hectii said, "the rms-average velocity of the helium atoms was 707.1 m/s. Let me do the calculations for the helium velocities, after the collisions. They'll look like this:

$$\sqrt[2]{\frac{902.37^2+430.96^2+55.64^2+998.46^2+171.98^2+985.11^2+348.25^2+937.40^2}{8}}$$

Helium rms-average velocity: 707.11 m/s.
appeared on their displays.

"Helium had starting and ending velocities of 707.1 m/s—that matches too," Pico said excitedly. "I'll try neon next. Before the collisions, the neon-20 atoms had an rms-average velocity of 316.23 m/s. If I put the new neon velocities into the equation, it'll look like this:"

$$\sqrt[2]{\frac{40.55^2+76.92^2+446.52^2+24.88^2+192.74^2+403.56^2+54.65^2+443.86^2}{8}}$$

Neon-20 rms-average velocity: 316.23 m/s.
appeared on their displays.

"This is amazing," Tera whispered. "Neon had a starting and ending rms-average velocity of 316.23 m/s. These final velocities are matching the original data, exactly! That suggests Pico's two-force collision equation is 100% accurate!"

"Argon had a starting rms-average velocity of 223.61 m/s. Let's see if it matches too," Hectii said, as she methodically keyed numbers into a pink data-input ball:

$$\sqrt[2]{\frac{297.55^2+107.08^2+311.52^2+54.39^2+285.36^2+136.28^2+129.71^2+288.40^2}{8}}$$

Argon-40 rms-average velocity: 223.61 m/s.
appeared on their displays.

"This is stunning," Tera pronounced. "Chip, link to my handheld, and let me do one. What was the starting rms-average velocity of krypton?"

"154.30 m/s," Pico said, as Tera started thumb-keying in the final-velocity values for krypton:

$$\sqrt[2]{\frac{193.63^2 + (-100.61)^2 + 204.56^2 + (-75.99)^2 + 216.58^2 + 26.67^2 + 199.02^2 + 89.51^2}{8}}$$

Krypton-84 rms-average velocity: 154.30 m/s.

appeared on their displays.

"It matches," Tera said victoriously. "The ending velocities are in the same root-mean-square relationship they were in before the collisions. But what does all of this actually mean?"

"Pico? Hectii?" Proge said, pausing before giving a hint. "Start with heat, does this statistical experiment show you something about heat?"

"Heat and temperature must be related to enclosed molecular momentum," Hectii put forth.

"At a given temperature," Pico said warily, "the rms-average velocities of molecules are always in a square-root relationship we could call a Graham's velocity-ratio."

"Graham's velocity-ratio is caused by the two-force collision model," Tera said. "And the two-force collision model is based on changes in molecular momentum and Newton's law of action-reaction."

"At a given temperature, each molecule has a different momentum, based on Graham's velocity-ratio," Hectii began to deduce. "Which means, temperature isn't simply a measure of the amount of atomic/molecular momentum in an object."

Pico's eyes widened with sudden comprehension. "But heat is… I know, heat must be the transfer of invo-atomic s-momentum to an object. If you add heat to a substance, the molecules and atoms gain momentum and fly faster."

"That makes sense," Tera said, nodding her head.

"And making something colder involves the removal of molecular momentum," Hectii expounded. "It sounds like we're getting close to uncovering a Space-sci Sherlock's scientific fact about heat.

"Wonderful," Proge gently celebrated. "Now, can you figure out what temperature is?"

"First, we need to know what the different molecules have in common," Pico said.

"Equalized molecular momentum," Hectii observed. "During the collisions, the hydrogen forwarded part of its momentum to the other atoms, and the other atoms forwarded part of their momentum to the hydrogen molecules."

"But only part of their momentum," Pico countered. "The amount of atomic momentum transferred is determined by the two-force collision model and Graham's velocity-ratios."

Hectii nodded. "Which means we'll have to change our definition of what equalized temperature is. How's this, equalized temperature occurs when the contac- ρ-force-rate of each of the molecules and atoms establishes a Graham's velocity-ratio relationship."

"Let's see if I understood that," Tera said tentatively. "If one material has more momentum than the Graham's ratio suggests, then during the two-force collisions, the extra atomic momentum will gradually migrate to the object which has less atomic/molecular momentum than the ratio suggests."

"Exactly," Hectii praised.

* * *

CONCLUSION: More research needs to be done into the relationship between mechanical energy and other theoretical forms of energy. Many common beliefs may actually be philosophical myths.

Murdered Energy Mysteries seeks to increase understanding of the various forms of momentum and momentum transfer, as well as the various forms of energy and energy transfer. The lack of understanding on the part of the scientific community is substantial, and more research needs to be done.

—Du-Ane Du, author of the edu-novel *Murdered Energy Mysteries* (Amazon, Kindle, e-book 2018, paperback 2021.)

More information, see:
Murdered Energy Mysteries,
an edu-novel

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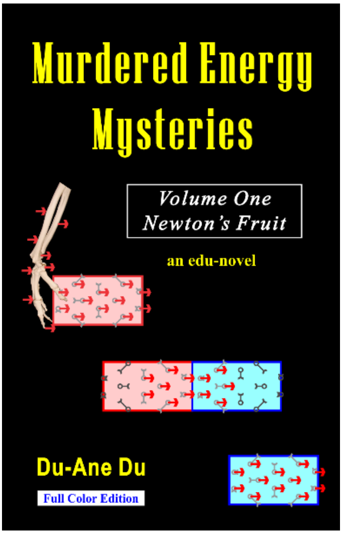

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