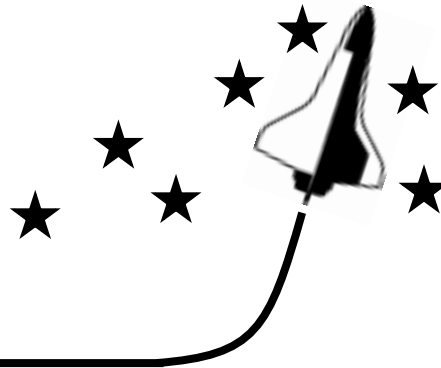


FACULTY NOTES

The LTAs and Spinoffs are designed so that each professor can implement them in a way that is consistent with his/her teaching style and course objectives. This may range from using the materials as out-of-class projects with minimal in-class guidance to doing most of the work in class. The LTAs and Spinoffs are amenable to small group cooperative work and typically benefit from the use of some learning technology. Since the objective of the LTAs and Spinoffs is to support the specific academic goals you have set for your students, the Faculty Notes are not intended to be prescriptive. The purpose of the Faculty Notes is to provide information that assists you to take full advantage of the LTAs and Spinoffs. This includes suggestions for instruction as well as answers for the exercises.



FACULTY NOTES

LTA 11

Helium Usage at Kennedy Space Center

Solutions

- 1) First use Boyle's Law to determine the volume at 3500 psia.

$$\begin{aligned}P_1 V_1 &= P_2 V_2 \\(14.7 \text{ psia})(70,000 \text{ scf}) &= (3500 \text{ psia})V_2 \\294 \text{ ft}^3 &= V_2\end{aligned}$$

Since we know that each railcar holds 1050 ft^3 ,

$$\frac{1050 \text{ ft}^3}{294 \text{ ft}^3 \text{ per day}} = 3.57 \text{ days}$$

Thus, the gaseous helium in one railcar will last 3.57 days (or they will use approximately 2 railcars of helium per week).

- 2) Here we use Boyle's Law once more to determine the volume at 3500 psia.

$$\begin{aligned}P_1 V_1 &= P_2 V_2 \\(14.7 \text{ psia})(1,000,000 \text{ scf}) &= (3500 \text{ psia})V_2 \\4200 \text{ ft}^3 &= V_2\end{aligned}$$

KSC will use 4200 ft^3 of gaseous helium from a railcar. Each railcar holds 1050 ft^3 , so

$$\frac{4200 \text{ ft}^3}{1050 \text{ ft}^3 \text{ per railcar}} = 4 \text{ railcars}$$

- 3) There are several steps/conversions we have to perform.

- a) First convert all temperatures to the Kelvin scale.

$$\begin{aligned}C &= 5/9(F - 32) & K &= C + 273 \\ \Rightarrow C &= 5/9(70 - 32) & \Rightarrow K &= -271.5 + 273 \\ \Rightarrow C &= 21.1^\circ \text{ C} & \Rightarrow K &= 1.5\end{aligned}$$

and

$$\begin{aligned}K &= C + 273 \\ \Rightarrow K &= 21.1 + 273 \\ \Rightarrow K &= 294.1\end{aligned}$$

So $70^\circ \text{ F} = 294.1 \text{ K}$ and $-271.5^\circ \text{ C} = 1.5 \text{ K}$

Now use the appropriate gas laws to convert 70,000 scf to liters at 47 psia and 1.5 K, i.e., 70,000 ft³ @ 14.7 psia and 294.1 K ⇒ x liters @ 47 psia and 1.5 K.

b) First change 70,000 ft³ to an equivalent volume of liters:

$$\frac{7000 \text{ ft}^3}{1} \cdot \frac{0.0283 \text{ m}^3}{\text{ft}^3} \cdot \frac{1000 \text{ dm}^3}{\text{m}^3} \cdot \frac{1 \text{ liter}}{\text{dm}^3} = 1,981,000 \text{ liters}$$

Thus, 70,000 ft³ of gaseous helium @ 14.7 psia and 294.1 K is equivalent to 1,981,000 liters of liquid helium @ 14.7 psia and 294.1 K.

c) If we keep the temperature constant at 294.1 K (and since the mass remains unchanged), we can use Boyle's Law to find the volume of helium needed at 47 psia.

P₁ = 14.7 psia; P₂ = 47 psia; V₁ = 1,981,000 liters; V₂ = unknown

$$\begin{aligned} P_1 V_1 &= P_2 V_2 \\ (14.7 \text{ psia})(1,981,000 \text{ ft}^3) &= 47(V_2) \\ 619,589 \text{ liters} &= V_2 \end{aligned}$$

Thus, the volume of helium needed at 47 psia is 619,589 liters.

d) If we now leave the pressure constant at 47 psia (mass remains unchanged), we can use Charles' Law to determine the new volume.

V₁ = 619,589 liters; V₂ = ?; T₁ = 294.1 K; T₂ = 1.5 K

$$\begin{aligned} \frac{V_1}{T_1} &= \frac{V_2}{T_2} \\ \Rightarrow \frac{619,589}{294.1} &= \frac{V_2}{1.5} \\ \Rightarrow V_2 &= 3,160 \text{ liters} \end{aligned}$$

Thus, KSC uses approximately 3,160 liters of liquid helium for normal operations.

3) Since one liquid helium trailer holds approximately 42,000 liters, each tanker will last

$$42,000 \text{ liters} \cdot \frac{1 \text{ day}}{3160 \text{ liters}} = 13.3 \text{ days}$$

4) 70,000 scf of gaseous helium @ \$0.075 per scf results in \$5,250.

3,160 liters of liquid helium @ \$2.00 per liter results in \$6,320.

The gaseous helium is more cost effective than the liquid helium.

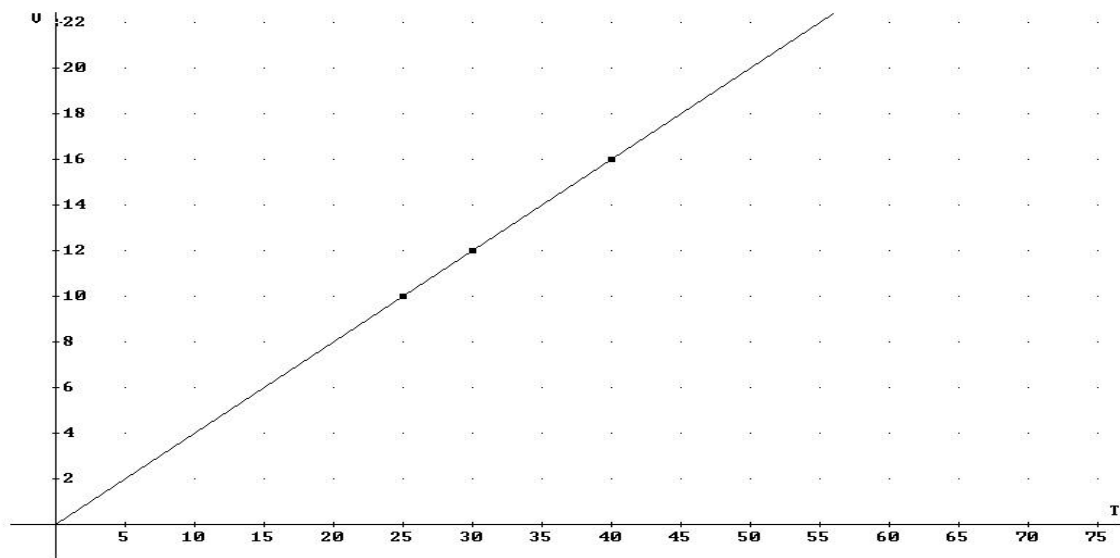
Mathematical Aside

Direct and Inverse Proportions

Solutions

Questions

- 1) $k = 0.4$ for each temperature/volume pair.
- 2)



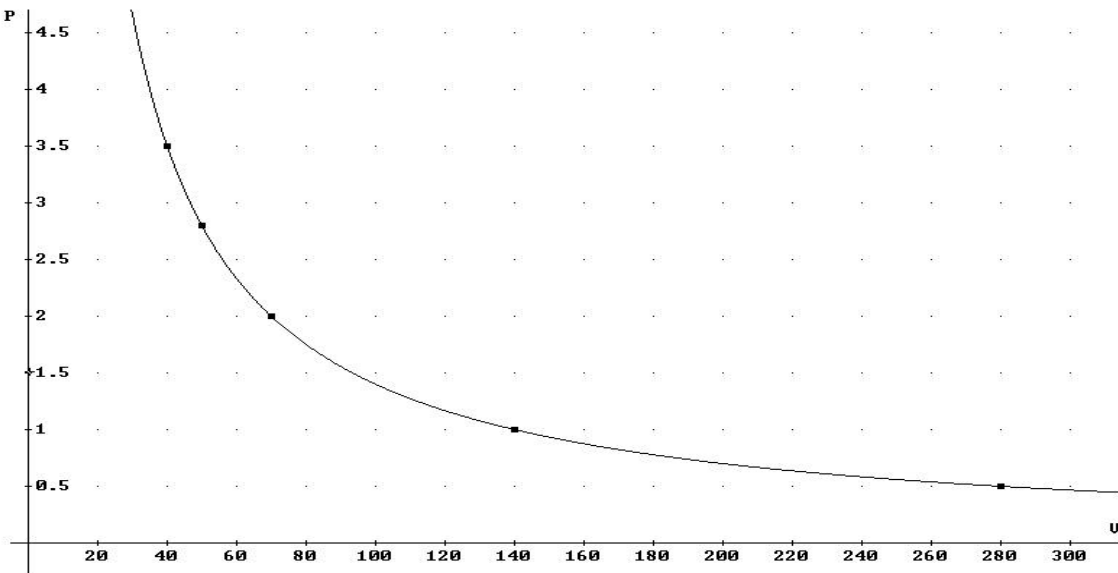
The shape of the graph is a straight line.

- 3) Since the volume divided by the temperature equals the constant 0.4 for each pair of data, the equation can be written as follows:

$$V = 0.4T \quad \text{or} \quad \frac{V}{T} = 0.4$$

- 4) $k = 140$ for each volume/pressure pair.

5)



Pressure approaches zero as volume becomes very large.

- 6) Since the product of the variables volume and pressure equals the constant 140 for each pair of data, the equation can be written as follows:

$$V \cdot P = 140 \quad \text{or} \quad P = \frac{140}{V}.$$

Exercises

- direct proportion
 - $k = 200$
 - $P = 200T$
- inverse proportion
 - $k = 200$
 - $M = \frac{200}{T}$
- direct proportion
 - $k = 3$
 - $y = 3x$
- inverse proportion
 - $k = 12$
 - $y = 12/x$

Mathematical Aside

The Gas Laws

Questions

- 1) The graph is linear and goes through the point $(0, 0)$, so it is a direct proportion.
- 2) $k = 6$
- 3) Notice that the pressure is very large when the volume approaches zero, and similarly the pressure is nearly zero when the volume is very large. This indicates that there is an inverse relationship between volume and pressure.

Mathematical Aside

Unit Analysis

Solutions

Exercises

1. a) 22.36 mph
b) 1.17 hours
2. a) 44.1 psia
b) 303.85 kPA
- 3) 14,524 ft²