

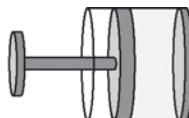
## 2015 AP® PHYSICS 2 FREE-RESPONSE QUESTIONS

3. (12 points, suggested time 25 minutes)

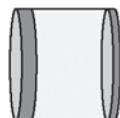
Students are watching a science program about the North Pole. The narrator says that cold air sinking near the North Pole causes high air pressure. Based on the narrator’s statement, a student makes the following claim: “Since cold air near the North Pole is at high pressure, temperature and pressure must be inversely related.”

- (a) Do you agree or disagree with the student’s claim about the relationship between pressure and temperature? Justify your answer.

After hearing the student’s hypothesis, you want to design an experiment to investigate the relationship between temperature and pressure for a fixed amount of gas. The following equipment is available.



Cylinder with Movable Piston



Cylinder with Fixed Lid

A cylinder with a movable piston, shown above on the left

A cylinder with a fixed lid, shown above on the right

Note: The two cylinders have gaskets through which measurement instruments can be inserted without gas escaping.

A pressure sensor

A basin that is large enough to hold either cylinder with a lot of extra room

A source of hot water

A source of mixed ice and water

A meterstick

A thermometer

A stopwatch

- (b) Put a check in the blank next to each of the items above that you would need for your investigation. Outline the experimental procedure you would use to gather the necessary data. Make sure the outline contains sufficient detail so that another student could follow your procedure.

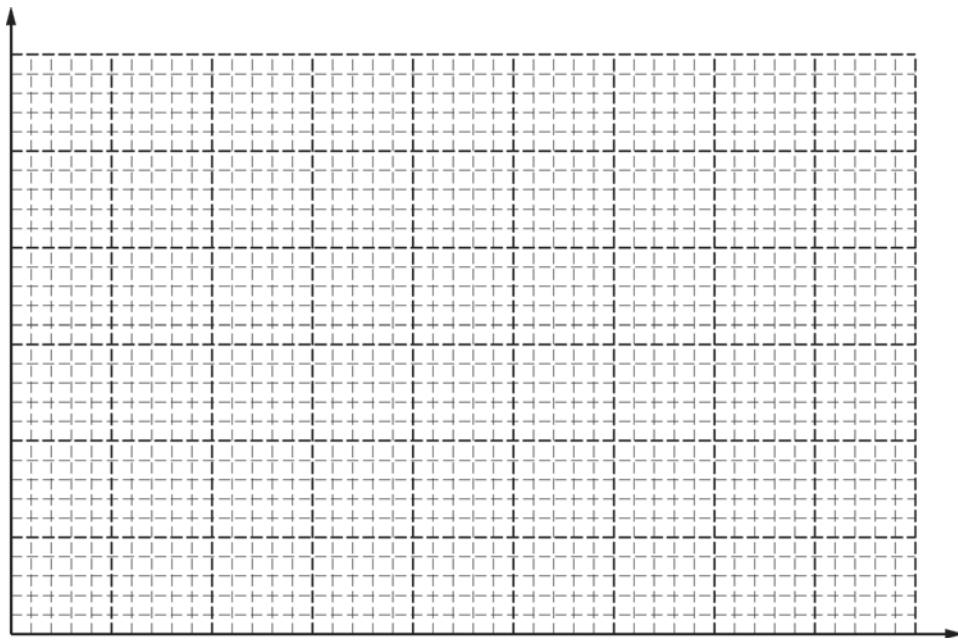
The table below shows data from a different experiment in which the volume, temperature, and pressure of a sample of gas are varied.

Trial Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Volume ( $\text{cm}^3$ )	10.0	5.0	4.0	3.0	5.0	4.0	10.0	5.0	3.0	4.0	5.0	10.0	3.0	5.0
Pressure (kPa)	100	200	250	330	220	270	110	230	380	290	240	120	420	250
Temperature ( $^\circ\text{C}$ )	0	0	0	0	20	20	20	40	40	40	60	60	70	70

- (c) What subset of the experimental trials would be most useful in creating a graph to determine the relationship between temperature and pressure for a fixed amount of gas? Explain why the trials you selected are most useful.

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- (d) Plot the subset of data chosen in part (c) on the axes below. Be sure to label the axes appropriately.  
Draw a curve or line that best represents the relationship between the variables.



- (e) What can be concluded from your curve or line about the relationship between temperature and pressure?

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**Question 3**

**12 points total**

**Distribution  
of points**

(a) 2 points

For indicating that the ideal gas law ( $PV = nRT$  or  $PV = NkT$ ) gives the relevant relationship between pressure and temperature of a gas and attempting to use it to support some reasoning 1 point

For indicating that the volume and number of moles (or particles) of gas are held constant 1 point

Note: The student will not be penalized for not specifying that pressure and temperature are only directly proportional when the temperature is measured in Kelvin.

*Alternate Solution*

*Alternate Points*

*For indicating that the density of a sample of gas increases as its temperature decreases (if the pressure and number of moles or molecules of gas are held constant), and a sample of denser gas will sink below samples of gas that are less dense* 1 point

*For indicating that the gas near the North Pole is not a closed system and its pressure will increase as additional sinking gas molecules are added to it* 1 point

(b) 4 points

For selecting one of the cylinders and indicating or implying that volume is held constant 1 point

For selecting all the equipment described in the procedure and no extraneous equipment 1 point

For describing a method of measuring the temperature of the enclosed gas 1 point

For describing a method for measuring the pressure at more than just two temperatures 1 point

Example: Insert the thermometer and pressure sensor in the gasket to measure the gas temperature and pressure. Place the cylinder in the bath with hot (cold) water. Take measurements periodically as the bath water cools (heats) over time.

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**Question 3 (continued)**

**Distribution  
of points**

(c) 2 points

For selecting a set of trials in which volume is held constant and explaining that the volume must be held constant to test the relationship between pressure and temperature

1 point

For selecting trials in which volume is  $5.0 \text{ cm}^3$ , and explaining that there are the most trials for this volume, and the most trials will result in the most reliable test

1 point

*Alternate Solution*

*Alternate points*

*For selecting the full set of trials and explaining that the effect of changing volume on the relationship between pressure and temperature can be taken into account by multiplying pressure by volume (or plotting  $P/T$  as a function of  $1/V$ , etc.)*

1 point

*For explaining that selecting the most trials will result in the most reliable test OR that selecting the widest range of pressure values will result in the most precise determination of the proportionality constant relating pressure and temperature*

1 point

(d) 3 points

For plotting  $P$  as a function of  $T$  (or  $T$  as a function of  $1/P$ , etc.) OR plotting  $PV$  as a function of  $T$  (or  $P$  as a function of  $V/T$ , etc.) for each trial selected in part (c)

1 point

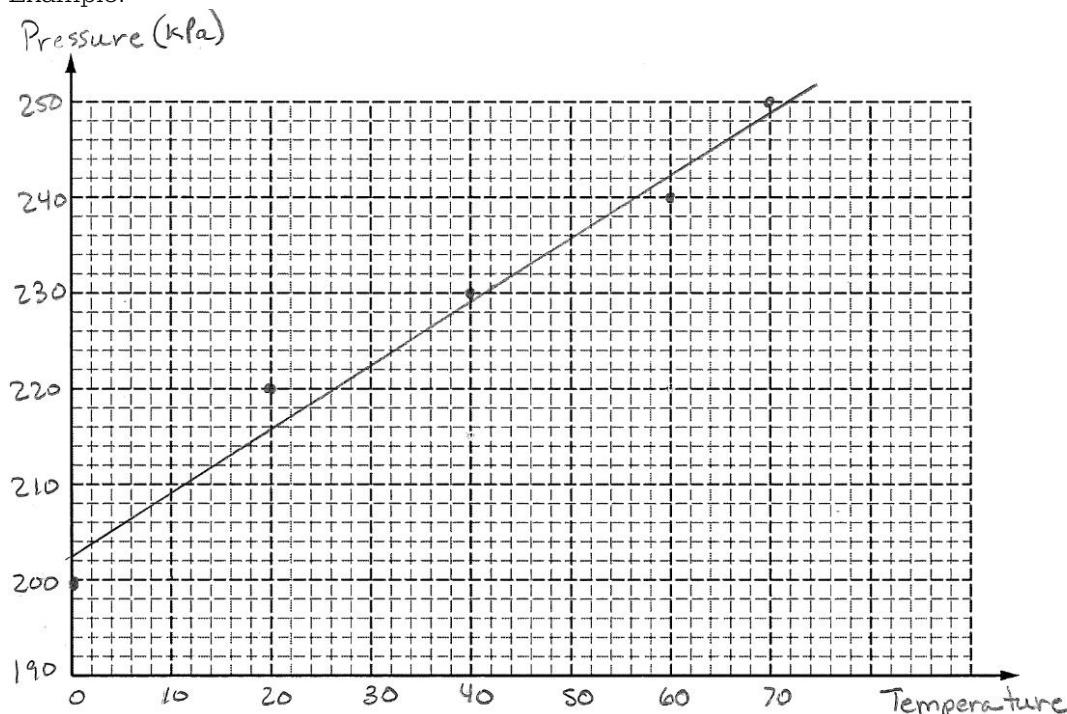
For appropriate axis labels with units and appropriate scales

1 point

For drawing an appropriate best-fit line or curve

1 point

Example:



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**Question 3 (continued)**

**Distribution  
of points**

- (e) 1 point

For correctly describing the relationship depicted in part (d)  
Examples:

The relationship between  $P$  and  $T$  is linear.  
The relationship between  $P$  and  $V/T$  is hyperbolic.

1 point