AP® PHYSICS 2
2015 SCORING GUIDELINES

Question 3

12 points total

<div align="right">

Distribution of points

</div>

(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.
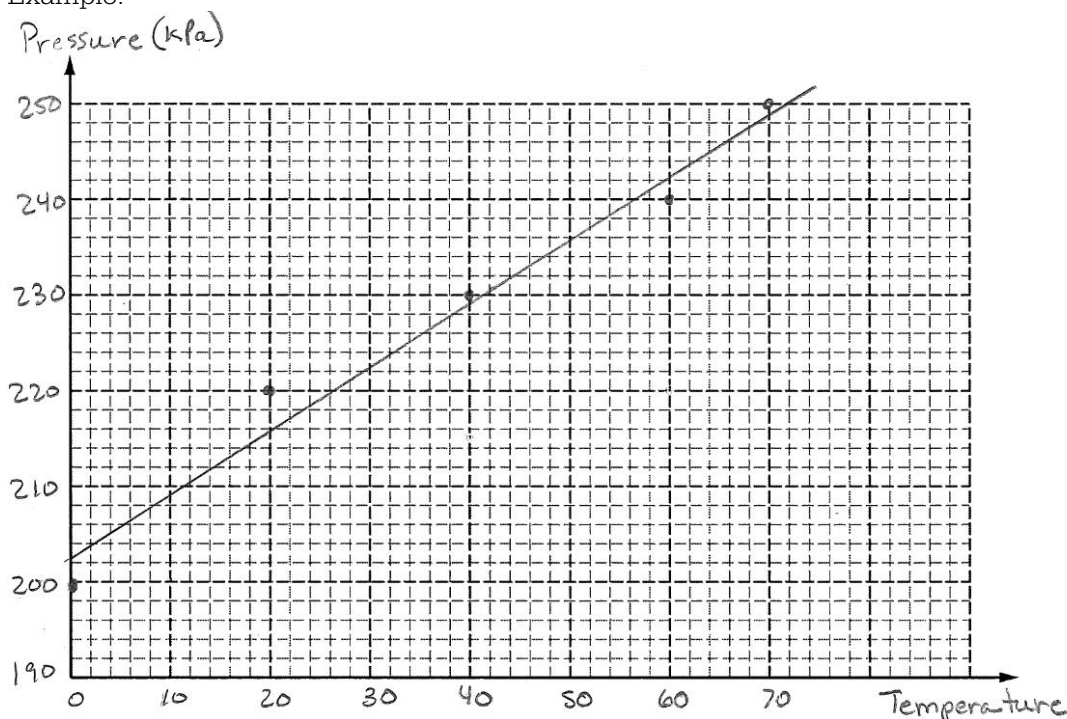
Distribution of points

(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 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   *1 point*
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.)

For explaining that selecting the most trials will result in the most reliable test OR   *1 point*
that selecting the widest range of pressure values will result in the most
precise determination of the proportionality constant relating pressure and
temperature

(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:

<div align="right">Distribution
of points</div>

(e)   1 point

For correctly describing the relationship depicted in part (d)   1 point
Examples:
     The relationship between P and T is linear.
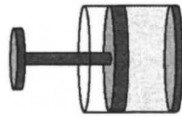   The relationship between P and V/T is hyperbolic.

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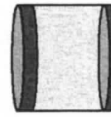
(a) Do you agree or disagree with the student's claim about the relationship between pressure and temperature? Justify your answer.

I do not agree with the students claim. Using the ideal gas law PV=nRT, P and T are directly related, not inversely.

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 source of mixed ice and water
✓ A basin that is large enough to hold   ___ A meterstick
    either cylinder with a lot of extra room   ✓ A thermometer
✓ A source of hot water   ✓ 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.

Fill the basin with the hot water. Place a thermometer and a pressure sensor in the fixed cylinder. Place the cylinder in the basin of hot water. Every minute, record the temperature and pressure of the gas in the cylinder. Repeat for a cold water bath, with the gas originally beginning at room temperature for both cases.

GO ON TO THE NEXT PAGE.

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 (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 (°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.

Trials 2,5,8, 11, and 14 are useful. The volume is constant for these values, so the only unknown variables being tested are temperature and pressure. Also, there are more data points, which can reduce uncertainty.

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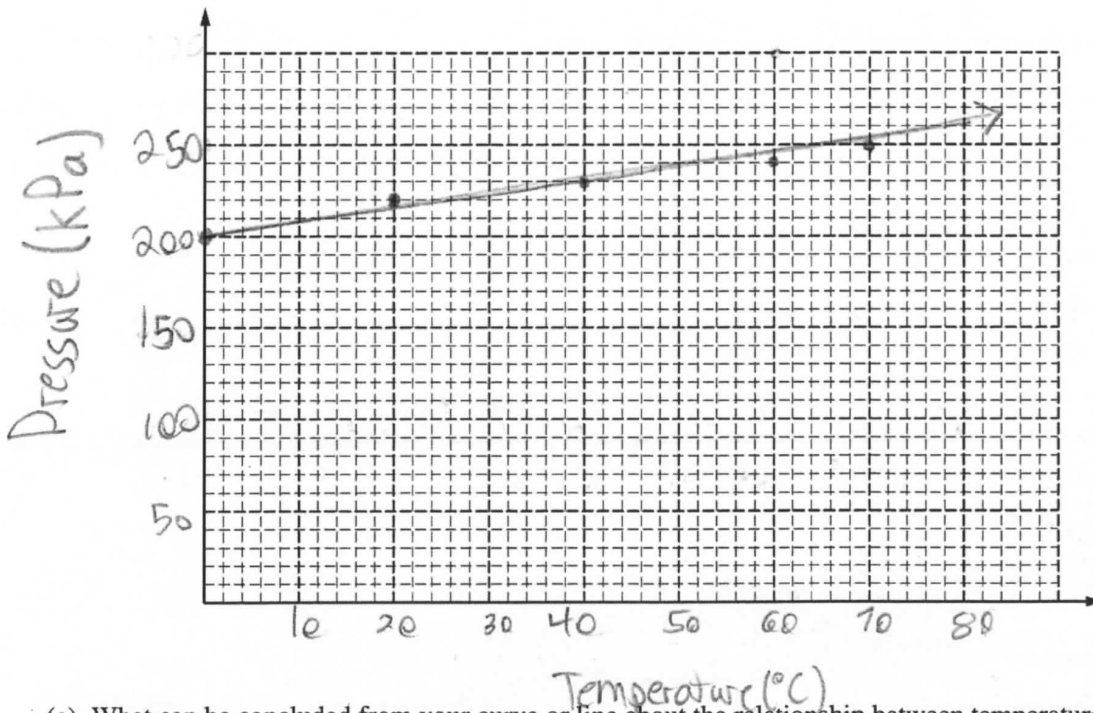
(e) What can be concluded from your curve or line about the relationship between temperature and pressure?

The relationship between temperature and pressure is linear, thus they are directly related.
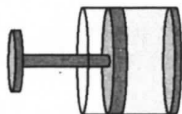
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3. (12 points, suggested time 25 minutes)

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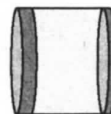
(a) Do you agree or disagree with the student's claim about the relationship between pressure and temperature? Justify your answer.

> I disagree with the student's claim that there is an inverse relationship between pressure and temperature. According to the ideal gas law, which is $PV = nRT$, an increase in pressure would increase the temperature of the gas, therefore meaning that temperature and pressure are directly related.

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 student will place the cylinder with fixed lid (which has a set amount of gas in terms of volume) in a basin filled with hot water. After about 5 minutes, the student shall take the cylinder out of the basin and measure its pressure and temperature using the pressure sensor and thermometer, respectively. The student shall repeat this process for three trials to ensure accuracy. Then the student shall replace the hot water in the basin with mixed ice and cold water and repeat the experiment again, collecting the data in another three trials.

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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 (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 (°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.

Trial number 2, 5, 8, 11, and 14 are useful for creating the graph because in determining the relationship between temperature and pressure, one must keep the volume of the sample of gas constant, as it is not a variable. In this case, these five trials were useful as the volume for each trial was kept constant (5.0 cm³)

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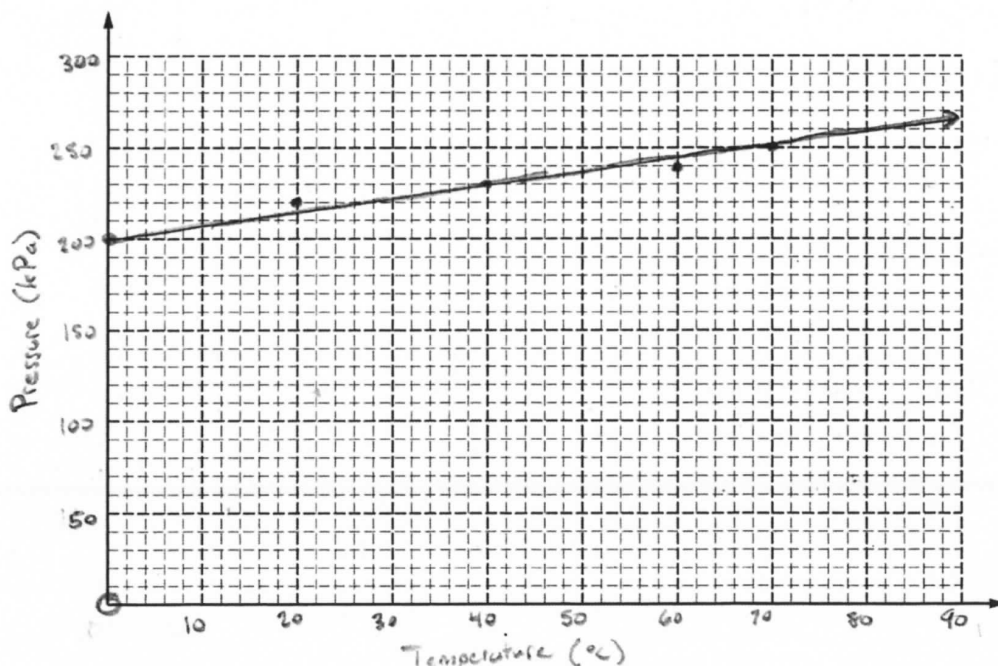
(e) What can be concluded from your curve or line about the relationship between temperature and pressure?

An increase in temperature causes an increase in pressure at about a constant rate. As a result, there is a direct relationship between temperature and pressure.
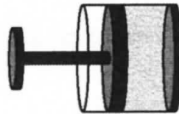
GO ON TO THE NEXT PAGE.

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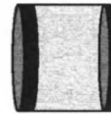
(a) Do you agree or disagree with the student's claim about the relationship between pressure and temperature? Justify your answer.

I disagree with the student's claim because ~~pressure and temperature~~ ~~are~~ as temperature rises, pressure increases, and as it decreases, pressure decreases. ~~scribble~~

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.

1. Fill the basin with hot water and record the temperature of the water. Record the initial ~~pressure~~ height of the piston in the
2. ~~Place the cylinder in the basin and record the~~ both cylinder with a meterstick, and then place the cylinder in the basin.
3. After 30 seconds, record the height of the piston.
4. Add the mixed ice water into the basin and let it settle, record the new temperature.
5. After 30 seconds, record the new height of the piston.

The increase or decrease in the height of the piston signifies the increase or decrease in the pressure inside the cylinder.

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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 (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 (°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. The most useful trials would be trials 2, 5, 8, 11, and 14 because they show how when temperature increases, the pressure increases as well, and the volume of these trials is the same, so it is for a fixed amount of gas.

(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.
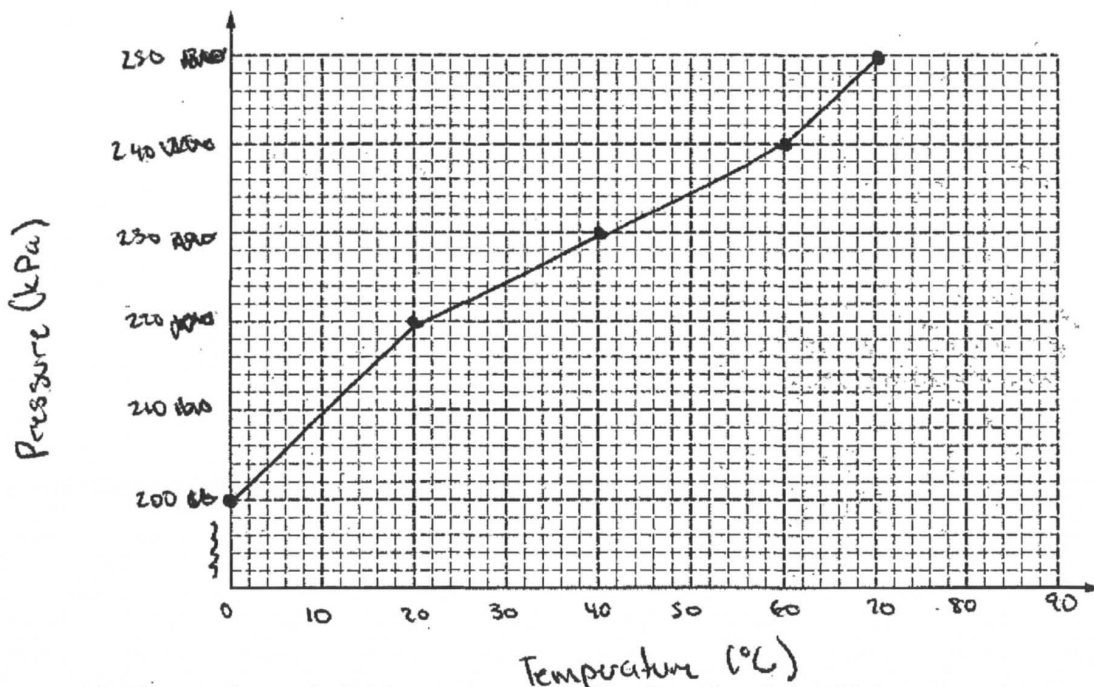
(e) What can be concluded from your curve or line about the relationship between temperature and pressure? It can be concluded that as the temperature an increases of a gas increases, then the pressure increases.

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Question 3

Overview

This was a thermodynamics lab design problem that required students to consider the ideal gas law and relationship between state variables. Students were asked to design an experiment to explore the relationship between pressure and temperature, and to plot and interpret results.

Sample: P2Q3 A
Score: 11

This response is clear and very readable. The only point not earned was in part (a), where there is no mention of holding volume or amount of gas constant.

Sample: P2Q3 B
Score: 7

Part (a) earned 1 point for using the ideal gas law to indicate the relationship between pressure and temperature. Part (b) earned 2 points. The cylinder with fixed volume was selected, and a reference to the constant volume was made in the description. All the equipment described in the procedure was selected. There is no clear indication of where the temperature and pressure were measured, which was required since many students measured the temperature of the water and presumably assumed the gas had the same temperature. Multiple measurements are taken at each of the hot and cold temperatures, but only at these two temperatures. Part (c) earned 1 point for selecting the set of data where the volume was held constant at 5 cm^3. Part (d) earned full credit, and part (e) earned no credit.

Sample: P2Q3 C
Score: 4

Part (a) earned no credit. Part (b) earned 1 point for using all the equipment that was chosen. Part (c) earned 1 point for picking a set of data with the same volume. Part (d) earned 2 points, for graphing pressure as a function of temperature and correctly scaling and labeling the axes. Part (e) earned no credit.