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AP PHYSICS 2

AP物理II 新样题

「2021 版本」

有干货 x 有陪伴 x 有进步

AP Physics 2

TestDaily荣誉出品

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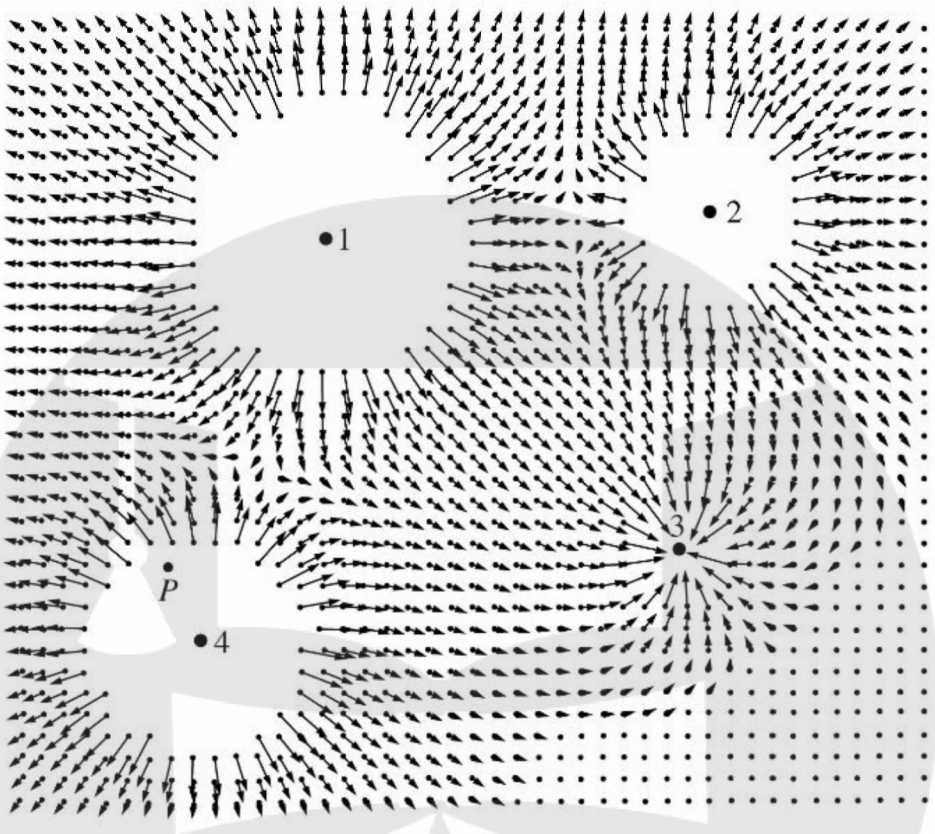
Section I: Multiple-Choice Question-Part 1

Questions 1 through 2 refer to the following material.



The figure shows the electric field in a region surrounding four charged particles, labeled 1, 2, 3, and 4, that are held in place. (Vectors with very large magnitude are not shown.)

1. A small positive test charge is held at point P. Which of the following is closest to the direction of the force exerted on the test charge?

A. 

B. 

C. 

D. 

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2. Which of the following indicates the particles with charges of the greatest and least magnitude?

A.

Greatest	Least
4	2

B.

Greatest	Least
3	1

C.

Greatest	Least
2	4

D.

Greatest	Least
1	3

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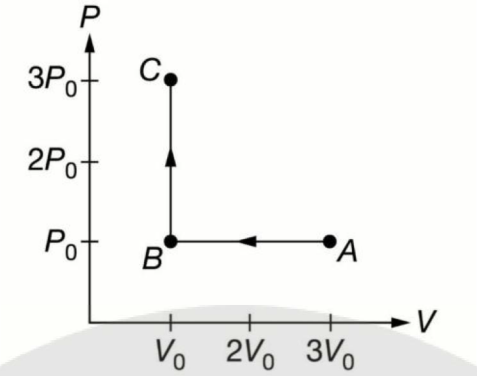
Questions 3 through 4 refer to the following material.



A sealed cylinder with a moveable piston contains ***N*** molecules of an ideal gas. The gas is initially in state ***A*** shown on the ***PV*** diagram, where ***P*** is pressure and ***V*** is volume. The gas is then taken through the two processes shown.

3. Which of the following correctly ranks the average speed U of the molecules in states A, B, and C?

A. $(v_B = v_C) > v_A$

B. $v_C > v_B > v_A$

C. $(v_A = v_C) > v_B$

D. $v_B > (v_B = v_C)$

4. Which of the following correctly ranks the magnitude of the force ***F*** the gas exerts on the piston in states A, B, and C?

A. $F_A > F_C > F_B$

B. $F_C > F_B > F_A$

C. $(F_A = F_C) > F_B$

D. $F_C > (F_A = F_B)$

From Here, Go Anywhere
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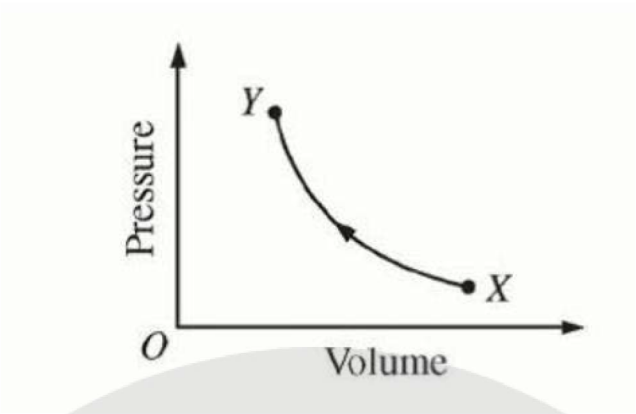

5. The graph shows the pressure as a function of volume for a sample of gas that is taken from state X to state Y at constant temperature.

Which of the following indicates the sign of the work done on the gas, and whether thermal energy is absorbed or released by the gas during this process?

A.

Work Done	Thermal Energy
Positive	Absorbed

B.

Thermal Energy	Work Done
Positive	Released

C.

Thermal Energy	Work Done
Negative	Absorbed

D.

Work Done	Thermal Energy
Negative	Released

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6. A student is asked to use the steps listed below to induce a positive charge on an aluminum soda can. In what order could the steps be done to accomplish the task? Select two answers.

Step W: Bring a negatively charged rod near, but not touching, the can.

Step X: Ground the can.

Step Y: Remove the ground from the can.

Step Z: Move the charged rod away from the can.

☐W, X, Y, Z

☐W, X, Z, Y

☐X, W, Y, Z

☐X, W, Z, Y

7. A tunnel has two openings, with one opening a few meters higher than the other. If air moves past the higher opening at a greater speed than air moves past the lower opening, which of the following describes what happens inside the tunnel? Select two answers.

☐Air moves from the higher opening toward the lower opening.

☐Air moves from the lower opening toward the higher opening.

☐The pressure near the higher opening is greater than the pressure near the lower opening.

☐The pressure near the lower opening is greater than the pressure near the higher opening.

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8. An ideal gas may be taken from one state to another state with different pressure, volume, and temperature along several different paths. Quantities that will always be the same for this process, regardless of which path is taken, include which of the following? Select two answers.

☐The change in internal energy of the gas.

☐The energy exchanged between the gas and its surroundings.

☐The work done by the gas.

☐The change in temperature of the gas.

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Section I: Multiple-Choice Question-Part 2

1. Water of density 1000 kg/m3 is pumped through a straight, horizontal hose and out a nozzle that has an opening with a cross-sectional area 10 times smaller than that of the hose. The water exits the nozzle at a speed of 10 m/s. The difference between the pressure of the fluid when it is in the hose near the pump and as it exits the nozzle is

A. 4.5×10^{3} Pa

B. 4.95×10^{4} Pa

C. 9.9×10^{4} Pa

B. 4.95×10^{6} Pa

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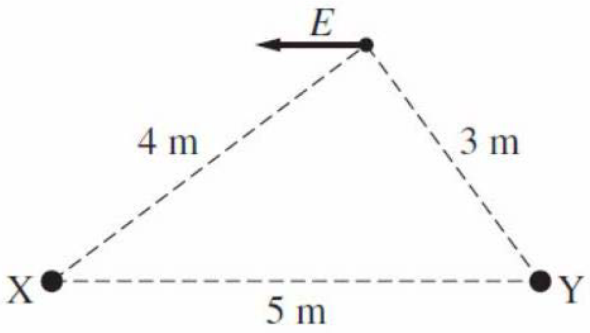

2. Two charged spheres, X and Y, are held fixed at two vertices of a triangle, as shown. The direction of the electric field E at the third vertex due to the two spheres is also shown.

Which of the following correctly indicates the sign of the charges on the spheres?

A.

Sphere X	Sphere Y
Positive	Positive

B.

Sphere X	Sphere Y
Positive	Negative

C.

Sphere X	Sphere Y
Negative	Positive

D.

Sphere X	Sphere Y
Negative	Negative

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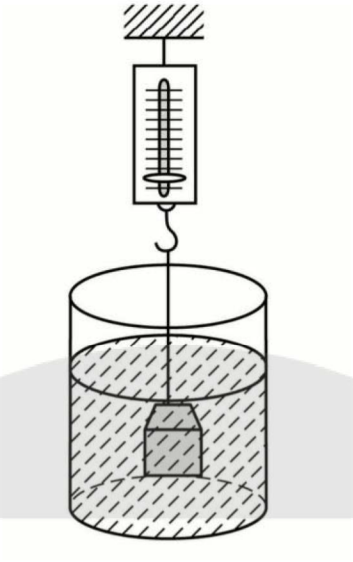

3. The figure shows an object of mass 0. 4 kg that is suspended from a scale and submerged in a liquid. If the reading on the scale is 3 N, then the buoyant force that the fluid exerts on the object is most nearly

A. 1. 3N

B. 1. 0N

C. 0. 75N

D. 0. 33 N

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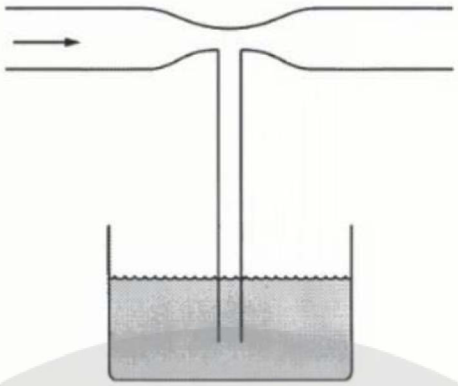

4. A T-shaped tube with a constriction is inserted in a vessel containing a liquid, as shown in the figure.

What happens if air is blown through the tube from the left, as shown by the arrow in the figure?

A. The liquid level in the tube rises to a level above the surface of the liquid surrounding the tube.

B. The liquid level in the tube falls below the level of the surrounding liquid.

C. The liquid level in the tube does not change.

D. The liquid level in the tube depends on the speed at which the air flows.

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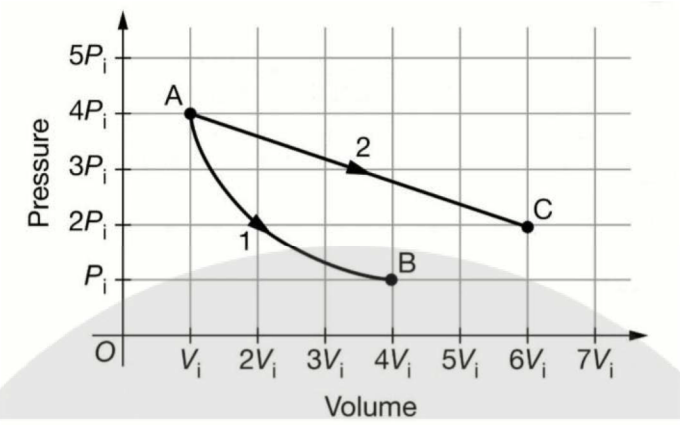
Section II: Free-Response Question



1. A sample of monatomic ideal gas is confined in a cylinder with a frictionless piston. The gas is taken through two thermal processes (process 1 and process 2), as shown.

a. Does the graph indicate that the process that takes the gas from state A to state B is a constant temperature process? Justify your answer using details from the graph.

b. Is the internal energy of the gas in state A greater than, less than, or equal to the internal energy of the gas in state B? Justify your answer.

c. Consider process 2, where the gas is taken from state A to state C. At which of the labeled states, A or C, is the average kinetic energy of the molecules larger? Justify your answer using specific values from the graph.

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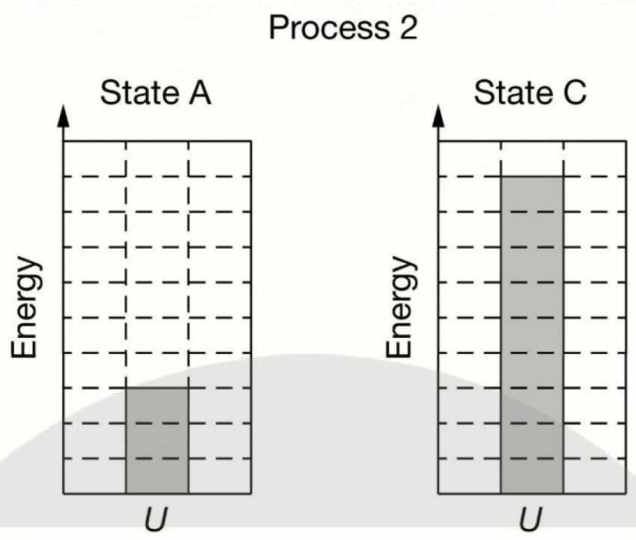
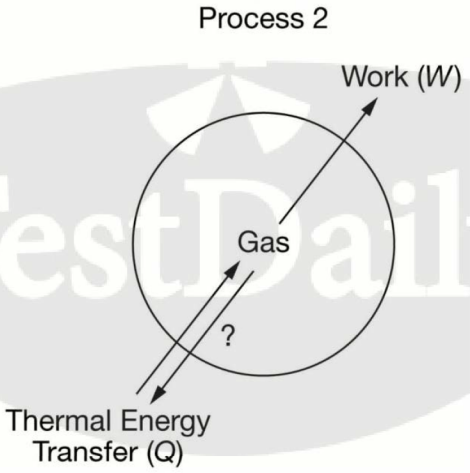


A student draws the correct bar charts shown representing the internal energy U of the gas at states A and C. The charts are drawn to the same scale.

d. Describe how the bar charts support or contradict your answer to **part c**, including reference to the size of the bars and the specific values from **part c**.



The student also draws a diagram to show the direction (not the magnitude) of the net transfers of energy into and out of the gas in process 2. The direction of the work is correct, but the student is not sure which way the thermal energy arrow should point.

e. What is the correct direction of thermal energy transfer, into or out of the gas? Justify your answer.

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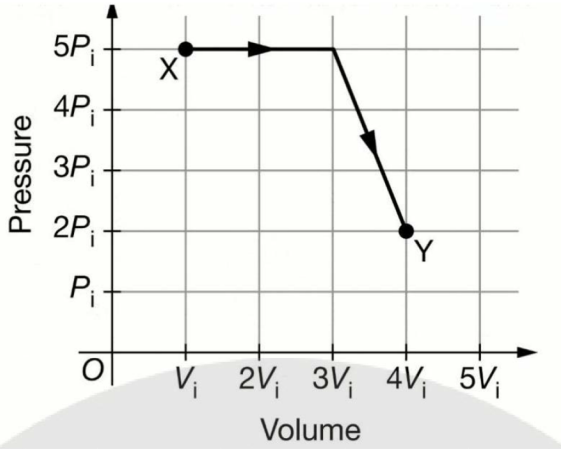

A sample of the gas is taken from state *X* to state *Y* by the processes shown above. The product of ***P***i and ***V***i has a value equal to ***M***.

f. What is the magnitude of the work done by the gas as it goes from state X to state Y? Explain your reasoning.

g. If the net change in internal energy as the gas goes from state X to state Y is 4. 5***M***, how much energy is transferred by heating or cooling during the processes? Explain your reasoning

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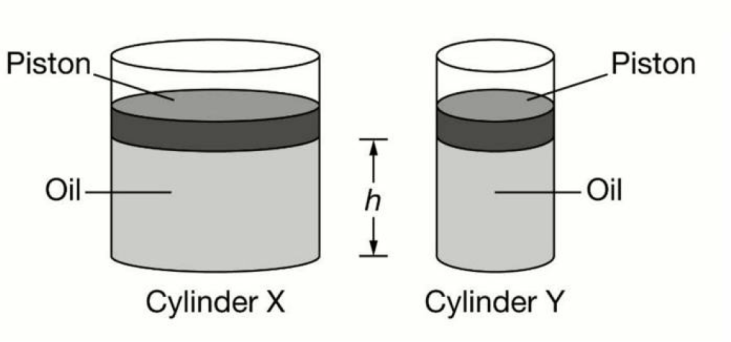

2. Cylinders X and Y shown above are each partially filled to the same height ***h*** with an incompressible oil of density ρ. Cylinder X has a cross-sectional area of A_X and cylinder Y has a cross-sectional area of A_Y where $A_X > A_Y$. Each cylinder is sealed by a piston that can move with negligible friction. The pistons have the same density and thickness. The piston in cylinder X has mass M_X and the piston in cylinder Y has mass M_Y. The atmospheric pressure is P_{atm}.

a. Compare the absolute pressure at the bottom of cylinders X and Y. Justify your answer.

b. Is the downward force exerted on the bottom of cylinder X by the oil greater than, less than, or equal to the downward force exerted on the bottom of cylinder Y by the oil? Explicitly indicate if a comparison cannot be made. Justify your answer using physics principles.

c. Determine an expression for the downward force exerted on the bottom of cylinder X in terms of the given quantities and physical constants, as appropriate.

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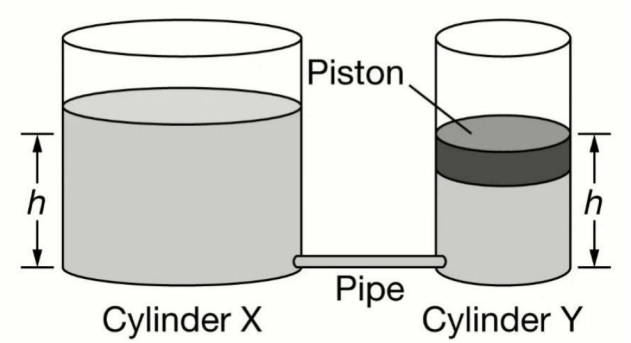

Cylinders X and Y are then connected by a pipe that is small enough so that the amount of oil the pipe contains is negligible. The piston above cylinder X is removed. The system comes to rest with the height of the oil in each cylinder at the positions shown, where the original height h is indicated on each cylinder.

d. In a clear, coherent paragraph-length response, use concepts of pressure and forces to explain why the system comes to rest with the oil at the heights shown. Include an explanation of why the displacements of the oil levels from the height h are different for the two cylinders.

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2021 Digital Exam Practice

AP Physics 2: Algebra-Based

Scoring Materials for Digital Exam Practice

Please note: the digital exam practice resource was developed for students to complete technology checks, experience the digital platform, and practice answering exam questions, including each type of multiple-choice and free-response question they will encounter on exam day.

This digital exam practice is not a full-length exam, and it does not represent the complete scope of content and skills that students will see on the actual AP exam. This digital exam practice includes only content that would typically be taught in the first half of the school year, following the unit sequence in the AP Physics 2: Algebra-Based Course and Exam Description. For more information on the 2021 Exam format, please visit: apcentral.collegeboard.org/pdf/ap-2021-exam-formats.pdf

AP Exams are scored differently than traditional high school or college exams. When an AP Exam is administered, psychometric analysis determines the score ranges corresponding with each AP Exam score (5, 4, 3, 2, and 1) based on a composite score scale that combines and weights the different exam parts. Earning 40-50% of the available points can result in a score of 3 or better on many AP Exams. However, because the number of points corresponding with each AP Exam score can vary on different exams, students and teachers should not use the results of the digital exam practice to predict performance on the 2021 AP Exam.

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Multiple-Choice Answer Key

Multiple-Choice Question		Answer
Part I:	1	B
	2	D
	3	C
	4	D
	5	B
	6	A, C
	7	B, D
	8	A, D
Part II:	1	C
	2	B
	3	A
	4	B

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Question 1: Qualitative/Quantitative Translation — 15 points

a.

For describing that temperature is related to the product of pressure and volume — **1 point**

For indicating that pressure times volume is always 4PiVi — **1 point**

Example response for part a.

Yes. Temperature is related to pressure times volume and the graph shows that is always 4PiVi

Total for part a. 2 points

b.

For correctly relating the internal energies consistent with (a) with some attempt at a justification. — **1 point**

For indicating that internal energy depends on temperature — **1 point**

Example response for part b.

Internal energy depends on temperature, and the temperatures are the same, so the internal energy in A is the same as in B.

Total for part b. 2 points

c.

For indicating that the product of pressure and volume is 12PiVi for state C, which is greater than the 4PiVi for state A, so the gas in state C is at a higher temperature — **1 point**

For indicating that the average kinetic energy of the molecules of the gas is directly proportional to the temperature, so the average kinetic energy of the molecules is larger in state C. — **1 point**

Example response for part c.

Temperature is a measure of the average kinetic energy. The product of pressure and volume is 12PiVi for state C, which is greater than the 4PiVi for state A, so the gas in state C is at a higher temperature. That means that state C has a higher average kinetic energy.

Total for part c. 2 points

d.

For indicating whether the bar charts are consistent with student's part c. response, with an attempt at a justification using values from c. or the bar charts — **1 point**

For identifying that internal energy increases and comparing this increase to the change in temperature identified in part c. — **1 point**

For comparing the ratio of the internal energies and the ratio of temperatures determined using specific values in part c. — **1 point**

Example response for part d.

The bar chart shows that state C has three times the internal energy of state A. That means the temperature of state C is three times that of state A. That is consistent with the values of pressure times volume in my answer to part (c).

Total for part d. 3 points

e.

For a justification in terms of the first law of thermodynamics: Delta U = Q + W — **1 point**

For using the correct signs for the change in internal energy and the indicated direction of the work arrow in the figure to determine the correct direction of thermal energy transfer. — **1 point**

Example response for part e.

The work removes energy from the gas. Since the internal energy increases and Delta U = Q + W, thermal energy must be transferred into the gas.

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f.	For a correct answer of W=13.5M, with an attempt at justification	**1 point**
	For an indication of use of the area under the graph	**1 point**
	Scoring note: Correct answer in terms of PiVi is also acceptable.	

Example response for part f.

The work is the area under the graph. The area under the horizontal process is 2 wide by 5 high. Under the diagonal process it is (1/2) 1 wide by 3 high plus 1 wide by 2 high. That gives 10 + 1.5 + 2 equals 13.5M

Total for part f. 2 points

g.	Correct answer: *Delta U = 4.5M = Q + W = Q – 13.5M* *Q = 18M*	
	For a correct justification that includes the first law of thermodynamics.	**1 point**
	For correct substitutions, including signs, consistent with part (f)	**1 point**
	Scoring note: Answer in terms of PiVi also acceptable.	

Example response for part g.

Delta U = Q+W, so 4.5M = Q-13.5M and Q=18M

Total for part g. 2 points

Total for Question 1 15 points

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Question 2: Paragraph Argument Short Answer — 10 points

a.

For indicating that P(bottom), x = P(bottom), y with an attempt at a justification — **1 point**

For a correct justification addressing contributions to any two of the oil, pistons, and atmosphere. — **1 point**

Example response for part a.

The pressure at the bottom is atmospheric pressure plus the pressure due to the pistons and oil. Since the density and height of the oil is the same, and so are the density and thickness of the pistons, the pressure due to the pistons and oil are the same.

Total for part a. 2 points

b.

For a correct response consistent with the previous answer. — **1 point**

Example response for part b.

Force is pressure times area. Applying this principle to the situation, cylinder X has a greater area, so there is a greater force on its bottom.

c.

For including a correct term for the pressure contribution of any one contribution from the fluid, piston, or atmosphere — **1 point**

For including correct terms for the other two pressure contributions from the fluid, piston, or atmosphere — **1 point**

Example response for part c.

Fdown =DghA_x + (M_x)g + Patm(A_x)

Note: A maximum of 1 point is earned if there are any extraneous terms.

Total for part c. 2 points

d.

For indicating that at equilibrium the pressures exerted on the bottoms of the cylinders (or at the same height within the oil) must be equal, in the context of attempting to address the removal of the piston — **1 point**

For indicating that removing the piston's mass from cylinder X will decrease the pressure or force at the bottom of cylinder X — **1 point**

For indicating that to compensate for the change in pressure, the height of oil on the left must increase and the height on the right must decrease — **1 point**

For indicating that the change in volume must be the same for both cylinders and the cross-sectional area of cylinder X is greater, so the change of height in cylinder X is less — **1 point**

For a logical, relevant, and internally consistent argument that addresses the question asked and follows the guidelines described in the published requirements for the paragraph-length response — **1 point**

Example response for part d.

The pistons reach equilibrium when the pressure at the bottom of the cylinders is the same. Removing the piston decreases the force, and thus the pressure, at the bottom of cylinder X. To compensate, oil moves from cylinder Y to cylinder X until the pressure is again the same at the bottom of the cylinders. Since the area of cylinder X is larger, piston X moves a smaller distance than piston Y for the same volume change.

Total for part d. 5 points

Total for Question 2 10 points

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Section I: Multiple-Choice Question-Part 1

1. **考点：**考察 Unit 3 Electric force, field, and potential 中电场的矢量图表示法和库仑定律

题目：根据电场矢量图判断 P 点放一个正的检验电荷受到的电场力什么方向

解答：根据矢量图看 P 点附近的电场可以得 P 点的电场应该为 B 选项向上偏左一点的方向，再根据正电荷所受电场力和电场方向相同，所以选 B。

2. **考点：**考察 Unit 3 Electric force, field, and potential 中电场矢量图和点电荷的电场公式。

题目：根据电场矢量图找出电荷量最大和最小的点。

解答：图中画出的距离每个电荷最近的电场矢量都是差不多大小，但是有的离电荷近有的离得远。根据电场公式 E=kQ/r^2，在距离远的地方产生相同大小的电场说明电荷量也越大，所以 1 最大 3 最小，选 D。

3. **考点：**考察 Unit 2 Thermodynamics 中的理想气体状态方程和分子运动理论。

题目：根据 PV 图对 ABC 三个状态的分子平均速率排序。

解答：分子平均速率跟温度正相关，而根据理想气体状态方程，温度又和压强体积乘积 PV 成正比，所以看图中三个点的 PV 乘积，有 A=C>B，所以速度排序也是如此，选 C。

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4. **考点：**考察 Unit 2 Thermodynamics 里压力和压强的关系

题目：根据 PV 图判断气体对活塞的力

解答：根据 F=PA，对同一个活塞来说，气体压强大则力大，根据 PV 图，三点压强的关系是 C>A=B，所以选 D。

5. **考点：**考察 Unit 2 Thermodynamics 中的热力学第一定律

题目：根据等温过程的 PV 图判断对气体做功和吸放热的正负号。

解答：图中的曲线上箭头是从右向左，表示体积减小，是个压缩过程，所以对气体做正功。再根据热力学第一定律 dU=W+Q，由于温度不变，内能变化为 0，所以 W>0 就需要 Q=-W<0，表示气体放热，选 B。

6. **考点：**考察 Unit 3 Electric force, field, and potential 中的感应起电。

题目：要让一个铝罐带正电应该按什么顺序操作，双选题。

解答：让一个带负电的棒靠近铝罐可以在近处感应出正电远处感应出负电，如果让铝罐接地则罐上只有正电（负电跑到大地里），但是先接好地还是先让棒靠近是一样的，所以 W 和 X 的顺序可以交换。之后必须先把地断开，让正电荷留在铝罐上，再移走负电棒，否则先移走负电棒的话没有外电场则负电荷又会跑回铝罐与正电荷中和，所以是先 Y 后 Z。综上所述，A（WXYZ）或 C（XWYZ）正确。

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7. **考点：**考察 Unit 1 Fluid 中的伯努利方程。

题目：一个管道一端比另一端高，高的那端流速大，问流动方向和两端压强。

解答：根据伯努利方程，$P+\rho gh+\frac{1}{2}\rho v^2$不变，高的那端 h 大 v 也大，则必然 P 要小，所以 D 对；气体会从压强大的地方往压强小的地方流动，所以 B 对。

8. **考点：**考察 Unit 2 Thermodynamics 中的热力学内能、热力学第一定律。

题目：理想气体从一个状态经过不同过程到另一个状态，什么量是不变的。

解答：一个给定的状态会有确定的温度，而内能与温度成正比，给定状态有确定的内能，所以从一个状态到另一个状态不论经历怎样的过程内能变化和温度变化都固定，所以选 AD。但是对气体做功（PV 曲线下方面积）和吸放热（Q=U-W）会和经历的过程有关，BC 不对。

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Section I: Multiple-Choice Question-Part 2

1. **考点：**考察 Unit 1 Fluid 中的连续性方程和伯努利方程。

题目：已知水的密度，管道和喷嘴的横截面积之比，喷嘴处流速，求管道和喷嘴的压强差。

解答：根据连续性方程$A_1v_1 = A_2v_2$，得到管道中流速$v_1 = v_2/10 = 1\ \text{m/s}$。再根据伯努利方程$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$（水平管道可省略高度项），得到压强差$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) = 4.95 \times 10^4\ \text{Pa}$，选 B。

2. **考点：**考察 Unit 3 Electric force, field, and potential 中的电场叠加和点电荷的电场。

题目：已知 XY 两个电荷在给定点处产生的总电场，求 XY 的电荷符号。

解答：总电场是 XY 各自产生的电场的矢量和，而 XY 的电场只能沿着两条直角边，为了总电场向左，需要一个向左上一个向左下，则 X 产生向左下指向 X 的电场，说明 X 带负电；Y 产生向左上背向 Y 的电场，说明 Y 带正电，选 C。

3. **考点：**考察 Unit 1 Fluid 中的浮力和受力平衡。

题目：已知浸没在液体中的物体质量、弹簧秤读数，求浮力。

解答：物体受到向下的重力、向上的弹簧秤拉力和向上的浮力，根据受力平衡，浮力等于重力减去拉力，所以$F_\text{B} = mg - T = 0.4 \times 10\ \text{N} - 3\ \text{N} = 1\ \text{N}$。

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4. **考点：**考察 Unit 1 Fluid 中的连续性方程和伯努利方程和液体压强差方程。

题目：一个通入气体的 T 型管道下方伸入液体中，求管中液面高度。

解答：根据连续性方程，横管中间截面积小、流速大；再根据伯努利方程，流速大的地方压强小；再根据液体压强差方程，高处压强小低处压强大，所以管中页面应该比周围高，选 A。

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Section II: Free-Response Question

1. part a.

考点：考察 Unit 2 Thermodynamics 中的理想气体状态方程和等温过程。

题目：图中 A-B 的过程是否是等温过程，用图中信息说明。

解析：根据理想气体状态方程，T 正比于 PV 乘积，从 A 到 B 的过程中 PV 乘积始终是 $4P_iV_i$，所以是等温过程。

采分点和示例：

a.	For describing that temperature is related to the product of pressure and volume	**1 point**
	For indicating that pressure times volume is always 4PiVi	**1 point**
	Example response for part a. *Yes. Temperature is related to pressure times volume and the graph shows that is always 4PiVi*	
		Total for part a. 2 points

part b.

考点：考察 Unit 2 Thermodynamics 中的内能概念。

题目：比较图中 A-B 的内能。

解析：内能由温度决定，由于 AB 的温度相同，所以内能相同。

采分点和示例：

b.	For correctly relating the internal energies consistent with (a) with some attempt at a justification.	**1 point**
	For indicating that internal energy depends on temperature	**1 point**
	Example response for part b. *Internal energy depends on temperature, and the temperatures are the same, so the internal energy in A is the same as in B.*	
		Total for part b. 2 points

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part c.

考点：考察 Unit 2 Thermodynamics 中的分子平均动能和理想气体状态方程。

题目：图中 A-C 两点分子平均动能的比较。

解析：分子平均动能正比于温度，而温度正比于 PV，在图中 A 点的 PV 乘积是$4P_iV_i$，C 点是$12P_iV_i$，所以 C 点温度高、分子平均动能大。

采分点和示例：

c.	For indicating that the product of pressure and volume is 12PiVi for state C, which is greater than the 4PiVi for state A, so the gas in state C is at a higher temperature	**1 point**
	For indicating that the average kinetic energy of the molecules of the gas is directly proportional to the temperature, so the average kinetic energy of the molecules is larger in state C.	**1 point**
	Example response for part c. *Temperature is a measure of the average kinetic energy. The product of pressure and volume is 12PiVi for state C, which is greater than the 4PiVi for state A, so the gas in state C is at a higher temperature. That means that state C has a higher average kinetic energy.*	
		Total for part c. 2 points

part d.

考点：考察 Unit 2 Thermodynamics 中的内能和理想气体状态方程。

题目：对比 bar chart 所表示的内能和之前 part c.的计算是否一致。

解析：在 bar chart 中 C 的内能是 A 的三倍，表示 C 的温度也是 A 的三倍，和之前 part c.对 PV 乘积的计算结果一致。

采分点和示例：

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d.	For indicating whether the bar charts are consistent with student's part c. response, with an attempt at a justification using values from c. or the bar charts	**1 point**
	For identifying that internal energy increases and comparing this increase to the change in temperature identified in part c.	**1 point**
	For comparing the ratio of the internal energies and the ratio of temperatures determined using specific values in part c.	**1 point**
	Example response for part d. *The bar chart shows that state C has three times the internal energy of state A. That means the temperature of state C is three times that of state A. That is consistent with the values of pressure times volume in my answer to part (c).*	
		Total for part d. 3 points

part e

考点：考察 Unit 2 Thermodynamics 中的热力学第一定律。

题目：给出过程 2 的 PV 图，分析这个过程是吸热还是放热。

解析：根据热力学第一定律 Delta U=Q+W，由于过程 2 的方向是从左向右表示外界对气体做了负功，但内能增大，说明必须是吸热。

采分点和示例：

e.	For a justification in terms of the first law of thermodynamics: Delta U = Q + W	**1 point**
	For using the correct signs for the change in internal energy and the indicated direction of the work arrow in the figure to determine the correct direction of thermal energy transfer.	**1 point**
	Example response for part e. *The work removes energy from the gas. Since the internal energy increases and Delta U = Q + W, thermal energy must be transferred into the gas.*	

part f.

考点：考察 Unit 2 Thermodynamics 中的 PV 图。

题目：根据过程的 PV 图求做功。

解析：做功是曲线下方的面积，在图中是一个长方形的面积加梯形的面积，长方形面积是 5Pi*2Vi=10M，梯形面积是 0.5*(5Pi+2Pi)*1Vi=3.5M，所以总做功是 13.5M。

采分点和示例：

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f.	For a correct answer of W=13.5M, with an attempt at justification	**1 point**
	For an indication of use of the area under the graph	**1 point**
	Scoring note: Correct answer in terms of PiVi is also acceptable.	
	Example response for part f.	
	The work is the area under the graph. The area under the horizontal process is 2 wide by 5 high. Under the diagonal process it is (1/2) 1 wide by 3 high plus 1 wide by 2 high. That gives 10 + 1.5 + 2 equals 13.5M	
		Total for part f. 2 points

part g.

考点：考察 Unit 2 Thermodynamics 中的热力学第一定律。

题目：根据过程的 PV 图和内能变化求吸放热。

解析：根据热力学第一定律 Delta U=Q+W，由于代入 Delta U=4.5M，W=-13.5M（因为是气体对外做功所以取-），得 Q=18M>0，是吸热。

采分点和示例：

g.	Correct answer: *Delta U = 4.5M = Q + W = Q – 13.5M* *Q = 18M*	
	For a correct justification that includes the first law of thermodynamics.	**1 point**
	For correct substitutions, including signs, consistent with part (f)	**1 point**
	Scoring note: Answer in terms of PiVi also acceptable.	
	Example response for part g.	
	Delta U = Q+W, so 4.5M = Q-13.5M and Q=18M	
		Total for part g. 2 points

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2. part a.

考点：考察 Unit 1 Fluid 中静止液体的压强。

题目：比较两个盛有相同高度油的圆柱底面压强。

解析：底面压强等于液体的压强加活塞的压强加大气压，由于液体的密度和高度、活塞的密度和高度都相同，所以底面压强也相同。

采分点和示例：

a.	For indicating that P(bottom), x = P(bottom), y with an attempt at a justification	**1 point**
	For a correct justification addressing contributions to any two of the oil, pistons, and atmosphere.	**1 point**
	Example response for part a. *The pressure at the bottom is atmospheric pressure plus the pressure due to the pistons and oil. Since the density and height of the oil is the same, and so are the density and thickness of the pistons, the pressure due to the pistons and oil are the same.*	
		Total for part a. 2 points

part b.

考点：考察 Unit 1 Fluid 中压强和压力的关系。

题目：比较两个圆柱底面的压力。

解析：压力等于压强乘以面积。由 part a 的结论两个圆柱底面压强相同，但 X 的面积大，所以 X 的压力大。

b.	For a correct response consistent with the previous answer.	**1 point**
	Example response for part b. *Force is pressure times area. Applying this principle to the situation, cylinder X has a greater area, so there is a greater force on its bottom.*	

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part c.

考点：考察 Unit 1 Fluid 中压强和压力的关系、静止液体的压强。

题目：推导圆柱 X 底面压力表达式。

解析：压力=压强*面积，而压强等于液体的压强+活塞的压强+大气压，其中液体压强公式为$P = \rho gh$，而活塞压强不需要单独算出因为活塞压强*面积就是活塞的重力 Mg。所以压力$F = \rho ghA_{\mathrm{X}} + M_{\mathrm{X}}g + P_{\mathrm{atm}}A_X$。

采分点和示例：

c.	For including a correct term for the pressure contribution of any one contribution from the fluid, piston, or atmosphere	**1 point**
	For including correct terms for the other two pressure contributions from the fluid, piston, or atmosphere	**1 point**
	Example response for part c. Fdown =DghA_x + (M_x)g + Patm(A_x)	
	Note: A maximum of 1 point is earned if there are any extraneous terms.	
	Total for part c.	**2 points**

part d.

考点：考察 Unit 1 Fluid 中压力和压强的关系、静止液体的压强和质量守恒。

题目：当 X 的活塞移除后，解释两个圆柱里液面高度的变化。

解析：由于两个圆柱连通，在平衡状态两个圆柱底面压强必须相同。X 的活塞移除后左边压力变小，为了补偿减小的压力，液体会从 Y 流向 X 使 X 的液体高度增大、对底面压强增大。由于液体的总量不变，Y 中液体减小的体积和 X 增大的体积相同，而 X 的截面积比 Y 大，所以 X 液面上升的高度要比 Y 液面下降小。

采分点和示例：

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d.	For indicating that at equilibrium the pressures exerted on the bottoms of the cylinders (or at the same height within the oil) must be equal, in the context of attempting to address the removal of the piston	**1 point**
	For indicating that removing the piston's mass from cylinder X will decrease the pressure or force at the bottom of cylinder X	**1 point**
	For indicating that to compensate for the change in pressure, the height of oil on the left must increase and the height on the right must decrease	**1 point**
	For indicating that the change in volume must be the same for both cylinders and the cross-sectional area of cylinder X is greater, so the change of height in cylinder X is less	**1 point**
	For a logical, relevant, and internally consistent argument that addresses the question asked and follows the guidelines described in the published requirements for the paragraph-length response	**1 point**

Example response for part d.

The pistons reach equilibrium when the pressure at the bottom of the cylinders is the same. Removing the piston decreases the force, and thus the pressure, at the bottom of cylinder X. To compensate, oil moves from cylinder Y to cylinder X until the pressure is again the same at the bottom of the cylinders. Since the area of cylinder X is larger, piston X moves a smaller distance than piston Y for the same volume change.

Total for part d. 5 points

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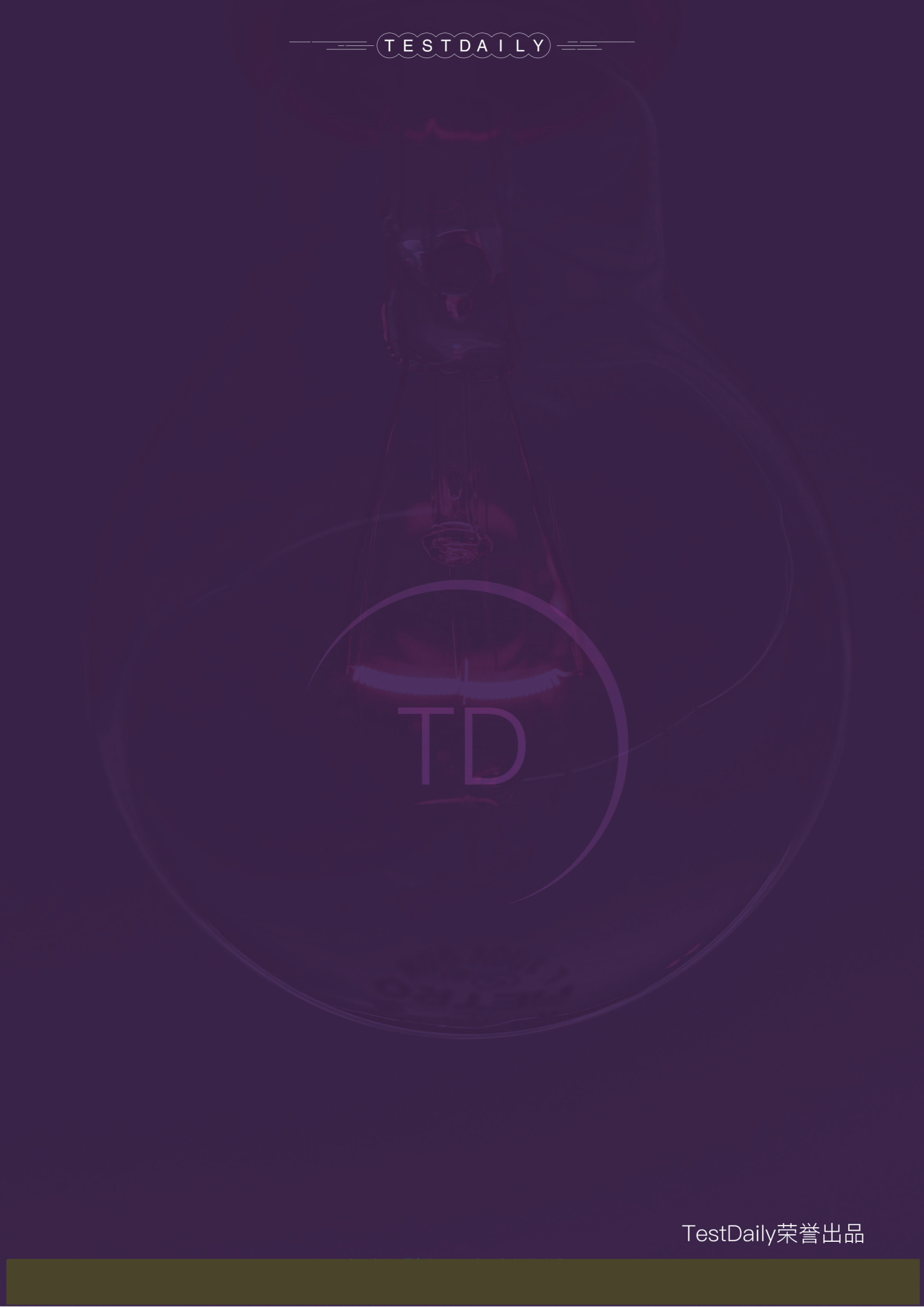
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