A-Level Physics

Non-Flow Processes

Question Paper

Time available: 48 minutes
Marks available: 36 marks

1. (a) Which row in the table below shows

- **Process 1** in which work done is zero, and
- **Process 2** in which the change in internal energy is zero?

Tick (✓) **one** box.

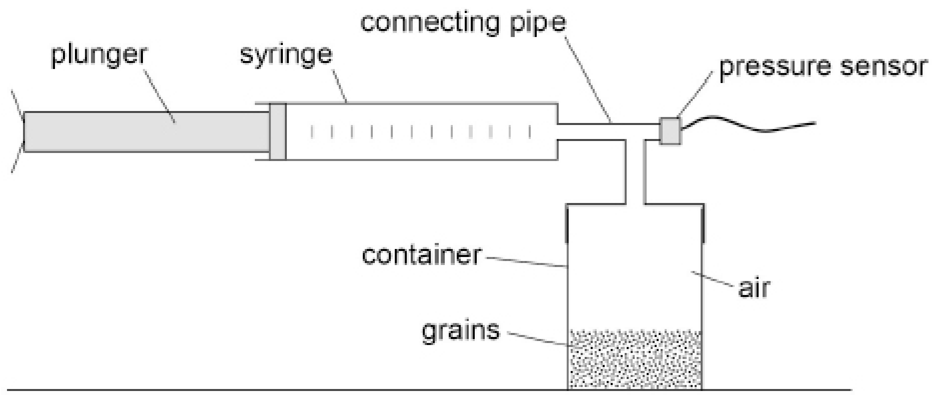
Process 1	**Process 2**	
constant pressure	isothermal	☐
constant volume	adiabatic	☐
constant pressure	adiabatic	☐
constant volume	isothermal	☐

(1)

(b) When irregular particles are packed, air gaps are left between the particles.
The true volume of a quantity of irregular particles must be determined using a method that does not include the volume of the air spaces between them.

The apparatus shown in **Figure 1** is used by an agricultural engineer to measure the true volume of some grains.

Figure 1



The volume of air in the syringe is 1.00×10^{-4} m^3.
The volume of the **empty** container and connecting pipe is 2.80×10^{-4} m^3.
Grains of total true volume V are now placed in the container and the lid is screwed on.
The pressure inside both the syringe and the container is 1.01×10^5 Pa.
The plunger is slowly pushed fully into the cylinder of the syringe, compressing the air isothermally.
The pressure increases to 1.83×10^5 Pa.

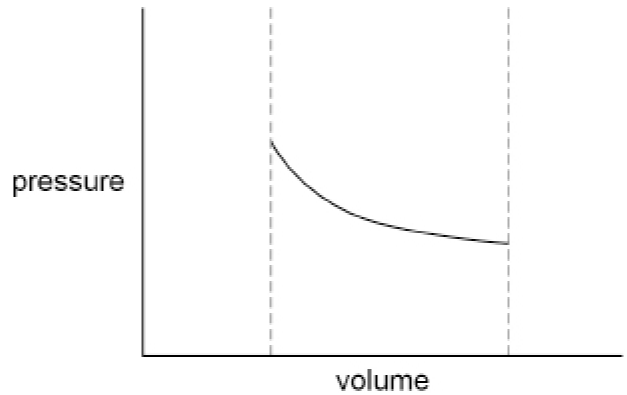
Determine V.

V = _______________ m^3

(3)

Figure 2 shows how the pressure in the container and syringe varies with volume as the plunger is pushed in fully very slowly.

Figure 2



(c) Sketch on **Figure 2** the variation of pressure with volume when the plunger is pushed in fully very quickly and then left for several seconds.
Assume no leakage past the plunger.

(2)

(d) Explain why the compression of a gas can be considered to be an isothermal change when the gas is compressed very slowly.

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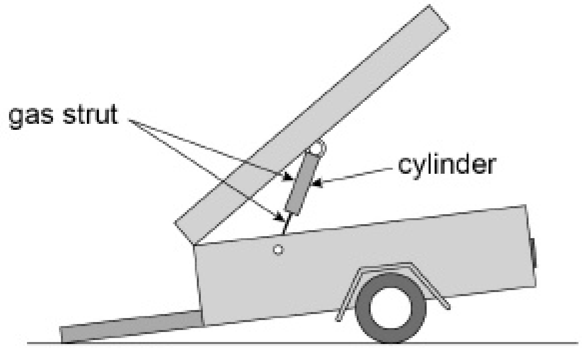
(2)
(Total 8 marks)

2. The diagram shows a gas strut supporting the lid of a trailer.



A fixed mass of nitrogen gas is sealed into the cylinder of the strut.

(a) The gas is initially at a pressure of 1.2×10^6 Pa, a volume of 9.0×10^{-5} m^3 and a temperature of 290 K.

When the lid is closed quickly the gas is compressed rapidly to a final volume of 6.8×10^{-5} m^3.

Calculate the pressure and temperature of the gas at the end of the compression assuming the compression to be an adiabatic process.

adiabatic index γ for nitrogen = 1.4

pressure = ____________________ Pa

temperature = ____________________ K

(4)

(b) Explain why the rapid compression of the gas can be assumed to be an adiabatic process.

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(2)

(c) When the lid is closed slowly, the compression can be assumed to be isothermal.

The gas can be compressed either isothermally or adiabatically from the same initial conditions to the same final volume.

Compare without calculation the work done in each process.

(3)

(Total 9 marks)

3. A spray can contains liquid paint with compressed gas in the space above it, as shown in **Figure 1**. Pressing down the cap opens a valve which allows the gas to expand, forcing paint through the nozzle. The cap is pressed until all the paint is expelled, leaving the can filled with gas at a pressure which is still greater than atmospheric.

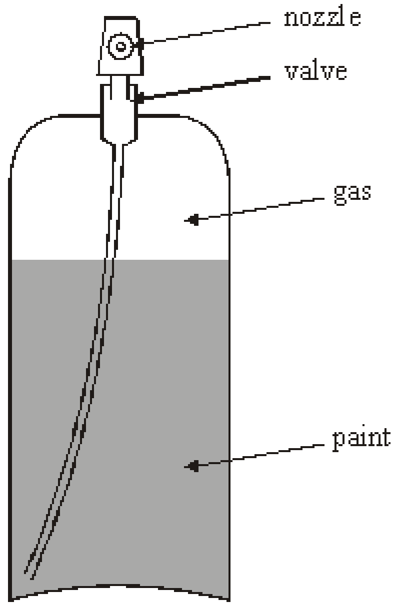

Figure 1

(a) The can has an internal volume of 6.6×10^{-4} m^3 and initially contains 5.0×10^{-4} m^3 of paint. The gas in the can is at an initial pressure of 7.8×10^5 Pa. The pressure of the gas left in the can when all the paint has just been expelled is 1.9×10^5 Pa. Show that the expansion of the gas was an approximately isothermal process.

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(2)

(b) The cap is now pressed again to open the valve and is held down to allow the gas to expand rapidly into the air around the can. The atmospheric pressure is 9.8×10^4 Pa and the temperature of the gas at the start of the expansion is 22 °C.

(i) Explain why this expansion can be considered to be approximately adiabatic.

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(ii) Calculate the total volume that the gas would occupy if it were collected at atmospheric pressure immediately after the expansion.

γ for the gas = 1.4

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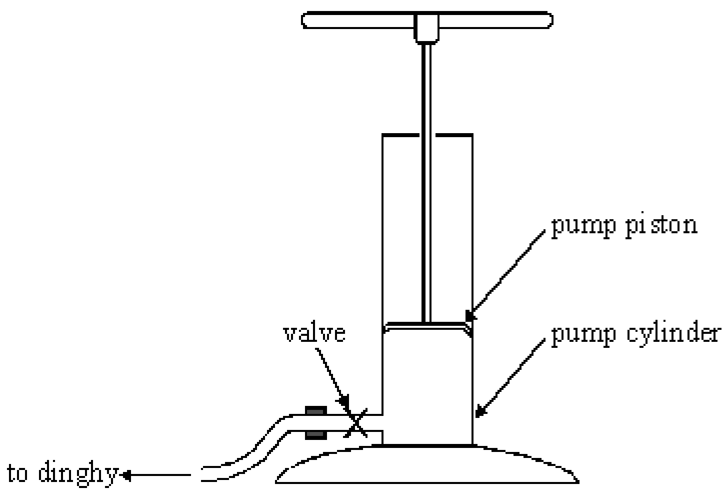
(3)

(Total 5 marks)

4. The diagram below shows a pump used to inflate a rubber dinghy. When the piston is pushed down, the pressure of air in the cylinder increases until it reaches the pressure of the air in the dinghy. At this pressure the valve opens and air flows at almost constant pressure into the dinghy.



(a) The pump is operated quickly so the compression of the air in the cylinder before the valve opens can be considered adiabatic.
At the start of a pump stroke, the pump cylinder contains 4.25×10^{-4} m^3 of air at a pressure of 1.01×10^5 Pa and a temperature of 23 °C. The pressure of air in the dinghy is 1.70×10^5 Pa.

Show that, when the valve is about to open, the volume of air in the pump is 2.93×10^{-4} m^3.

γ for air = 1.4

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(2)

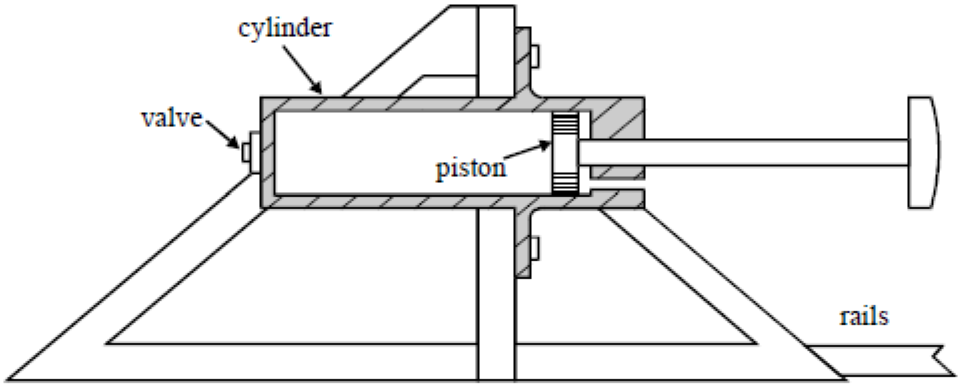
(b) Calculate the temperature of the air in the pump when the valve is about to open.

(3)

(c) State, explaining your reasons, whether the volume of air in the cylinder at the point when the valve opens would be less than, equal to or greater than 2.93×10^{-4} m^3 if the compression of the air had been carried out very slowly. You may find it helpful to sketch a *pV* diagram of the compression.

(3)
(Total 8 marks)

5. The diagram shows a section through a buffer used to arrest the motion of railway trucks at a quarry. When a truck collides with the buffer, the air inside the cylinder is compressed as the piston is forced along the cylinder. The reaction force exerted by the compressed air on the piston is used to decelerate the truck.



(a) Explain why the compression of the air can be considered to be adiabatic.

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(2)

(b) When the pressure reaches 1.5 MPa, a valve opens to allow a controlled release of air, in order to reduce the effects of impact damage and recoil. Before the collision the volume of air in the cylinder is 3.5×10^{-2} m^3, and its pressure and temperature are 100 kPa and 17°C, respectively.

(i) Show that the volume of air in the cylinder when the valve is on the point of opening is 5.1×10^{-3} m^3.

γ for air = 1.4

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(ii) Calculate the temperature of the air in the cylinder when the valve is on the point of opening.

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(4)

(Total 6 marks)