PEARSON EDEXCEL IAL PHYSICS · YPH11

PHYSICS



EXAM QUESTION PACK

UNIT 5: THERMODYNAMICS

SCORE	PERCENTAGE
/34	%

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Q1.

A weather balloon takes scientific equipment high into the atmosphere to monitor atmospheric conditions.

A weather balloon is filled with hydrogen at a temperature of 22.5 °C and a pressure of 1.02×10^5 Pa. The volume of the balloon is 7.50 m^3.

The balloon rises through the atmosphere to a maximum height. At the maximum height, the temperature of the hydrogen in the balloon is –48.0 °C and the pressure of the hydrogen in the balloon is 8.40×10^4 Pa.

(a) Calculate the volume of the balloon at the maximum height.

(3)

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Volume of balloon = ...

(b) Calculate the decrease in the mean kinetic energy of a hydrogen molecule in the balloon as the balloon rises to the maximum height.

(2)

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Decrease in mean kinetic energy = ...

(Total for question = 5 marks)

Q2.

Lead shot consists of small lead spheres.

Originally lead shot was made by dripping molten lead through a copper sieve from the top of a 'shot tower'. The lead cooled as it fell, before landing in water and producing solid lead spheres. Figure 1 shows a shot tower, and figure 2 shows the process of making lead shot in a shot tower.



(Source: © Espresso Addict)

Figure 1

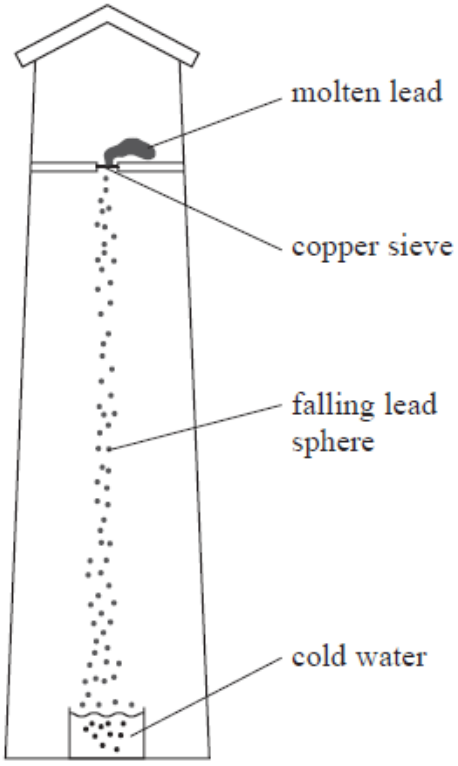


Figure 2

To avoid producing steam, the temperature of a lead sphere was below 100 °C as it reached the cold water.

(a) (i) A lead sphere falls through a distance of 41.5 m.

Show that it takes about 3 s for the lead sphere to fall through this distance.
Assume that resistive forces are negligible.

(2)

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(ii) The lead sphere has a radius of 1.2 mm. As it falls it cools from 615 K to 370 K.

The molten lead solidifies at 601 K.

Calculate the mean rate at which energy is transferred from the lead sphere to the surroundings.
You should assume that the specific heat capacities of liquid lead and solid lead are the same.

density of lead = 1.13×10^4 kg m^{-3}
specific latent heat of lead = 2.47×10^4 J kg^{-1}
specific heat capacity of lead = 130 J kg^{-1} K^{-1}

(6)

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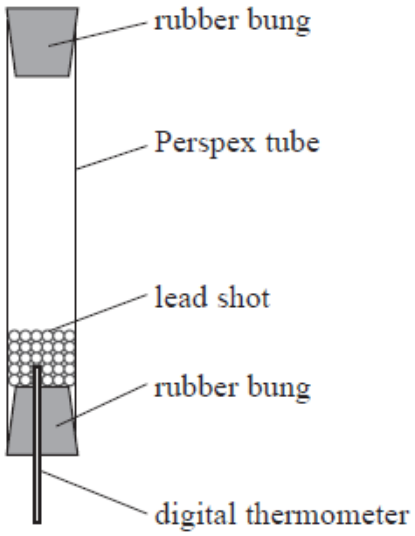
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Mean rate of energy transfer from lead = ...

(b) A teacher demonstrates a mechanical method to determine the specific heat capacity of lead. Some lead shot at room temperature is placed in a Perspex tube.



The teacher turns the tube upside down, and the lead shot falls through a distance *d*.

The teacher repeats this *N* times and measures the final temperature of the lead shot.
The change in temperature $\Delta\theta$ of the lead shot is calculated.

The teacher uses the values of *d*, *N* and $\Delta\theta$ to determine a value for the specific heat capacity *c*

of the lead.

(i) Explain why the mass of lead shot in the tube should not affect the value of $\Delta\theta$.

(2)

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(ii) Assess whether this method would produce an accurate value for c.

(2)

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(Total for question = 12 marks)

Q3.

The spectrum of light emitted by the star Chi Lupi provides evidence of mercury atoms in the outer layers of the star. The light emitted from the star is compared with light emitted from a mercury lamp on Earth.

(a) The lamp contains 1.65×10^{19} mercury atoms in a volume of 1.50×10^{-5} m^3. The pressure of the mercury vapour is 4.25×10^4 Pa.

Calculate the mean kinetic energy of the mercury atoms.

(3)

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Mean kinetic energy of mercury atoms = ...

(b) One line in the spectrum of light from Chi Lupi has a wavelength of 576.933 nm.

The equivalent line in a mercury spectrum produced on Earth is 576.959 nm.

A student concluded from this data that Chi Lupi is moving towards the Earth, and that the relative velocity of Chi Lupi is about 1400 m s^{-1}.

Deduce whether the student's conclusions are correct.

(4)

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(c) The surface temperature of Chi Lupi is twice the surface temperature of the Sun.

The radius of Chi Lupi is three times the radius of the Sun.

State where Chi Lupi would be located on the Hertzsprung-Russell diagram.

(1)

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(Total for question = 8 marks)

Q4.

Cocoa powder, milk and hot water are mixed together to produce a 'hot chocolate' drink. The mass of the drink is 275 g, and its initial temperature is 71.5 °C.

Ice at 0.0 °C is added to the drink to reduce its temperature. Research indicates that the maximum serving temperature of any hot drink should be 58.0 °C.

Deduce whether 4.0 g of ice would be enough to bring the temperature below 58.0 °C.

specific latent heat of ice = 3.34×10^5 J kg^{-1}
specific heat capacity of 'hot chocolate' = 3750 J kg^{-1} $°C^{-1}$
specific heat capacity of water = 4190 J kg–1 $°C^{-1}$

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(Total for question = 5 marks)

Q5.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Boyle's law states that, under certain conditions, the pressure exerted by a gas is inversely proportional to the volume occupied by the gas.

Which of the following conditions is **not** necessary?

☒ **A** The gas must be ideal.

☒ **B** The mean kinetic energy of the molecules must stay constant.

☒ **C** The molecules in the gas must be identical.

☒ **D** The number of molecules in the gas must stay constant.

(Total for question = 1 mark)

Q6.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

In an experiment to determine the specific latent heat of vaporisation of water L_V, a student used an electrical heater to boil water in a beaker.

The experimental data gave $L_V = 2.20$ MJ kg^{-1}. The textbook value of L_V is 2.26 MJ kg^{-1}.

Which of the following could be an explanation for this difference in the values of L_V?

☒ **A** Some energy is transferred to the surroundings.

☒ **B** The heater power was underestimated.

☒ **C** The student did not stir the water.

☒ **D** The heater is inefficient.

(Total for question = 1 mark)

Q7.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A fixed mass of a gas occupies a constant volume. The temperature of the gas is increased.

Which of the following is **not** true?

☒ **A** The internal energy of the gas increases.

☒ **B** The mean kinetic energy of the molecules increases.

☒ **C** The mean momentum of the molecules increases.

☒ **D** The pressure exerted by the gas increases.

(Total for question = 1 mark)

Q8.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A fixed mass of an ideal gas has a volume V and exerts a pressure p. The absolute temperature of the gas is T. When the gas is heated, the new pressure is $4p$.

Which row of the table gives correct values of the new volume and the new temperature?

		Volume	Temperature
☒	**A**	$\frac{V}{2}$	$2T$
☒	**B**	$\frac{V}{2}$	$4T$
☒	**C**	$2V$	$2T$
☒	**D**	$2V$	$4T$

(Total for question = 1 mark)

Mark Scheme

Q1.

Question Number	Answer		Mark
(a)	Use of $pV = NkT$	(1)	
	Temperature converted to kelvin	(1)	
	$V = 6.9\ \text{m}^3$	(1)	3
	Example of calculation		
	$\frac{pV}{T} = \text{a constant}$		
	$\frac{8.4 \times 10^4\ \text{Pa} \times V}{(273 - 48)\ \text{K}} = \frac{1.02 \times 10^5\ \text{Pa} \times 7.50\ \text{m}^3}{(273 + 22.5)\text{K}}$		
	$\therefore V = \frac{1.02 \times 10^5\ \text{Pa} \times 7.5\ \text{m}^3 \times (273 - 48)\ \text{K}}{(273 + 22.5)\text{K} \times 8.4 \times 10^4\ \text{Pa}} = 6.93\ \text{m}^3$		
(b)	Use of $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$	(1)	
	Decrease = 1.5×10^{-21} J	(1)	2
	Example of calculation		
	$\Delta(\text{mean kinetic energy}) = \frac{3}{2}1.38 \times 10^{-2}\ \text{J K}^{-1}(-48 - 22.5)\text{K}$		
	$\therefore \Delta(\text{mean kinetic energy}) = -1.46 \times 10^{-21}\ \text{J}$		
	Total for question		5

Q2.

Question Number	Answer		Mark
(a)(i)	Use of appropriate equation of motion	(1)	
	$t = 2.9$ (s)	(1)	2
	Example of calculation		
	$s = ut + \frac{1}{2}at^2$		
	$\therefore -41.5\ \text{m} = 0.5 \times (-9.81\ \text{m s}^{-2})\ t^2$		
	$t = \sqrt{\frac{-41.5\ \text{m}}{-0.5 \times 9.81\ \text{m s}^{-2}}} = 2.91\ \text{s}$		
(a)(ii)	Use of $V = \frac{4}{3}\pi r^3$	(1)	
	Use of $\rho = \frac{m}{V}$	(1)	
	Use of $\Delta E = mc\Delta\theta$	(1)	
	Use of $\Delta E = L\Delta m$	(1)	
	Use of $P = \frac{\Delta W}{\Delta t}$	(1)	
	$P = 1.6$ W (allow ecf from (a)(i))	(1)	6
	Example of calculation		
	$V = \frac{4}{3}\pi(1.2 \times 10^{-3}\ \text{m})^3 = 7.24 \times 10^{-9}\ \text{m}^3$		
	$m = 7.24 \times 10^{-9}\ \text{m}^3 \times 1.13 \times 10^{4}\ \text{kg m}^3 = 8.18 \times 10^{-5}\ \text{kg}$		
	$E = 8.18 \times 10^{-5}\ \text{kg} \times 130\ \text{J kg}^{-1}\ \text{K}^{-1} \times (615\ \text{K} - 370\ \text{K}) = 2.61\ \text{J}$		
	$E = 8.18 \times 10^{-5}\ \text{kg} \times 2.47 \times 10^{4}\ \text{J kg}^{-1} = 2.02\ \text{J}$		
	$P = \frac{(2.61\ \text{J} + 2.02\ \text{J})}{2.9\ \text{s}} = 1.60\ \text{W}$		
(b)(i)	Change in gravitational potential energy of the lead shot and change in internal energy are both proportional to the mass of lead shot **Or** E_k $(= \frac{1}{2}mv^2)$ and $\Delta E = mc\Delta\theta$ both include the same mass **Or** E_{grav} $(= mg\Delta h)$ and $\Delta E = mc\Delta\theta$ both include the same mass	(1)	
	So, mass cancels and $\Delta\theta$ is independent of the mass (if no energy is transferred to the surroundings) (dependent upon MP1)	(1)	2
(b)(ii)	Not all the energy will be used to increase the temperature of the lead shot **Or** some energy will be transferred to the surroundings **Or** not all the lead shot will fall through a distance d	(1)	
	The method will not be accurate, as it will give a value of c that is too large **Or** The method will not be accurate as the (measured) temperature change will be too small	(1)	2
	Total for question		12

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Q3.

Question Number	Answer	Mark
(a)	Use of $pV = NkT$ (1) Use of $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$ (1) $\frac{1}{2}m\langle c^2\rangle = 5.8 \times 10^{-20}$ J (1) Example of calculation $T = \frac{pV}{Nk} = \frac{4.25\times10^{4}\text{ Pa} \times 1.50\times10^{-5}\text{ m}^3}{1.65\times10^{19} \times 1.38\times10^{-23}\text{ J K}^{-1}} = 2800$ K $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2} \times 1.38 \times 10^{-23}\text{ J K}^{-1} \times 2800\text{ K} = 5.80 \times 10^{-20}$ J	3
(b)	Use of $\frac{v}{c} = \frac{\Delta\lambda}{\lambda}$ with wavelength measured on Earth in denominator (1) v = 13500 m s^{-1} (1) The student is correct to say that the star is moving towards the Earth, as the measured wavelength is less than that from the lamp spectrum. (1) Comparison of calculated velocity with 1400 m s^{-1} and appropriate conclusion. (1) Example of calculation $v = \frac{\Delta\lambda}{\lambda}c = \frac{(576.933\text{-}576.959)\times10^{-9}\text{m}}{576.959 \times10^{-9}\text{ m}} \times 3.00\times10^{8}\text{ m s}^{-1} = (-)1.35\times10^{4}\text{ m s}^{-1}$ So the star's velocity is much larger than 1400 m s^{-1}	4
(c)	On the main sequence, above the position of the Sun **Or** above and to the left of the position of the Sun (1)	1
	Total for question	8

Q4.

Question Number	Answer	Mark
	Energy transferred from hot liquid = energy transferred to ice + energy transferred to cold water (1) [This may be implicit] Use of $E = mc\Delta\theta$ (1) Use of $E = mL$ (1) Mass of ice required to cool drink to 58 °C is 2.4×10^{-2} kg **Or** Final temperature using 4 g of ice is 69 °C (1) Valid conclusion based on a consideration of their calculated value in comparison with a corresponding value in the question. (1) <u>Example of calculation</u> Energy transferred from hot liquid = energy transferred to ice + energy transferred to cold water $0.275\ \text{kg} \times 3750\ \text{J kg}^{-1}\text{K}^{-1} \times (71.5 - 58.0)\text{K}$ $= \text{m} \times 3.34 \times 10^5\ \text{J kg}^{-1} + \text{m} \times 4190\ \text{J kg}^{-1}\text{K}^{-1} \times (58.0 - 0)\text{K}$ $\therefore 1.39 \times 10^4\text{J} = \text{m} \times (3.34 \times 10^5 + 2.43 \times 10^5)\ \text{J kg}^{-1}$ $\therefore m = \frac{1.39 \times 10^4\ \text{J}}{5.77 \times 10^5\ \text{J kg}^{-1}} = 2.41 \times 10^{-2}\ \text{kg} = 24\ \text{g}$ So 4 g would not bring the temperature below the ideal serving temperature.	5
	Total for question	5

Q5.

Question Number	Answer	Mark
	C is the correct answer, as the molecules do not have to be identical	**(1)**

Q6.

Question Number	Answer	Mark
	B is the correct answer A is incorrect, as this would increase the value of L_V C is incorrect, as it's not necessary to stir boiling water D is incorrect, as this would increase the value of L_V	(1)

Q7.

Question Number	Answer	Mark
	C is the correct answer, as the mean momentum of the molecules is zero	(1)

Q8.

Question Number	Answer	Mark
	A is the correct answer, as $pV \propto T$	(1)