

KEELE UNIVERSITY

LEVEL 1 EXAMINATIONS, 2009

Level 1 (PRINCIPAL COURSE)

FRIDAY 16TH JANUARY 2009, 16.00–18.00

PHYSICS/ASTROPHYSICS

MODULE PHY-10011

NATURE OF MATTER

Candidates should attempt ALL of PARTS A and B, and TWO questions from PART C. PARTS A and B should be answered on the exam paper; PART C should be answered in an answer book which should be attached to the exam paper at the end of the exam with a treasury tag.

PART A yields 16% of the marks, PART B yields 24%, PART C yields 60%. You are advised to divide your time in roughly these proportions.

Figures in brackets [] denote the marks allocated to the various parts of each question. Tables of physical and mathematical data may be obtained from the invigilator.

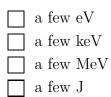
Registration Number

А	C1	Total
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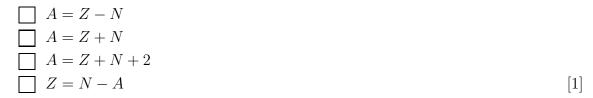
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PAI	RT A TICK THE BOX BY THE ANSWER YOU JUE (MARKS ARE NOT DEDUCTED FOR INC	OGE TO BE CORRECT CORRECT ANSWERS).	HentBounty.com
A1	The absolute temperature of an ideal gas is a mea	sure of	2.0
	 the mean molecular mass of the molecules in t the average kinetic energy of the molecules in the mean velocity of the molecules in the gas the specific heat of the gas 	the gas	[1]
A2	Heat is added to a gas, which is kept at constant	volume. The gas	
	 does work on its surroundings does no work on its surroundings has work done on it by the surroundings stays at the same temperature as its surround 	ings	[1]
A3	If a system undergoes an isothermal change then		
	 its temperature rises at a constant rate there is no exchange of energy with the surrou no work is done on or by the system the temperature of the system stays constant 	undings	[1]
A4	The molecules in 1 kg-mole of an ideal diatomic ga internal energy of the gas, according to the classic		
	$\Box \frac{1}{2}RT \qquad \Box \frac{3}{2}RT \qquad \Box \frac{5}{2}RT$	$\Box \frac{7}{2}RT$	[1]
A5	An isolated system is taken very slowly from an in this process, an amount of heat Q enters the syst system. What other property of the system chang chemical composition mass	tem, and work W is done	-
	temperature		[1]
	number of moles		[1]

	2 Stillde	
A6	The Kinetic Theory of gases works best for	THO.
	 diatomic gases gases just above their liquefaction point gases at low densities gases at very high densities 	1]
A7	On a phase diagram, the <i>triple point</i> describes the point at which	
	 three different gases can co-exist independently in a gas mixture all three phases of a substance (gas, liquid, solid) can co-exist tri-atomic gases (such as CO₂) are found 	
	a solid can exist in three different crystalline forms	[1]
A8	Which of the following is true for the molar specific heat at constant pressure, and the molar specific heat at constant volume, $C_{\rm v}$, of a monatomic gas: $\Box C_{\rm p}$ is always greater than $C_{\rm v}$ $\Box C_{\rm p}$ is always the same as $C_{\rm v}$ $\Box C_{\rm p}$ is sometimes less than, sometimes greater than, $C_{\rm v}$	$C_{\rm p},$
	\Box $C_{\rm p}$ is always less than $C_{\rm v}$	[1]
A9	 Hydrogen atoms in the interstellar gas display translational motion only translational and rotational motion translational and vibrational motion translational, rotational and vibrational motion 	[1]
A10	The energy of a photon is, in the usual notation,	
	$\square hf \qquad \square hp \qquad \square h/p \qquad \square p/h$	[1]
A11	 ¹²C and ¹³C are both isotopes of carbon because they contain the same number of neutrons in the nucleus contain the same number of particles in the nucleus contain the same number of protons in the nucleus 	
	contain the same number of protons in the nucleus	[1]

StudentBounts.com A12 The binding energy of a valence (outer) electron in an atom is typically



A13 Atomic number Z, atomic mass number A and neutron number N are related by



A14 The 'dimensions' of an atom are typically



A15 Classical physics fails to explain the photoelectric effect because the measured kinetic energy of the emitted electrons

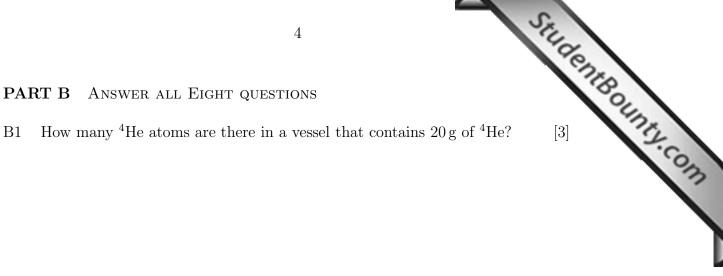
- depends on the intensity of the incident light
- depends on the frequency of the incident light
 - does not depend on the properties of the incident light
 - depends on the nature of the surface
- A16 Which of the following indicate the photon (i.e. 'particle') nature of electromagnetic radiation?
 - interference
 - the Compton effect
 - constancy of speed in any inertial reference frame
 - diffraction

[1]

[1]

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B2 For a sample of gas, the difference in the heat capacities at constant pressure and at constant volume $C_{\rm p} - C_{\rm v} = 34.8 \,\mathrm{J}\,\mathrm{K}^{-1}$. Find (a) the number of moles, (b) the heat capacity at constant pressure given that the gas is monatomic. [3]

B3 Sketch the temperature-dependence of the specific heat at constant volume, $C_{\rm v}$, for a solid. Label the essential features of the plot. [3]

B4The van der Waals equation of state is

$$\left(P + \frac{a}{V^2}\right)(V - b) = RT$$

StudentBounty.com Sketch the phase diagram (i.e. P against V) for a 'real' (as opposed to 'ideal') gas that obeys the van der Waals equation of state; your sketch should include a P - V curve for temperatures well below, and well above, the critical temperature $T_{\rm c}$. [3]

The density of solid arsenic is 5730 kg m^{-3} . Estimate the distance between B5[3]arsenic atoms in a piece of solid arsenic.

B6What is the de Broglie wavelength associated with a neutron which has kinetic energy $5 \,\mathrm{keV}$? [3]

StudentBounts.com A gas at pressure P is contained in a cylindrical vessel. The gas does work on B7a friction-free piston by raising it by a small distance dx. Show that the work done by the gas is dW = P dV, where dV is the change in gas volume.

B8A radio transmitter with power 3000 W transmits at frequency 500 MHz. How [3]many photons are emitted per second?

PART C ANSWER TWO OUT OF FOUR QUESTIONS

- StudentBounty.com (a) In the context of Kinetic Theory, what is meant by the term *degree of free*-C1. dom?
 - (b) What is the theorem of Equipartition of Energy?
 - (c) Assuming that $C_{\rm p} C_{\rm v} = R$, in the usual notation, use the Equipartition Theorem to show that the ratio of specific heats $C_{\rm p}/C_{\rm v} = \gamma$ has the value 9/7 for a gas consisting of diatomic molecules that both rotate and vibrate. |10|
 - (d) Would you expect this result to be valid for low, intermediate or high temperatures? Explain your answer. [6]
 - (e) Sketch the temperature-dependence of the specific heat at constant volume for (i) a monatomic gas and (ii) a diatomic gas. Label the essential features of the plot in each case. [8]

C2.(a) What is meant by an *adiabatic process*? [3]

- (b) How are pressure and volume related for an adiabatic change? [3]
- (c) Neon gas, at an initial temperature of 20° C and 1 atmosphere pressure, is compressed adiabatically to one-sixth its initial volume. Assuming that the ratio of specific heats for neon is $\gamma = 5/3$, determine the pressure and temperature of the gas following compression. $[2 \times 5]$
- (d) If the compression in part (c) had been performed isothermally rather than adiabatically, what would the pressure and temperature following compression be, assuming that the gas had the same initial conditions? $[2 \times 5]$
- (e) If the gas in parts (c) and (d) had been O_2 rather than Ne, what factor(s) in the calculation would have been different? [4]

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[3]

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StudentBounts.com (a) Show that the Bragg condition for the reflection of X-rays of wavelength λ C3. from crystal planes whose spacing is d is

 $2d\sin\theta = n\lambda$,

where θ is the angle between the incident direction and the crystal plane, and n is an integer. |10|

- (b) X-rays of wavelength 0.158 nm are reflected from a cubic CsCl crystal; the first order reflection occurs at 15.7°. What value does this give for the interplanar spacing of CsCl? [4]
- (c) How many other (higher) orders can in principle be observed using X-rays of this wavelength? [8]
- (d) X-rays having twice the energy are reflected from CsCl; at what angle is the first order reflection seen? [8]
- C4. (a) The radius, R, of an atomic nucleus of atomic number A is given, to a good degree of accuracy, by

$$R = 1.2 \times 10^{-15} A^{1/3} \mathrm{m}$$
;

calculate the radius of a $^{212}_{84}$ Po nucleus.

- (b) An α particle $\binom{4}{2}$ He) is confined in a $\binom{212}{84}$ Po nucleus. Assuming non-relativistic mechanics, what is the uncertainty, ΔV , in the velocity of the α particle? [10]
- (c) If its actual speed inside the nucleus, V, is the same as ΔV , what is the kinetic energy of the α particle, in MeV? $\left[5\right]$
- (d) The $^{212}_{84}$ Po nucleus undergoes α decay, as follows:

$$^{212}_{84}\text{Po} \rightarrow ^{208}_{82}\text{Pb} + \alpha$$
.

Work out the Coulomb potential energy, in MeV, of the α particle in the electric field of the $^{208}_{82}$ Pb nucleus *just after* it has left the Pb nucleus. [Assume that the ${}^{208}_{82}$ Pb nucleus is the same size as the ${}^{212}_{84}$ Po nucleus, and that the dimensions of the α particle are negligible.] [6]

(e) By how much does the kinetic energy of the α particle fall short of breaking away from the Pb nucleus? [4]

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