Physics: B.1, B.3
Higher level
Paper Example

Thursday 25 September 2025

75 minutes

Student name

Instructions to candidates

- Write your name in the box above.
- Do not open this examination paper until instructed to do so.
- A graphic display calculator is required for this paper.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- Unless otherwise stated in the question, all numerical answers should be given exactly or correct to three significant figures.
- The maximum mark for this examination paper is **[48 marks] + [9 bonus marks]**.
- Bonus marks do not count toward total. The bonus question is for practice purpose only.

Q:	1	2	3
Marks:	/13	/27	/8

Total
/48

14 pages

Please **do not** write on this page.

Answers written on this page
will not be marked.

Answers must be written within the answer boxes provided. Full marks are not necessarily awarded for a correct answer with no working. Answers must be supported by working and/or explanations. Solutions found from a graphic display calculator should be supported by suitable working. For example, if graphs are used to find a solution, you should sketch these as part of your answer. Where an answer is incorrect, some marks may be given for a correct method, provided this is shown by written working. You are therefore advised to show all working.

1. [Maximum mark: 13]

[ideal gas law]

(a) You might see people write the ideal gas law in one of the two forms:

$$PV = Nk_BT,$$

or

$$PV = nRT.$$

Identify the meaning of every variable in these 2 equations. [2]

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(b) What are the assumptions of ideal gas law (list 3)? [3]

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(c) Here are some experimental data of real gases, what can you notice from the diagrams. State one observation. [1]

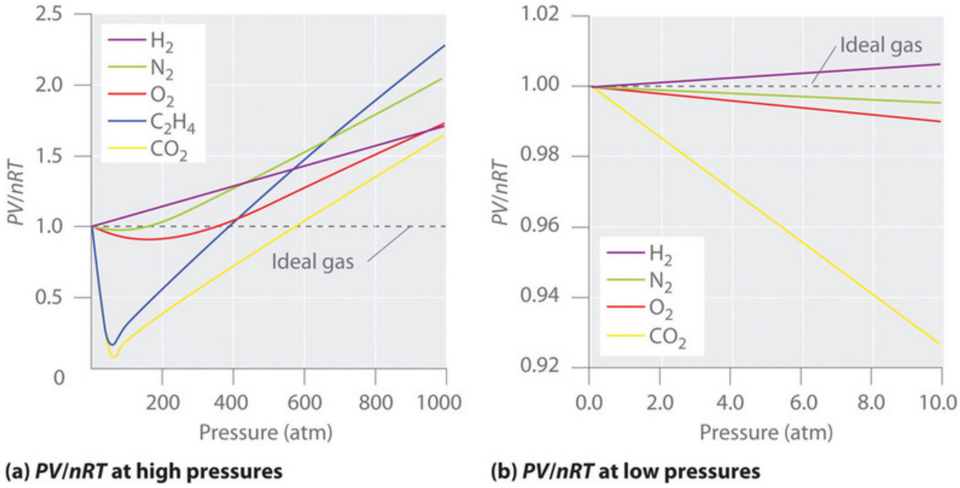

Figure 1: Real gases measured at 273 K.

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(d) To model the behavior of real gases, the van der Waals correction applies upon the ideal gas law:

$$P = \frac{RT}{V/n - b} - \frac{a}{(V/n)^2},$$

where a and b are constants. What are the constants corresponding to? Sate and explain your reasoning. (Hint: You may want to rearrange this formula so that one side equals to nRT.) [4]

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(e) The total internal energy U of a ideal gas can be described by the equipartition theorem.

$$U = \frac{3}{2} N k_B T.$$

Derive the ideal gas law, starting from this formula. [3]

(i) Option 1: Do the question directly

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(ii) Option 2: (Bonus!) Include derivation of pressure's relationship with the average translational speed of molecules. Do no use that expression directlyl. Sate all the assumptions you used. (Hint: Pressure is momentum transfer per unit area per unit time on the container walls.) (Another hint: think about the derivation of $\bar{E_k} = \frac{3}{2}k_B T$ on oxford IB physics 2014 edition page 109.) [+9 extra marks]

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2. [Maximum mark: 27]

[states of matter and heat transformations]

(a) To measure the heat capacity of an object, all you usually have to do is to put it in thermal contact with another object whose heat capacity you know. As an example, suppose that a chunk of metal is immersed in boiling water (100 °C), then is quickly transferred into a calorimeter containing 250 grams of water at 20 °C. After a minute or so, the temperature of the contents of the calorimeter is 24 °C. Assume that during this time no significant energy is transferred between the contents of the cup and the surroundings. The heat capacity of the cup itself if negligible.

(i) How much heat is gained by the water? [2]

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(ii) How much heat is lost by the metal? [1]

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(iii) What is the heat capacity of this chunk of metal? [2]

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(iv) If the mass of the chunk of metal is 100 gram, what is its specific heat capacity? [2]

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(b) Suppose that you have some steaming boiled beans. There are two containers that you can choose from: a plate (very flat, without concavity) and a bowl. Which container would you choose if you want to cool the beans faster? Explain. [4]

(c) Explain briefly why molecules solid sates are relatively motionless compared to the molecules in fluids. [2]

(d) Your 200 gram cup of tea is boiling-hot (assume 100 °C). About how much ice should you add to bring it down to 65 °C? (Assume that the ice is initially at -15 °C. The specific heat capacity of ice is 2.1 J/kg·°C.) [4]

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(e) When spring finally arrives in mountains, the snow pack may be 2 meters deep, composed of 50% of ice and 50% of air. Direct sunlight provides about 1000 watts/m^2 (1 watt = 1 J/s) to earth's surface, but the snow might reflect 90% of this energy. Answer the following questions to estimate how many weeks the snow pack should last, if direct solar radiation is the only source of energy.

(i) Calculate the energy required to melt 1 m^3 of snow (50% of ice and 50% of air). [2]

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(ii) Estimate the energy absorbed from sunlight per second per m^2. [1]

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(iii) Hence, estimate the time for melting. [4]

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(f) Why isolated systems tends to evolve towards thermal equilibrium overtime? Explain by dividing the system into subsystems based on temperature gradient. [3]

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3. [Maximum mark: 8]

[Blackbody radiation] Stars can be approximately modeled as blackbodies that emit a continuous spectrum of electromagnetic radiation. The Sun's surface temperature is about 5800 K, and its blackbody spectrum peaks in the green region of the visible spectrum (around 500 nm).

(a) Explain why stars can be modeled as blackbodies. [1]

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(b) Using Wien's displacement law, describe what happens to the wavelength of peak intensity as the surface temperature of a star increases. [1]

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(c) The Sun's peak emission is in the green part of the spectrum, yet the Sun appears white or yellowish to the human eye. Explain why. [1]

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A distant star has a radius $R = 2.0\ R_{sun}$ and a surface temperature of 10,000 K, where the Sun's radius is $R_{sun} = 7.0\times10^{2}$ m and its surface temperature is $T_{sun} = 5800$ K.

(d) Derive an expression for the ratio of luminosities of the star and the Sun. [2]

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(e) Calculate this ratio for the given data. [1]

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(f) Explain qualitatively why even a small increase in temperature leads to a large increase in luminosity. [1]

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(g) Describe one assumption made in applying the Stefan–Boltzmann law to stars and comment on its validity. [1]

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END OF EXAM

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