

Week 34

A-Level Physics

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

Topic 16 quiz	2
Exercise sheet 16.1	5
Past-paper questions 16.1	10
Exercise sheet 16.2	12
Past-paper questions 16.2	17

A-Level Physics

Name: _____ Score: _____

1. Internal energy is the sum of which energies?

- ☐ the random kinetic energy of the molecules
- ☐ the potential energy between the molecules
- ☐ the bulk kinetic energy of the whole object
- ☐ the weight of the object

Tick every correct option.

2. The work done by a gas expanding at constant pressure is:

- ☐ $p \Delta V$
- ☐ $\frac{p}{\Delta V}$
- ☐ pV^2
- ☐ $\frac{\Delta V}{p}$

3. A moving train's bulk kinetic energy counts as part of its internal energy.

- ☐ True ☐ False

4. When a gas expands, it does work on its surroundings.

- ☐ True ☐ False

5. Internal energy depends only on the state of the system, not on the path taken to reach it.

- ☐ True ☐ False

6. The first law of thermodynamics: $\Delta U = q +$ _____.

7. For an ideal gas, the internal energy is:

- ☐ $\frac{3}{2}nRT$
- ☐ pV exactly
- ☐ $mc\Delta T$
- ☐ $\frac{1}{2}mv^2$

8. 100 J of heat is added to a gas while 30 J of work is done **on** it. What is the rise in internal energy?

_____ J

9. For an ideal gas, if the absolute temperature doubles, the internal energy multiplies by:

10. In an isothermal change of an ideal gas, the internal energy does not change.

☐ True ☐ False

A-Level Physics

1. **the random kinetic energy of the molecules; the potential energy between the molecules**

Internal energy = random molecular KE + intermolecular PE. The object's overall motion (bulk KE) is separate.

2. **$p\Delta V$**

Force = pA , distance = Δx , so work = $pA\Delta x = p\Delta V$.

3. **False**

No — internal energy is the energy of the *random* molecular motion, not the whole object moving along.

4. **True**

Yes — it pushes the piston/atmosphere outward. So the work done *on* the gas is negative.

5. **True**

Yes — U is a function of state (T , p , V , amount); two routes to the same state give the same U .

6. **W**

$\Delta U = q + W$, where W is the work done **on** the gas and q is the heat added.

7. **$\frac{3}{2}nRT$**

No intermolecular PE, so U is all kinetic: $U = \frac{3}{2}NkT = \frac{3}{2}nRT$.

8. **130 J**

$\Delta U = q + W = 100 + 30 = 130$ J.

9. **2**

$U = \frac{3}{2}nRT \propto T$, so doubling T doubles U .

10. **True**

For an ideal gas $U \propto T$, so constant T means $\Delta U = 0$ (and then $q = -W$).

16.1 Internal energy

Name: _____ Class: _____ Date: _____

Total: 21 marks

KEY WORDS internal energy 内能 • kinetic energy 动能 • temperature 温度 • ideal gas 理想气体
• thermodynamic temperature 热力学温度

Objective

Build the skills to answer exam questions on **internal energy**.

You must be able to:

- describe internal energy as the random **kinetic** + **potential** energy of molecules
- relate a **temperature** rise to an internal-energy rise
- use $U = \frac{3}{2}nRT$ for an ideal gas

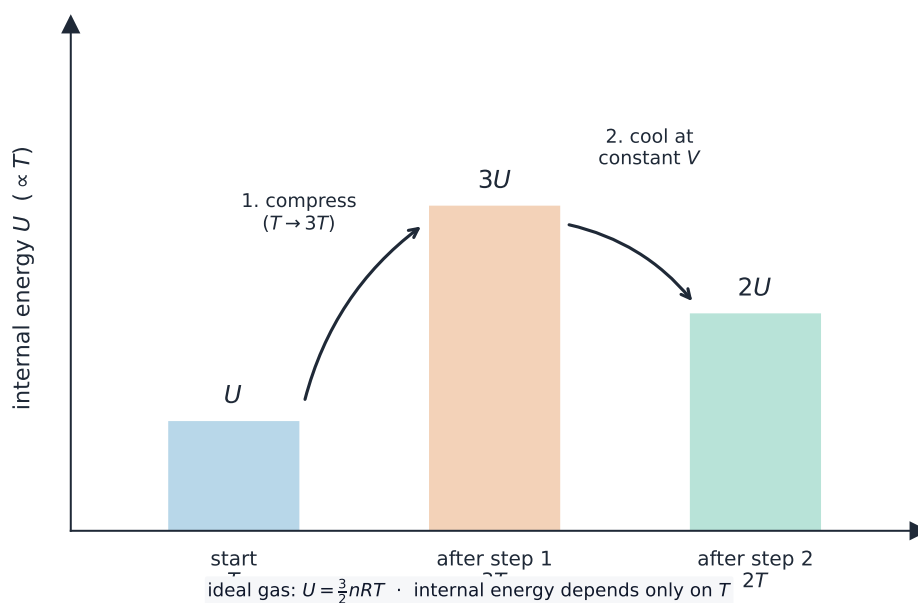
1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Internal energy

The **internal energy** U is the sum of the **random kinetic** energy and the **potential** energy of all the molecules:

random kinetic energy of molecules	+	potential energy between molecules
= internal energy U		



Internal energy rises with temperature

- U depends only on the **state** (T , p , V , amount) — not the path.
- For an **ideal gas**, intermolecular forces are ignored ($PE = 0$), so U is **all kinetic**: $U = \frac{3}{2}nRT$, directly proportional to T .
- Raising the temperature raises the molecules' KE, so raises U . During **boiling/melting**, U rises through **PE** (bonds breaking) at constant temperature.

2 Practice

Now apply the methods above.

2.1 State the **two** contributions to the internal energy of a substance. [2]

2.2 State what happens to a body's internal energy when its **temperature rises**. [1]

2.3 State why an **ideal gas** has zero molecular potential energy. [1]

2.4 Write the expression for the internal energy of an ideal gas. [1]

3 Exam-style questions

3.1 The internal energy of an **ideal gas** depends only on its: [1]

- **A** pressure
 - **B** volume
 - **C** thermodynamic temperature
 - **D** mass
-

3.2 The thermodynamic temperature of an ideal gas is **doubled**. State what happens to its internal energy. [1]

3.3 Explain why a substance's internal energy **increases** during boiling, even though its **temperature** stays constant. [2]

3.4 Explain why the internal energy of a gas is **not** the same as the kinetic energy of the moving container it is in. [2]

3.5 A sealed cylinder contains an ideal gas at thermodynamic temperature T , with internal energy U . A piston compresses the gas, raising its temperature to $4T$, and work W is done on the gas during the compression. The gas is then cooled at **constant volume** until its temperature is $2T$.

(a) **State** what is meant by the internal energy of a system. [2]

(b) **Explain** why, for an **ideal gas**, the internal energy depends only on the thermodynamic temperature. [2]

(c) **Complete** the table, giving each entry in terms of some or all of W and U . [4]

process	work done on the gas	thermal energy supplied to the gas	increase in internal energy
compression to $4T$	W	_____	_____
cooling to $2T$	_____	_____	_____

(d) **State and explain** what happens to the mean speed of the molecules during the cooling. [2]

Solutions

2.1 The **random kinetic energy** of the molecules and the **potential energy** between the molecules.

2.2 It **increases** (the molecules' random kinetic energy rises).

2.3 Its molecules are assumed to have **no forces** between them (except during collisions), so there is no intermolecular potential energy.

2.4 $U = \frac{3}{2}nRT$ (or $\frac{3}{2}NkT$).

3.1 **C** — thermodynamic temperature.

3.2 It **doubles** ($U \propto T$ for an ideal gas).

3.3 Energy goes into increasing the molecular **potential energy** as bonds are broken/molecules separated; the kinetic energy (temperature) stays the same, so U rises with constant T .

3.4 Internal energy is the energy of the **random** molecular motion; the container's motion is **bulk/ordered** kinetic energy of the whole body, which is separate from U .

3.5 (a) The **sum of the random kinetic and potential energies** of all the molecules of the system.

(b) The molecules of an ideal gas exert no forces on each other except in collisions, so their total **potential** energy is zero and the internal energy is purely kinetic; the mean molecular kinetic energy is $\frac{3}{2}kT$, so the internal energy depends only on T — not on the volume or the pressure separately.

(c) Internal energy is proportional to T : it is U at T , $4U$ at $4T$ and $2U$ at $2T$.

process	work done on the gas	thermal energy supplied	increase in internal energy
compression to $4T$	W	$3U - W$	$+3U$
cooling to $2T$	0	$-2U$	$-2U$

(d) The mean speed **decreases**, because the mean kinetic energy $\frac{3}{2}kT$ falls with the temperature and the molecular mass is unchanged.

4 (a) (i) State what is meant by the internal energy of a system.

.....

.....

..... [2]

(ii) Explain why the internal energy of an ideal gas is directly proportional to the thermodynamic temperature of the gas.

.....

.....

..... [2]

(b) A sample of an ideal gas at thermodynamic temperature T has internal energy U .

The gas is compressed so that its temperature increases to $3T$.
During this compression, work W is done on the gas.

The gas is then cooled at constant volume so that its temperature decreases to $2T$.

Complete Table 4.1 to show, in terms of some or all of W , T and U , the work done on the gas, the thermal energy supplied to the gas and the increase in internal energy of the gas for each of the two processes.

Table 4.1

	work done on gas	thermal energy supplied to gas	increase in internal energy of gas
compression	$+W$		
cooling			

[4]

[Total: 8]

4 (a) (i) State what is meant by the internal energy of a system.

.....

.....

..... [2]

(ii) Explain why the internal energy of an ideal gas is directly proportional to the thermodynamic temperature of the gas.

.....

.....

..... [2]

(b) A sample of an ideal gas at thermodynamic temperature T has internal energy U .

The gas is compressed so that its temperature increases to $3T$.
During this compression, work W is done on the gas.

The gas is then cooled at constant volume so that its temperature decreases to $2T$.

Complete Table 4.1 to show, in terms of some or all of W , T and U , the work done on the gas, the thermal energy supplied to the gas and the increase in internal energy of the gas for each of the two processes.

Table 4.1

	work done on gas	thermal energy supplied to gas	increase in internal energy of gas
compression	$+W$		
cooling			

[4]

[Total: 8]

16.2 The first law of thermodynamics

Name: _____ Class: _____ Date: _____

Total: 16 marks

KEY WORDS first law of thermodynamics 热力学第一定律 • internal energy 内能 • pressure 压强
• volume 体积 • temperature 温度

Objective

Build the skills to answer exam questions on the **first law of thermodynamics** and work done by/on a gas.

You must be able to:

- state the **two ways** to change a system's internal energy
- use $W = p\Delta V$ and the **sign** of work done on vs by a gas
- use the **first law** $\Delta U = q + W$ and apply it to real situations

1 Worked examples

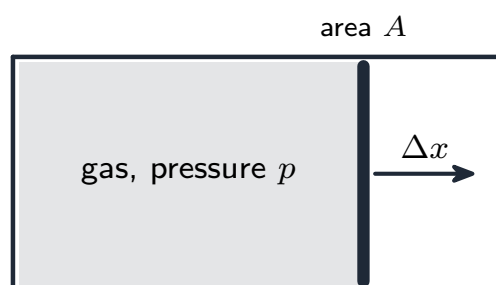
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Two ways to change internal energy

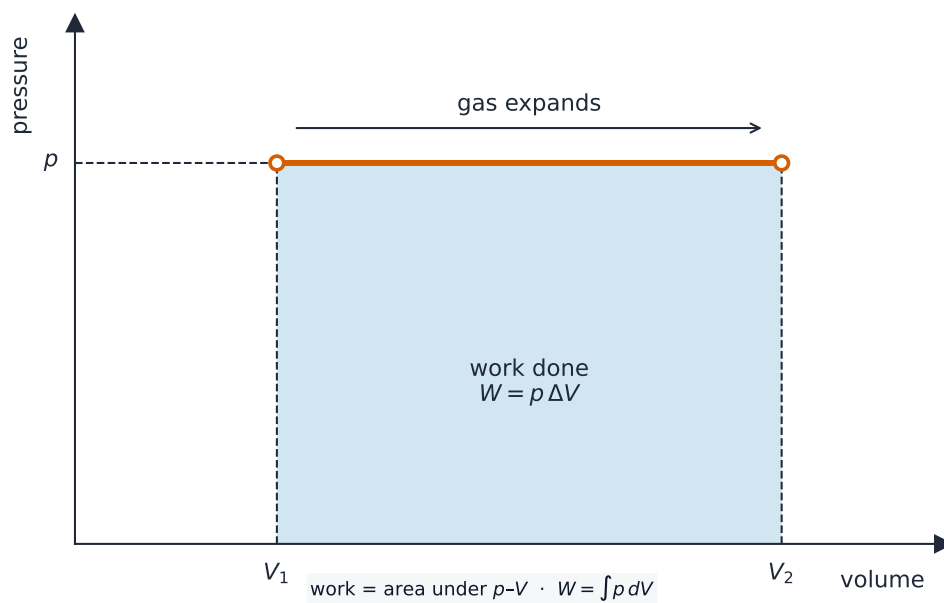
The internal energy of a system changes only by **heating it** (energy q) or by **doing work on it** (work W). The **first law** combines them.

■ Work done by a gas

At constant pressure, a gas changing volume does work:



$$W = p \Delta V = pA \Delta x$$



Work done by a gas is the area under p - V

$$W = p\Delta V.$$

■ First law of thermodynamics

$$\Delta U = q + W,$$

where ΔU = increase in internal energy, q = energy added **by heating**, W = work done **on** the gas.

- **compressed:** W on the gas is **positive** (gas gains energy);
- **expands:** W on the gas is **negative** (gas does work on surroundings);
- **constant volume:** $W = 0$, so $\Delta U = q$.

Worked example. A gas at 1.0×10^5 Pa expands from 2.0 to $5.0 \times 10^{-3} \text{ m}^3$: work done **by** the gas = $p\Delta V = (1.0 \times 10^5)(3.0 \times 10^{-3}) = 300 \text{ J}$.

■ Applying the first law

Worked example (a bicycle pump warms up). Air is compressed **quickly**, so almost no heat escapes ($q \approx 0$). Work is done **on** the gas ($W > 0$), so $\Delta U = q + W > 0$ — the internal energy and therefore the **temperature rise**. (An expanding gas does the opposite — it **cools**.)

2 Practice

Now apply the methods above.

2.1 State the **two ways** in which the internal energy of a system can be changed. [2]

2.2 Write the formula for the work done when a gas changes volume at **constant pressure**. [1]

2.3 A gas at 1.0×10^5 Pa expands by 3.0×10^{-3} m³. Find the work done **by** the gas. [2]

2.4 State the **sign** of the work done **on** a gas when it is **compressed**. [1]

3 Exam-style questions

3.1 When a gas is **compressed**, the work done **on** the gas is: [1]

- **A** negative
- **B** zero
- **C** positive
- **D** undefined

3.2 A gas is heated with 500 J of energy, and 200 J of work is done **on** it. Find the change in **internal energy**. [2]

3.3 A gas at constant pressure 2.0×10^5 Pa is **compressed** from 4.0×10^{-3} to 1.0×10^{-3} m³,

while 800 J is removed by cooling. Calculate the change in internal energy ΔU . [4]

3.4 Use the first law of thermodynamics to explain why a bicycle pump becomes **warm** when air is pumped quickly. [3]

Solutions

2.1 By **heating** it (transferring thermal energy to it) and by **doing work** on it.

2.2 $W = p\Delta V$.

2.3 $W = p\Delta V = (1.0 \times 10^5)(3.0 \times 10^{-3}) = 300 \text{ J}$.

2.4 Positive.

3.1 C — positive.

3.2 $\Delta U = q + W = 500 + 200 = 700 \text{ J}$.

3.3 Compressed $\rightarrow$ work done **on** gas is positive: $W = p|\Delta V| = (2.0 \times 10^5)(3.0 \times 10^{-3}) = 600 \text{ J}$; cooling removes energy, so $q = -800 \text{ J}$; $\Delta U = q + W = -800 + 600 = -200 \text{ J}$.

3.4 The air is compressed quickly, so little heat leaves ($q \approx 0$); work is done **on** the gas, so W is positive; by $\Delta U = q + W$, $\Delta U > 0$, so the internal energy and temperature **rise** — the pump feels warm.

- 2 (a) State **two** ways in which the first law of thermodynamics describes that the internal energy of a system may be changed.
- 1
-
- 2
-
- [2]
- (b) (i) Use the first law of thermodynamics to explain why a bicycle pump gets hot when it is used to pump up a tyre quickly.
-
-
-
-
-
- [3]
- (ii) With reference to molecular energies, explain why the temperature of water remains at 100 °C when it vaporises in a kettle, even though it is being heated.
-
-
-
-
-
- [3]
- [Total: 8]