Trent University: PHYS 2700H – Thermal Physics 2025 – 2026

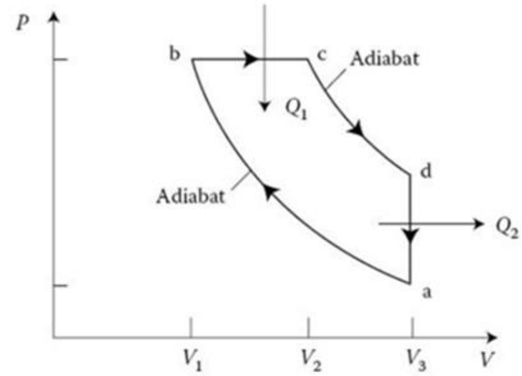
Midterm: Tuesday Feb 24, 2026 Name:___________________

Allowed: Formula sheet (given), calculator, 1 hour 50 minutes

PART 1 – answer questions **1-8** in your exam booklet and **then** use your scratch card:
One scratch = **100%**; two scratches = **33%**; three scratches = **25%** (part 1 total is 50%)
PART 2 – answer questions **9 & 10** in the exam booklet provided (each question here is worth 25%)

Qu's 1-2) A model of a diesel engine cycle is shown.

1) Which of the following statements about this cycle is most correct?



A. Work is done **on** the gas between a and b & b and c, and **by** the gas between c and d only.
B. Work is done **by** the gas between a and b only, and **on** the gas between c and d only.
C. Work is done **on** the gas between a and b only, and **by** the gas between b and c & c and d.
D. Work is done **on** the gas between b and c only, and **by** the gas between d and a only.
E. Work is done **by** the gas between b and c only, and **on** the gas between d and a only.

2) Calculate which of the following expressions represents the *efficiency* of this engine in terms of the temperatures of the gas during the cycle:

A. $1-\frac{1}{\gamma}\frac{T_d-T_a}{T_c-T_b}$ **B.** $1-\frac{T_d-T_a}{T_c-T_b}$ **C.** $1-\frac{1}{\gamma}\frac{T_b-T_c}{T_a-T_d}$ **D.** $\gamma\frac{T_c-T_d}{T_b-T_a}$ **E.** $1-\frac{1}{\gamma}\frac{T_a-T_d}{T_c-T_b}$

3) Suppose a supply of cooling water, initially at 290 K, removes the heat produced by a gas compressor that isothermally compresses 10 moles/minute of helium from 1 atm to a pressure of 10 atm at 300 K. Treat helium as an ideal gas and the compressor as 100% efficient. What is the minimum flow rate of the cooling water in litres/minute? [The specific heat of water is 4.18 J/g/K, its density is 1000 kg/m^3, and the work done on an ideal gas that isothermally changes volume from V_i to V_f is $W=-nRT\ln(V_f/V_i)$].

A. 0.14 L/min **B.** 0.28 L/min **C.** 0.56 L/min **D.** 1.4 L/min **E.** 3.4 L/min

Qu's 4-5) One mole of an ideal diatomic gas is taken from a temperature of 290 K and volume of 21 litres to a temperature of 330 K and volume of 22 litres by following a straight-line path on a *PV* diagram. Which of the following is the change in internal energy of the gas?

A. $\Delta U = 1160$ J **B.** $\Delta U = 831$ J **C.** $\Delta U = 499$ J **D.** $\Delta U = 230$ J **E.** $\Delta U = 115$ J

5) Which of the following is the work done on the gas and the heat flow into the gas?

A. $W = 120$ J, $Q = 711$ J **B.** $W = 72$ J, $Q = 427$ J **C.** $W = -168$ J, $Q = 992$ J **D.** $W = -120$ J, $Q = 951$ J **E.** $W = -72$ J, $Q = 571$ J

Qu's 6 and 7: Suppose there exists an algebraic relationship between the three variables r, c, s.

6) Which of the following then holds?

A. $\left(\frac{\partial r}{\partial c}\right)_s \left(\frac{\partial c}{\partial s}\right)_r = -\left(\frac{\partial r}{\partial s}\right)_c$ **B.** $\left(\frac{\partial r}{\partial c}\right)_s \left(\frac{\partial c}{\partial s}\right)_r = \left(\frac{\partial s}{\partial r}\right)_c$ **C.** $\left(\frac{\partial r}{\partial c}\right)_s \left(\frac{\partial c}{\partial s}\right)_r = -\left(\frac{\partial s}{\partial r}\right)_c$

D. $\left(\frac{\partial r}{\partial c}\right)_s \left(\frac{\partial c}{\partial s}\right)_r = \left(\frac{\partial r}{\partial s}\right)_c$ **E.** $\left(\frac{\partial r}{\partial c}\right)_s \left(\frac{\partial s}{\partial r}\right)_c = -\left(\frac{\partial c}{\partial s}\right)_r$

7) If we consider the equation of state for an ideal gas (namely, $PV = nRT$) and treat variables *r* as *P*, *c* as *V*, and *s* as *T*, which of the following expressions is on the left hand side (and therefore also the right hand side) of the correct answer to Question 6?

A. P **B.** $-\frac{nR}{V}$ **C.** T **D.** nRT **E.** $\frac{V}{nR}$

8) Based on the steam table on the right, which of the following statements is most correct about some heat capacities of water vapour?

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	P = 0.10 MPa (99.61°C)			
Sat.†	1.6941	2505.6	2675.0	7.3589
50				
100	1.6959	2506.2	2675.8	7.3611
150	1.9367	2582.9	2776.6	7.6148
200	2.1724	2658.2	2875.5	7.8356
250	2.4062	2733.9	2974.5	8.0346
300	2.6389	2810.7	3074.5	8.2172
400	3.1027	2968.3	3278.6	8.5452
500	3.5655	3132.2	3488.7	8.8362
600	4.0279	3302.8	3705.6	9.0999
700	4.4900	3480.4	3929.4	9.3424
800	4.9519	3665.0	4160.2	9.5682
900	5.4137	3856.7	4398.0	9.7800
1000	5.8755	4055.0	4642.6	9.9800
1100	6.3372	4259.8	4893.6	10.1698
1200	6.7988	4470.7	5150.6	10.3504
1300	7.2605	4687.2	5413.3	10.5229

A. c_p increases from about 1.5 J/g/°C at boiling temperature to about 2.0 J/g/°C at about 1000 °C .

B. c_v increases from about 2.0 J/g/°C at boiling temperature to about 2.5 J/g/°C at about 1000 °C

C. c_v increases from about 2.7 J/g/°C at boiling temperature to about 4.6 J/g/°C at about 1000 °C .

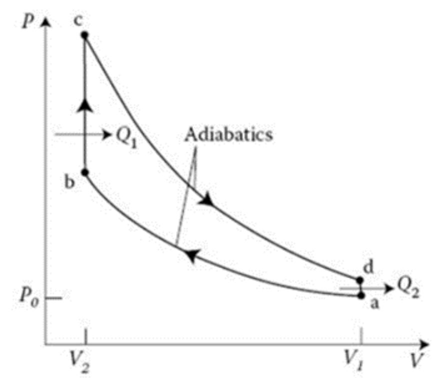
D. c_p increases from about 2.5 J/g/°C at boiling temperature to about 3.5 J/g/°C at about 1000 °C .

E. c_p increases from about 2.0 J/g/°C at boiling temperature to about 2.5 J/g/°C at about 1000 °C .

PART II –answer <u>both</u> questions in the exam booklet provided

9. a) An *ideal gas* operates as the working substance in a *Carnot refrigerator*. Select such a process and draw this on the following diagrams, all drawn on the same page above one another, with labels including key points labelled abcd:
i) a *PV* diagram
ii) a *PT* diagram
iii) a *UV* diagram
iv) a *UT* diagram
v) a *UH* diagram
b) A Carnot refrigerator with an arbitrary working substance is operated between two heat reservoirs of 400 K and 300 K.
i) If the refrigerator requires 1000 kJ of energy per cycle, how much heat does it remove from the cold reservoir per cycle?
ii) What is the coefficient of performance of this refrigerator?

10. A simplified description of a gasoline engine is shown, with air as the working substance (which we shall treat as an ideal diatomic gas), and P_0 being atmospheric pressure, P_{atm}. The volume indicated is the volume of <u>one</u> cylinder of a four-cylinder engine.



a) If $V_1 = 6V_2$ and $P_{\text{d}} = 2P_{\text{atm}}$ then what are the values of P_{b} and P_{c}?

b) The work done on an ideal gas when it is compressed adiabatically from an initial state (P_i, V_i) to a final state (P_f, V_f) is given by:

$$W = \frac{P_i V_i}{\gamma - 1}\left[\left(\frac{V_i}{V_f}\right)^{\gamma-1} - 1\right]$$

Given this, if $V_2 = 0.1\text{ L}$ find the total work done per cycle by the four-cylinder engine.

c) What is the maximum calculated power output from the engine in horsepower if the engine operates at 3000 rpm?