UNIVERSITY OF LONDON

B.Sc. (ENGINEERING) EXAMINATION 1962

PART I

for Internal and External Students

(6) APPLIED HEAT

Friday, 22 June: 10 to 1

Answer FIVE questions.

All pressures quoted are absolute.

Callendar Abridged Steam Tables are supplied.

1. An amount of carbon dioxide of mass 10 lb passes from a large storage cylinder, wherein the fluid is maintained constantly in state-A, through a valve, into a rigid vessel, initially evacuated. Finally, when the valve has been closed and the contents of the vessel are at rest, the fluid in the vessel is in state-B.

In the interval between the above-mentioned initial and final states, a stirrer, projecting into the vessel and operated from outside, does work of 70 Btu on the contents. Calculate the heat-transfer to the contents during the same interval.

The properties of carbon-dioxide for state-A and state-B are given in the following extract from tables of the properties of that substance:

	state-A		state-B	
temperature	60	°F	200	°F
pressure	500	lbf/in^2	300	lbf/in^2
specific enthalpy	290·9	Btu/lb	334·8	Btu/lb
specific entropy	1·2252	Btu/lb °R	1·3214	Btu/lb °R
specific volume	0·1937	ft^3/lb	0·5166	ft^3/lb

2. According to the Abridged Callendar Steam Tables, the specific volume, v, for superheated states may be found from the specific enthalpy, h, and the pressure, P, by using a formula of the form,

$$v = A(h - h_0)/P,$$

where the constant quantities A and h_0 are given in these tables.

Show that this implies that the increment in specific enthalpy divided by the increment in specific internal energy (for the same two such states) is a constant number, k. Using the constant quantities given in the tables, evaluate k.

Show that it is also implied that for an isentropic change Pv^k remains constant.

Steam initially at a pressure of 100 lbf/in^2 and having a specific volume of 5 ft^3/lb expands reversibly in an adiabatic enclosure until the final pressure is 60 lbf/in^2. Determine the final specific volume.

Turn over

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3. A steadily operating pneumatic motor develops a shaft power of 0·1 kW when supplied with dry air at a pressure of 150 lbf/in^2 and at a temperature of 26·85 °C, (=300 °K), and exhausting at 15 lbf/in^2. The motor is adiabatic and the isentropic efficiency (i.e. the ratio of the actual enthalpy drop to the isentropic enthalpy drop from the same initial state to the same final pressure) is 0·7 .The change in specific kinetic energy between supply and exhaust is negligible.

Determine the temperature of the air leaving the motor, (°C), and the mass flow rate expressed in gramme per second.

Air may be taken to be a perfect gas for which R = 0·0686 Chu/lb °K and c_v = 0·1715 Chu/lb deg C.

(1 Chu/lb = 4·1868 J/g = 4·1868 kW s/kg)

4. An amount of steam having a mass of 20 lb is initially at a temperature of 801 °F and a pressure of 250 lbf/in^2. It undergoes a reversible process which is a straight line on the temperature-entropy plane and at the end of which the temperature is 233 °F and the pressure is 15 lbf/in^2.

Calculate the heat-transfer to the system and the work done by the system.

5. Describe any engine test which you have performed in a laboratory. Illustrate your answer with sketches. Discuss the observations required to draw up an energy account ('heat balance') and indicate the accuracies to be expected for the various terms.

6. Explain (with reference exclusively to fluid phases) what is meant by:

saturation line, saturated liquid, saturated vapour, superheated vapour, critical point. Illustrate your answer by sketches of pressure-volume and pressure-temperature diagrams.

Describe the variation of the latent heat and of the specific volumes in the neighbourhood of the critical point.

A rigid closed vessel is to contain at 212 °F such amounts of liquid water and saturated water vapour as will ensure that if the vessel be heated the contents will pass through the critical point. Determine the initial proportion of liquid by volume.

(The specific volume of H_2O at the critical point is 0·0503 ft^3/lb and that of the saturated liquid at 212 °F is 0·016 72 ft^3/lb).

7. An amount of a perfect gas has initially a volume of 1 ft^3 at a pressure of 15 lbf/in^2 and a temperature of 60 °F. It undergoes reversibly the following cycle of operations through state-points 1, 2, 3 and 4:

(1 ... 2) isentropic compression to a pressure of 750 lbf/in^2,
(2 ... 3) isobaric (i.e. constant pressure) expansion to a volume of 0·1 ft^3,
(3 ... 4) isentropic expansion to a volume of 1 ft^3, and
(4 ... 1) isochoric (i.e. constant volume) pressure reduction to a pressure of 15 lbf/in^2.

Determine

(*a*) the temperature for state-2,
(*b*) the temperature for state-3,
(*c*) the temperature for state-4 and
(*d*) the cycle efficiency.

(Take c_p/c_v = 1·4)

8. A twin cylinder single-acting single-stage air compressor has bores of 4 in, strokes of 6 in and runs at 300 rev/min. It takes in air at 15 lbf/in^2 and 70 °F and discharges it at 45 lbf/in^2 and 230 °F. Assuming that compression is reversible and follows a law of the type Pv^n = a constant (where n is a constant), and neglecting clearance, pressure drop across valves and heat transfer during entry and discharge, determine

(a) the power required to drive the compressor, and

(b) the heat transfer rate from the air.

The air may be taken to be a perfect gas for which c_p/c_v is 1·4.

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E. J. LE FEVRE

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-2} \quad -(1)$$

$$\& \quad p_1 V_1^{\gamma} = p_2 V_2^{\gamma} \quad -(2)$$

$$(1) \times \quad T_1 V_1 = T_2 V_2^{\gamma-1} V_1 \qquad V_1 = \frac{T_2 V_2^{\gamma-1} V_1}{T_1}$$

$\therefore$ ~~$P_1 \; P_2 V_2$~~

$$\frac{P_1 V_1^{\gamma}}{T_1 V_1^{\gamma-1}} = \frac{p_2 V_2^{\gamma}}{P_2 V_2^{\gamma-1}}$$

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