Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: **CHAMBER OF MINES OF SOUTH AFRICA – CERTIFICATE IN MINE ENVIRONMENTAL CONTROL**	EXAMINER**: JOHAN PIENAAR**
PAPER 2 – THERMAL ENGINEERING	MODERATOR: **MARTHINUS VD BANK**
SUBJECT CODE: **COMMEC2**	
EXAMINATION DATE: **07 MAY 2025**	TOTAL MARKS: **[100]**
TIME: **14:00 – 17:00 (3 HOURS)**	PASS MARK: **(60%)**

NUMBER OF PAGES: **9 (including Psychrometric Chart)**

SPECIAL REQUIREMENTS:

All candidates are advised to read the below instructions/requirements and adhere to them. Not adhereing to them could lead to the loss of marks.

THIS IS **NOT** AN **OPEN BOOK EXAMINATION**.

FORMULA HANDOUTS AVAILABLE INSTRUCTIONS TO CANDIDATES:

1. Answer all 4 questions **legibly** in English.
2. Write your **ID number** on the outside cover of each book used and on any graph paper or other loose sheets handed in.

NB: Your name **must not** appear on any answer book or loose sheets.

3. Show all calculations and **check calculations on which the answers are based**.
4. Hand-held electronic calculators may be used for calculations.
5. Write **legibly** in ink on the **right-hand page** only – **left hand pages will not be marked**.
6. Illustrate your answers by means of sketches or diagrams wherever possible.
7. Answers must be given to an accuracy which is typical of practical conditions.

NB: Ensure that the correct unit of measure (SI unit) is recorded as marks will be deducted from answers if the incorrect unit is used. (Even if the calculated value is correct).

8. Please note that you are not allowed to contact your examiner or moderator regarding this examination.
9. Cell phones and any other electronic devices are **NOT** allowed in the examination room. **Only Calculator**
10. **The following chart is included: Psychrometric chart: 95.0 kPa**

QUESTION 1

1.1. A clerk in a metallurgical plant complains that the office in which she works is hot.
One wall in particular appears to radiate heat into this office, this wall separates the office from an adjoining furnace room.
The wall adjoining with the furnace room measures 4m (W) x 2m (H).
This wall comprises of a 200mm thick; double-brick wall with a 15mm thick layer of plaster on either side of the wall.
The surface temperature of this wall is measured to be 115°C (on the furnace side of the wall and 55°C (on the office side of the wall).
An air conditioner maintains the air temperature inside the office at a constant 26.5°C.

Given that:

- The thermal conductivity of brick is 0.7 W/m°C.
- The thermal conductivity of plaster is 0.93 W/m°C.
- The surface (skin and clothes) temperature of the clerk averages 28°C.
- That side of the clerk's body facing the "hot" wall has a surface area of 0.8m².
- That side of the clerk's body facing the "hot" wall has an emissivity and view factor with the wall of 0.95.

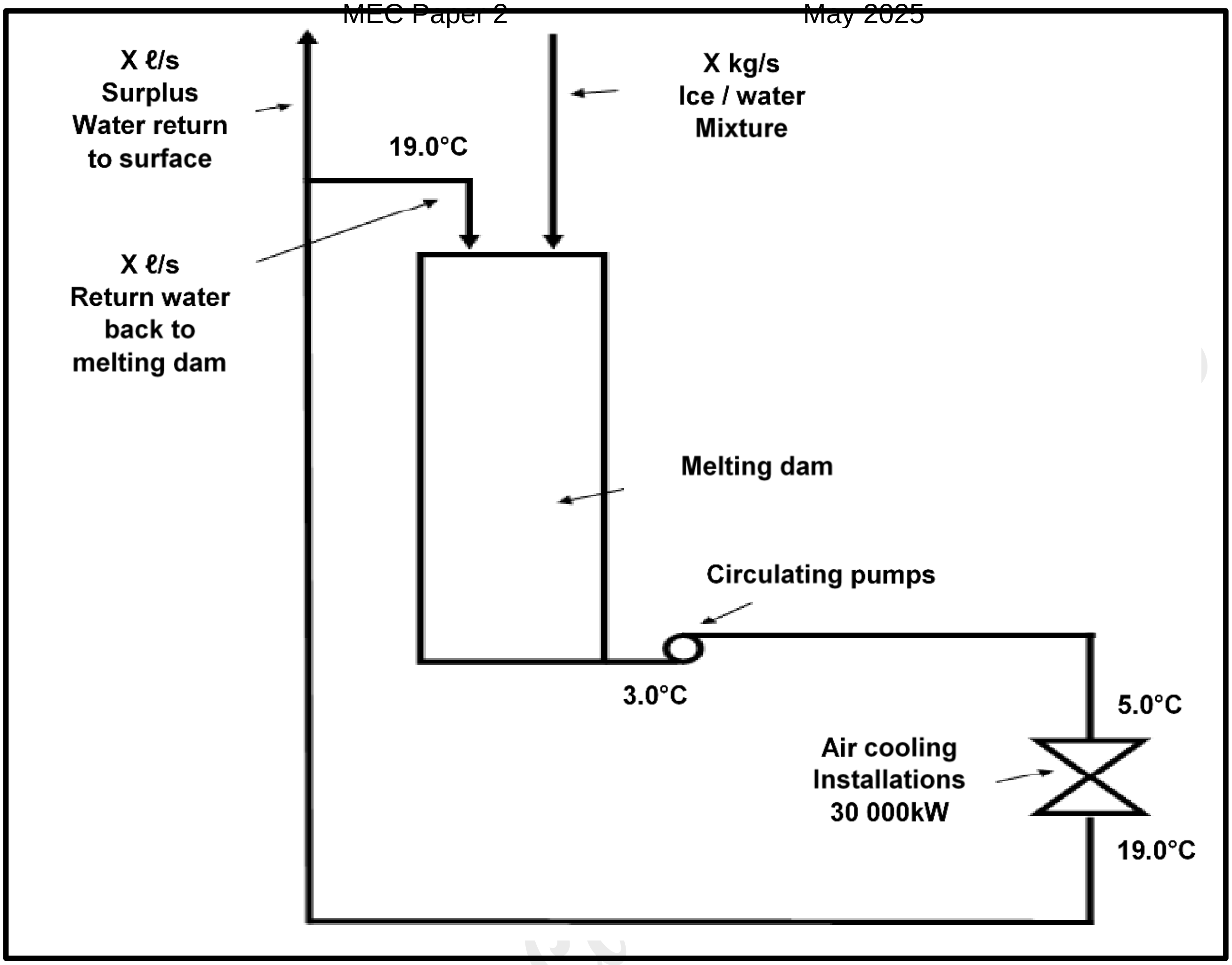
Determine the following:

1.1.1 At what rate does heat pass through the wall by means of conduction? (3)

1.1.2 The convective heat transfers co-efficient for the wall. (4)

1.1.3. How much radiated heat is received by the clerk. (3)

1.2. At a deep mine, a new project is being developed. Computer simulation has confirmed the calculated additional cooling load for this new project to be 30 000kW. As this project site has a long life (15 years) and is deep (max depth = 3600m) the decision has been taken to use ice to supply the additional cooling load required. The water will leave the underground ice discharge dam at 3°C arrive at the air-cooling installations at 5°C and return to the same dam at 19°C. Clearly state all assumptions.



Determine the following:

1.2.1. How much ice must be produced at the surface ice plant. (13)

1.2.2. Determine how much water must be circulated underground, between the air cooling installations and the underground ice discharge dam. (1)

1.2.3. Assuming that the surplus "melt" water is pumped to surface from the lowest level, assuming overall pump efficiency of 68%, how much power is used to pump this surplus "melt' water back to surface? (2)

1.2.4. If ice was not used and all cooling water was pumped back to the surface refrigeration systems, assuming the same pump head and efficiency, how much power would be required to pump this cooling water out of this mine? (2)

1.2.5. Discuss the difference between your answers to 1.2.3 and 1.2.4 (above) (2)

Total Marks: (30)

QUESTION 2

2. The following measurements were made on a R134a refrigeration plant operating under full load conditions (table with the Saturation points of Refrigerant R134a is included as well).

Evaporator

Water flow rate	75.5 ℓ/s
Water temperature (in)	17.7°C
Water temperature (out)	3.5°C
Evaporator temperature	0.5°C

Condenser

Water flow rate	128 ℓ/s
Water temperature (in)	42.8°C
Water temperature (out)	54.5°C
Condenser temperature	58.5°C

Compressor

Motor amperage	114.6A
Voltage	6 600V
Power factor	0.92
No of phases	3
Calculated compressor motor efficiency	83%

Condenser cooling tower

Water temperature (in)	55.8°C
Water temperature (out)	43.9°C
Water flow rate	131.2ℓ/s
Pump input power rating	300kW

Bulk air cooler

Water temperature (in)	5.2°C
Water temperature (out)	16.3°C
Water flow rate	106.2ℓ/s
Pump input power rating	230kW

Temperature °C	Pressure mPa	Vapour Volume m³/kg	Liquid density kg/m³	Enthalpy		Entropy	
				Liquid kJ/kg	Vapour kJ/kg	Liquid kJ/kgK	Vapour kJ/kgK
-80	0,00365	4,29	1524	-1,546	248,8	0,5623	1,858
-75	0,00545	2,94	1511	4,536	251,8	0,5934	1,841
-70	0,00795	2,07	1498	10,64	254,9	0,6238	1,826
-65	0,01135	1,48	1485	16,77	258,0	0,6536	1,613
-60	0,01587	1,08	1472	22,92	261,2	0,6828	1,801
-55	0,02179	0,803	1458	29,11	264,3	0,7114	1,790
-50	0,02942	0,606	1444	35,33	267,4	0,7400	1,780
-45	0,03908	0,465	1431	41,58	270,6	0,7673	1,771
-40	0,05118	0,361	1417	47,88	273,7	0,7946	1,763
-35	0,06612	0,284	1402	54,22	276,8	0.8214	1,756
-30	0,08436	0,226	1388	60,60	280,0	0,8479	1,750
-25	0,10640	0,181	1373	67,03	283,1	0,8740	1,745
-20	0,13270	0,147	1358	73,51	286,1	0,9000	1,740
-15	0,16390	0,121	1343	80,05	289,2	0,9252	1,735
-10	0,20050	0,100	1327	86,64	292,2	0,9504	1,732
-5	0,24320	0,083	1311	93,29	295,2	0,9753	1,728
0	0,29250	0,069	1295	100,0	298,1	1,000	1,725
5	0,34920	0,058	1278	106,8	301,0	1,024	1,723
10	0,41390	0,050	1261	113,6	303,9	1,049	1,721
15	0,48740	0,042	1244	120,5	306,6	1,073	1,718
20	0,57020	0,036	1226	127,5	309,3	1,096	1,717
25	0,66340	0,031	1207	134,6	312,0	1,120	1,715
30	0,76750	0,027	1188	141,8	314,5	1,144	1,713
35	0,88350	0,023	1168	149,0	317,0	1,167	1,712
40	1,01220	0,020	1147	156,4	319,2	1,190	1,710
45	1,15450	0,017	1125	163,8	321,3	1,214	1,709
50	1,31130	0,015	1103	171,4	323,3	1,237	1,707
55	1,48370	0,013	1079	179,1	325,1	1,260	1,705
60	1,67270	0,012	1053	187,0	326,6	1,283	1,702
65	1,88000	0,010	1026	195,1	327,8	1,307	1,699
70	2,10560	0,009	996,9	203,4	328,7	1,331	1,670
75	2,35230	0,008	964,7	212,0	329,1	1,355	1,691
80	2,62130	0,007	928,7	221,1	328,9	1,380	1,685
85	2,91470	0,006	887,3	230,7	32719	1,406	1,677
90	3,23480	0,005	837,3	241,3	325,6	1,434	1,666
95	3,58530	0,004	770,8	253,7	320,7	1,467	1,649
100	3,97200	0,003	645,5	272,7	307,0	1,517	1,609
101*	4,05500	0,002	509,1	289,4	289,4	1,561	1,561

* Critical point

Saturation points of Refrigerant 134 A

2.1. Comment on the accuracy of the measurements on the waterside showing all calculations on which your answer is based. (11)

2.2. With reference to the enclosed saturation point data sheet for refrigerant R134a, perform a heat balance on the refrigerant side of the circuit given that the compressor discharge refrigerant enthalpy is 320kJ/kg. (15)

2.3. What is the refrigerant mass flow rate at the inlet to the compressor? (3)

2.4. What is the plant duty based on the refrigerant side calculations and what conclusions do you draw regarding errors in measurements obtained? (1)

Total Marks: (30)

QUESTION 3

3. A base metal mine is extending its workings and you are required to determine whether acclimatisation will be necessary (a reject temperature of higher than 27.5°C will necessitate acclimatisation). Information from 12 different stope reports is summarised in the table below. The air reaches the new stoping section (which consists of 3 stopes in series) at 23.5/26.5°C, and 15.0m³/s is available. The air must ventilate these three new stopes, which each has a mean virgin rock temperature of 35.3°C, 34.3°C and 33.3°C respectively.

   Note: A simple method of expressing the heat gain in a stope is as a function of the difference between the virgin rock temperature and the entering dry-bulb temperature.

Air entering the stope		Air leaving the stope		Qty	VRT	Stope heat gain
Wet bulb (°C)	Dry bulb (°C)	Wet bulb (°C)	Dry bulb (°C)	(m³/s)	(°C)	(kW)
18.5	21.0	21.5	22.0	18.3	32.3	212
22.5	24.0	23.8	24.2	24.3	30.6	136
20.2	22.0	22.5	23.0	20.2	32.3	184
18.5	20.5	22.8	23.3	13.9	32.3	230
17.6	19.1	20.8	21.4	8.6	23.6	100
12.4	14.7	15.3	16.9	24.9	23.7	187
17.0	19.5	21.0	22.3	6.7	23.7	96
20.5	21.6	25.4	26.2	8.0	30.3	166
23.2	25.1	24.4	24.8	10.8	27.3	53
18.4	19.9	19.7	20.5	16.2	22.7	76
22.0	25.5	24.4	26.0	16.4	33.3	153
20.5	25.0	22.8	26.3	17.3	33.3	160

3.1. Assuming that the air leaves each stope with a dry-bulb temperature of 2°C higher than the wet-bulb temperature. Calculate the wet-bulb temperature leaving each stope on its way to the next stope and state whether acclimatisation is necessary. The barometric pressure is 95kPa. (25)

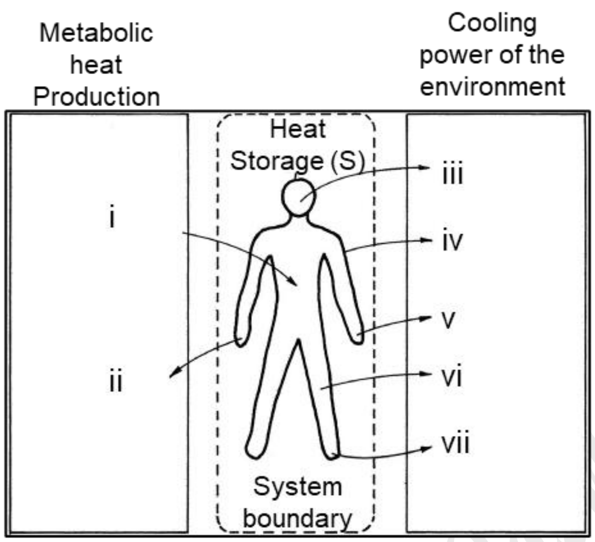
Total Marks: (25)

QUESTION 4

4.1. Please explain the six factors governing the flow of heat from rock into air. (3)

4.2. List 5 advantages and disadvantages of using ice as a medium for providing underground cooling in a deep mine (depth > 3000m). (5)

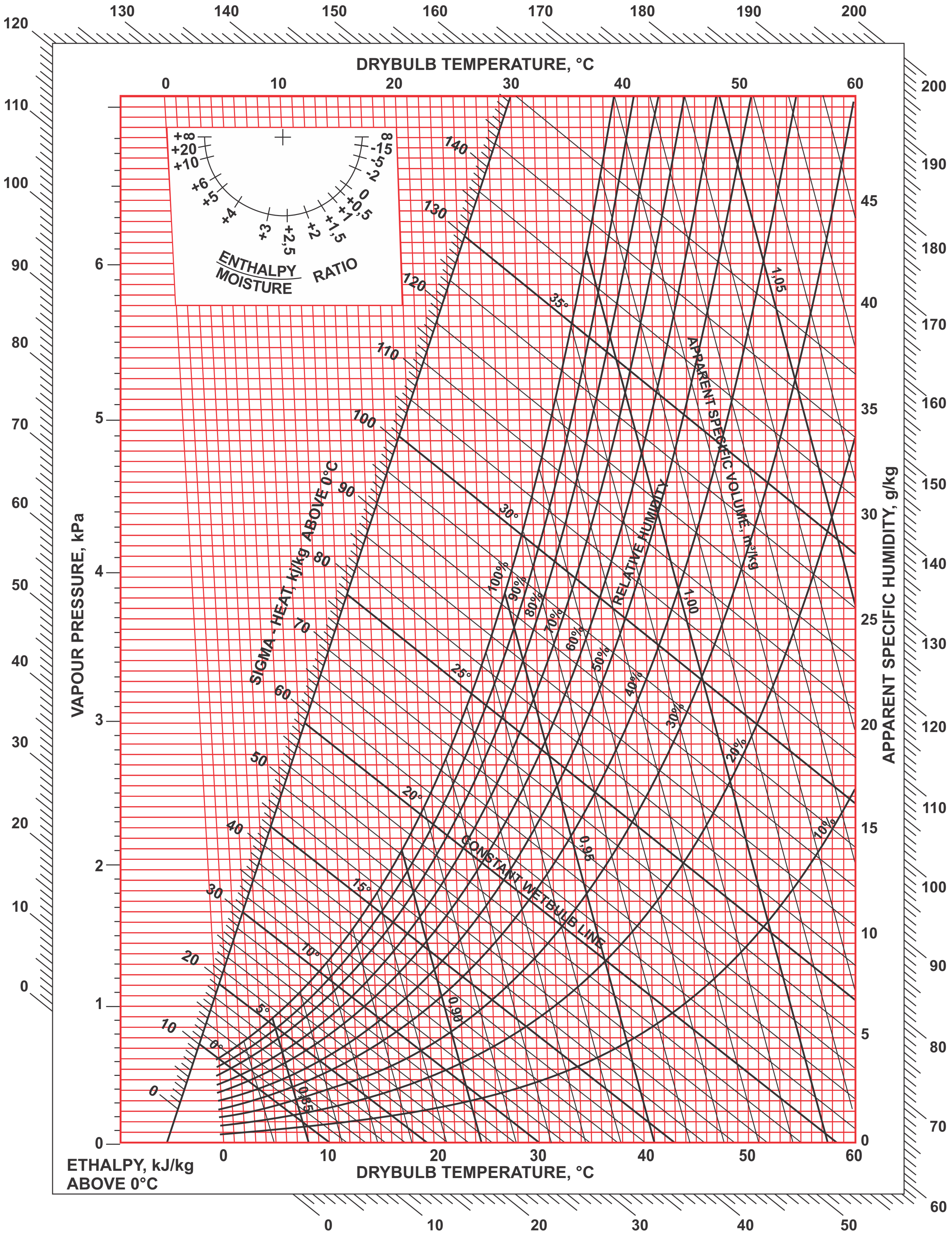
4.3. List (i to vii) the metabolic heat production and energy balance on the human body as depicted in the schematic below. (7)



$$M - W - Q - S = R + C + E + G$$

Total Marks: (15)

PSYCHROMETRIC CHART
95,0 kPa



A.W.T.B.

CHART NO 8
95,0 kPa