Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: **CHAMBER OF MINES OF SOUTH AFRICA – CERTIFICATE IN MINE ENVIRONMENTAL CONTROL** PAPER 2 – **MEC INTERMEDIATE** SUBJECT CODE: **COMIMEC2** EXAMINATION DATE: **18 NOVEMBER 2022** TIME: **14:30 – 17:30 (3 HOURS)**	**EXAMINER:** M VAN DER BANK **MODERATOR:** C MALEBANYE **TOTAL MARKS:** 100 **PASS MARK:** 60

NUMBER OF PAGES: 12

SPECIAL REQUIREMENTS:

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

FORMULA HANDOUTS ARE AVAILABLE 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 your 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 measurement (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 the examiner or moderator regarding this examination.
9. Cell phones and any other electronic devices are **NOT** allowed in the examination room.
10. **The following Psychrometric charts are included: 82.5 kPa and 87.5 kPa, 95.0kPa, 105.0 kPa, 110.0 kPa and 112.5 kPa are provided for Question 2 and Question 4.2.**
11. **NB: Hand in the Psychrometric Chart with your answer book.**

QUESTION 1

1.1 State the thermal capacity values of:

1.1.1 Ice (2,094 kJ/kg°C) (1)

1.1.2 Coal (1,005 kJ/kg°C) (1)

1.1.3 Quartzite (0.837 kJ/kg°C) (1)

1.2 Define the following:

1.2.1 Power (2)

Is the timed rate at which energy is released, expressed in watt (joules per second) or kilowatt (Kilo-joules per second)

1.2.2 Latent Heat of Fusion (2)

That which causes a change of state of a substance from a liquid to a solid e.g. water that changes to ice

1.2.3 Latent Heat of Evaporation (2)

That which causes a change of state of a substance from a liquid to a vapour e.g. water that changes into water vapour

1.2.4 Heat Transfer Processes (2)

The main "driving force" which causes heat to be transferred, is the difference in temperature between two substances or bodies. As mentioned earlier, heat always flows from a higher temperature (hot body) to a lower temperature (cold body).

1.2.5 Wet-Bulb Temperature (2)

<u>Together with the dry-bulb temperature it is a measure of the evaporating capacity of the air in ℃.</u>

1.3 There are three different heat effects on the human body. Please list and explain/define them. (8)

<u>Answer: Page 31-32</u>

Heat can affect a worker in three different ways:

- Physiological effects
- Psychological effects
- Productivity effects (Work Performance)

<u>**Physiological effects**</u>

Is where the body tries to compensate by sweating more profusely when air temperatures and / or work rate increases. The evaporation of sweat produces cooling of the human body, but however, if thermal conditions deteriorate (temperature, humidity and velocity), the rate of sweat evaporation is greatly reduced, resulting in very little cooling. Working at a high rate in such conditions may result in the following heat disorders:

- Cramps
- Heat rash
- Dehydration
- Heat exhaustion
- Heat stroke

For the symptoms, signs, causes, treatment and prevention of the abovementioned heat disorders, refer to the “Heat Stress” notes, page 68.

Psychological Effects

Is where the mental and physical activities (human performance) are affected differently by heat. Some activities may improve as heat levels increase, but then deteriorates as the heat levels exceed a certain critical level.

A worker’s ability to concentrate diminishes and become less aware of visual signals, resulting in making more errors and increased accident rates. It is also a well – known fact that tempers become worse under hot conditions.

Productivity Effects

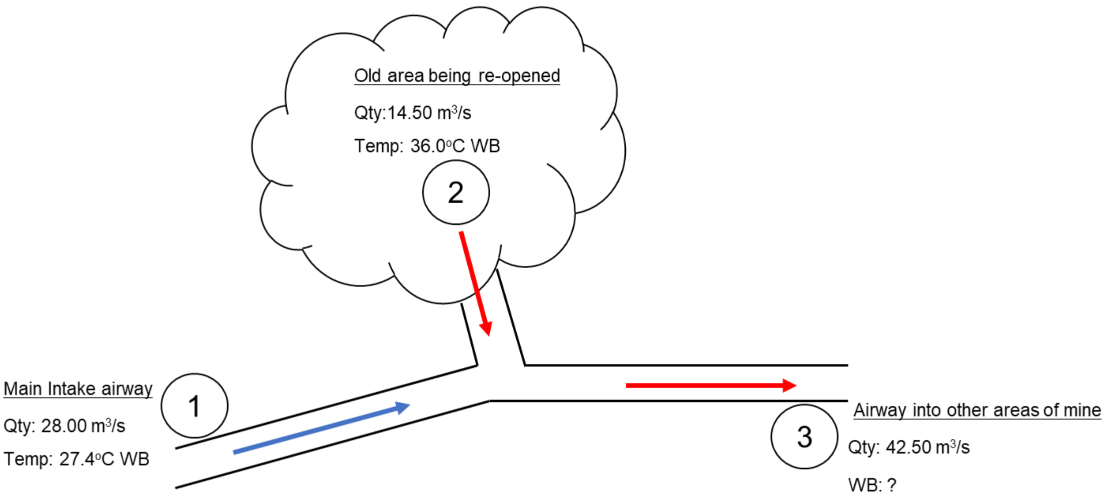
The performance of all tasks is adversely affected at temperatures above 27,0ºC. Experiments done by the Chamber of Mines Research Organisation (COMRO) have shown that with wet-bulb temperatures of 27,0ºC and lower, even with low air velocities, a person’s work performance is unaffected.

1.4 What are the main methods of reducing the effects of heat? (5)

Answer: Page 33-35

- Reducing heat-flow from rock
- Removal of machinery
- Dilution by ventilation
- Acclimatisation
- Refrigeration

1.5 You are required to calculate the wet-bulb temperature of an area that will be opened for mining to be done in the near future. Calculate the wet-bulb temperature of air flowing in airway three (3) and give comment if the condition will be conducive for mining to be done going into other areas of the mine in airway 3. (5)



Answer: Page 61

Answer

Now $(Q_1 \times T_1) + (Q_2 \times T_2) = (Q_1+Q_2)\, T_3$

$$\therefore T_3 = \frac{(Q_1 \times T_1) + (Q_2 \times T_2)}{(Q_1 + Q_2)}$$

$$= \frac{(14.5 \times 36) + (28 \times 27.4)}{(14.5 + 28.0)}$$

$$= \frac{(522 + 767.2)}{42.5}$$

$$= \frac{1289.2}{42.5}$$

$\therefore$ Wet bulb after mixing = 30.3ºC (The temperature is conducive and work may continue at the downstream end of this working place.)

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QUESTION 2

2.1 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 ≥25.0°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 m³/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. Assume 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 95 kPa.

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

Answer

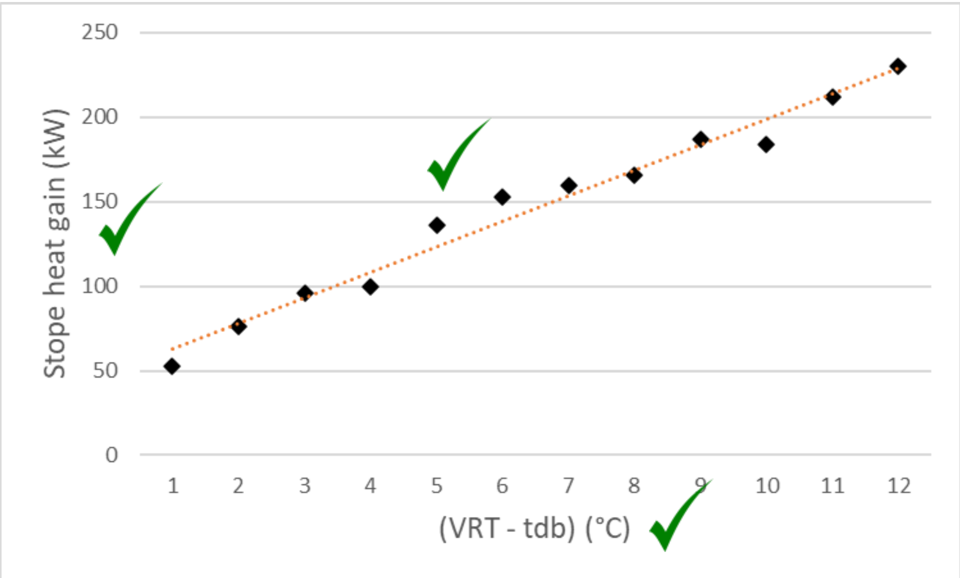
In each of the stope reports summarised in the table given the air absorbs a different amount of heat (kW), mainly because of the difference between the VRT and the entering dry-bulb temperature of the air.

The information given can be summarised as follows;

Air entering the stope	VRT	VRT – Entering t_{db}	Stope heat gain
Dry-bulb (°C)	(°C)	(°C)	(kW)
21.0	32.3	11.3	212
24.0	30.6	6.6	136
22.0	32.3	10.3	184
20.5	32.3	11.8	230
19.1	23.6	4.5	100
14.7	23.7	9.0	187
19.5	23.7	4.2	96
21.6	30.3	8.7	166
25.1	27.3	2.2	53
19.9	22.7	2.8	76
25.5	33.3	7.8	153
25.0	33.3	8.3	160

✓ **(1)**

A graph of the stope heat gain versus (VRT – entering t_{db}) can now be plotted.



(3)

A straight line can now be fitted to these points and the stope heat gain applicable for any value of (VRT – entering t_{db}) can now be read of the graph.

Stope 1

From the 95 kPa psychrometric chart at 23.5/26.5 °C read off the properties of the air:

Specific volume of air entering stope 1 = 0.933 m^3/kg ✓ **(1)**

Specific heat of air entering stope 1 = 71.3 kJ/kg ✓ **(1)**

Mass flow of entering stope 1 = Q/v

15.0 / 0.933

16.1 kg/s ✓ **(1)**

The VRT in the stope = 35.3 °C

Therefore (VRT – t_{db}) = (35.3-26.5) °C

= 8.8 °C ✓ **(1)**

From the graph the heat gained in the stope is **<u>172 kW</u>** ✓ **(1)**

The heat gained per kg as follows:

Heat gained (ΔS) = kW (air) massflow of air

$$= \frac{172}{16.1}$$

= 10.7 kJ/kg ✓ **(1)**

Therefore the Sigma heat of the air leaving the stope can be determined as follows;

Sigma heat of air leaving stope 1 = Sin + ΔS

= 71.3 + 10.7

= 82 kJ/kg ✓ **(1)**

From the 95 kPa psychrometric chart the wet-bulb temperature at a Sigma heat of 82 kJ/kg can be read off (keep in mind that the difference between the dry-bulb and wet-bulb temperature is given as 2 °C)

The temperature of the air leaving the first stope is 26.1 / 28.1 °C ✓ **(1)**

Stope 2

The dry-bulb temperature entering stope 2 = 28.1 °C

Sigma heat of air into stope 2 = 82 kJ/kg ✓ **(1)**

The VRT in the stope = 34.3 °C

Therefore (VRT – tdb) = (34.3 – 28.1) °C

= 6.2 °C

From the graph the heat gained in the stope is **<u>127 kW</u>** ✓ **(1)**

The heat gained per kg as follows:

Heat gained (ΔS) = kW (air) massflow of air

$$= \frac{127}{16.1}$$

= 7.9 kJ/kg ✓ **(1)**

Therefore the Sigma heat of the air leaving the stope can be determined as follows;

Sigma heat of air leaving stope 2 = Sin + ΔS

= 82 + 7.9

= 89.9 kJ/kg ✓ **(1)**

From the 95 kPa psychrometric chart the wet-bulb temperature at a Sigma heat of 89.9 kJ/kg can be read off (keep in mind that the difference between the dry-bulb and wet-bulb temperature is given as 2 °C)

The temperature of the air leaving the second stope is 27.8 / 29.8 °C ✓ **(1)**

Stope 3

The dry-bulb temperature entering stope 3 = 29.8 °C

Sigma heat of air into stope 3 = 89.9 kJ/kg ✓ **(1)**

The VRT in the stope = 33.3 °C

Therefore (VRT – tdb) = (33.3 – 29.8) °C

= 3.5 °C ✓ **(1)**

From the graph the heat gained in the stope is **80 kW** (1)

The heat gained per kg as follows:

Heat gained (ΔS) = kW (air) massflow of air

$$= \frac{80}{16.1}$$

= 5 kJ/kg (1)

Therefore the Sigma heat of the air leaving the stope can be determined as follows;

Sigma heat of air leaving stope 3 = Sin + ΔS

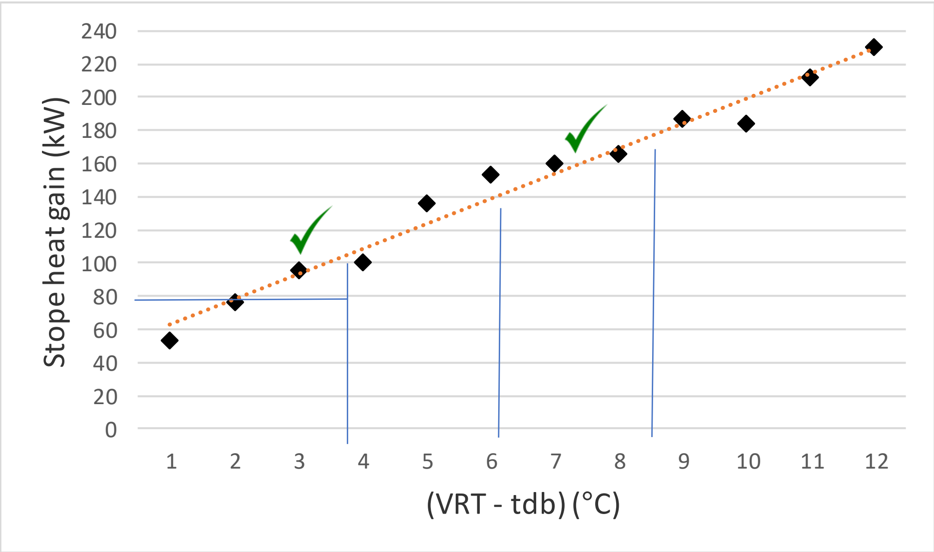
= 89.5 + 59

= 94.9 kJ/kg (1)

From the 95 kPa psychrometric chart the wet-bulb temperature at a Sigma heat of 94.9 kJ/kg can be read off (keep in mind that the difference between the dry-bulb and wet-bulb temperature is given as 2 °C)

The temperature of the air leaving the third stope is 28.8 / 30.8 °C (1)

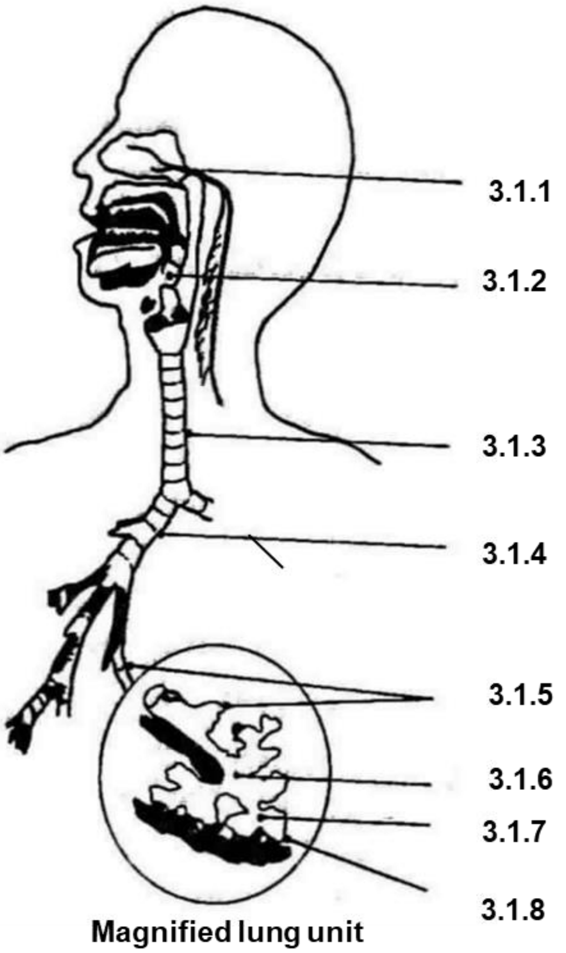
Therefore acclimatisation would be required in stopes 2 and 3 (wet-bulb temperatures higher than 27.5 °C) (2)



[25]

QUESTION 3

3.1 The diagrammatic sketch of the human respiratory system below indicates the air passages consist of the human, please indicate all the parts on the sketch below from 3.1.1 to 3.1.8 (8)



IMEC Workbook 2, Pg 212

3.1.1 Nasal cavity

3.1.2 Throat

3.1.3 Windpipe

3.1.4 Bronchus (windpipe division)

3.1.5 Bronchiole (secondary divisions)

3.1.6 Alveolar duct (minute branches)

3.1.7 Atrium

3.1.8 Alveoli (air sacs)

3.2 Name five of the physical characteristics of airborne particulates of dust. (5)

IMEC Workbook 2, Pg 167

The following parameters can be used to describe airborne particulates and the extend to which they are found in air:

- The number of particles per unit volume.
- The size distribution of the particles.
- The mass of the particles per unit volume.
- The total surface area of particles per unit volume.
- The chemical composition of the particles.

3.3 What is the five factors to be considered for industrial water supply? (5)

IMEC Workbook 2, Pg 194

The suitability of an industrial water supply depends mainly on five factors, namely:-

a) Its acidity. (pH)

b) The concentration of solids in solution and in suspension.(e.g. dust).

c) Its pressure.

d) Its temperature.

e) Its flow rate.

3.4 Explain the effects of good and poor illumination and give two examples of each. (4)

IMEC Workbook 2, Pg 320

Good Illumination

There is no doubt that good or improved illumination underground and/or on surface have the following beneficial effects:

- Decreases the risk of accidents and reduce errors.
- Increases productivity.
- Improve working conditions, morale and motivation.
- Preserves human energy.
- Reduce eye-strain and minor illnesses.
- Prevent the accumulation of waste and rubbish.
- Better utilisation of men and material.
- Improve the ability to move around and provide greater safety.

Poor Illumination

Poor illumination can be an important contributing factor to the following:

- Tiredness: people using their hands and eyes to perform work under poor illumination tires more quickly.
- Accidents: causes loss of money, life and incalculable suffering.
- Poor productivity: caused by low morale and motivation in the work force.
- Safety hazard: dangerous acts and working conditions cannot be easily noticed or detected.
- Causes eye-strain and minor eye illnesses.
- Hamper the ability to move around easily.
- Sharp increase in the number of errors by workers.
- Wastage of material and damage to equipment.
- Accumulation of waste, rubbish and old explosives that can pose a fire hazard and unhealthy environments.

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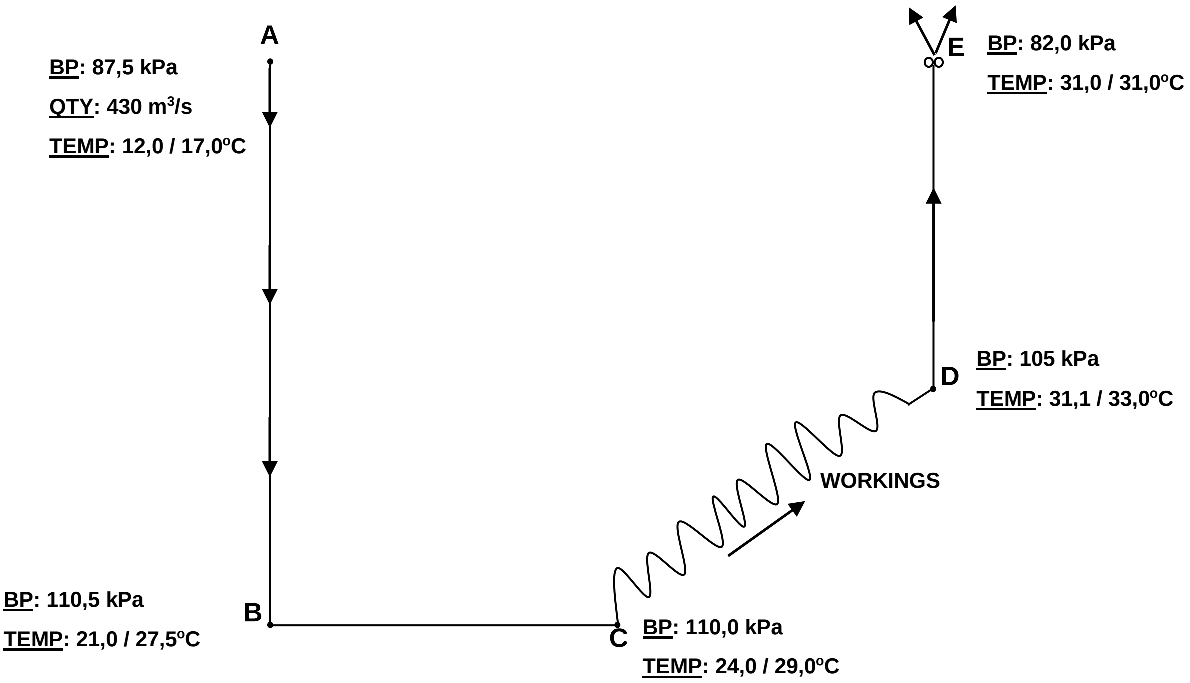
QUESTION 4

4.1 The attached sheet marked Annexure A indicates an example of a Psychrometric Chart. Name all the components of the chart as indicated in the sketch? (8)

IMEC Workbook 2, Pg 150

4.2 From the below sketch, calculate the quantities at B,C,D and E assuming there are no air leakages? (10)



IMEC Workbook 2, Pg 134-135

Answer

Mass-flow at A = $\dfrac{Q}{ASV}$ (where ASV = 0,965m^3/kg from 87,5 kPa psychrometric chart)

$= \dfrac{430}{0,965}$

= **445,6 kg/s**

But mass-flow remains constant throughout the system.

Therefore mass-flow A (M_A) = 445,6 kg/s = $M_B = M_C = M_D = M_E$

Now if M = $\dfrac{Q}{ASV}$

Then Q = M x ASV

∴ **Q_B** = M x ASV (where ASV = 0,799 m^3/kg from 110,0 kPa Psychrometric chart)

= 445,6 x 0,799

= **$356,0\ m^3/s$**

Then Q = M x ASV

∴ **Q_c** = M x ASV (where ASV = 0,808 m^3/kg from 110,0 kPa Psychrometric chart)

= 445,6 x 0,809

= **$360,9\ m^3/s$**

Then Q = M x ASV

∴ **Q_d** = M x ASV (where ASV = 0,874 m^3/kg from 105,0 kPa Psychrometric chart)

= 445,6 x 0,809

= **$389,5\ m^3/s$**

Then Q = M x ASV

∴ **Q_e** = M x ASV (where ASV = 1.12 m^3/kg from 82.5,0 kPa Psychrometric chart)

= 445,6 x 0,809

= **$499,1\ m^3/s$**

4.3 Define the following:

- Charles' Law (2)

  This law states, that at constant pressure, the volume of a given mass of a gas is directly proportional to the absolute temperature.
  Now remember, from the Heat Notes, absolute temperature (Kelvin):
  K = 273 + ºC (Dry-Bulb)
  Therefore (at constant pressure)
  Where V = Volume (m3, m3/s, m3/kg)
  T = Absolute temperature (K)
  Subscripts 1 and 2 have the same meaning as stated with Boyle's Law.

- Universal Gas Law (2)

  This law is a combination of Boyle's and Charles' Laws. It express the relationship between pressure, volume and absolute temperature.

  Therefore

  Where P = Absolute pressure (Pa, kPa)

  V = Volume (m3, m3/s, m3/kg)

  T = Absolute temperature (K)

IMEC Workbook 2, Pg 112-113

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TOTAL MARKS: [100]

Annexure A – Question 4.1 Answer Sheet