Minerals Council South Africa

EXAMINATION MEMORANDUM

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SUBJECT:
CHAMBER OF MINES OF SOUTH AFRICA – INTERMEDIATE CERTIFICATE IN MINE ENVIRONMENTAL CONTROL
PAPER 2

SUBJECT CODE: COMIMEC2

EXAMINATION DATE: 09 NOVEMBER 2020

TIME: 14:30 – 17:30
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<td>
EXAMINER: JJ PIENAAR

MODERATOR: N. KRUGER

TOTAL MARKS: 100

PASS MARK: 60
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NUMBER OF PAGES: 10

SPECIAL REQUIREMENTS:
THIS IS **NOT** AN OPEN BOOK EXAMINATION. THERE IS **NO** FORMULA HANDOUT

INSTRUCTIONS TO CANDIDATES:

1. Answer all questions **legibly** in English.

Write your **ID number** on the outside cover of each book used and on any graph paper or other loose sheets handed in. **Psychrometric chart at 105 kPa and 120 kPa is provided for Question 3.**

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

2. Show all calculations **and check calculations on which the answers are based.**
3. Hand-held electronic calculators may be used for calculations.
4. Write **legibly** in ink on the **right hand page** only – **left hand pages will not be marked**.
5. Illustrate your answers by means of sketches or diagrams wherever possible.
6. Answers must be given to an accuracy which is typical of practical conditions.
   NB Ensure that the correct unit of measure (SI unit) are recorded as marks will be deducted from answers if the incorrect unit is used. (Even if the calculated value is correct).
7. In answering the questions, full advantage should be taken of your practical experience as well as data given.
8. Please note that you are not allowed to contact your examiner or moderator regarding this examination.
9. Cell phones are **NOT** allowed in the examination room.

QUESTION 1 **(Definitions)**

1.1. Define Boyle's Law and give the formula including all SI units (4)

This law states, that at a constant temperature (½), the volume (½) of a given mass of a gas (½) is inversely proportional (½) to the absolute pressure exerted on it (½).

Therefore, $P_1V_1 = P_2V_2$ (at constant temperature) (½)

Where P = Absolute pressure (kPa, Pa) (½)

V = Volume (m^3, m^3/s, m^3/kg) (½)

1.2. Define the Universal Gas Law and give the formula including all SI units (4)

This law is a combination of Boyle's and Charles' Laws (½). It expresses the relationship between pressure (½), volume (½) and absolute temperature. (½)

Therefore

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad (½)$$

Where P = Absolute pressure (Pa, kPa) (½)

V = Volume (m^3, m^3/s, m^3/kg) (½)

T = Absolute temperature (K) (½)

1.3. Define Barometric pressure (kPa) (3)

Is the pressure measured by a barometer (½) and can be defined as the total pressure exerted (½) by all the components of the atmosphere (½) at a certain point on the earth (½). Air exerts pressure because it has a mass (½) which is subject to the earth's gravitational force (9.79 m/s^2) (½)

1.4. Define Toxicology (2)

Toxicology is the study of the action (½) of poisonous substances (½) (solids, liquids, gases) on the living organism (½) or it is the science that studies the poisonous properties of a substance (½).

1.5. Define Exposure (2)

Is the potential contact at a worker's exchange boundaries (½) (e.g. lung or skin) with chemical, physical (½) or biological pollutants (½) whilst at the workplace. (½)

1.6. Define Acute Exposure: (1)

Means "exposure for a short duration" and refers to one single exposure over a period of time (½) which can be measured in seconds, minutes or hours and implies an accident. (½)

1.7. Define Chronic Exposure: (1)

Is the opposite of acute and therefore means "exposure for a long duration" and refers to long-term exposure over a period of time (½), which can be measured in days, weeks or years (½).

1.8. Define Epidemiology (1)

Epidemiology is a study of the process (½) whereby the effect of exposures on human is determined (½).

1.9. Define Regulation 4.17.1 as per MHSA with regards to noise exposure. (2)

When the equivalent noise exposure (½) in any place at or in any Mine or works where persons may travel or work (½) exceed 85 dB (A) (½), the Manager shall take the necessary steps to reduce the noise to below 85 dB (A) (½).

Total Marks: **(20)**

QUESTION 2 **(Theory)**

2.1. Give the approximate VRT increase per kilometre for: (3)

Gauteng / West Wits:	9.0°C	(1)
Free State:	14.6°C	(1)
Klerksdorp:	10.5°C	(1)

2.2. List the requirements of an ideal dust sampling instrument. (5)

Measure accurately the dangerous dust in the air. (1)
Be portable, robust and dependable. (1)
Be easy to use and to evaluate the samples. (1)
Take a sample over a long enough period so as to obtain a representative sample. (1)
Not require external power supplies, e.g., electric mains or compressed air. (1)

2.3. List 5 Reasons for Sampling Mine Water (5)

(Any 5 of the following):
To determine the amount of silica dust present in the water. (1)
Bacteriological analysis (E Coli 1, etc.) (1)
Chemical analysis for dissolved and suspended solids, toxic metallic and chemical compounds. (1)
To determine the pH value of the water (Acidity / Alkalinity). (1)
To determine the amount of free chlorine in water. (1)
For radio-active analysis. (1)
For legal compliance. (1)

2.4. State the average composition and concentration of gasses of dry air at sea level (4)

Nitrogen (N_2):	78.08%	(1)
Oxygen (O_2):	20.95%	(1)
Carbon dioxide (CO_2):	0.03%	(1)
Argon (Ar) and rare gases:	0.93%	(1)

2.5. List the four conditions which must exist for an underground flammable gas explosion to occur: (4)

The gas must be produced or present. (1)
The gas concentration must reach the explosive concentration / range. (1)
There must be sufficient oxygen present in the atmosphere. (1)
A flame or spark must ignite the gas. (1)

2.6. Describe the effects or symptoms on people when they are exposed to various concentrations of oxygen deficiency. (5)

At 17% oxygen by volume, the breathing rate increases. (1)
At 14% oxygen by volume, faster breathing and dizziness occur. (1)
At 13% oxygen by volume, high breathing rate, headaches, dizziness and buzzing of the ears occur. (1)
At 10% by volume, high breathing, rapid pulse and unconsciousness occur. (1)
At 9% and below by volume, rapid collapse, coma and sudden death will occur. (1)

2.7. List the five main methods of reducing the effects of heat. (5)

Reducing heat-flow from rock (1)
Removal of machinery (1)
Dilution by ventilation (1)
Acclimatisation (1)
Refrigeration (1)

2.8. List the four environmental factors that are central to the assessment of heat stress. (4)

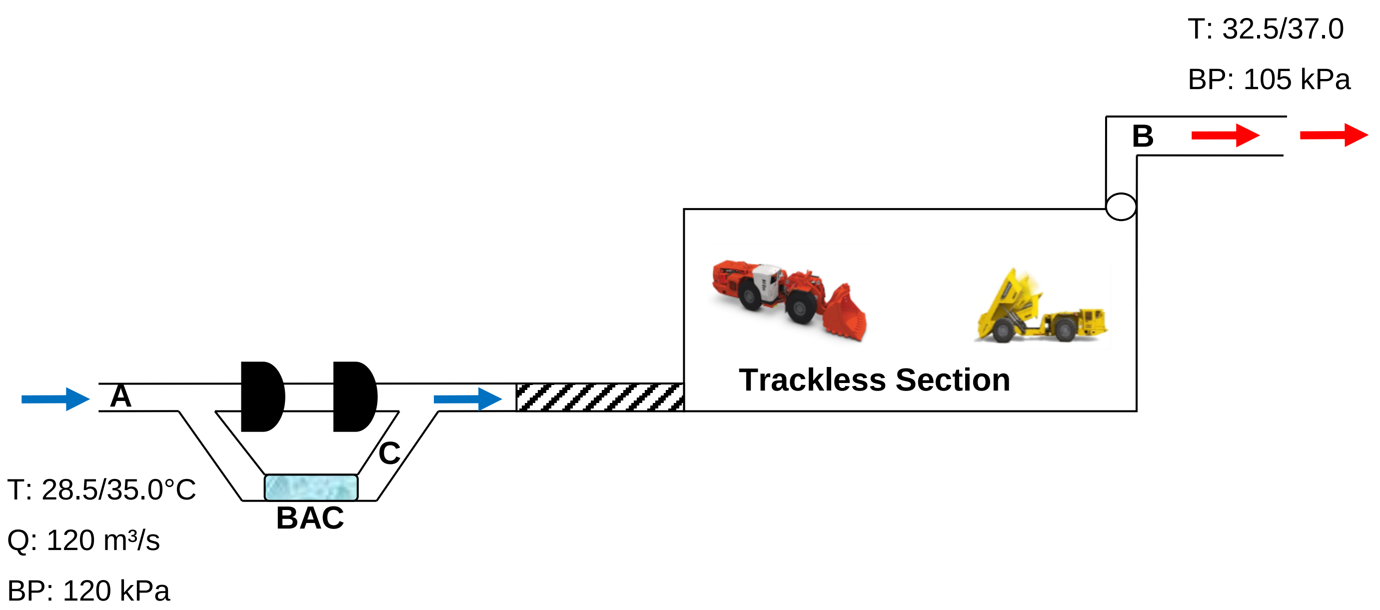
Air temperatures (wet and dry bulb) (1)
Air speed (1)
Humidity of the air (1)
Radiant heat – Globe temperature (where applicable) (1)

Total Marks: (35)

QUESTION 3 **(Psychrometry)**

NOTE! - Ensure that the correct units of measure **(SI unit)** are recorded as answers will be marked wrong if the incorrect unit is used, even if the value calculated is correct.
If psychrometric charts are not used with these questions, it will **NOT** be marked.

3.1. A trackless section in a deep underground mine experienced high reject temperatures and installed a BAC on the intake side of the section. (12)



By using psychrometric charts calculate the following parameters:

a) Calculate the total heat load in the trackless section with the readings at points A & B before the BAC was installed. (Ignore the effects of auto-compression): (2)

Sigma Heat of intake air at A = 79.3 kJ/kg (120 kPa chart at 28.5 / 35.0)
Sigma Heat of return air at B = 106.2 kJ/kg (105 kPa chart at 32.5 / 37.0)

Sigma Heat from workings = ∑H return air – ∑H intake air
= 106.2 – 79.3
= 26.9 kJ/kg (1)

Thus Heat from workings = Mass flow x Δ ∑ Heat
= 157.9 x 26.9
= 4 247.5 kW (1)

Mass flow = (120 / 0.76)
= 157.9 kg/s

b) The BAC installed is rated at 5 000 kW, but can only operate at 50% of the designed duty due to insufficient water supply. Determine what will be the expected wet and dry bulb temp's at point C (BAC return). Assume the air / water heat transfer was 100%. (4)

BAC operating duty = Design duty x (rating % / 100)
= 5000 x (50 / 100)
= 2 500 kW (1)

BAC Δ ∑ Heat = BAC duty / Mass flow
= 2500 / 157.9
= 15.8 kJ/kg (1)

BAC Return ∑ H = Intake ∑H - Δ∑H
= 79.3 - 15.8
= 63.5 kJ/kg (1)

BAC return wet bulb temp = 24.2°C (from 120 kPa chart at 63.5 kJ/kg)
Assume that dry bulb temp is the same as air is saturated. (1)

c) Determine the wet and dry bulb temperatures at point B (trackless return) with the BAC operating. The return humidity is 70%. (3)

∑ H at Trackless return = ∑ BAC outlet + ∑ workings
= 63.5 + 26.9
= 90.4 kJ/kg (1)

Trackless return wet bulb temp = 29.3˚C (from 105 kPa chart at 90.4 kJ/kg) (1)
Return dry bulb temp = 34.0°C (from 105 kPa chart at 70% humidity) (1)

d) An additional trackless fleet has been allocated to increase production and will generate at least 1 200 kW more heat into the section. Determine new reject temperature at point B. (3)

New fleet Δ ∑ heat = heat / mass flow
= 1200 / 157.9
= 7.6 kJ/kg (1)

Δ H at Trackless return = ∑ BAC outlet + ∑ workings + ∑ new fleet
= 63.5 + 26.9 + 7.6
= 98.0 kJ/kg (1)

New return wet bulb temp = 30.9°C (from 105 kPa chart at 98.0 kJ/kg) (1)

3.2. A Bulk Air Cooler (BAC) was installed in the main intake to an underground trackless section. The water intake temperature was 10°C, water outlet temperature only 18°C with a flow rate of 80 ℓ/s. An air volume of 100 m³/s enters the BAC at 29.0 / 32.0°C with a barometric pressure of 120 kPa (13)

a) Calculate the water heat transfer duty of the BAC and the air mass flow through the BAC (2)

Water heat transfer duty

W = M x Cp x ΔT M = 80 ℓ/s
= 80 x 4.187 x (18 – 10) Cp = 4.187
= 2 679.7 kW (1)

M = Q / ASV
= 100 / 0.754
= 132.6 kg/s

ASV of BAC intake = 0.754 m^3/kg
(120 kPa chart at 29.0 / 32.0) (1)

b) The wet bulb air outlet temperature of the BAC if it was operating at 100% and 50% efficiencies. (7)

The heat transfer to the air is less due to the water /air inefficiencies.

100% air duty = Water duty
= 2679.7 kW
efficiency = 100% (1)

Δ∑ heat at 100% = BAC duty / Mass flow
= 2679.7 / 132.6
= 20.2 kJ/kg (1)

∑ heat BAC out = ∑ heat in - Δ∑
= 81.4 – 20.2
= 61.2 kJ/kg

∑ Heat of BAC intake = 81.4 kJ/kg
(120 kPa chart at 29.0 / 32.0) (1)

Thus wet bulb temp BAC outlet = 23.4°C (air saturated at BAC outlet) (1)

50% air duty = Water duty x (50/100)
= 2679.7 x 0.5
= 1339.9 kW
efficiency = 50% (1)

Δ∑ heat at 50% = BAC duty / Mass flow
= 1339.9 / 132.6
= 10.1 kJ/kg (1)

∑ heat BAC out = ∑ heat in - Δ∑
= 81.4 – 10.1
= 71.3 kJ/kg

∑ Heat of BAC intake = 81.4 kJ/kg
(120 kPa chart at 29.0 / 32.0) (1)

Thus wet bulb temp BAC outlet = 26.5°C (air saturated at BAC outlet) (1)

c) What is the minimum BAC efficiency to be maintained to ensure an outlet wet bulb temperature of not less than 25°C (3)

Δ∑ heat required = ∑ heat in - ∑ heat out
= 81.4 - 66.3 _ Heat of BAC outlet = 66.3 kJ/kg
= 15.1 kJ/kg (120 kPa chart at 25.0 / 25.0) (1)

Air duty required = Δ∑ x Mass flow
= 15.1 x 132.6
= 2002.3 kW (1)

Efficiency required = Air duty / water duty x 100
= 2002.3 / 2679.7 x 100
= 74.7 %

BAC heat transfer duty may not be less than 75% (1)

d) What will be the main reason for a BAC to start losing efficiency if the water flow remains constant? (1)

Heat transfer efficiency loss is mainly due to incorrect spray patterns when the supply water flow remains unchanged. Spray nozzle openings have increased and must be replaced to ensure an effective spray pattern. (1)

Total Marks: (25)

QUESTION 4 **(General Calculations)**

4.1. A quantity of 585 m³/s enters a downcast shaft of a mine at a barometric pressure of 88.2 kPa and a temperature of 20.0/27.5°C. At the bottom of the shaft the barometric pressure is 115.8 kPa and the temperature is 25.3/36.2°C. Assuming no leakage, calculate the quantity at the bottom of the shaft. (4)

$$\frac{P1V1}{T1} = \frac{P2V2}{T2} \quad (1)$$

$$V2 = \frac{88.2 \times 585\ (273 + 36.2)}{115.8 \times (273 + 27.5)} \quad (2)$$

$$= 458.5\ m^3/s \quad (1)$$

4.2. Calculate the VRT for a depth of 2100 metres for a mine to be sunk somewhere in Africa. It is known that the surface rock temperature is 22˚C and the temperature gradient is 17°C per km. (3)

VRT = Surface rock temp + (Temp gradient x depth in km) (1)
= 22 + (17 x 2100/1000) (1)
= 22 + 35.7
= 57.7°C (1)

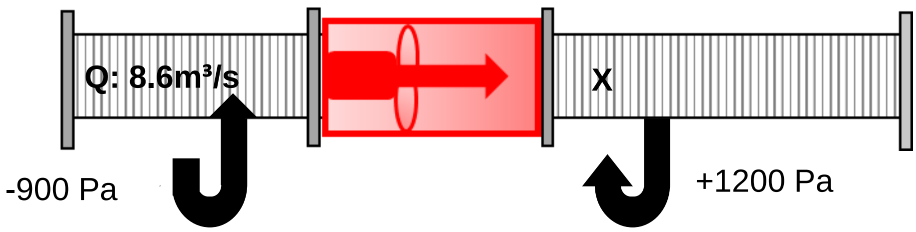
4.3. 8.3ℓ/s of water enters a cooling car at 8.0°C and leaves at 19.0°C after it absorbed heat from the air. Calculate the amount of heat transferred from the air to the water (Cooling car duty). (2)

Q = M x Cp x Δt
= 8.3 x 4,187 x 11
= 382 kJ/s or kW

M = 8.3ℓ/s = 8.3 kg/s (1)
Cp = 4.187 kJ/kg°C
Δt = 19.0 – 8.0 = 11.0°C

Heat absorbed = 382 kW (1)

4.4. An axial flow fan is installed in a vent column, with the static pressure readings taken by means of a vertical manometer. The measured barometric pressure at the locality of this installation is 102.5 kPa. If the fan intake quantity is 8.6 m³/s calculate the quantity at the fan discharge (x), assuming the temperature remains constant. (4)



Absolute pressure at fan intake (P1) = BP - Gauge Pressure (vacuum)

$= 102.5 - 0.9$

$\therefore P1 = 101.6 \text{ kPa}$ (1)

Absolute pressure at fan discharge (P2) $= BP + \text{Gauge Pressure}$

$= 102.5 + 1.2$

$\therefore P2 = 103.7 \text{ kPa}$ (1)

$P1V1 = P2V2$ (1)

$$V2 = \frac{P1V1}{P2}$$

$$= \frac{101.6 \times 8.6}{103.7}$$

$= 8.43 m^3/s$ (1)

4.5. The following measurements were taken underground:

Air-stream 1:

Wet bulb temperature = 24.0°C

Air-stream 2:

Qty: 30 m^3/s

Wet bulb temperature 30.5°C

Calculate the air quantity to be supplied from air-stream 1 to make sure that the wet-bulb temperature after mixing does not exceed 27.0°C. (5)

$(Q_1 \times T_1) + (Q_2 \times T_2) = (Q_3 \times T_3)$ (1)

$(Q_1 \times 24) + (30 \times 30.5) = (Q_1 + 30)\ 27$ (1)

$24Q_1 + 915 = 27Q_1 + 810$

$915 - 810 = 27Q_1 - 24Q_1$ (1)

$105 = 3Q_1$ (1)

$Q_1 = 105/3$

$Q_1 = 35 m^3/s$ (1)

4.5. The velocity through a stope face is 0.32 m/s and the kata reading is 4.8 mKalories/cm^2/s. What is the wet-bulb temperature in that stope? (2)

$H = 0.7\theta + \theta\sqrt{v}$ (1)

Then $\theta = \dfrac{H}{0.7 + \sqrt{v}}$

$= \dfrac{4.8}{0.7 + \sqrt{0.32}}$

$= \dfrac{4.8}{1.266}$

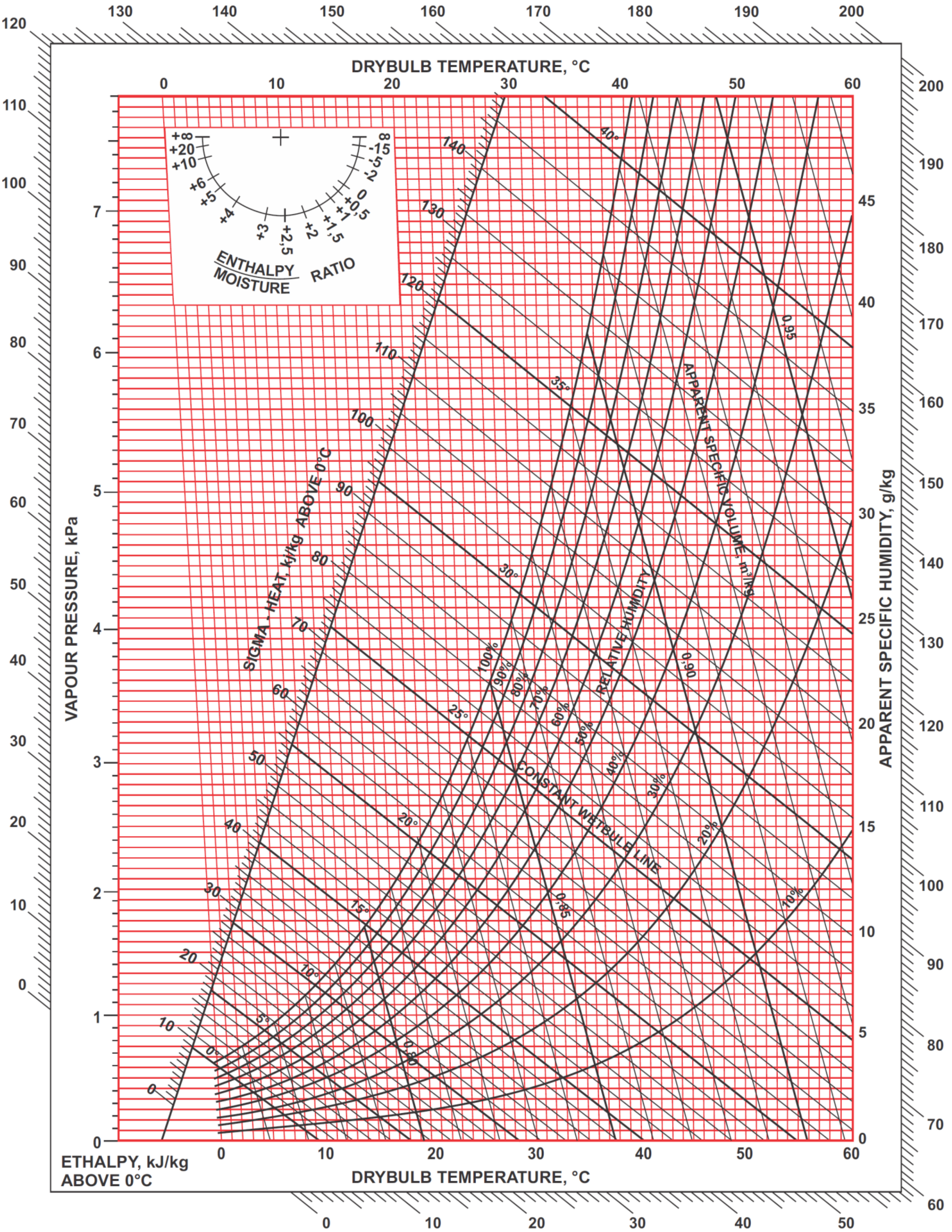
$= 3.79$

$\therefore$ wet bulb temperature $= 36.5 - 3.8$

$= 32.7°C$ (1)

Total Marks: (20)

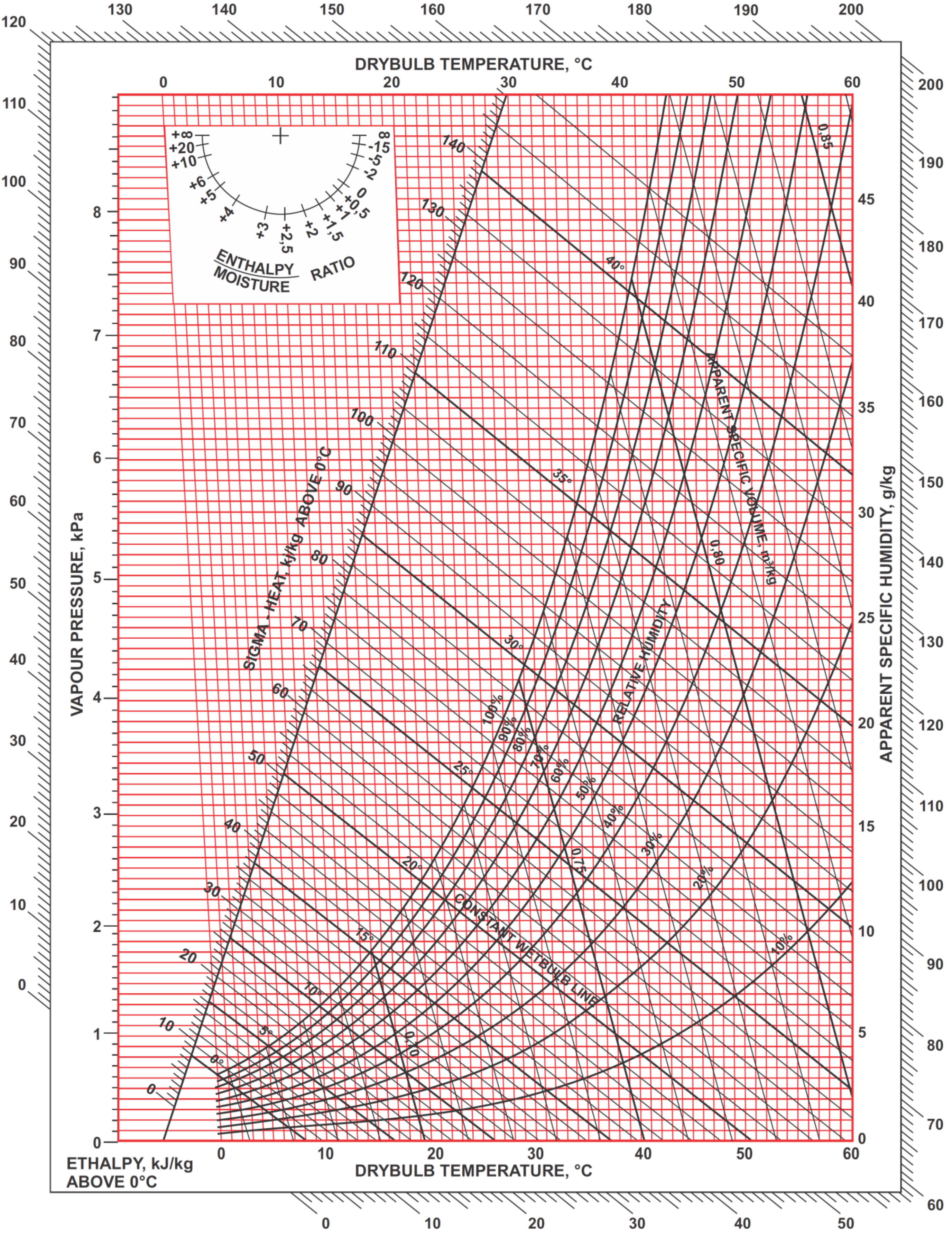
PSYCHROMETRIC CHART
105,0 kPa



A.W.T.B.

CHART NO 12
105,0 kPa

PSYCHROMETRIC CHART
120,0 kPa



A.W.T.B.

CHART NO 18
120,0 kPa