Chamber of Mines of South Africa

EXAMINATION PAPER

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA – CERTIFICATE IN MINE ENVIRONMENTAL CONTROL PAPER 1 - FLOW DYNAMICS, AIRFLOW, FANS, MINE WATER	**EXAMINER:** Tsietsi B Letanta **MODERATOR:** Frank von Glehn
SUBJECT CODE: **COMMEC1**	**TOTAL MARKS:** [100]
EXAMINATION DATE: 08 MAY 2017	**PASS MARK:** (60%)
TIME: 14:30 – 17:30	

NUMBER OF PAGES: 11

SPECIAL REQUIREMENTS:

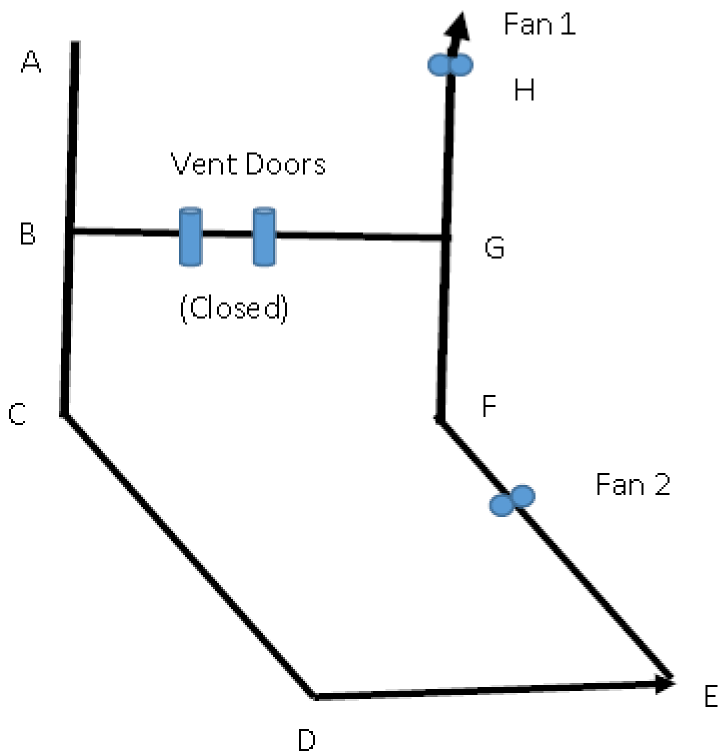
THIS IS NOT AN **OPEN BOOK EXAMINATION**.
INSTRUCTIONS TO CANDIDATES:

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) are recorded as marks will be deducted from answers if the incorrect unit is used. (even if the calculated value is correct).
8. In answering the questions, full advantage should be taken of your practical experience as well as data given.
9. Please note that you are not allowed to contact your examiner or moderator regarding this examination.
10. Cell phones are **NOT** allowed in the examination room.

QUESTION 1



In the airway shown above, Fan 1 is on surface and the fan air inlet density is 0, 9 kg/m^3. Fan 2 is underground where the air density is 1, 2 kg/m^3. There is no leakage and natural ventilation effects can be ignored. Use the Fan curves that are supplied and include them with your answer sheet.

1.1 If the measured volume and pressure at Fan 1 is 100 m^3/s at 3 kPa, what will be the pressure and volume measured at Fan 2? (13)

The important aspect of this question is that because <u>there is change in densities</u>, the mass flow in kg/s must be determined through the circuit. Fan1 on surface handles 100 m^3/s of air at a density of 0,9 kg/m^3. The mass flow of air handled by the fan can be determined as follows. (1)

$$M = Q \times w \quad (1)$$
$$= 100 \times 0{,}9 \quad (1)$$
$$= 90 \text{ kg/s} \quad (1)$$

But Fans 1 and 2 are in series (doors closed on interval and therefore the fans can be seen as in true series), therefore the mass flow of air through Fan 2 must also be 90 kg/s.

Quantity of air handled by Fan 2 = $\frac{m}{w}$ (1)

= $\frac{90}{1.2}$ (1)

= 75 m^3/s (1)

From the curve for fan 2 read off the pressure = 2667 Pa (1)

Fan 2 handles 75 m^3/s @ 2667 Pa {2500 – 2800} (1)

1.2 If Fan 1 operates alone and densities do not change, what will be the pressure and volume at Fan 1? (10)

If Fan1 operated alone, it would operate at a density of 0,9 kg/m^3. The present quantity through the mine at 0,9 kg/m^3 is 100 m^3/s. The present pressure loss in the mine has to be calculated and this has to be determined at an air density of 0,9 kg/m3. But because the fans are in true series the total pressure loss in the mine at 0,9 kg/m^3 will be equal to the pressure over Fan1 plus the pressure over fan 2.

Pressure of Fan 1 at 0.9 kg/m^3 = 3000 Pa (given)

Pressure over Fan 2 at 0,9 kg/m^3:

$$\frac{P2}{P1} = \frac{w2}{w1} \qquad (1)$$

$$P2 = P1 \times \frac{w2}{w1} \qquad (1)$$

$$P2 = 2667 \times \frac{0.9}{1.2}$$

= 2000 Pa { 1900 – 2100} (1)

Note: p_2 is the pressure if Fan 2 was to operate at an air density of 0,9 kg/m^3, the <u>fan curve for Fan 2 is at an air density of 1,2 kg/m^3.</u> (1)

Therefore the total pressure loss for the mine at an air density of 0,9kg/m^3 as follows:

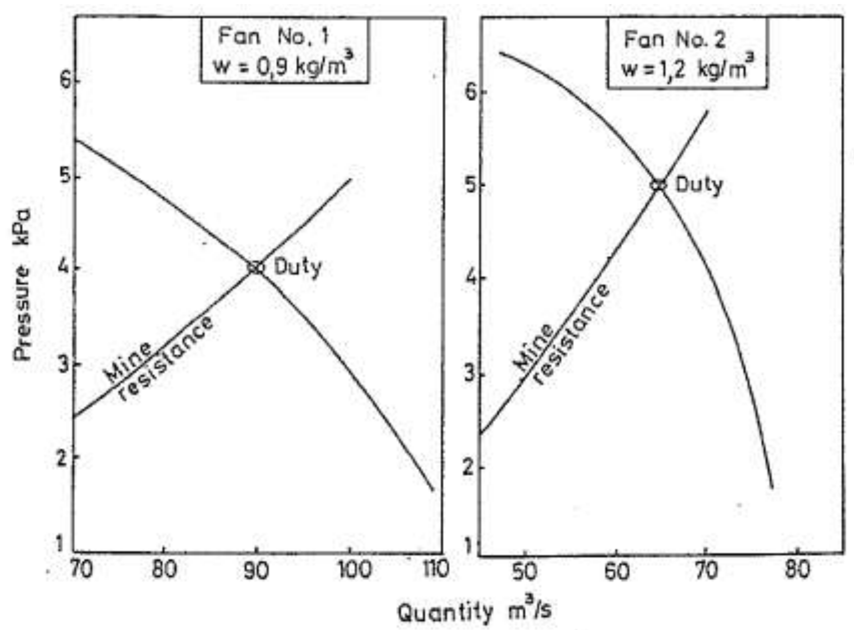
$$P_{0,9} = 3000 + 2000$$
$$= 5000 \text{ Pa (2)}$$

A pressure of 5000 Pa is required to draw 100 m^3/s through the mine at an air density of 0,9 m^3/s *(Note: This is not yet the duty of fan 1, a common mistake made by students).* (1)

Use this pressure and quantity and plot a resistance curve for the mine on the curve given for Fan1. (1)

Now if Fan1 operates alone, the system resistance curve of the mine would not change (assuming densities remain constant). Therefore at the intersection of the mine system resistance curve and the Fan1 curve read off the duty for fan1: (1)

Fan 1 would handle 89, 8 m^3/s @ 4 030 Pa ….(less than the original 100m^3/s) (1)



4 Marks for the graphs

1.3 If Fan 2 operates alone and densities do not change, what will be the pressure and volume measured at fan 2? (10)

If Fan 2 operated alone, it would operate at a density of 1,2 kg/m^3. (1)

The present pressure loss in the mine has to be calculated and this has to be determined at an air density of 1,2 kg/m^3.

Pressure loss of mine at 1,2 kg/m^3:

$$\frac{P2}{P1} = \frac{w2}{w1} \qquad (1)$$

$$P2 = P1 \times \frac{w2}{w1} \qquad (1)$$

$$P2 = 5000 \times \frac{1.2}{0.9} \qquad (1)$$

$$= 6667 \text{ Pa} \qquad (1)$$

The quantity through the mine at an air density of 0,9 kg/m^3 is 100 m^3/s, the quantity of air at 1,2 kg/m^3 can be determined as follows:

$$Q_1 \times w_1 = Q_2 \times w_2$$

$$Q2 = Q1 \times \frac{w1}{w2} \qquad (1)$$

$$Q2 = 100 \times \frac{0.9}{1.2}$$

$$= 75 \text{ m}^3\text{/s} \qquad (1)$$

A pressure of 6 667 Pa is required to draw 75 m3/s through the mine at an air density of 1,2 kg/m3 (Note: This is not yet the duty of Fan 2, a common mistake made by students).

Use this pressure and quantity and plot a resistance curve for the mine on the curve given for Fan 2.
(1)

Now if Fan 2 operates alone, the system resistance curve of the mine would not change (assuming densities remain constant). Therefore at the intersection of the mine system resistance curve and the Fan 2 curve read off the duty for fan 2: (1)

Fan 2 would handle 65 m3/s @ 5 000 Pa (1)

[33]

QUESTION 2

2.1 Define natural ventilation pressure [NVP]. (3)

NVP is the pressure created in a ventilation network due to the density difference between air at the top and bottom of the downcast and upcast shafts (1). In deep hot mines there is usually a large difference between surface and underground temperatures – there is a difference in density between air on surface and underground and this causes air to move from high to low density (1). The NVP will either assist or retard fans in the system. When NVP assists a fan, it tends to move air in the same direction as the fan.(1) The NVP can be said to lower the system resistance curve against which the fan operates. This means the fan will handle more air at lower pressure. The value of NVP can be subtracted from the system resistance curve at several different quantities until sufficient points are obtained to plot a system – NVP curve. The fan operating point is then given by the intersection of the system – NVP curve and the fan curve.

2.2 The surface barometric pressure on a mine is 86 kPa. The mean density in the 2000m downcast shaft is 1.2 kg/m³. Ignoring secondary air flow effects, determine the nominal barometric pressure at the shaft bottom. (4)

delta p = rho g H (1)
= 1.2 x 2000 x 9.8
= 23.52 kPa (1)
=> BP = 86 + 23.52 (1)
= 109.5 kPa (1)

2.3 In the same mine the mean density in the upcast shaft is 1.1 kg/m³. What is the approximate natural ventilation pressure in this system? (4)

delta p = 1.1 * 2000*9.8 (1)
= 21.56 kPa. (1)
NVP = 23.52 – 21.56 (1)
= 1.96 kPa (1)
OR
NVP=(wdown-wup) * H * g

2.4 If the air flow in the shafts is 500 kg/s, what is the net air power saving and what annual cost savings are related to this air power? Assume an electricity cost of 116 c/kWh. (4)

Air power = 500*1.96/wmean (1) wmean = (1.2+1.1)/2=1.15
500*1.96/1.15 = 852 kW.
116 c/kWhr = R10161.60/kW/yr (1)
so saving = 852*10161.60 (1)
= R8 657 683.20 (1)
= R8 657 683 or R8.66m

2.5 What is the static pressure [kPa] in a water column at the bottom of the same shaft? Ignore secondary flow effects. (3)

P = rho g h (1)
= 1000 * 9.8 * 2000 (1)
= 19.6 MPa (1)

2.6 If the head loss in the column is 1 m/100 m, and assuming a water flow of 200 l/s, what power could potentially be generated by a turbine which is 80 % efficient? (4)

Head loss = 20 m. (1)
Turbine power = 200 * (2000-20) *9.8 * 0.8 /1000 (2)
= 3.1 MW (1)

2.7 Assuming a pump efficiency of 75% and again assuming a head loss of 1 m/100 m, what is the annual pumping cost of returning this water to Surface? (3)

Pump power = (2000+20)*9.8*200/1000/0.75 (1)
= 5279 kW* R10161.60 (1)
= R 53 643 086 (1)

[25]

QUESTION 3

Water is pumped at an average rate of 12.96 ML per day to surface from the main pump station 1 800m below surface. The amount of fissure water entering the mine is equivalent to 0.4 tons per ton of rock broken.

3.1 The total rock broken is 150 000 tons per month. Assuming a 30 day month, what is the service water usage in tons per ton broken? (3)

Fissure water per month = 150 000 x 0.4
= 60 000 tons per month
= 60 000 x 1000/30
= 2 000 000 = 2Ml/day (1)
Balance is service water = 12.96 – 2.0
= 10.96 Ml/day (1)
Water usage per month = 10 960 000 x 30 days / 1000 l/ton x 150 000 tpm
= 2.19 tons per ton broken. (1)

3.2 If the mine pumps water for 24 hours every day:

i) What size pipe would be used? (Assume standard sizes)? State any assumptions made. (2)

Determine the water pumping rate in litres/second.

12 960 000 l/day /24 /3600 = 150 l/s (1)

Assume an economic velocity of 2-3 m/s, the pipe would be 305 or 254mm (1)

ii) Assuming the pipe size determined above, what is the pump shaft power (pump input power) required? Assume a pump efficiency of 70%. (3)

Assume 305mm pipe – head loss approximately 1.4 m/100m. (1)

Total head loss for 1 800 metres = 25.2 metres. (1)

Power = Q x 1825.2 x 9.79 x 1.0 / (1000 x 0.70) = 3 829 kW. (1)

3.3 The electrical supply contract (with ESCOM) allows the mine to pump for 19 hours per day:

i) Assuming standard sizes, what size pump would you use? Give reasons for your answer. (2)

Determine the water pumping rate in litres/second.

12 960 000 l/day /19 /3600 = 189.5; say 190 l/s. (1)

Assume an economic velocity of 2-3 m/s; the pipe size would be 353 or 305 mm. (1)

ii) Using the pipe size as determined above, what is the pump shaft power (pump input power) required? Assume a pump efficiency of 70%. (5)

Assume 353mm pipe – head loss approximately 1.1 m/100m. (1)

Total head loss for 1 800 metres = 19.8 metres. (1)

The total head for pumping is 1 800 + 19.8 = 1819.8 metres (1)

Power = Q x Ht x g x SG / (1000 x efficiency) (1)

= 190 x 1819.8 x 9.79 x 1.0 / (1000 x 0.70) = 4 836 kW. (1)

3.4 The average electricity cost is 116 cents per kWh (assume no daily variations).

i) What is the annual electricity cost for pumping 24 hours per day? (2)

Annual pumping cost for 24 hr/day = 365 days x 24 hrs x 3 829 kW x R1.16 (1)

= R38 908 766. (1)

ii) What is the annual electricity cost for pumping 19 hours per day? (2)

Annual pumping cost for 24 hr/day = 365 days x 19 hrs x 4 836 kW x R1.16 (1)

= R38 903 686 (1)

3.5 Mention four places where shock losses occur in a water reticulation system and give examples of how these losses can be avoided or minimised. (4)

I. Bends should be as smooth as possible. (1 each)
II. Valves must be correctly sized and always fully open.
III. Fittings – T-pieces should be avoided and replaced with Y –pieces.
IV. Orifice plates must only be installed where necessary.
V. Abrupt changes in sizes must be kept to a minimum and correct gaskets used.
VI. Strainers must be kept to a minimum and correct gaskets used.
VII. Foreign objects –dirt, rocks, hard hats, etc

[23]

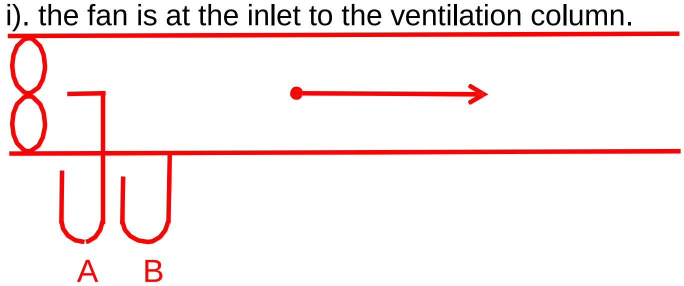
QUESTION 4

4.1 Mention any four methods of ventilating sinking shafts. (4)

I. Force system. (1 each)
II. Exhaust system.
III. Force – Exhaust system.
IV. Reversing the airflow direction.
V. Using downcast and upcast compartments

4.2 With the aid of sketches, describe how fan total pressure, fan static pressure and fan velocity pressure can be measured, when;

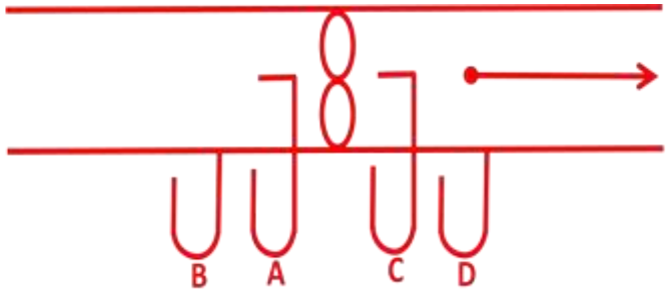
i). the fan is at the inlet to the ventilation column.



(2)

Fan total pressure = A (1)
Fan static pressure = B (1)
Fan velocity pressure = A - B (1)

ii). the fan is in the middle of the ventilation column.



(2)

Fan total Pressure = A – C (or B – D) (1)

Fan static pressure = A – D (1)

Fan velocity pressure = (A – B) = (C – D) (1)

iii). the fan is at the discharge of the ventilation column.

(2)

Fan total Pressure = B (1)

Fan static pressure = A (1)

Fan velocity pressure = (B – A) (1)

(15)

[19]

TOTAL MARKS: [100]

ID No.. Question 1

NB: Include this in your answer book.