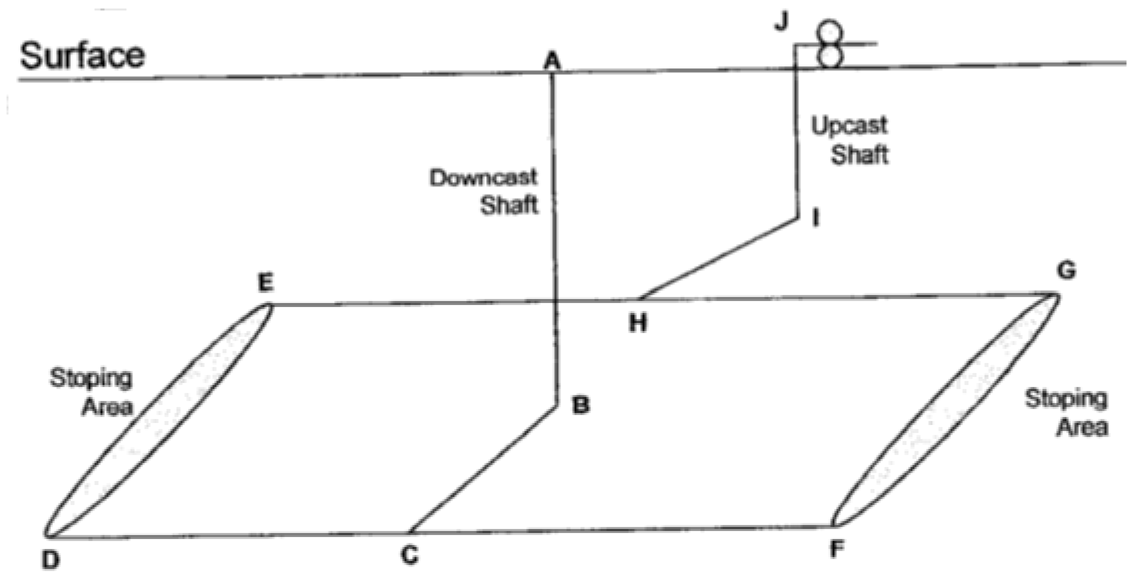
Chamber of Mines of South Africa

# EXAMINATION PAPER

| **SUBJECT:**<br>CHAMBER OF MINES OF SOUTH AFRICA – CERTIFICATE IN MINE ENVIRONMENTAL CONTROL<br><br>PAPER 1 - FLOW DYNAMICS, AIRFLOW, FANS, MINE WATER<br><br>**SUBJECT CODE:** **COMMEC1**<br><br>**EXAMINATION DATE:** 09 OCTOBER 2017<br><br>**TIME**: 14:30 – 17:30 | **EXAMINER:**<br>Tsietsi B Letanta<br><br>**MODERATOR:**<br>Frank von Glehn<br><br>**TOTAL MARKS:** [100]<br><br>**PASS MARK:** (60%) |
|---|---|

| **NUMBER OF PAGES:** 10 |
|---|
| SPECIAL REQUIREMENTS:<br>THIS IS NOT AN **OPEN BOOK EXAMINATION**.<br>INSTRUCTIONS TO CANDIDATES:<br>1. Answer all 4 questions **legibly** in English.<br>2. Write your **ID number** on the outside cover of each book used and on any graph paper or other loose sheets handed in.<br>**NB:** Your name **must not** appear on any answer book or loose sheets.<br>3. Show all calculations **and check calculations on which the answers are based.**<br>4. Hand-held electronic calculators may be used for calculations.<br>5. Write **legibly** in ink on the **right hand page** only – **left hand pages will not be marked**.<br>6. Illustrate your answers by means of sketches or diagrams wherever possible.<br>7. Answers must be given to an accuracy which is typical of practical conditions.<br>**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).<br>8. In answering the questions, full advantage should be taken of your practical experience as well as data given.<br>9. Please note that you are not allowed to contact your examiner or moderator regarding this examination.<br>10. Cell phones are **NOT** allowed in the examination room. |

## QUESTION 1




The diagram above shows the main ventilation connections in a mine. The downcast shaft (A-B) is 5.5 metres in diameter with an air velocity of 10.5 m/s. The upcast shaft (I-J) is 4.0 metres in diameter. The stoping areas (D-E & F-G) comprise numerous large parallel airways and the resistance in these branches can be assumed to be zero (0). Ignore the effects of leakage and compressed air. The air density in the fan drift is 1.01 kg/m³. Branch resistances and mean densities are listed in the following table.

| Branch | Resistance ($Ns^2/m^8$) | Density ($kg/m^3$) |
|---|---|---|
| A – B | 0.006 | 1.06 |
| B – C | 0.055 | 1.18 |
| C - D | 0.05 | 1.19 |
| C –F | 0.055 | 1.20 |
| D –E | 0 | |
| F –G | 0 | |
| E –H | 0.038 | 1.10 |
| G - H | 0.04 | 1.09 |
| H – I | 0.006 | 1.09 |
| I -J | 0.0035 | 1.05 |

1.1 Calculate the air quantity at the main fans (4)

The area of the downcast shaft is 5.52 x π/ 4 = 23.76 $m^2$ at a density of 1.06 $kg/m^3$. (1)

The mass flow through the mine is thus 249.46 x 1.06 = 264.4 kg/s. (1)

Assuming no leakages, the mass flow in the fan drift will be the same (264.4 kg/s). (1)

The air quantity in the fan drift (at a density of 1.01 $kg/m^3$) will be 264.4/1.01 = 261.8 $m^3/s$. (1)

1.2 Calculate the mean velocity in the upcast shaft (3)

Mass flow = 264.4 kg/s. (1)

Air quantity in the upcast shaft (at a density of 1.05 $kg/m^{3)}$ is 26.4 /1.05 = 251.8 $m^3/s$.

Area of upcast shaft = $4^{2}$* 3.14/4 = 12.56 $m^2$ so Velocity = 251.6/12.56 = 20.0m/s ((1)

1.3 Calculate the main fan pressure (10)

In order to determine the fan pressure, the mine resistance must be known. Resistances will vary according to density - all resistances should be corrected to the density in the fan drift (given as 1.01 kg/m3). The corrected resistances are as follows:

| Branch | Resistance ($Ns^2/m^8$) | Density ($kg/m^3$) | Corr. Resistance |
|---|---|---|---|
| A – B | 0.006 | 1.06 | 0.0057170 |
| B – C | 0.055 | 1.18 | 0.0470763 |
| C - D | 0.05 | 1.19 | 0.0424370 |
| C –F | 0.055 | 1.20 | 0.0462917 |
| D –E | 0 | | |
| F –G | 0 | | |
| E –H | 0.038 | 1.10 | 0.0348909 |
| G - H | 0.04 | 1.09 | 0.0370642 |
| H – I | 0.006 | 1.09 | 0.0055596 |
| I -J | 0.0035 | 1.05 | 0.0033667 |

(0.5 Each)

Airway A-B is in series with B-C, thus 0.0057170 + 0.0470763 = 0.0527933 (0.5)

Airway H-I is in series with I-J, thus 0.0055596 + 0.0033667 = 0.0089263 (0.5)

Resistance C-D-E-H is 0.0424370 + 0 + 0.0348909 = 0.0773279 (1)

Resistance C-F-G-H is 0.0462917 + 0 + 0.0370642 = 0.0833559 (1)

C-D-E-H in parallel with C-F-G-H is 0.0200643 (1)

Total mine resistance is 0.0527933 + 0.0200643 + 0.0089263 = 0.0817839 (1)

Using the air quantity determined in 1.1, the fan pressure is then:

$P = R \times Q^2 = 0.0817839 \times 261.8^2 = 5\,605$ Pa (1)

1.4 Calculate the fan shaft power if the main fan is 74% efficient. (2)

Air power is 261.8 x 5 605 / 1 000 = 1 467 kW (1)

Fan shaft power is 1 467 / 0.74 = 1 983 kW (1)

1.5 What is the pressure loss in airway B – C? If this airway could be enlarged such that the new corrected resistance is 0.030 $Ns^2/m^8$; what would be the effect on the fan shaft power? Assume the fan efficiency remains constant. (6)

The air quantity in airway B-C is 264.4 / 1.18 = 224.1 m3/s. (0.5)

The pressure loss in airway B-C is 224.12 x 0.055 = 2 762 Pa (0.5)

The decrease in total mine resistance is 0.0470763 – 0.030 = 0.0170763 (1)

Mine total resistance (original) is 0.0817839. (1)

New mine resistance would be 0.0817839 – 0.0170763 = 0.0647076. (1)

The fan pressure would be $0.0647076 \times (261.82)^2 = 4\,435$ Pa (1)

Air power is 261.8 x 4 435 / 1 000 = 1 161 kW (0.5).

Fan shaft power is 1 161 / 0.74 = 1 569 kW (0.5).

**[25]**

**QUESTION 2**

9.6 $m^3/s$ of air is flowing in a 760 mm diameter column at a density of 1.15 $kg/m^3$. An evaseé is fitted to the delivery of this column and the outlet area of this evaseé is 0.8 m2. The pressure loss due to friction and shock in the evaseé is 45Pa.

Calculate:

2.1 The theoretical static pressure regain in the evaseé. (10)

Velocity in column = Q/A = 9.6/0.454 = 21.14 m/s. (2)

VP in column = $wV^2/2$ = ($21.05^2$ x 1.15)/2 256.9 Pa. (2)

Velocity in evaseé = Q/A = 9.6/0.8 = 12m/s. (2)

VP in evaseé = $wV^2/2$ = 1.15 x $12^2$ = 82.8 Pa. (2)

Theoretical regain in SP = (256.9 – 82.8) Pa = 174.1 Pa. (2)

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2.2 The actual or practical static pressure regain in the evaseé. (2)

Friction or shock losses = 45 Pa (1)

Actual regain = 174.1 = 45 = 129 Pa (1)

2.3 The efficiency of the evaseé'. (3)

Efficiency of evaseé = Actual regain/ Theoretical regain x 100. (1)
= (129 /174) x 100 (1)
= 74.1 % (1).

2.4 Give reasons why an evaseé is fitted to the outlet of a ventilation system. (3)

An evaseé is normally fitted to the discharge of a system to convert the wasted velocity pressure into useful static pressure. This is done by enlarging the area at the discharge of the system thus decreasing the air velocity and hence the velocity pressure. This reduction in velocity pressure then represents a gain in static pressure.

2.5 Define the concept "shock losses". (3)

Shock losses occur when the direction of air is deviated from a straight line or its velocity is changed, swirls and eddies are set up which destroys some of the ventilating pressure.

2.6 Mention 4 causes of shock losses in an airway. (4)

a) Intake of a duct/tunnel (entrance loss)
b) Outlet of a duct/tunnel (exit loss)
c) Bend in the airway
d) Obstruction in the airway
e) Sudden changes in airway size

**[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 / 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. (Hint: Make use of the chart provided). (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%. (5)

Assume 305mm pipe – head loss approximately 1.4 m/100m. (2)

Total head loss for 1 800 metres = 25.2 metres. (2)

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 ESKOM) allows the mine to pump for 19 hours per day:

i) Assuming standard sizes, what size pipe 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 19 hr/day = 365 days x 19 hrs x 4 836 kW x R1.16 (1)

= R38 903 686 (1)

3.5 Define Terminal velocity. (2)

The velocity of water flowing down an open ended vertical column, where the fiction losses are equivalent to the gravitational acceleration.

Meaning that the water cannot flow any faster down the column, because the shear and drag forces within the column fully cancel the gravitational force of the earth.

3.6 Briefly describe any two methods of controlling physical fouling within a water reticulation system.

a) Water Clarification

Used when level of suspended solids is high, generally inorganic and polyelectrolyte polymer flocculants are used in clarification equipment.

b) System Design

Where possible turbulent flow should be maintained in equipment as this reduces the deposition of solids.

c) Limiting Concentrations

By increasing the “blow-down” rate, the concentration of suspended solids is reduced. Controlling cycles of concentration within a system reduces fouling deposition.

d) Slipstream filters

The size of the filter is dependent upon the level of suspended solids reduction required – the filter must be large enough to handle 3 – 10% of the recirculation rate.

e) Air rumbling and back flushing

A stream of pressurised air is injected into the equipment. The airflow rate should be sufficient to at least double the normal velocities within the equipment. This dislodges the deposit and forces it out of the equipment.

f) Chemical dispersants

Generally, surface active agents such as natural organics, surfactants and other synthetic polymers are used.

**[25]**

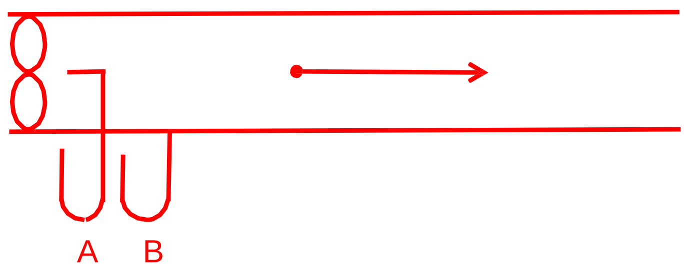
**QUESTION 4**

4.1 Mention any three methods of ventilating sinking shafts. (3)

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;

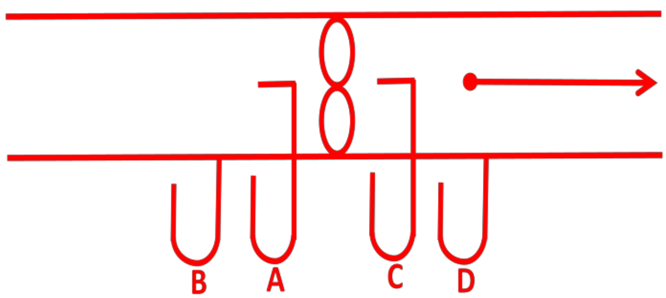
i). the fan is at the inlet to the ventilation column.




(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.



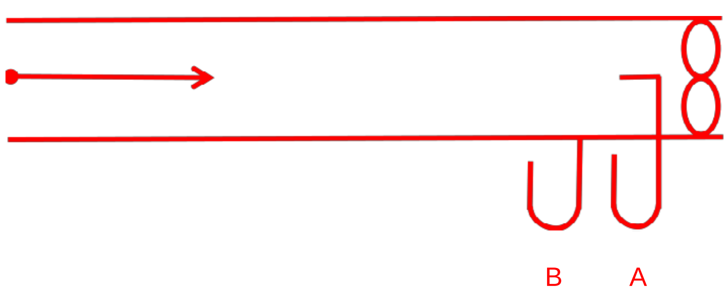

(2)

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

Fan static pressure = D – A (1)

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

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




(2)

Fan total Pressure = 0 - B (1)

Fan static pressure = 0 - A (1)

Fan velocity pressure = (B – A) (1) (15)

4.3 The resistance of three airways that are connected in series are:

i) $A = 0.075\ Ns^2/m^8$

ii) B = 0.049 Ns2/$m^8$

iii) $C = 0.06\ Ns^2/m^8$

A quantity of $57.4m^3/s$ is measured in airway B. Calculate the pressure loss in each airway, the overall resistance and the overall pressure loss of the system. (7)

Airway B

$P = RQ^2 = 0.049 \times 57.4^2 = 161.44$ Pa (1)

Since the airways are in series the same volume will flow through each airway, assuming no leakage.

Airway A

$P = RQ^2 = 0.075 \times 57.4^2 = 247.11$ Pa (1)

Airway C

$P = RQ^2 = 0.06 \times 57.4^2 = 197.69$ Pa (1)

Pressure loss for airways in series = P Airway A = P airway B + P airway C

= (161.44 + 247.11 + 197.69) Pa (1)

= 606.24 Pa (1)

Overall resistance = Overall Pressure drop / total volume$^2$

$= 606.24/57.4^2$ (1)

$= 0.184\ Ns^2/m^8$ (1)

**[25]**

**TOTAL MARKS: [100]**