Indian Institute of Technology (Indian School of Mines) Dhanbad
Department of Mining Engineering
Monsoon End Semester Examination 2023-2024 for BTech + Int. MTech Students (97 nos.)
Subject: Mine Environmental Engineering (Code: MND 406) **Venue: NLHC LH 3-7**

Time: 180 minutes (04:00 PM – 07:00 PM) || Date: 19-11-2023 || Maximum Marks: 84

Answer all questions of the two sections & marks are assigned to each section/question

Section A: Short Answer Type Question (answer in max. 4-5 lines only) – 44 marks

Answer all the questions (pointwise if requires explanation) and each question carries 1 mark

1. Write the relationship to estimate safe distance and length of boreholes to be drilled while approaching a water-logged working by means of narrow roadways **(i)** if approaching from bottom side and **(ii)** if exact location of the area is not known?

The safe distance up to which the workings may be driven depends on the water pressure and the nature of ground. It can be determined by using the formula

$$t = \frac{pb}{4\tau}$$

where b is the length of the longest side of the roadway section (m); p is the water pressure at the floor level of the approaching working (tf/m2 or m WG); s is the shortest distance between the approaching mine working and the water-logged area. It must be at least equal to the longest side of the roadway section when the direction of force is acting against the face, and equal to the roadway height when the direction of force is acting against the roadway side; t is the shear strength of the ground (tf/m2)

When approaching a water-logged area from its bottom side, the determined value of s should be increased by 50 per cent.

A further 25 m should be added to it if the exact location of the area is not known.

2. **(i)** Write the chemical reaction which occurs during acid-mine drainage? **(ii)** Convert 1 m WG into tf/m^2, kgf/m^2 and N/m^2.

$FeS_2 + 3O_2 + 3H_2O \rightarrow Fe(OH)_2 + 2\ H_2SO_4$

1 tf/m^2 = 1 m WG = 1000 kgf/m^2 = 10^4 N/m^2

3. **(i)** What is the purpose of using safety boring machines? **(ii)** What are the symptoms of the miner's disease nystagmus?

For tapping off old water-logged workings by means of long boreholes or for putting advance boreholes when driving exploratory headings in anticipation of danger from accumulations of water or gas, rotary core boring machines equipped with a special safety boring outfit or apparatus is used.

Symptoms of the miner's disease nystagmus - oscillations of the eyeballs, slow adaptation of the, eyes to both light and dark and other neurotic effects. The sufferers also have a marked dislike for bright light.

4. **(i)** What is the minimum illumination required to avoid nystagmus? **(ii)** Why there are fewer reporting of miner's disease pneumoconiosis in low rank coal mines?

Minimum illumination required to avoid nystagmus is 0.4 lm/ft^2.

Fewer occurrences of pneumokoniosis in low-rank coal mines as compared to anthracite mines have been found to be due to the fact that vitricin in low-rank coals contains antibiotics which inhibit tubercular infection.

5. **(i)** What is the best position for collecting dust sample in a mine? **(ii)** Write the name of three instruments used for dust sampling in mines.

The best sample having direct relevance to health hazard is one collected at the breathing point of the worker.

Gravimetric Dust Sampler, Konimeter, Real-time Aerosol Monitor etc.

6. **(i)** What are the average values of reflectance of coal and whitewashed surface? **(ii)** At a measurement station, the air quality parameters $PM_{2.5}$, NO_2 and O_3 have the AQI sub-index values as 180, 96, and 84, respectively. What is AQI for the station?
Reflectance of coal- 5%, whitewashed surface- 60%.
AQI is 180

7. **(i)** What are the preparatory measures for resuscitation? **(ii)** Is it possible to breathe without heart activity or vice versa? Explain.
Proper positioning of patient
Ensuring free air passages:
Retaining the body heat:
The oxygen-enriched blood, aided by heart action, supplies the necessary oxygen to the body cells for the combustion of the nutrient material producing, in the biochemical process, water and a small quantity of carbon dioxide which dissolve in the venous blood but diffuse out of it during its transit through the lungs. For resuscitation, therefore, the lungs of the patient must be ventilated with adequate quantity of air or oxygen by artificial respiration and the heart muscles and other important nerve centres must be excited or stimulated to restore the normal blood circulation.

8. **(i)** What are the different circumstances where resuscitation is required? **(ii)** Mention the different methods of resuscitation.
The principal causes of such accidents are:
(a) Throttling of the inspired air due to trapment under the fall of debris, crushing of the chest, compression of the windpipe, and drowning.
(b) Inhaling oxygen-deficient atmospheres.
(c) Inhalation of toxic gases. The inhalation of small quantities of toxic gases present in the mine atmosphere may do harm to the supply of oxygen to the body cells. With carbon monoxide poisoning, resuscitation of the patient using large quantities of oxygen must be commenced at the earliest opportunity. With poisoning by nitrous gases, on the other hand, artificial respiration with the application of pressure on the chest and lungs should not be attempted. Only oxygen must be administered and greatest heart activity promoted.
(d) Electric shocks from voltages greater than 42 V affect the respiratory centre paralysing the oxygen supply to the body cells.
The methods of artificial respiration can be divided into the following two groups:
(a) Manual methods using hands
(b) Mechanical methods using resuscitators

9. Describe the following terms: **(i)** Luminous flux **(ii)** Radiant flux **(iii)** Illuminance **(iv)** Glare
Luminous flux is the time flow rate of light energy. The unit of luminous flux, the lumen, is most frequently used to describe the lighting power of light sources.
Luminous flux differs from radiant flux. It is the measure of the total power of light emitted.
llluminance is the amount of light falling on a surface. The unit of measurement is lux (lx) and lumen /m^2.
There are two types of glare: disability glare and discomfort glare. Disability glare is defined as glare resulting in decreased visual performance and visibility. The cause is stray light which enters the eye and scatters inside. This produces a veiling luminance

over the retina, which has the effect of reducing the perceived contrast of the objects being viewed. Discomfort glare causes fatigue and pain caused by high and non-uniform distributions of brightness in the observer's field of view.

10. **(i)** When it is required to introduce Cunningham's correction in settling velocity of dust particles? **(ii)** Which one is more susceptible to tuberculosis disease and fibrosis of lungs: asbestosis or silicosis?

Stokes' law of gravitational settling does not hold good for very fine particles, since when particles become small compared to the mean free path of gas molecules, the viscous resistance decreases and consequently the terminal velocity increases.

For such particles Cunningham developed the following relation: $\boldsymbol{v_c = v_s\left(1 + 1.7\frac{l}{D}\right)}$

where $\boldsymbol{v_c}$ = true terminal velocity, $\boldsymbol{v_s}$ = terminal velocity as calculated by Stokes' equation and *l* = mean free path of the gas molecules $\approx 10^{-7}$ m under ordinary atmospheric conditions.

Tuberculosis- Silicosis; Fibrosis- Asbestosis

11. What are collagenous and non-collagenous pneumoconiosis?

Noncollagenous pneumoconiosis is caused by nonfibrogenic dusts and is characterized by

(i) alveolar architecture remaining in tact.

(ii) minimal stromal reaction consisting mainly of reticulin fibres and

(iii) reversibility of dust reaction.

Examples of noncollagenous pneumokoniosis are stannosis caused by tin oxide and barytosis caused by barium sulphate.

Collagenous pneumokoniosis is characterized by

(i) permanent alteration or destruction of alveolar architecture,

(ii) collagenous stromal reaction of moderate to maximal degree and

(iii) permanent scarring of lungs.

It may be caused by fibrogenic dusts or altered tissue response to non-fibrogenic dusts.

12. Draw a spirogram showing Tidal Volume (TV), Inspiratory Reserve Volume (IRV), Expiratory Reserve Volume (ERV) Residual Volume (RV), Total Lung Capacity (TLC), Vital Capacity (VC).

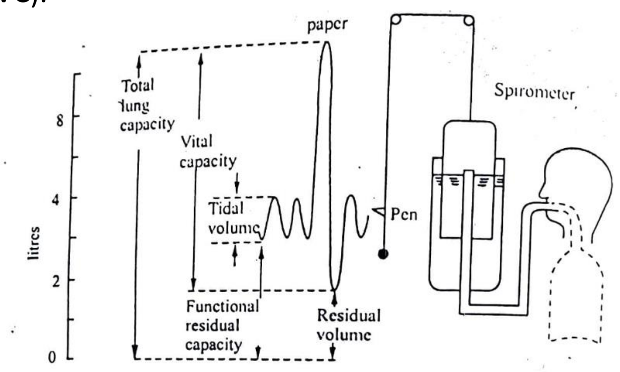


Figure 7.2 Spirogram.

13. Differentiate between inhalators and resuscitators.

Resuscitators do not require any manual assistance in their operation and ensure uniform respiration. Many types of resuscitators are available each with its own characteristic principles of operation. Basically, a resuscitator consists of a supply of oxygen, a mechanism for forced breathing, and a mask that fits over the face of the victim.

It must be borne in mind that the quantity of oxygen available with a reviving apparatus is very small, usually 280 to 420 litre which is sufficient only for 20-30 min duration of use. Inhalators or oxygen reviving apparatus supply oxygen to the patient in response to his own breathing demands. They are used in cases of asphyxia where the casualty has at least partial control of respiration but is not getting enough oxygen, or where the casualty has ceased to respire but has regained consciousness after successful resuscitation

14. Draw a curve between percentage deposition and dust particle diameter showing retention of mineral dust in human respiratory system.

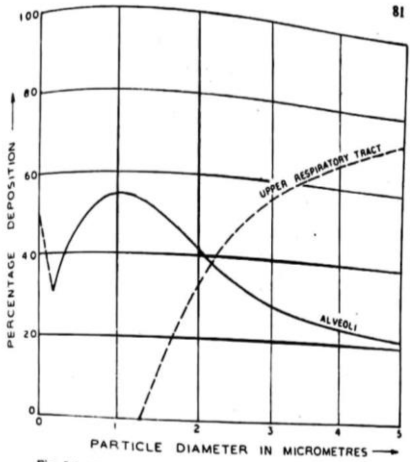
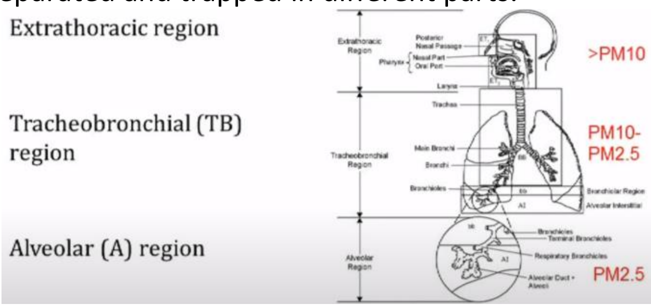


Fig. 2.1 Retention of mineral dust in human respiratory system.

15. Draw a suitable diagram of human respiratory system showing the different sizes of dust getting separated and trapped in different parts.

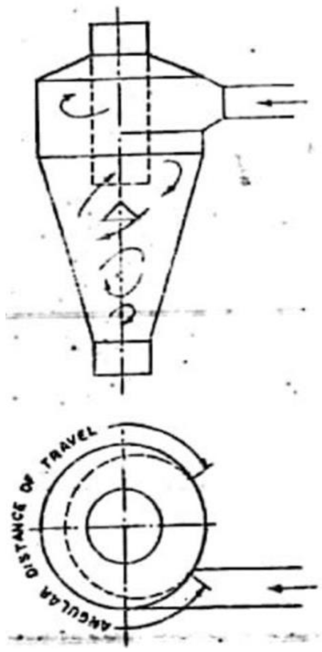


16. Differentiate between air-lift pumps and submersible pumps.

De-watering of a flooded mine in which water has risen into the shaft(s) may be done by suspended electrical vertical centrifugal/turbine pumps, air-lift pumps, or electrical submersible pumps installed in the shaft. In the air-lift pump (Fig. 8.19), compressed air produced by an efficient compressor is used for pumping out water. The compressed air is fed through a pipe to the bottom end of a larger pipe immersed in water where it forms a mixture with water having a density less than that of water so that it rises upwards through the larger pipe constituting the rising main. The actual head of an air -lift pump is given by $H = \frac{\eta t(\rho_w - \rho_m)}{\rho_m}$ (m)

where n = efficiency which depends on the ratio H: t; t = immersion depth (m); ρ_w = density of water to be pumped (kg/m^3); ρ_m = density of compressed air-water mixture (kg/m^3). Generally, the immersion depth is made 1.5 to 2 times the lift head. The main advantages of the air-lift pumps are: (a) there are no wearing parts, (b) fabrication is simple, (c) any kind of pipes can be used, and (d) water containing mud and sand can be pumped. The disadvantages, however, are that an efficient compressor must be available and the efficiency in normal operation is not higher than 0.2 to 0.3. They can be used only in emergencies as at low t: H ratios which are usually encountered in mines, the high cost on compressed air does not play an important role. Air-lift pumps had been used in the past for raising water from flooded shafts. Where electricity is available, submersible pumps offer the easiest means of dewatering mine shafts. The submersible pump is of the multi-stage centrifugal type with a motor coupled to it and the drive is from below. The squirrel cage motor is of the completely 'wet' type in which the motor is cooled and lubricated by water which circulates vigorously between the rotor and the stator and throughout the windings. The circulation ensures efficient cooling of the conductors and enables a high horsepower output to be obtained from a small frame size motor.

17. How dust is separated using cyclone separator?



Here, the dust-laden air is imparted a rotating motion by virtue of its tangential entry into the cyclone.
Owing to this rotational motion, the dust particles are subjected to a centrifugal force which imparts them a radial acceleration.
This radial acceleration is much higher than the acceleration due to gravity.
The air-stream entering the cyclone travels down in an outer vortex or spiral during the course of which it deposits its dust load on the walls of the cyclone and the clean air travels up again in an inner vortex before entering the exit duct.
The centrifugal force F acting on a dust particle moving with an angular velocity ω is given by the relation

$$\mathrm{F} = \frac{\pi D^3}{6}(\rho - \rho_a) r\omega^2 \qquad (2.24)$$

where r = radius of curvature of the path of the particle, D = diameter of the particle, ρ = density of the particle and ρ_a = density of air.
For attaining the terminal centrifugal settling velocity, F must be equal to the air resistance which, for spherical particles in streamline motion, is equal to $3\pi\mu D v_c$, (see equation 2.4)

or, $\frac{\pi D^3}{6}(\rho - \rho_a) r\omega^2 = 3\pi\mu D v_c$a

or, $$v_c = \frac{r\omega^2(\rho - \rho_a)D^2}{18\mu} \qquad (2.25)$$

where v_c = centrifugal settling velocity.

Combining equations 2.25 and 2.7 we have $v_c = \frac{r\omega^2}{g}$ $\qquad v_t = \frac{v^2}{rg} v_t$

(2.26)

where v_t = terminal velocity of gravitational settling and v = linear velocity of the rotating gas-stream.
Equation 2.26 shows that for any particle size, the centrifugal settling velocity can be increased by either increasing the speed of rotation of the air-stream or by decreasing the value of r.
It is for this reason that smaller cyclones are more efficient than larger ones.
The factor $\frac{v^2}{rg}$ is termed the separation factor.

18. Differentiate between warning message and action message during mine emergency notification plan.

'Action Messages' are addressed to persons whose attendance is required at once or who have to carry out duties immediately as outlined in their 'duty cards'. An action message chart must be prepared indicating the order in which messages are to be transmitted. Action messages must be short, clear and to the point.

Warning Messages are addressed to other key personnel whose attendance is required less urgently or who may have to prepare some action to be taken at a later stage or on receipt of a further message. A Warning Message Chart must be prepared for the mine and the area in which it is located. Warning messages should indicate clearly what has occurred and what action, if any, the person or organisation is required to prepare for.

Besides informing the mine rescue men, action messages should be sent to the following key persons at the mine:

(1) All mine officials; (2) Safety Engineer/Safety Officer; (3) Rescue Room In-charge; (4) Ventilation Officer; (5) Chief/Assistant Chief Surveyor/Surveyors; (6) Surface Manager; (7) Senior underground mechanical and electrical supervisory officials; (8) Senior officials on duty in emergency; (9) Welfare officer; (10) Medical officer; (11) First-aid attendants; (12) Banksman; (13) Lamproom in-charge; (14) Timekeeper; (15) Storekeeper; (16) Security, Main Gate Office; (17) Winding Engineman; (18) Fire Deputy; (19) Canteen Manager; (20) Public Telephone Exchange; (21) Colliery Engineer.

Warning messages should be sent to the following:

(1) Central/District Rescue Station; (2) Mines Inspectorate;

(3) Adjoining mines for assistance under mutual-aid plan; (4) Head office of the mine/Area/Headquarters, (5) Police authorities; (6) Doctors; (7) Local hospitals; (8) Connecting and adjoining mines endangered; (9) Mine Safety Council/Commission;

(10) Mineworkers' Union; (11) Overmen and Deputies Union; and (12) District Magistrate.

19. Classify different mine rescue breathing apparatus.

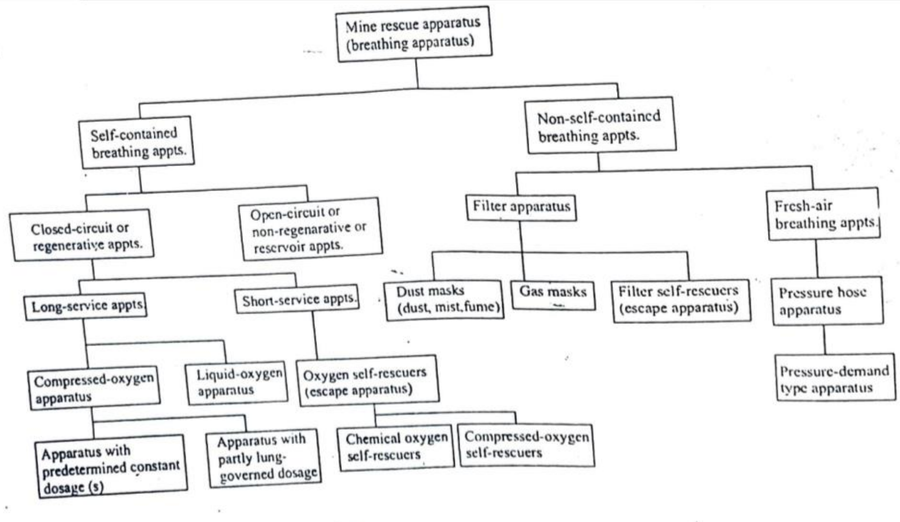


Figure 7.3 Classification of mine rescue apparatus.

20. What are the general design requirements of a self-contained breathing apparatus?

(1) Safety and reliability: (2) Simplicity: (3) Comfort: (4) Weight: (5) Compactness: (6) Durability: (7) Initial cost and ease and cost of maintenance.

(8) Compliance with the country's national standards.

21. Draw a schematic circuit diagram depicting air circulation system of Proto IV Self-Contained Closed Breathing Apparatus.

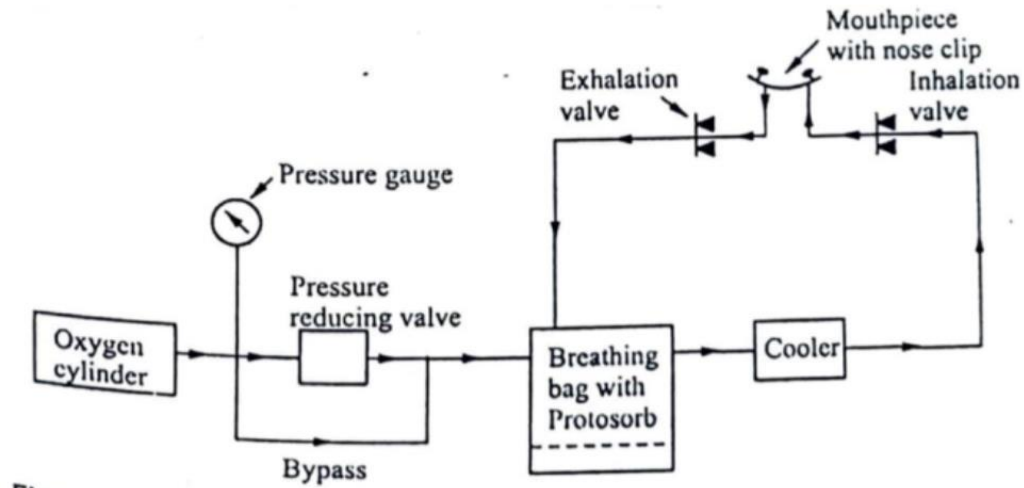
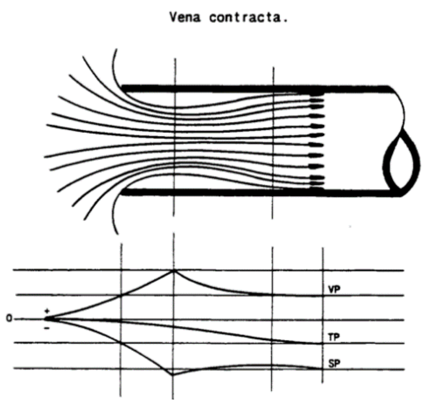


Figure 7.6 Schematic diagram of Proto IV 1980 breathing apparatus.

22. What is vena contracta and how it affects the total (static + velocity) pressure?



As air enters the hood, the cross-sectional area of flow contracts and forms a stream with cross-sectional area less than that of the duct. Thois contraction is called vena contracta. During this contraction, velocity increases and so velocity pressure also increases. From Bernoulli's theorem, TP= VP+SP, static pressure converted into velocity pressure. During this conversion of static pressure, a loss of energy results. The energy loss velocity pressure must be converted to pressure to velocity is approximately 2% of the static pressure. As the air moves further into the system, it expands to fill the duct. The velocity of the air decreases; thus, the VP is converted back to SP, and a further loss of energy results. This energy loss is much greater than that which occurred during the initial conversion because of the turbulence that exists on the perimeter of the air flow. The result of the formation of the vena contracta and the subsequent expansion of air to fill the duct is a loss in energy of the total pressure of the system. An objective of exhaust hood design is to design the hood to operate as efficiently as possible. This can be accomplished by minimizing the loss that results from the vena contracta.

23. Mention the different methods of dewatering underground waterlogged workings.

(1) By approaching the water-logged area up to a suitable point with one or two narrow mine roadways in order to bore and tap off the water.

(2) By putting long boreholes.

24. What are the precautions adopted while approaching water-logged workings?

During drivage of de-watering mine workings and tapping of water, a number of precautionary measures must be adopted. These include the following:

(1) For the safety of men engaged in de-watering operations, an escapeway, preferably a level one, must be provided. The escapeway must be properly: supported, be free from obstructions, and be electrically lighted. If an escapeway is steeper than 3°, it must be provided with a water drain, a raised travelling way, and a rope railing.

(2) The de-watering mine workings must be well-ventilated to remove any noxious gases such as carbon dioxide and hydrogen sulphide that may occur. If through

ventilation is not possible, provision for auxiliary ventilation must be made. Forcing ventilation system must be preferred.
(3) Open lights should not be used. Only electric safety lamps should be used, (4) Only experienced miners should be employed who should be equipped with self-rescuers.
(5) For rescue of men overcome with gases, a rescue team equipped with respiratory protective apparatus should be stationed near the place of work. The final boring and tapping of water should be done by the rescue men only.
(6) During tapping, workers from adjacent mine workings should be withdrawn. 3
(7) Necessary materials for erection of a dam should be stored at a suitable place and the dam site prepared. A bulkhead door must be built if high-pressure water is expected.
(8) All de-watering operations must be done according to a definite plan prepared by the mine management.
(9) All operations must be done under the supervision of an experienced supervisory official. The actual tapping operation must take place in the immediate presence of the official. In difficult cases, the presence of the mine manager is recommended.

25. Discuss the problems associated with lighting of underground coal mines.
Shadow
Glare
Low Reflectance: nature of surface
Equipment safety
Inflammable gas
Restricted and congested space

26. Mention the different methods of dust sampling in mines.
The present-day air-borne dust sampling methods can be classed as follows :
(a) filtration,
(b) sedimentation,
(c) inertial precipitation,
(d) thermal precipitation,
(e) electrical precipitation and
(f) optical methods based on light scattering

27. Mention the air inhaled rates and oxygen consumption rate for different degrees of exertion in humans.

Table 7.1 Air and oxygen consumption for different degrees of exertion

Activity	Air inhaled litres/minute	O_2-consumption litres/minute
Resting	8–10	0.3–0.4
Walking with rescue apparatus	15–20	0.6–0.9
Rescue drill	20–30	0.9–1.3
Moderate work with pauses	30–40	1.3–1.8
Hard work with pauses	40–50	1.8–2.3
Very hard work for short duration	60–90	2.7–4.0

28. Discuss design of exhaust hood.
Before designing an exhaust hood. it is important that the designer become familiar with the operation involved. The characteristics of the contaminant should be known. Is the contaminant a particulate, vapor, or gas? What is the toxicity of the

contaminant? Is the contaminant highly toxic, or is it relatively low in toxicity? By what method is the contaminant generated--evaporation, heat, splash. grinding, etc.? method of generation, how far is the contaminant dispersed? imparted to the contaminant that causes it to travel great distances from the source? Is the source relatively local, or is it a general source, generating contaminant over a large area? As a result of the Is motion. In addition, it is necessary to determine the location of the worker relative to the source of the contaminant. Does the worker move about, or is he stationary? What interaction is necessary between the worker and the contaminant source? How does the contaminating source flow in production? Does the process generate an air flow? Also, are there secondary air movements around the process that will affect the capture velocity if an exterior hood is used? After the operation is thoroughly understood, the designer should determine if hood designs have already been developed for the process. Many processes are similar in nature. It is possible that a hood design has already been developed and tested that will adequately meet the needs of the process being studied. Operations sect ion (Sect ion 5) of the Industrial Ventilation Manual. A number of such designs are presented in the Specific If a specific design cannot be found to handle the problem being studied, the designer should first consider the use of a total enclosure. The total enclosure is the most efficient for capturing and controlling the contaminant while using a relatively low rate of flow. If a total enclosure cannot be applied, can a partial enclosure or booth meet the needs of the process? If an enclosed hood cannot be used, then an exterior hood is required. It is necessary to determine where the hood can be located in relation to the source. The method of generation of contaminant may require that a receiving hood be used. In addition, if the contaminant is generated over a wide area, the use of a slot hood may be advisable. Heat-generated contaminant movement may require the application of a canopy-type hood above the process. Next, it is necessary to design the actual hood to be used. The capture velocity that is required should be determined. In determining the capture velocity, it is important that the designer consider the existence of process-induced motion, the quantity of contaminant that is generated, any secondary air currents that may require baffles or shields around the process, the toxicity of the contaminant, the approximate size of the hood that can be used, and potential contaminant escape. The designer then selects the hood that seems to best meet the needs of the system. The choice is not always clear cut, as it is necessary to give up certain operational advantages to obtain other operational advantages to meet the constraints of the process. Once the hood design has been chosen, the Q or rate of flow should be estimated based upon the capture velocity required and the location of the hood relative to the source. The size of the duct and hood face are then determined to provide the velocity that is desired. The designer should also estimate the effect of hood loss. This will be necessary when determining the size of air mover required or when adding a local exhaust system to a more general exhaust system. Finally, after the hood has been designed, it is desirable to perform tests to determine if the installed hood meets the design criteria. Are the rate of flow

RELATIONSHIP	FORMULA
The velocity at a point x distance from an unflanged exhaust hood. (Dalla Valle's formula)	$v = \dfrac{Q}{10x^2 + A}$
The velocity at a point x distance from a flanged exhaust hood	$v = \dfrac{Q}{0.75(10x^2 + A)}$
Theoretical static pressure of hood with no losses	$SP_h = VP = (v/4005)^2$
The coefficient of entry for a given hood--defined as ratio between actual flow and theoretical flow	$C_e = \sqrt{VP/SP_h}$
Relationship between the VP of the system, system, the hood entry loss, and the hood static pressure	$SP_h = VP + h_e$
The hood entry loss as a fraction of the duct VP	$h_e = (F)VP$
Actual rate of flow through a hood	$Q = 4005\ C_e \times \sqrt{SP_h} \times A$
The coefficient of entry as it relates to the hood entry loss	$C_e = \sqrt{1/(1+F)}$
The hood entry loss as it relates to the coefficient of entry	$h_e = \dfrac{(1 + C_e^2)}{C_e^2}$

and capture velocity adequate to capture and control the contaminant? Is the hood located in the appropriate place, and does the design prevent escape of the contaminant as a result of exterior air movement or process-induced movement?

29. Explain Brownian Motion of dust particles.

Owing to their small mass, submicroscopic particles (below 1 µm in size) are imparted a random motion by gas molecules bombarding on them.

The amount of displacement *x* in time *t* is given by Einstein as follows :

$$\boldsymbol{x = \sqrt{\frac{RT}{N}\frac{2t}{3\pi\mu D}}\,10^{9}}$$

where R = universal gas constant = 8314.4 J/(kmol K), T = temperature in K, N = number of gas molecules in 1 kmol = 6.06 x 10^{26}, $\boldsymbol{\mu}$= viscosity of gas = 1.8x 10^{-5} Pas for air at ordinary temperatures, and D = diameter of particle in µm.

For very fine particles obeying Cunningham's law, equation 2.13 can be modified to

$$\boldsymbol{x = \sqrt{\frac{RT}{N}\frac{2t}{3\pi\mu D}\left(1 + 1.7\frac{l}{D}\right)}\,10^{9}}$$

30. Enumerate the measures to be adopted for prevention of dust getting air-borne during mining operation e.g., drilling, coal winning and loading.

Water stemming: This consists of stemming a shot hole after charging with a plastic or p.v.c. bag (usually 0.15 mm thick) filled with water. Water, owing to its incompressibility, gives a better confinement to the charge so that a better efficiency of blasting is obtained.

Pulsed infusion: The loosening of coal with water infusion led to the development of pulsed infusion. Here, a pulse or shock is imparted to the water in the hole by firing an explosive charge in it so that the loosening effect is enhanced in addition to suppressing dust.

Water infusion- cleavage and cracks of coal seams have dust; infuse coal with water under pressure

Loading- wet muckpile before loading

coal winning- wet pneumatic picks, water sprays, wetting agents, foam+foaming agent

drilling- wet drilling by an optimum water pressure

31. What are the objectives of a central rescue station?

The objectives of a central rescue station are:

(1) Recommend formulations of mine rescue rules as well as rules for protection against toxic gases in auxiliary plants on the surface of mines;

(2) To draw mutual-aid plans under which neighbouring mines, after occurrence of a major mine disaster, assist each other on a reciprocal basis;

(3) To train directors or in-charges of rescue operations, leaders/captains, and apparatus mechanics or attendants in rescue and disaster techniques for mine rescue brigades, and also to conduct refresher training courses for them;

(4) To supervise the training of mine rescue brigades at mines and, under certain circumstances, even train mine rescue brigades;

(5) To guide and supervise the conduct of rescue and recovery and re-opening operations in mines;

(6) To maintain a permanent rescue corpse in constant readiness where the station is required to help in conducting rescue and recovery operations in mines falling within its radius of action;

(7) To store special types of equipment and apparatus for firefighting and mine rescue work;
(8) To supervise the working of district rescue stations;
(9) To inspect apparatus and equipment for mine rescue work maintained at mines and report defects and shortcomings to the management;
(10) To conduct approval tests and give expert opinion on new designs of equipment and apparatus for mine rescue work;
(11) To initiate development of new apparatus and equipment;
(12) To conduct approval tests of portable fire extinguishers for use in mines; and
(13) To advise on all matters concerning mine rescue, protection against toxic gases; fire protection, and working of seams or deposits liable to spontaneous combustion.
(14) To train specialised rescue teams for underwater rescue and recovery work and surface firefighting on the mine surface.

32. How rescue and recovery operation is carried out after occurrence of mine disasters?

Fresh-Air Base

With the main fan(s) running normally and the shaft in commission, the first rescue brigade and other crews and men whose presence is required underground enter the mine on orders from the director or man in-charge of operations after they are briefed by him on the objectives of the operations.
On entering the mine, the rescue brigade and other personnel should advance in fresh-air up to a point beyond which ventilation controls have been destroyed and establish a fresh-air base outbye that point.

First Exploration Ahead of Fresh-air Base

Exploration ahead of the fresh-air base is determined by the advisory committee after evaluation of conditions encountered by rescue teams.
As the fresh-air base is being set up, each brigade member, on orders from the captain, should carefully inspect and test his apparatus to ensure that the apparatus is air-tight and that its various parts are in safe working condition.
After the apparatus is satisfactorily tested, each member reports to his captain who examines each member and his apparatus, opens the cylinder valve and connects the breathing tubes to the facepiece.

Advancing Fresh-Air Base

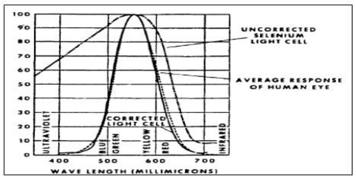
After returning to the fresh-air base, the captain reports his observations to the director of the rescue operations who, after full discussion with the captain and other members of the brigade, informs the captain of the second brigade in reserve of the prevailing conditions and orders him to proceed in the same manner as the first exploration if further explorations are indicated before the fresh-air base is advanced.
The brigade members hand over the apparatus to the apparatus mechanic, reporting any difficulties met with in their use.

Communication In Rescue Work

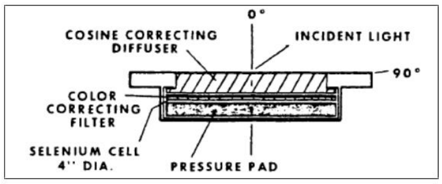
The director or man in-charge of operations at the first-air base must be in constant communication with the exploring brigades.
The brigade members must also be able to communicate between themselves.
A sound-powered telephone system adapted to an all-vision facepiece fitted with a speaking diaphragm was successfully developed by the MSA.
Battery-powered telephones can also be used.
Where such equipment is not available, lifeline or audible signals may be used and for communication between brigade members Klaxon horn may be used.

33. What is cosine and color correction in a photometer?

Color Correction: The response of the human eye (spectral luminous efficiency) for photopic (daylight) vision is shown in figure 2.7, along with the response curve for a typical uncorrected selenium photocell. The response of the cell differs significantly from that of the eye. This difference would cause a significant error in the measurement of visible light if the cell were not color corrected. This problem is corrected by the placement of filters on the surface of the photocell, which adjusts the response of the assembly to closely match that of the human eye. The response of a color-corrected photocell is also shown in figure 2.7.



(Source:www.cdc.govNioshminingpubspdfsic9074.pdf)
Figure 2.7: Function of color correcting filter on response of photocells.



(Source:www.cdc.govNioshminingpubspdfsic9074.pdf)
Figure 2.8: Diffusing cover for cosine correction on photometers.

The response of a photocell changes as the angle of light falling on its surface changes. At high angles of incidence, a greater portion of incoming light is reflected from the cell surface. This is because the reflectance of most surfaces increases as the angle of incidence increases. Errors in light measurement caused by these factors alone may be as much as 25 pct. The problem is corrected by placement of a diffusing cover over the photocell. This cover adjusts the level of light received by the cell to the correct proportion for various angles of incidence (fig 2.8).

34. What are the different types of photometric measurement carried out in a mine?

Photometric measurements in mines are of three types: illuminance measurement, Luminance measurement, and reflectance measurement.

35. Mention the different tests conducted to ensure proper functioning of a self-contained compressed-oxygen breathing apparatus.

The full test programme for self-contained compressed-oxygen breathing apparatus usually comprises:
(1) Leak tests at positive and negative pressures;
(2) Pre-flush test when a pre-flushing device is provided;
(3) Exhalation valve test;
(4) Inhalation valve test;
(5) Relief valve test for setting pressure;
(6) Pressure gauge equalization test;
(7) Lung demand valve test for response pressure and response volume,
(8) Constant dosage test;
(9) Breathing bag volume test;
(10) Bypass test;
(11) Whistle activation and duration tests: and
(12) High-pressure leak test.

The test programme for self-contained compressed-air breathing apparatus comprises:
(1) Leak tests at positive and negative pressures;
(2) Lung demand valve test for response pressure, and
(3) Exhalation valve test.

The test programme of self-contained chemical oxygen apparatus includes the following:

(1) O_2-content in the inspired air;
(2) Temperature of the inspired air;
(3) Inhalation resistance;
(4) Exhalation resistance; and
(5) CO_2-content of the exhaled air.

36. What is self-contained closed circuit oxygen self-rescuers and how it is different from filter self-rescuers?

A self-contained closed circuit self-rescuers breathing apparatus these are short-duration emergency gas respirators which provide protection against toxic and noxious gases in mine atmospheres and enable the wearer to escape from the danger zone to a place of safety but, unlike in filter self-rescuers, the exhaled air is regenerated and enriched with oxygen for rebreathing so that the wearer is independent of the surrounding atmosphere.

The chemical employed is potassium tetroxide (K_2O_4) which liberates oxygen and absorbs carbon dioxide according to the equations:

$2K_2O_4 + 2CO_2 \rightarrow 2K_2CO_3 + 3O_2$

$2K_2O_2 + 2H_2O \rightarrow 4KOH + 3O_2$

$2KOH + CO_2 \rightarrow K_2CO_3 + H_2O$

The following are the common features of filter self-rescuers masks which differ only in matters of details of construction but are based on the same basic principles.

A replaceable 'all-service'-type canister of oval cross-section containing mechanical and chemical filters deposed one above the other that remove toxic dusts, fumes, mists and smoke, absorb acid gases and organic vapours, and convert carbon monoxide to carbon dioxide.

The canister has openings at the top and at the bottom so that, when the wearer inhales, the external air surrounding him 'enters the bottom opening, passes upward through the filters arranged in layers. and leaves the canister through the top opening.

The elimination of irrespirable or toxic constituents of the air is effected by processes of chemical absorption. physical absorption, catalytic oxidation and mechanical filtration.

The absorbents used for the removal of gases and vapours are in the form of granules.

The various types of filtering layers commonly used in gas-mask canisters are:

(i) Cellulose particulate filter for removing dusts, fumes, mists and smoke;

(ii) Impregnated activated charcoal and caustite for absorbing organic vapours and acid gases;

(iii) Activated charcoal and baryta-charcoal for the removal of acid gases;

(iv) Silica gel or charcoal impregnated with sulphuric acid for the removal of ammonia;

(v) Charcoal impregnated with zinc chloride for removal of the bulk of water vapour; and

(vi) Anhydrous calcium chloride or calcium chloride-zinc chloride for removal of final traces of moisture.

The catalytic oxidation of carbon monoxide at ordinary temperatures to the relatively harmless carbon dioxide is effected by 'hopcalite', an activated granular mixture of manganese peroxide and copper oxide which was developed at the John Hopkins University, USA, in 1919

37. Briefly describe the physiological properties of dust.

Composition: Chemical and mineralogical composition of the dust particles determine the degree of virulence. While minerals like silica and asbestos are extremely hazardous, minerals like haematite have been reported to have a prophylactic effect on toxic dusts.

Size of Particle: This is the most important parameter of dust that governs its physiological effect. Most authors are agreed that the maximum tissue damage is caused by dusts of about 1 µm size and it decreases with particles of both higher and lower sizes. According to Hatch, tissue damage is negligible for particles above 2 to 3 µm size. This is mainly because of the fact that large particles of 5 µm size and above are usually trapped in the upper respiratory tract, such as the large bronchi, trachaea etc. whereas only particles of 1 µm or lesser size reach the alveoli of the lung. Again, of the latter, the maximum retention occurs for 1 µm particles whereas 0.25 µm particles lend themselves least to retention.

Concentration: Concentration of dust can be expressed as (a) mass of dust per unit volume of air, (b) number of particles per unit volume and (c) surface area of particles per unit volume. Mass concentration was the earliest-adopted indicator of dust hazard when sugartube method of dust sampling was prevalent in South Africa.

Time of Exposure: Experiments on animals show that larger lung dosages of dust produce faster development of silicosis and the same holds true for men also.

While with exposure to large dust concentrations, it takes only a year or a few years for the development of nodular fibrosis, the period of exposure required for the development of silicosis progressively increases with decreasing concentration.

38. Mention the different techniques for consolidation of roadway dust in mines.

Two common methods of consolidating roadway dust are (a) the calcium chloride method commonly used in British coal mines and

(b) the Salt crust process sometimes used in Germany.

39. What are the preventive measures adopted for dilution and suppression of air-borne dust?

Supression of air-borne dust, can be classified into two methods :

(a) wet suppression and

(b) dry suppression.

40. What are the different techniques adopted for cleaning dusty air in a coal mine?

The methods commonly used for cleaning air of its dust load are

(a) gravitational cleaning,

(b) inertial cleaning,

(c) scrubbing,

(d) filtration and

(e) electrical precipitation.

41. Draw a layout of a rescue station in a mine.

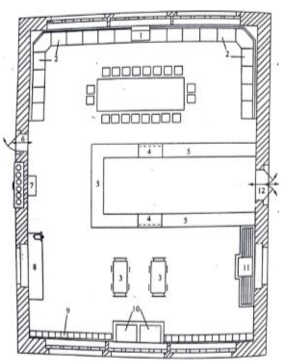


Figure 7.37 Layout of a rescue station (rescue room) at mine: 1: central test desk; 2: apparatus bench; 3: trolley; 4: flap with door; 5: counter; 6: emergency exit; 7: oxygen-filling pump; 8: work bench; 9: gas-mask cupboard; 10: disinfection chamber; 11: apparatus wash basin; 12: main entry and exit.

42. What are the points to be considered for designing a rescue chamber?

The rescue chambers should be designed keeping in view the following objectives:
(1) withstand low-intensity explosions,
(2) be designed as far as possible with a minimum height of 1.8 m and a floor area and volume adequate for the number of workmen likely to use them,
(3) be constructed of incombustible and heat-resistant materials; with temporary rescue chambers the construction materials should have at least 1-hour fireresistant rating,
(4) be located at easily accessible places in an area, where possible, free of combustible material in accordance with the maximum safe travelling distance which can be covered with or without the aid of a SCSR but inaccessible to air containing noxious smoke, fumes or gases,
(5) be equipped with a means for maintenance of a healthy respirable atmosphere,
(6) be equipped with a sufficient supply of potable water,
(7) be equipped with a means of communication with surface,
(8) be equipped with first-aid equipment.

43. How mine rescue is carried out through large-diameter boreholes?

Large-diameter drillholes and bored shafts have been successfully used in Germany, Holland and the USA, for rescuing miners trapped alive underground after a rock/coal outburst or inundation. Special rotary and down-the-hole drills have been developed for the purpose. Rescue drilling may be carried out from suitable underground workings or from the surface depending on the location of the trapped miners.

A probe/pilot hole of smaller diameter is first drilled to have access to the trapped men which is then reamed to a large diameter of 500 mm. It is possible today to drill rescue holes or shafts from the surface to a depth of 300 m through hard rock within a week.

The trapped miners can be expeditiously and safely rescued through the drillhole by means of a rescue capsule or cage. For the first time in India, 65 miners trapped in Mahavir Colliery, Raniganj, India, due to sudden irruption of water from water-logged workings in an overlying seam were rescued on November 15, 1989 by means of a rescue capsule through a 600-mm borehole. There must be a plan and strategy. Rescue of persons trapped underground after a mine disaster requires, in general, careful planning on many fronts so that minimum time is lost in starting rescue operations. The extent of planning required before putting the first probe hole depends on the situation arising out of the peculiar location of the possible site of entombment.

While planning for rescue by the conventional methods in the normal way, action should simultaneously be taken to procure a drill rig of proven design for putting boreholes for communication and rescue. For easy availability in an emergency, the drill rig may be located at a Mine Rescue Station or at any notified location and a drilling engineer appointed exclusively for the purpose of putting rescue boreholes.

The detection of trapped men is often difficult and remains somewhat of a guess estimate. Senior mine supervisory officials should jointly assess the probable presence and location of the men and the most likely because of their entombment. Rapid identification of the noises as signals and locating their source of emission point to the presence of men and their likely position is essential. The surveyor should then pinpoint this location on the mine plan for a probe hole (65-, 80- or 100-mm diameter) to be rapidly drilled to make the first contact.

Experience has shown that the initial probe drilling may end up in empty cavities or miss the targeted place due to deviation of the hole particularly when traversing through faulted ground or old workings. Once the primary contact is established, the men must be supplied with air, water, food, medicines, telephone and other moral boosting articles. During the probe drilling, it should be foreseen that no further hazards to the trapped men are created. The primary contact borehole should not be disturbed until a rescue hole is drilled and enlarged in stages if a drill rig which will drill 500-mm holes in one stage is not available. When the rescue borehole has made contact, the trapped men can be hoisted by means of a cylindrical rescue capsule with conical ends and a two-wing door, which should also be located at a Mine Rescue Station or at any notified location. A 440-mm diameter capsule is used in 500-mm diameter rescue boreholes.

44. How many permanent personnel should be there in central or district station?
The permanent personnel at every central or district station usually comprise a Superintendent who is a custodian of the station, one or two Assistant Superintendents, at least two instructors, two mechanics, and a rescue corps of six to nine active trained rescue men.

Section B: Numerical Problem Type Questions – 40 marks

Answer all the questions and each question carries 5 marks

45. (i) Water starts to flow into a sump initially containing 250 kilo-lit of water. The varying inflow rate of water is **4*t*** lit/min where ***t*** refers to time elapsed in minute. If the pumping rate of water out of the sump is 250 lit/min. Estimate the total volume of water in the sump after 3 hours in kilo-lit.

$$\int_0^{180} 4tdt = 2t^2 = 64800\ lit = 64.8\ kL$$

Volume in sump = 250 + 64.85 – 0.25x180 = 250 + 64.85 – 45 = 269.85 kL

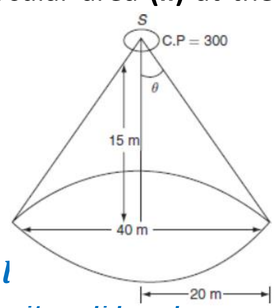
(ii) A wet drill drilling at a drift face produces a dust concentration of 400 ppcc (particles per cubic centimeters) in the respirable size range while the dust concentration rises to 700 ppcc, if the drilling is done dry. Calculate the amount of dust of respirable size produced per minute in either case if the drift face is ventilated by a tube delivering 2.5 m^3/s of fresh air. Also calculate the efficiency of dust suppression by wet drilling.

Wet = 400 x 2.5 x 10^6 x 60= 60 x 10^9 particles/min

Dry = 700 x 2.5 x 10^6 x 60= 105 x 10^9 particles/min

Efficiency = $\frac{105-60}{105} * 100 = 42.85\%$

46. A lamp having a candle power of 300 in all directions is provided with a reflector that directs 70% of total light uniformly on a circular area 40-m diameter. The lamp is hung at 15 m above the area. Calculate the illumination **(i)** in the circular area **(ii)** at the center and **(iii)** at the edge of the surface without reflector.



The illumination on the circular area

Area of circular area (A) = $\frac{\pi}{4}D^2 = 400\ \pi$ m^2

Solid angle, $\omega = 2\pi(1 - cos\theta) = 2\pi\left(1 - \frac{15}{\sqrt{15^2+20^2}}\right)$

$$= 0.8\pi\ steradians$$

(i) Illumination, E = $\frac{Flux}{Area} = \frac{Intensity*solid\ angle}{A} = \frac{300*0.8\pi}{400\pi} = 0.6\ l$

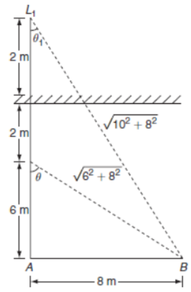
(ii) The illumination at the center with reflector 70% = $0.7 * \frac{Intensity*solid\ angle}{A}$

$$= 0.7 * \frac{300 * 4\pi}{400\pi} = 2.1\ lux$$

(iii) The illumination at the edge without reflector: $\frac{\boldsymbol{Intensity}}{\boldsymbol{r^2}} * \boldsymbol{cos\theta} = \frac{\mathbf{300}}{\sqrt{\mathbf{15^2+20^2}}^{\mathbf{2}}} * \frac{\mathbf{15}}{\sqrt{\mathbf{15^2+20^2}}}$= 0.288 lux

or

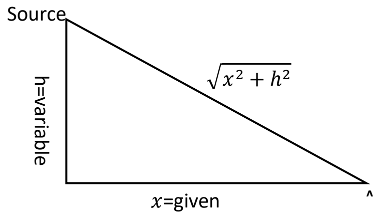
(i) A lamp of 250 candela is placed 2 m below a plane mirror that reflects 60% of light falling on it. The lamp is hung at 6 m above ground. Find the illumination at a point on the ground 8 m away from the point vertically below the lamp.



$$\frac{250}{\left(\sqrt{6^2+8^2}\right)^2} * \frac{6}{\sqrt{6^2+8^2}} + \frac{250*0.6}{\left(\sqrt{10^2+8^2}\right)^2} * \frac{10}{\sqrt{10^2+8^2}}$$

$$= 1.5 + 0.71 = \boldsymbol{2.21\ lux}$$

(ii) Find the height at which a light source having uniform spherical distribution should be placed over a floor in order that the intensity of horizontal illumination at a given distance from its vertical line may be greatest.



Illumination at point A (E) = $\frac{I}{x^2+h^2} * \frac{h}{\sqrt{x^2+h^2}} = \frac{Ih}{(x^2+h^2)^{1.5}}$

$$\boldsymbol{\frac{dE}{dh} = 0 = \frac{I}{(x^2+h^2)^{1.5}} - \frac{3Ih^2}{(x^2+h^2)^{2.5}}}$$

$$\boldsymbol{x^2 + h^2 = 3h^2}$$

Therefore, h = 0.707 x

47. (i) Calculate the terminal settling velocity of 0.3 µm diameter particles of limestone dust of specific gravity 2.78 in air.

(ii) What will be the error if the terminal velocity were calculated by Stokes' law without Cunningham's correction?

(iii) What will be the terminal velocity of 15 µm diameter particles of the same material in air? (Assume mean free path of the gas molecules as 10^{-7} m; viscosity of air as 1.85 x 10^{-5} Pa-sec)

$$\boldsymbol{D < \frac{1.141x10^{-3}}{\rho^{\frac{1}{3}}} = 0.00008114667186 = 81\ \mu m}$$

$$\boldsymbol{D > \frac{0.021}{\rho^{\frac{1}{3}}} = 0.001493497 = 1493\ \mu m}$$

Here, D = 0.3 $\boldsymbol{\mu m}$ which means it will follow streamline motion

$$\boldsymbol{v_t = \frac{D^2(\rho - \rho_a)g}{18\mu} = \frac{(3*10^{-7})^2(2780 - 1.29)*9.81}{18*1.8*10^{-5}} = 7.571*10^{-6} m/s}$$

Cunningham's correction, $\boldsymbol{v_c = v_s\left(1 + 1.7\frac{l}{D}\right) = 7.571*10^{-6}*\left(1 + 1.7*\frac{10^{-7}}{3*10^{-7}}\right) = 7.571*10^{-6}*1.57 = 11.88*10^{-6} m/s}$

$$\boldsymbol{v_t = \frac{D^2(\rho - \rho_a)g}{18\mu} = \frac{(15*10^{-6})^2(2780 - 1.29)*9.81}{18*1.8*10^{-5}} = 189299*10^{-7}}$$

$$\boldsymbol{= 0.02\ m/s}$$

48. (i) A 2 m x 1.2 m screen is covered by an exhaust hood. The gap between the hood and the screen at the periphery is 35 mm. Calculate the quantity of air to be exhausted per minute in order to maintain an inward air velocity of 0.25 m/s in the gap for vertical, horizontal and flanged hood.

Area = 2 * 1.2 = 2.4 m^2; x = 0.035 m;

$v = \frac{Q}{10x^2+A}$; $0.25 = \frac{Q}{10*0.035^2+2.4}$ or, Q = 0.603 m^3/s

$v = \frac{Q}{0.75(10x^2+A)}$; $0.25 = \frac{Q}{0.75(10*0.035^2+2.4)}$ or, Q = 0.452 m3/s

$v = \frac{0.71Q}{px}$; $0.25 = \frac{0.71Q}{2*(2+1.2)*0.035}$ or, Q = 0.078 m^3/s

(ii) Calculate the quantity of air that may be circulated at a coal face to dilute the dust produced by cutting to the permissible level of 3 mg/m^3 for particle size below 5 µm, if the cutting operation produces 2.1 g of dust below 5 µm size every minute. The air entering the face may be taken to have a dust load of 0.8 mg/m^3 in the size range of < 5 µm.

Q m^3/min; 2.1 g = 2100 g; Q*0.8 + 2100 = Q*3 ; 2.2*Q = 2100; Q = 954.5 m^3/min

49. A man while doing hard work in a confined space breathes 60.90 x 10^{-3} m^3 of air per minute. He consumes 2.5 x 10^{-3} m^3 of oxygen and produces 2.4 x 10^{-3} m^3 of carbon dioxide per minute. Calculate the composition of the exhaled air and quantity of fresh air necessary to be supplied so that the man is never left in an atmosphere containing more than 0.5% carbon dioxide. The composition of inhaled air is as follows: Oxygen (O_2)= 20.95% by volume; Carbon dioxide (CO_2)= 0.003% by volume; Nitrogen (N_2)= 78.09% by volume; other gases= 0.93% by volume.

For 0.03% CO2	For 0.003% CO2
In a minute, oxygen inhaled 0.2095 x 60.90 x 10^{-3} = 12.76 x 10^{-3} m^3 But he consumes 2.5 x 10^{-3} m^3 of oxygen and produces 2.4 x 10^{-3} m^3 of carbon dioxide Oxygen left = (12.76 - 2.5) x 10^{-3} = 10.26 x 10^{-3} Carbon dioxide present = 2.4 x 10^{-3} m^3 + 0.00003 x 60.90 x 10^{-3} = 2.42 x 10^{-3} m^3 Nitrogen inclusive of other gases don't undergo change= 0.7902 x 60.90 x 10^{-3} = 48.12 x 10^{-3} m^3 Total volume of exhaled air= (10.26 + 2.42 + 48.12) x 10^{-3}= 60.8 x 10^{-3} m^3 Composition of exhaled air is $O_2 = \frac{10.26\,x\,10^{-3}}{60.8\,x\,10^{-3}} x100$ = 16.88% $CO_2 = \frac{2.42x\,10^{-3}}{60.8\,x\,10^{-3}} x100$ = 3.98% $N_2 = \frac{48.12\,x\,10^{-3}}{60.8\,x\,10^{-3}} x100$ = 79.14% Total = O_2 + CO_2 + N_2 = 100% $O_2 = \frac{10.26\,x\,10^{-3}}{60.8\,x\,10^{-3}} x100$ = 16.88% In order to maintain the percentage of CO_2 at 0.5% in the air, the man should exhale an amount of carbon dioxide that forms 0.50-0.003= 0.497% of the air supplied	In a minute, oxygen inhaled 0.2095 x 60.90 x 10^{-3} = 12.76 x 10^{-3} m^3 But he consumes 2.5 x 10^{-3} m^3 of oxygen and produces 2.4 x 10^{-3} m^3 of carbon dioxide Oxygen left = (12.76 - 2.5) x 10^{-3} = 10.26 x 10^{-3} Carbon dioxide present = 2.4 x 10^{-3} m^3 + 0.00003 x 60.90 x 10^{-3} = 2.42 x 10^{-3} m^3 Nitrogen inclusive of other gases don't undergo change= 0.7902 x 60.90 x 10^{-3} = 48.12 x 10^{-3} m^3 Total volume of exhaled air= (10.26 + 2.42 + 48.12) x 10^{-3}= 60.8 x 10^{-3} m^3 Composition of exhaled air is $O_2 = \frac{10.26\,x\,10^{-3}}{60.8\,x\,10^{-3}} x100$ = 16.88% $CO_2 = \frac{2.42x\,10^{-3}}{60.8\,x\,10^{-3}} x100$ = 3.98% $N_2 = \frac{48.12\,x\,10^{-3}}{60.8\,x\,10^{-3}} x100$ = 79.14% Total = O_2 + CO_2 + N_2 = 100% $O_2 = \frac{10.26\,x\,10^{-3}}{60.8\,x\,10^{-3}} x100$ = 16.88% In order to maintain the percentage of CO_2 at 0.5% in the air, the man should exhale an amount of carbon dioxide that forms 0.50-0.03= 0.47% of the air supplied Since the man exhales 2.4 x 10^{-3} m^3 of carbon dioxide per minute, the fresh air supply per minute = case = $\frac{2.4\,x\,10^{-3}}{0.00497}$ = 0.482 m^3

50. The rate of emission of methane in a district is 0.13 m^3/s. Calculate the rate of ventilation required to keep down the gas content in the return to 0.75% if the intake air has a methane content of 0.1%.

Let Q m^3/s

0.001*Q + 0.13 = 0.0075*Q

0.0065*Q= 0.13

Q = 20 m^3/s

or

Samples of air collected in the intake and return gates of an advancing longwall face show 0.2% and 0.8% CH_4 respectively. Calculate methane emission per tonne of coal mined, if the face produces 1000 tons per day and an air quantity of 15 m^3/s circulates along the face.

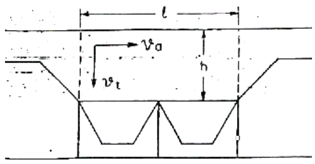
Let methane emission per tonne of coal mined= x m^3/ton

methane emission per unit time = 1000x m^3/day = 0.01155x m^3/s

0.002*15 + 0.01155x = 0.008*15

x= 7.8 m^3/ton

51. (i) Design a settling chamber for separating quartz dust down to 50 µm size from a stream of air flowing at the rate of 3 m^3/s. Assume velocity of air in the chamber (v_a)= 0.3 m/s, density = 2500 kg/m^3 and h=b.



$$D < \frac{1.141x10^{-3}}{\rho^{\frac{1}{3}}} = 0.0000840695 = 84\ \mu m$$

$$D > \frac{0.021}{\rho^{\frac{1}{3}}} = 0.00154729 = 1547\ \mu m$$

$$v_t = \frac{D^2(\rho - \rho_a)g}{18\mu} = \frac{(50 * 10^{-6})^2(2500 - 1.29) * 9.81}{18 * 1.8 * 10^{-5}} = 0.19\ m/s$$

$hb = h^2 = \frac{Q}{v_a} = \frac{3}{0.3}$; h = b = 3.16 m

$\frac{h}{l} = \frac{v_t}{v_a} = \frac{0.19}{0.3} = 0.63$; l = 5 m

(ii) A self-contained closed breathing apparatus (Drager BG 174) has oxygen cylinder volume of 2 liters holding 400 liters of O_2 at 200 bar and breathing bag volume of 5.5 liters along with protosorb canister. Oxygen flow rate is 1.5 lit/min for constant dosage and minimum 100 lit/min for lung-governed dosage. Endurance rated for the breathing apparatus is 4 hours during hard exertion at a working pressure of 200 bar. Verify the rated endurance of the breathing apparatus considering the rate of O_2 inhalation and consumption as 75 lit/min and 3 lit/min respectively during very hard work.

$$Actual\ endurance = \frac{400}{3} = 133.3\ min = 2.22\ hours$$

Will not provide endurance as it is rated

52. An air sample produces the following analysis: CH_4 - 8%, CO – 5%, H_2 – 3%. Determine the LFL, HFL and NFL of this mixture. Consider (i) lower flammability limit (LFL) of CH_4, CO, H_2 as 5%, 12.5% and 4% respectively; (ii) higher flammability limit (HFL) of CH_4, CO, H_2 as 14%, 74.2% and 74.2% respectively; and (iii) nose flammability limit (NFL) of CH_4, CO, H_2 as 5.9%, 13.8% and 4.3% respectively.

Subscripts 1, 2 and 3 for the three combustible gases and their percentage concentrations as p_1, p_2 and p_3 respectively. If they do not react chemically with each other then the mixture will have a total combustible concentration of $p_t = p_1 + p_2 + p_3$. Furthermore, Le Chatelier's Principle leads to the prediction that for gas flammability limits, L_1, L_2 and L_3 (where these can be upper, lower or nose limits), the corresponding gas flammability limit of the mixture, L_{mix}, will be given by:

$$\frac{p_t}{L_{mix}} = \frac{p_1}{L_1} + \frac{p_2}{L_2} + \frac{p_3}{L_3}$$

(i) For LFL; $\frac{p_t}{L_{mix}} = \frac{p_1}{L_1} + \frac{p_2}{L_2} + \frac{p_3}{L_3}$ or, $\frac{16}{L_{mix}} = \frac{8}{5} + \frac{5}{12.5} + \frac{3}{4}$ or, $L_{mix} = 5.82\%$

(ii) For HFL; $\frac{p_t}{L_{mix}} = \frac{p_1}{L_1} + \frac{p_2}{L_2} + \frac{p_3}{L_3}$ or, $\frac{16}{L_{mix}} = \frac{8}{14} + \frac{5}{74.2} + \frac{3}{74.2}$ or, $L_{mix} = 23.55\%$

(iii) For NFL; $\frac{p_t}{L_{mix}} = \frac{p_1}{L_1} + \frac{p_2}{L_2} + \frac{p_3}{L_3}$ or, $\frac{16}{L_{mix}} = \frac{8}{5} + \frac{5}{12.5} + \frac{3}{4}$ or, $L_{mix} = 6.62\%$

--Question Paper Ends Here--