SELF-ASSESSMENT - MODULE 3-5: Gas Movement

I. INFORMATION NEEDED TO CALCULATE PATIENT FLOW NEEDS

A. CALCULATIONS:

1. $\textit{Weight in kg} = \dfrac{\textit{Weight in pounds}}{2.2}$
2. $\dot{V}_E = V_t \times f$
3. $V_t = \dfrac{\dot{V}_E}{f}$
4. $f = \dfrac{\dot{V}_E}{V_t}$
5. Patient peak inspiratory flow demand (PIF) = $\dot{V}_E \times (I + E)$
6. Patient peak inspiratory flow demand (PIF) = $\dfrac{V_t}{t_I} \times 60$

B. ADULT NORMAL VALUES:

1. Inspiratory Time: 0.8 – 1.2 seconds
2. Tidal Volume: spontaneous 5 – 8 mL/kg of IBW
3. Respiratory Rate: 10 – 20 breaths/min
4. Minute volume: 5 – 10 L/min
5. I : E Ratio: 1 : 2 to 1 : 4
6. Normal range for adult inspiratory flow: 24 – 30 L/min, but may be as high as 60-100 L/min.

C. EXERCISES:

1. A patient's weight is measured as 150 pounds. What is the range of normal tidal volumes?

   a.

$$\textit{Weight in kg} = \frac{\textit{Weight in pounds}}{2.2} = \frac{150\ \textit{lbs}}{2.2\ \textit{lbs}/\textit{kg}} = 68.18\ \textit{kg} \approx 68.2\ \textit{kg}$$

$$\textit{Tidal Volume} = 5\text{ - }8\ \textit{mL}/\textit{kg}$$

$$68.2\ \textit{kg} \times 5\ \textit{mL}/\textit{kg} = 341\ \textit{mL} \quad 68.2\ \textit{kg} \times 8\ \textit{mL}/\textit{kg} = 545\ \textit{mL}$$

2. A patient's weight is measured as 200 pounds. What is the range of normal tidal volumes?

a. $$\textit{Weight in kg} = \frac{\textit{Weight in pounds}}{2.2} = \frac{200\ lbs}{2.2\ lbs/kg} = 90.9\ kg$$
$$\textit{Tidal Volume} = 5\text{ - }8\ mL/kg$$
$$90.9\ kg \times 5\ mL/kg = 455\ mL \quad 90.9\ kg \times 8\ mL/kg = 727\ mL$$

3. A patient's weight is measured as 40 kilograms. What is the range of normal tidal volumes?

a. $$\textit{Tidal Volume} = 5\text{ - }8\ mL/kg$$
$$40\ kg \times 5\ mL/kg = 200\ mL \quad 40\ kg \times 8\ mL/kg = 320\ mL$$

4. A patient has a tidal volume of 600 mL and a frequency of 20/min. Calculate the minute ventilation ($\dot{V}_E$).

a. $$\dot{V}_E = V_t \times f = 600\ mL/breath \times 20\ breaths/\text{min} = 12{,}000\ mL/\text{min} = 12\ L/\text{min}$$

5. A patient has a tidal volume of 350 mL and a frequency of 15/min. Calculate the minute ventilation ($\dot{V}_E$).

a. $$\dot{V}_E = V_t \times f = 350\ mL/breath \times 15\ breaths/\text{min} = 5{,}250\ mL/\text{min} = 5.3\ L/\text{min}$$

6. A patient has a $\dot{V}_E$ of 12.5 L/min and a frequency of 25/min. Calculate the average tidal volume.

a. $$V_t = \frac{\dot{V}_E}{f} = \frac{12.5\ L/\text{min}}{25\ breaths/\text{min}} = 0.5\ L/breath$$

7. A patient has a $\dot{V}_E$ of 8.4 L/min and a frequency of 14/min. Calculate the average tidal volume.

a. $$V_t = \frac{\dot{V}_E}{f} = \frac{8.4\ L/\text{min}}{14\ breaths/\text{min}} = 0.6\ L/breath$$

8. A patient has a $\dot{V}_E$ of 10 L/min and a tidal volume of 500 mL. Calculate the frequency.

a. $$f = \frac{\dot{V}_E}{V_t} = \frac{10\,L/\min}{500\,mL/breath} = \frac{10\,L/\min}{0.5\,L/breath} = 20\,breaths/\min$$

9. A patient has a $\dot{V}_E$ of 5.8 L/min and a tidal volume of 400 mL. Calculate the frequency.

a. $$f = \frac{\dot{V}_E}{V_t} = \frac{10\,L/\min}{500\,mL/breath} = \frac{10\,L/\min}{0.5\,L/breath} = 20\,breaths/\min$$

10. If the patient's V_t is 550 mL, and the inspiratory time is 0.9 seconds, calculate the patients peak inspiratory flow.

a. PIF = $$\frac{V_t}{t_I} = \frac{550mL}{0.9\sec} \times 60 = \frac{0.55L}{0.9\sec} \times 60\sec/\min = .611 \times 60 = 36.7\,L/\min$$

11. If the patient's V_t is 680 mL, and the inspiratory time is 1.2 seconds, calculate the patients peak inspiratory flow.

a. PIF = $$\frac{V_t}{t_I} = \frac{680mL}{1.2\sec} \times 60 = \frac{0.68L}{1.2\sec} \times 60\sec/\min = .567 \times 60 = 34\,L/\min$$

12. If the patient's $\dot{V}_E$ is 10.5 L/min, the f is 12/min, and the inspiratory time is 1.0 seconds, calculate the peak inspiratory flow.

a. PIF = $$V_t = \frac{\dot{V}_E}{f} = \frac{10.5\,L/\min}{12\,breaths/\min} = 0.875\,L/breath$$

$$\frac{V_t}{t_I} = \frac{0.88L}{1.0\sec} \times 60\sec/\min = .733 \times 60 = 53\,L/\min$$

13. If the $\dot{V}_E$ is 7.6 L/min, the f is 16/min, and the inspiratory time is 0.8 seconds, calculate the peak inspiratory flow

a. PIF = $$V_t = \frac{\dot{V}_E}{f} = \frac{7.6\,L/\min}{16\,breaths/\min} = 0.475\,L/breath$$

$$\frac{V_t}{t_I} = \frac{0.48L}{0.8\sec} \times 60\sec/\min = .6 \times 60 = 36\,L/\min$$

14. Given a frequency of 20/min and a tidal volume of 500 mL, calculate the patient's minute ventilation.

a. $\dot{V}_E = V_t \times f = 500 \, mL/breath \times 20 \, breaths/\text{min} = 10{,}000 \, mL/\text{min} = 10.0 \, L/\text{min}$

15. Given a frequency of 15/min and a tidal volume of 600 mL, calculate the patient's minute ventilation.

a. $\dot{V}_E = V_t \times f = 600 \, mL/breath \times 15 \, breaths/\text{min} = 9{,}000 \, mL/\text{min} = 9.0 \, L/\text{min}$

16. Given a frequency of 25/min and a tidal volume of 800 mL, calculate the patient's minute Ventilation.

a. $\dot{V}_E = V_t \times f = 800 \, mL/breath \times 25 \, breaths/\text{min} = 20{,}000 \, mL/\text{min} = 20.0 \, L/\text{min}$

17. Given a minute ventilation of 7.5 L/min and a frequency of 16/min, calculate the average tidal volume.

a. $V_t = \frac{\dot{V}_E}{f} = \frac{7.5 \, L/\text{min}}{16 \, breaths/\text{min}} = 0.469 \, L/breath = 469 \, mL/breath$

18. Given a minute ventilation of 10. 0 L/min and a frequency of 12/min, calculate the average tidal volume.

a. $V_t = \frac{\dot{V}_E}{f} = \frac{10 \, L/\text{min}}{12 \, breaths/\text{min}} = 0.833 \, L/breath = 833 \, mL/breath$

19. Given a minute ventilation of 12.5 L/min and a frequency of 21, calculate the average tidal volume.

a. $V_t = \frac{\dot{V}_E}{f} = \frac{12.5 \, L/\text{min}}{21 \, breaths/\text{min}} = 0.595 \, L/breath = 595 \, mL/breath$

20. Given a minute ventilation of 8.4 L/min and a tidal volume of 600 mL, calculate the frequency.

a. $f = \frac{\dot{V}_E}{V_t} = \frac{8.4 \, L/\text{min}}{600 \, mL/breath} = \frac{8.4 \, L/\text{min}}{0.6 \, L/breath} = 14 \, breaths/\text{min}$

21. Given a minute ventilation of 8.8 L/min and a tidal volume of 550 mL, calculate the frequency.

a. $$f = \frac{\dot{V}_E}{V_t} = \frac{8.8\,L/\text{min}}{550\,mL/breath} = \frac{8.8\,L/\text{min}}{0.55\,L/breath} = 16\,breaths/\text{min}$$

22. Given a minute ventilation of 6.4 L/min and a tidal volume of 400 mL, calculate the frequency.

a. $$f = \frac{\dot{V}_E}{V_t} = \frac{6.4\,L/\text{min}}{400\,mL/breath} = \frac{6{,}4\,L/\text{min}}{0.4\,L/breath} = 16\,breaths/\text{min}$$

23. Given an inspiratory time of 1.2 seconds and a peak inspiratory flow of 35 L/min, calculate the tidal volume.

a. $$PIF = \frac{V_t}{t_I} \times 60, \frac{PIF \times t_I}{60} = V_t = \frac{35\,L/\text{min} \times 1.2\text{ sec}}{60\,\text{min}/\text{sec}} = 0.7\,L = 700\,mL$$

24. Given an inspiratory time of 1.0 second and a peak inspiratory flow of 28 L/min, calculate the tidal volume.

a. $$PIF = \frac{V_t}{t_I} \times 60, \frac{PIF \times t_I}{60} = V_t = \frac{28\,L/\text{min} \times 1.0\text{ sec}}{60\,\text{min}/\text{sec}} = 0.467\,L = 467\,mL$$

25. Given a tidal volume of 450 mL and an inspiratory time of 1.4 seconds, calculate the peak inspiratory flow.

a. $$PIF = \frac{V_t}{t_I} \times 60 = \frac{450\,mL}{1.4\,sec} \times 60\,\text{sec}/\text{min} = 19{,}286\,mL/min = 19.3\,L/\text{min}$$

26. Given a tidal volume of 625 mL and an inspiratory time of 0.8 seconds, calculate the peak inspiratory flow.

a. $$PIF = \frac{V_t}{t_I} \times 60 = \frac{625\,mL}{0.8\,sec} \times 60\,\text{sec}/\text{min} = 46{,}875\,mL/\text{min} = 46.9\,L/\text{min}$$

27. Given a minute ventilation of 12 L/min, and a I:E ratio of 1:3, calculate the minimal inspiratory flow needed to meet the patients inspiratory needs.

a. PIF = $$\dot{V}_E \times (I + E) = 12\,L/\text{min} \times (1+3) = 12\,L/\text{min} \times 4 = 48\,L/\text{min}$$

28. Given a minute ventilation of 8.6 L/min, and a I:E ratio of 1:2, calculate the minimal inspiratory flow needed to meet the patients inspiratory needs.

a. PIF = $\dot{V}_E \times (I+E) = 8.6\,{}^{L}\!/_{min} \times (1+2) = 8.6\,{}^{L}\!/_{min} \times 3 = 25.8\,{}^{L}\!/_{min}$

II. CALCULATING SYSTEM TOTAL FLOW

A. An air-entrainment nebulizer is set at an FIO_2 of 0.40 and the oxygen flowmeter is set at 8 liters/min. Calculate the following:

1. Air:O_2 ratio: $air : oxygen = \frac{100 - FIO_2}{FIO_2 - 21} = \frac{100-40}{40-21} = \frac{60}{19} = 3.2 \approx 3:1$
2. O_2 liter Flow: **8 $^{L}/_{min}$**
3. Air Liter Flow: $Air\ Flow = Air\ Ratio \times Oxygen\ Flow = 3 \times 8\,{}^{L}\!/_{min} = 24\,{}^{L}\!/_{min}$
4. Total Liter Flow: **Oxygen Flow + Air Flow = 8 $^{L}/_{min}$ + 24 $^{L}/_{min}$ = 32 $^{L}/_{min}$**

B. The air-entrainment mask is set at an FIO_2 of 0,28 and the oxygen flowmeter is set at 3 liters/min. Calculate the following:

1. Air:O_2 ratio: $air : oxygen = \frac{100 - FIO_2}{FIO_2 - 21} = \frac{100-28}{28-21} = \frac{72}{7} = 10.3 \approx 10:1$
2. O_2 liter Flow: **3 $^{L}/_{min}$**
3. Air Liter Flow: $Air\ Flow = Air\ Ratio \times Oxygen\ Flow = 10 \times 3\,{}^{L}\!/_{min} = 30\,{}^{L}\!/_{min}$
4. Total Liter Flow: **Oxygen Flow + Air Flow = 3 $^{L}/_{min}$ + 30 $^{L}/_{min}$ = 33 $^{L}/_{min}$**

C. An air-entrainment nebulizer is set at an FIO_2 of 0.70 and the oxygen flowmeter is set at 6 liters/min. Calculate the following:

1. Air:O_2 ratio: $air : oxygen = \frac{100 - FIO_2}{FIO_2 - 21} = \frac{100-70}{70-21} = \frac{30}{49} = 0.61 \approx 0.6:1$
2. O_2 liter Flow: **6 $^{L}/_{min}$**
3. Air Liter Flow: $Air\ Flow = Air\ Ratio \times Oxygen\ Flow = 0.6 \times 6\,{}^{L}\!/_{min} = 3.6\,{}^{L}\!/_{min}$
4. Total Liter Flow: **Oxygen Flow + Air Flow = 6 $^{L}/_{min}$ + 3.6 $^{L}/_{min}$ = 9.6 $^{L}/_{min}$**

D. An air-entrainment mask is set at an FIO_2 of 0.50 and the oxygen flowmeter is set at 8 liters/min. Calculate the following:

1. Air:O_2 ratio:

$$air : oxygen = \frac{100 - FIO_2}{FIO_2 - 21} = \frac{100-50}{50-21} = \frac{50}{29} = 1.7:1$$

2. O_2 liter Flow: **8 L/min**

3. Air Liter Flow:

$$Air\ Flow = Air\ Ratio \times Oxygen\ Flow = 1.7 \times 8\ L/min = 13.6\ L/min$$

4. Total Liter Flow: **Oxygen Flow + Air Flow = 8 L/min + 13.6 L/min = 21.6 L/min**

E. An air-entrainment nebulizer is set at an FIO_2 of 1.0 and the oxygen flowmeter is set at 15 liters/min. Calculate the following:

1. Air:O_2 ratio:

$$air : oxygen = \frac{100 - FIO_2}{FIO_2 - 21} = \frac{100-100}{100-21} = \frac{0}{79} = 0:1$$

2. O_2 liter Flow: **15 L/min**

3. Air Liter Flow:

$$Air\ Flow = Air\ Ratio \times Oxygen\ Flow = 0 \times 15\ L/min = 0\ L/min$$

4. Total Liter Flow: **Oxygen Flow + Air Flow = 15 L/min + 0 L/min = 15 L/min**

F. Assuming the flowrate stays the same on an air-entrainment device, what happens to total liter flow as the FIO_2 increases? **IT GOES DOWN**

G. The concentration of oxygen delivered by an air-entrainment system can be varied by:

1. Altering the size of the jet orifice
2. Altering the size of the air entrainment ports
3. Both 1 and 2.

H. Backpressure on an air-entrainment system decreases the volume of fluid or gas entrained. This causes the oxygen concentration delivered by the system to ____________.

1. Increase
2. Decrease
3. Stay the same

III. PATIENT NEEDS AND DEVICE DELIVERY

A. You are setting up an air-entrainment mask at an FIO_2 of 0.40 and the oxygen flowmeter is set at 12 l/min. The patient's tidal volume is 600 mL and the inspiratory time is 1.5 seconds. Is the flow from this system meeting the patient's inspiratory needs?

1. Air: Oxygen Ratio: $$air : oxygen = \frac{100 - FIO_2}{FIO_2 - 21} = \frac{100-40}{40-21} = \frac{60}{19} = 3.2 \approx 3:1$$

2. Total Liter Flow: **Oxygen Flow + Air Flow = 12 $^{L}/_{min}$ + 36 $^{L}/_{min}$ = 48 $^{L}/_{min}$**

3. Peak Inspiratory Flowrate: $$\frac{V_t}{t_I} \times 60 = \frac{0.6\,L}{1.5\,sec} \times 60\,{}^{sec}/_{min} = 0.4 \times 60 = 24\,{}^{L}/_{min}$$

4. Is the $FDO_2 \geq FIO_2$? YES NO

5. What FIO_2 would the patient actually receive?

   a. 0.40
   b. Less than 0.40
   c. Greater than 0.40

B. You are setting up an air-entrainment nebulizer with an aerosol mask at an FIO_2 of 0.70 and the oxygen flowmeter is set at 12 L/min. The patient's minute ventilation is 8 L/min, the inspiratory time is 0.5 seconds, and the respiratory rate is 10/min. Is the flow from this system meeting the patient's inspiratory needs?

1. Air: Oxygen Ratio: $$air : oxygen = \frac{100 - FIO_2}{FIO_2 - 21} = \frac{100-70}{70-21} = \frac{30}{49} = 0.61 = 0.6:1$$

2. Total Liter Flow: **Oxygen Flow + Air Flow = 12 $^{L}/_{min}$ + 7.2 $^{L}/_{min}$ = 19.2 $^{L}/_{min}$**

3. Peak Inspiratory Flowrate: $$V_t = \frac{V_E}{f} = \frac{8\,{}^{L}/_{min}}{10\,{}^{breaths}/_{min}} = 0{,}8\,{}^{L}/_{breath}$$ $$\frac{V_t}{t_I} \times 60 = \frac{0.8\,L}{0.5\,sec} \times 60\,{}^{sec}/_{min} = 1.6 \times 60 = 96\,{}^{L}/_{min}$$

4. Is the $FDO_2 \geq FIO_2$? YES NO

5. What FIO_2 would the patient actually receive?

   a. 0.70
   b. Less than 0.70
   c. Greater than 0.70

C. You are setting up an air-entrainment nebulizer with a tracheostomy mask at an FIO_2 of 0.35 and the oxygen flowmeter is set at 15 L/min. The patient's minute ventilation is 8 L/min and the I:E ratio is 1:3. Is the flow from this system meeting the patient's inspiratory needs?

1. Air: Oxygen Ratio: $air : oxygen = \frac{100 - FIO_2}{FIO_2 - 21} = \frac{100-35}{35-21} = \frac{65}{14} = 4.6 \approx 5:1$

2. Total Liter Flow: **Oxygen Flow + Air Flow = 15 $^{L}/_{min}$ + 75 $^{L}/_{min}$ = 90 $^{L}/_{min}$**

3. Peak Inspiratory Flowrate: $\dot{V}_E \times (I+E) = 8 \,{}^{L}\!/_{min} \times (1+3) = 8 \,{}^{L}\!/_{min} \times 4 = 32 \,{}^{L}\!/_{min}$

4. Is the $FDO_2 \geq FIO_2$? YES NO

5. What FIO_2 is the patient actually receiving?

   a. 0.35
   b. Less than 0.35
   c. Greater than 0.35

D. You are setting up an air-entrainment nebulizer with a Briggs (t-) adapter at an FIO_2 of 0.60 and the oxygen flowmeter is set at 12 L/min. The patient's tidal volume is 400 mL and the inspiratory time is 0.9 seconds. Is the flow from this system meeting the patient's inspiratory needs?

1. Air: Oxygen Ratio: $air : oxygen = \frac{100 - FIO_2}{FIO_2 - 21} = \frac{100-60}{60-21} = \frac{40}{39} = 1:1$

2. Total Liter Flow: **Oxygen Flow + Air Flow = 12 $^{L}/_{min}$ + 12 $^{L}/_{min}$ = 24 $^{L}/_{min}$**

3. Peak Inspiratory Flowrate: $\frac{V_t}{t_I} \times 60 = \frac{0.4\,L}{0.9\,sec} \times 60 \,{}^{sec}\!/_{min} = 0.44 \times 60 = 26.7 \,{}^{L}\!/_{min}$

4. Is the $FDO_2 \geq FIO_2$? YES NO

5. What FIO_2 would the patient receive?

   a. 0.60
   b. Less than 0.60
   c. Greater than 0.60

E. Given a minute ventilation of 6.8 L/min and a I:E ratio of 1:1.5, calculate the minimal inspiratory flow needed to meet the patient's inspiratory needs.

1. PIF: $\dot{V}_E \times (I + E) = 6.8 \,{}^{L}\!/_{min} \times (1 + 1.5) = 6.8 \,{}^{L}\!/_{min} \times 2.5 = 17.0 \,{}^{L}\!/_{min}$

2. The doctor has ordered an air-entrainment mask set at an FIO_2 of 0.40 and the oxygen flowmeter is set at 6 L/min. Is the total flowrate from this system sufficient to meet the patient's inspiratory needs?

$$air : oxygen = \frac{100 - FIO_2}{FIO_2 - 21} = \frac{100 - 40}{40 - 21} = \frac{60}{19} = 3.2 \approx 3:1$$

Oxygen Flow + Air Flow = 6 $^{L}/_{min}$ + 18 $^{L}/_{min}$ = 24 $^{L}/_{min}$

3. What will happen to the FIO_2 we are giving the patient? **THE DEVICE'S TOTAL FLOW EXCEEDS THE PATIENT'S INSPIRATORY FLOW RATE SO THE DESIRED FIO_2 WILL BE DELIVERED.**

F. Given a minute ventilation of 11 L/min and an I:E ratio of 1:2, calculate the minimal inspiratory flow needed to meet the patients inspiratory needs.

1. PIF: $\dot{V}_E \times (I + E) = 11 \,{}^{L}\!/_{min} \times (1 + 2) = 11 \,{}^{L}\!/_{min} \times 3 = 33 \,{}^{L}\!/_{min}$

2. The doctor has ordered an air-entrainment nebulizer with an aerosol mask at an FIO_2 of 0.60 and the oxygen flowrate is set at 10 L/min. Is the total flowrate from this system sufficient to meet the patient's inspiratory needs?

$$air : oxygen = \frac{100 - FIO_2}{FIO_2 - 21} = \frac{100 - 60}{60 - 21} = \frac{40}{39} = 1:1$$

Oxygen Flow + Air Flow = 6 $^{L}/_{min}$ + 18 $^{L}/_{min}$ = 24 $^{L}/_{min}$

3. What will happen to the FIO_2 we are giving the patient? **THE DEVICE'S TOTAL FLOW DOES NOT EXCEED THE PATIENT'S INSPIRATORY FLOW RATE SO THE DESIRED FIO_2 WILL NOT BE DELIVERED.**

IV. OXYGEN DELIVERY SYSTEMS

A. According to Egan, there are four categories of oxygen delivery systems,
1. **LOW-FLOW DEVICES**
2. **HIGH-FLOW DEVICES**
3. **RESERVOIR SYSTEMS**
4. **ENCLOSURES**

B. The most common low-flow system is the **NASAL CANNULA**.

1. This system should be run between **$^{1}/_{4}$** & **8** liters per minute oxygen flow and will deliver approximately **24** - **40** % oxygen.

2. The oxygen concentration of this system depends on the patients respiratory pattern. As the patient begins to breathe more deeply and rapidly, the oxygen concentration will go (up or down).

C. Even though reservoir systems run at close to the same flow rates of oxygen, the concentrations of oxygen provided are higher. Why is this? **RESERVOIR SYSTEMS INCORPORATE A MECHANISM FOR GATHERING AND STORING OXYGEN BETWEEN PATIENT BREATHS.**

D. Why is the oxygen concentration with most low-flow, reservoir and enclosure systems variable? **THE TOTAL FLOW IS LESS THAN THE PATIENT'S INSPIRATORY FLOW RATE**.

E. What do all high flow systems have in common? **TOTAL FLOW EXCEEDS THE PATIENT'S INSPIRATORY FLOW RATE**.

F. Name four different systems or set ups that will provide a fixed oxygen concentration.

1. **AIR-ENTRAINMENT MASKS**
2. **AIR-ENTRAINMENT NEBULIZERS**
3. **BLENDERS**
4. **DUAL FLOWMETERS**

G. Scenario: You are called to set up oxygen on a patient in the Emergency Department. You are told the patient is 72 years old with a history of emphysema. He is in obvious respiratory distress (respiratory rate 28, accessory muscle use and bilateral wheezing) and his oximetry (SpO_2) on room air is 86%. You decide you would like to begin at approximately 30% oxygen. Which oxygen delivery system(s) would be appropriate?

1. **AIR-ENTRAINMENT MASK TO DELIVER A PRECISE CONCENTRATION IN THE FACE OF A VARIABLE RESPIRATORY RATE AND PATTERN.**

H. What is the formula for calculating minute ventilation ($\dot{V}_E$)? $\boxed{\dot{V}_E = V_t \times f}$

I. What is the formula for calculating peak inspiratory flow (PIF)?

Patient peak inspiratory flow demand (PIF) = $\boxed{\dot{V}_E \times (I + E)}$ or $\boxed{\frac{V_t}{t_I} \times 60}$

J. What is the calculation for normal spontaneous tidal volume (V_t)? **5 to 8 $^{mL}/_{kg}$ IBW**

K. Convert 180 pounds to kilograms.

$$Weight\ in\ kg = \frac{Weight\ in\ pounds}{2.2}$$
$$Weight\ in\ kg = \frac{180\ lbs}{2.2} = 81.8\ kg$$

L. What is the frequency of a person with a minute ventilation of 10 L/min and a tidal volume of 500 mL?

$$f = \frac{\dot{V}_E}{V_t} = \frac{10\ L/\text{min}}{500\ mL/breath} = \frac{10\ L/\text{min}}{0.5\ L/breath} = 20\ breaths/\text{min}$$

M. What is the tidal volume of someone with a minute ventilation of 8 L/min and a frequency of 15 breaths/minute?

$$V_t = \frac{\dot{V}_E}{f} = \frac{8\ L/\text{min}}{15\ breaths/\text{min}} = 0.533\ L/breath = 533\ mL/breath$$

N. You have a nebulizer and aerosol mask set up at an FIO_2 of 0.75. Calculate the air:oxygen entrainment ratio.

$$air : oxygen = \frac{100 - FIO_2}{FIO_2 - 21} = \frac{100 - 75}{75 - 21} = \frac{25}{54} = 0.46 \approx 0.5 : 1$$

1. If you run your oxygen flow at 10 L/min, what will the air entrainment be?

$$Air\ Flow = Air\ Ratio \times Oxygen\ Flow = 0.5 \times 10\ L/min = 5\ L/min$$

2. What is the total flow provided to the aerosol mask?
Total Flow = Oxygen Flow + Air Flow = 10 $^{L}/_{min}$ + 5 $^{L}/_{min}$ = 15 $^{L}/_{min}$

3. Your patient needs 30 L/min flow. Are you delivering enough flow with your device to meet their inspiratory needs? YES NO

4. If not, what will happen to the inspired oxygen concentration? **IT WILL BE REDUCED**.

5. If not, what can you do to correct the situation? **USE AN ALTERNATE SYSTEM LIKE A BLENDER OR A DUAL FLOWMETER SYSTEM.**

O. I have a patient who needs 16 L/min inspiratory flow and an FIO_2 of 0.40. I have an air and oxygen flowmeter and want to mix (blend) these gases together in the proper ratios and flows to meet my patient's needs.

$$air : oxygen = \frac{100 - FIO_2}{FIO_2 - 21} = \frac{100 - 40}{40 - 21} = \frac{60}{19} = 3.2 \approx 3 : 1$$

1. Where should I set the oxygen flowmeter? **4 L/min**

2. Where should I set the air flowmeter? **12 L/min**

P. If an oxygen flowmeter is set at 10 L/min and an air flowmeter is set at 17 L/min, what is the oxygen concentration being delivered?

$$FDO_2 = \frac{\textit{Oxygen Flow Rate} + (.2 \times \textit{Air Flow Rate})}{\textit{Total Flow}}$$

$$FDO_2 = \frac{10 + (.2 \times 17)}{27} = \frac{10 + 3.4}{27} = \frac{13.4}{27} = .496 \approx 0.50$$

Q. Which states of matter are considered fluids?

1. **GASES**

2. **LIQUIDS**

R. Define flow and give an example of one of its unit of measure.

1. Definition: **THE BULK MOVEMENT OF A SUBSTANCE THROUGH SPACE EXPRESSED AS VOLUME OF FLUID MOVED PER UNIT OF TIME.**
2. Unit of measure: **LITERS PER MINUTE, LITERS PER SECOND**

S. Pressure is defined as force/specific surface area. For a static fluid, pressure is dependent on **VELOCITY** x **CROSS-SECTIONAL AREA**.

T. **VISCOSITY** is the property of a fluid that opposes flow.

U. Three patterns of fluid flow are:

1. **LAMINAR**

2. **TURBULENT**

3. **TRANSITIONAL**

V. Poiseuille's Law describes the factors effecting laminar flow. Write the formula below and define the variables.

$$P = \frac{\dot{V} 8 \ell n}{\pi r^4}$$

P = Driving pressure (to move gas through a tube)

– fluid viscosity (n)

– tube length (l)

– flow (?)

– radius (r)

W. If viscosity of gas or the length of the tube increases, what happens to driving pressure? (if flow is to remain the same) **INCREASES**

X. If the radius of the tube decreases, what happens to driving pressure? (if flow is to remain the same) **INCREASES**

1. In what situation might this apply clinically? **BRONCHOSPASM**

Y. A fluids flow becomes turbulent when the Reynolds number is > **2,000**

Z. What is the formula for Reynolds number? Define the variables.

$$\textit{Reynold's Number} = \frac{v \times d \times 2r}{h}$$

v = ***linear velocity (distance/time)***

d = ***fluid density (weight/volume)***

r = ***tube radius (size of opening)***

h = ***fluid viscosity (thickness, stickiness)***

AA. If fluid velocity, fluid density or tube radius go up, the Reynolds number will **INCREASE**.

BB. If fluid viscosity goes down, Reynolds number will **DECREASE**.

CC. What is the Bernoulli Effect? **AS FLUID FLOWS THROUGH A TUBE AND MEETS A RESTRICTION, THE FORWARD VELOCITY WILL INCREASE AND THE LATERAL WALL PRESSURE WILL DECREASE**.

DD. Fluid velocity at a constant flow varies inversely with its **LATERAL WALL PRESSURE**.

EE. What is the Venturi Principle? **IF GAS FLOWING THROUGH A TUBE MEETS A SMALL ENOUGH CONSTRICTION, THE PRESSURE WILL DROP TO SUB ATMOSPHERIC AND ACTUALLY ENTRAIN A SECOND GAS (FLUID)**.

FF. Fluids have three kinds of energy

1. **POTENTIAL**
2. **KINETIC**
3. **PRESSURE**

GG. Gravity increases the effect of **POTENTIAL** energy.

HH. **KINETIC** energy is the result of fluid in motion (velocity).

II. **PRESSURE** energy is the lateral force exerted by moving fluid on the walls of its container.

JJ. One of the Laws of Thermodynamics states that the energy at any point in a fluid stream is the same through the stream where energy = Velocity or Kinetic Energy x Lateral Pressure Energy. As a tube narrows, the velocity will **INCREASE** and the lateral pressure will **DECREASE**.

KK. This Bernoulli Effect will allow for fluid **ENTRAINMENT** at the point of narrowing.

LL. Entrainment with an air injector is dependent on the size of the

1. **JET ORIFICE OPENING**

2. **AIR ENTRAINMENT PORT**

MM. Clinical examples of Respiratory Therapy equipment that uses this theory are

1. **AIR-ENTRAINMENT MASKS**

2. **AIR-ENTRAINMENT NEBULIZERS**

NN. A clinical example of Respiratory Therapy equipment that uses the Bernoulli Effect is **AIR-ENTRAINMENT NEBULIZERS**.

OO. Pressure past the narrowing point can be almost completely restored if the angle of the tube dilation does not exceed **15** degrees.

PP. A smaller jet or larger entrainment port will allow **GREATER** air entrainment.