EMT-2/3 Level Intro to Math & Exercises

The EMT-2 level of practice requires some simple math at times. An EMT-2, given a dose of medication, must be able to draw up and administer the correct volume to yield that dose. On occasion an EMT-2 must be able to figure pediatric dosages based on weight.

IV infusions are often regulated to two speeds: very slow and very fast (TKO and wide open) but there are times when a particular rate is desired. The EMT-2 has to calculate the correct drip rate.

For those of us who'd rather chew aluminum foil than do arithmetic, that's the bad news. The good news is that the calculations required in the field are pretty standardized. Only a few dosages are required for the EMT-2 to learn. More good news is that simple (non-programmable) calculators *are* allowed - in class and in the state exam.

This topic will be covered in class, but all students should be familiar with these basic concepts beforehand.

MEASUREMENT - Core concepts

Distance, volume and mass

In each of these, one unit of measurement can spawn larger and smaller units. Certain standard prefixes denote the relationships. Some important prefixes are:

centi = 1/100
milli = 1/1,000
deci = 1/10
kilo = 1000

Distance is measured in meters

1/100 meter = 1 centimeter (cm)
1/1,000 meter = 1 millimeter (mm)
1,000 meters = 1 kilometer (km)

Volume (the amount of space something takes up) is measured in liters

1/1000 liter = 1 milliliter (ml)

As it happens, the milliliter was devised to be the volume of a box, one centimeter on each side. So it is also called also called a cubic centimeter or cc

The gram is used to measure mass (which is the same thing as weight, unless you're an astronaut or a physicist).

1,000 grams = 1 kilogram (kg)
1/1,000 gram = 1 milligram (mg)

And there are drugs so powerful they have to be measured in micrograms (a millionth of a gram).

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Drug dosages are usually measured in units of *mass* (mostly milligrams, sometimes grams) But EMTs have to convert to units of *volume* (milliliters) to figure out how much to draw up in a syringe.

Confusion sometimes arises over the similarity in sound between milligrams (mg) and milliliters (ml).

UNITS USED IN EMS PRACTICE

kg - Kilogram - unit of mass 2.2 pounds in a kilogram

g - Gram - also a unit of mass. One thousand of them make up a kilogram

mg - Milligram - an even smaller unit of mass. One thousand of them will make up a gram. (and a million of them will equal a kilogram)

l - Liter - a unit of volume, only a little larger than a quart. Often in EMS we measure IV fluid in liters and measure oxygen flow in lpm

dl - Deciliter - also a unit of volume, one tenth of a liter. For an EMS use of dl, turn on the glucometer.

ml - Milliliter - a unit of volume. One thousand of them will make up a liter. Frequently called a cubic centimeter (cc)

mm - Millimeter - a very short unit of length. One of the very few things EMTs measure in millimeters is pupil size.

mEq - Milliequivalent - a bizzaro unit of the chemical combining potential of an electrolyte solute. The important thing about the mEq is the fact that sodium bicarb is measured in mEq.

Gtt - Gtt means “drop” - It is latin (guttae) for drops

Converting from the “English” system units to metric:

Drugs given to children are usually calculated on the basis of their weight. Since that is usually available in pounds, we have to convert to kilograms. This is the only common conversion in EMS.

With a calculator, dividing by 2.2 is easy. Without a calculator, a very close approximation can be had by subtracting 10% from the number of pounds, then cutting the remainder in half.

Example: a child weighs 36 lbs. Ten percent of 36 is 3.6 which you can be forgiven for rounding up to 4. 36 - 4 = 32. Cut that in half to get 16. The kid weighs pretty close to 16 kg.

TWO EQUATIONS TO MEMORIZE

The formula for calculating the volume of medication to draw up for a particular dose is done according to this formula. This one is essential for every EMT-2 or 3 to know well.

$$\text{VOLUME to be administered (ml)} = \frac{\text{DESIRED DOSE}}{\text{CONCENTRATION of med.}}$$

The dose is usually in mg, and the concentration in mg / ml but grams are used for some medications, and for others (not in the EMT-2 or 3 curriculum) even milliequivalents may be used.

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Calculating the IV drip rate, when you have been instructed to give a particular volume of fluid in a particular time span, is done as follows:

$$\frac{\text{VOLUME to be infused (ml)}}{\text{TIME of infusion (min.)}} \times \text{DROPS / ml for the IV set being used} = \text{FLOW RATE (in drops / min.)}$$

In other words, divide the time period by the amount you've been ordered to run in during that time. Then multiply that number by the number on the package for the IV tubing you just opened (usually 10 or 60). That's the number of drops that should fall in the chamber in a minute's time.

There's a shortcut that will (usually) make this formula unnecessary. But it's important to know it anyway.

IV CALCULATION RULES AND SOME HELPFUL SHORTCUTS:

Rule 1:
A mini-drip set has 60 drops to the ml
(The drops are so tiny that each is 1/60 of a ml.)

Rule 2:
A macro-drip (maxi-drip) set has 10 drops to the ml
(The drops are so big that each is 1/10 of a ml.)

Rule 3:
Always convert flow rates to ml/hr
(If you're calculating based on time periods other than one hour, still convert the flow rate to ml/hr. Then run the I.V. for whatever the correct time period is.)

Short cut Rule 1:
If you're using a mini-drip set you don't need to do arithmetic
(Drops/minute is *the same number* as ml/hour. They were nice to us for once.)

Short cut Rule 2:
If you're using a 10-drop macro-drip set your magic number is 6.
(If you know the number of ml/hr you need and you want the **D**rops/min to run, then **D**ivide by 6.)
(If you know the drops/min. that it's running and you want the **M**l/hr that this will produce, then **M**ultiply by 6)

Example 1: You start a line with a mini-drip (60 drops / ml) set and the E.R. orders a flow rate of 72 ml / hr. No math needed. Run it at 72 drops / min.

Example 2: The IV is a macro (10 drops / ml). You've been told to give 300 ml / hr and now you have to figure how many drops / min will yield that rate. You want **D**rops/min so **D**ivide - by 6 in this case. 300 / 6 = 50. Run the IV at 50 drops / min.

Example 3: You want to know how fast an IV is running. You just counted 80 drops in a minute, and since you want **M**illiliters per hour, you **M**ultiply - by 6 since you're using a 10-drop set. 80 x 6 = 480. Your flow rate is 480 ml / hr.
The basis of the shortcuts lies in the arithmetic.

Using the original formula with a 60-drop I.V. set would result in dividing by 60 and then multiplying that result by 60 (Try it.) Why bother multiplying and then dividing by the same number? With a 60-drop set it cancels out, and the flow rate (ml/hr) is the same as the drip rate (drops/min)

With a 10-drop set, you end up dividing by 60, and then multiplying that result by 10. That's the same as just dividing by 6.

IMPORTANT:

Where the original formula is most needed, is the situation where the order is not for a given flow rate in ml / hr, but involves a total amount of fluid to be given over a time **period other than 60 minutes** (e.g. 300 ml to be infused over 40 minutes) It is not a common order for EMTs to receive, but it is part of the state curriculum.

So learn the formulas, but in reality, you can use the factors for most problems.

PRACTICE PROBLEMS

You've counted an IV drip rate the way you count a pulse, for 15 seconds. There were only six drops in 15 seconds. How many milliliters per hour is this? It's a big 10-drop set.

6 drops in 15 seconds = 24 drops/minute
24 x 6 = 144 144 ml / hr

Using a mini-drip set for an I.V. in an 87-year-old female with a history of heart problems, you wish to run it at no more than 60 ml / hr. How many drops per minute is this?

No math to do with a mini-drip. 60 ml / hr is 60 drops / min. 60 gtts / min.

"Run the I.V. as fast as it will go," shouts your partner. However it's not a great vein, and the big 10-drop set you use is still dripping at only about 20 drops in 15 seconds. What's the flow rate?

20 x 4 = 80 drops per minute
80 x 6 = 480 ml. per hour 480 ml / hr

Your patient complained only of a slightly irregular pulse, and you started a 20-gauge I.V. using a 250-ml bag of saline. Thank goodness you used a 10-drop set, because her B.P. just bottomed out.

The E.R. physician said to open the I.V. up wide, and you do so. You count about 35 drops in 15 seconds. Will you need to change the I.V. bag during your 20-minute transport?

35 drops in 15 seconds = 140 drops per minute
140 x 6 = 840 ml / hr.
840 ml / hr for 20 minutes will yield 280 ml.
Yup. You'll run out before you reach the E.R. Yes.

Your patient has signs of dehydration, which you report to the E.R. physician.. His reply: "lung sounds are clear, you said? OK, go ahead and run the I.V. at 500 cc an hour."

What drip rate will give you a flow rate of 500 ml / hr ? (You're using a 10-drop IV set.)

500 divided by 6 = 83 and change 83 drops / min

And since counting for a whole minute can be burdensome, you figure that in a 15-second time
period, you will need to see one quarter of that number. Set the IV so 20 or 21 drops fall during

15 seconds.

You are ordered to give your patient 30 mg of a particular medication. Looking at the label on the vial, you see that the concentration is 5 mg/ml. Dose divided by concentration gives volume to be administered. So: 30 / 5 = 6. You draw up and inject 6 ml of the solution.

Another medication is more dilute: only 0.4 mg / ml. When you are ordered to give 2 mg of this med, you must divide 2 mg by 0.4 mg / ml. Turns out that 2 divided by 0.4 equals 5. You must infuse 5 ml. of this solution.

REVIEWING I.V. DRIP RATES

I.V. drip sets come in mini-drip sizes, where the drops are so small there are 60 drops per ml. They also come in two maxi-drip sizes. The more common in our borough is the 10-drop-per-ml size, but there are also some 15-drop-per-ml sets out there.

Converting drops/min to ml/hour

The shortcuts

With a 60-drop minidrip set, DROPS / MIN = ML / HR (no math needed)

With a 10-drop maxi set, DROPS / MIN x 6 = ML / HR

With a 15-drop maxi set, DROPS / MIN x 4 = ML / HR

DRIP RATE PROBLEMS

1) So let's assume that an I.V. with a minidrip tubing is running at about 80 drops per minute. How many ml/hr is that?

2) What if an I.V. with a 10-drop maxidrip set were running at the same 80 drops per minute. How many ml/hr is that?

3) What if you have a 10-drop maxidrip tubing in place, and decide that you want to run the I.V. at 300 ml/hr - how many drops per minute will give you that?

4) You are instructed to give a bolus of 400 cc to your trauma patient, and you want to finish it up right at the time you hit the E.R. - 30 minutes from now. How many ml/hr will give you 400 cc in 30 minutes? How many drops/min gives you this rate if you're using a 10-drop maxidrip?

5) A child weighing about 20 pounds is very dehydrated and needs an I.V. bolus of 20 ml/kg over the next 15 minutes. What sort of drip set do you want to use? Why?

First off, how many kg is 20 lbs?

Then how big a bolus will 20 ml/kg be?

To run that in over 15 minutes, how many drops per minute would that be with a (60-drop) minidrip set?

With a (10-drop) maxidrip?

6) You're using one of the less common 15-drop maxidrip sets to give a fluid bolus of warmed saline to a severely hypothermic adult. Mat-Su protocols call for 20 ml/kg as a bolus. Assume you want to give that over the next 20 minutes, and that she weighs about 110 lbs. Can you count that many drops/minute, or will you just have to go by the markings on the bag?

How many kg? What size bolus?

How many drops/minute?

7) "They want to know how fast we're running the IV," says your partner. "Are you running it TKO?" You count for 15 seconds and see 9 drops fall in that time. You're using a 10-drop set. Is that TKO?

8) When you get into the E.R. a nurse hangs the IV bag on a handy pole. It's much higher than it was in the ambulance, and now you count almost 25 drops in 15 seconds' time. What is the new flow rate?

ANSWERS TO IV DRIP RATE

AND DRUG DOSAGE PROBLEMS

PROBLEM 1 - ANSWER
With a mini-drip (60-drop/ml) IV set there's little need to do arithmetic. 80 drops/min. *equals* **80 ml/hr**.

PROBLEM 2 - ANSWER
With a 10 drop mongo-drip set the magic number is 6, and since we want Ml/hr we'll Multiply. 80 x 6 = **480 ml/hr**.

PROBLEM 3 - ANSWER
We want Drops/min. so we'll Divide (by six, since it's a 10-drop set)
300/6 = **50 drops/min**.

PROBLEM 4 - ANSWER
First, how do you find convert 400ml/30 min. to ml/hr? You could do it intuitively, saying that 30 min. is half of an hour, so multiply the flow rate by 2. (So 400 ml over 30 min. is the same *rate* as 800 ml/hr.) After that it's the same simple process of dividing the flow rate by 6 to get the drip rate: 800/6 = **133 drops/min**.

Intuition is fine, but some of us don't have much (especially in math) The drip rate equation, on the other hand, works consistently. Volume (in ml) divided by time (in minutes) times the drops/min for that IV set will equal the drip rate. So 400 / 30 = 13.3 and 13.3 x 10 = 133. You'll run the IV at **133 drops / min**.

PROBLEM 5 - ANSWER
10% of 20 = 2 and 20 - 2 = 18 and 18 / 2 = 9, so a 20-pound kid weighs **9 kg**.

20 x 9 = 180, so the bolus should be **180 ml**.

The drip rate equation is volume over time, multiplied by the drops per ml.

180 / 15 = 12 . And 12 x 60 (if we're using a 60-drop minidrip set) is 720. But **720 drops per minute** might be difficult to regulate.

In fact it will be a moderately fast rate even with a 10-drop set.
180 / 15 = 12. And 12 x 10 = **120 drops per minute**.

PROBLEM 6 - ANSWER

110 pounds is about **50 kg**. (110-10% equals approx 100. Cut that in half, and

you've got 50)

20 ml/kg for a 50 kg. patient = 20 ml. x 50 = **1,000 ml**. (a whole liter)

To infuse 1,000 ml in 20 minutes with a 15-drop set, divide the volume (in ml) by the time period (in minutes) and multiply it by 15 (drops/ml of the drip set).

1,000 / 20 = 50. And 50 x 15 = 750. And **750 drops per minute** is too fast to count; it'll be a steady stream. So just keep an eye on the total you've given. Guard against the "runaway IV."

PROBLEM 7 - ANSWER

You counted for 15 seconds (same way you count pulses) and saw 9 drops fall. 4 x 9 = 36. So you've got a drip rate of 36 drops/min. Using the shortcut for a maxi-drip (10-drop) IV set: you want the **M**l / hr so you **M**ultiply. By 6 in this case ('cause you're using a 10-drop maxi-drip set). 36 x 6 = 216 gtt/min. That's way more than TKO (TKO stands for "to keep open," and depending on what you read, is anywhere up to 60 ml/hr.)

PROBLEM 8 - ANSWER

Easy one: 25 drops in 15 seconds' time = a rate of 100 drops/min. (25 x 4 = 100).
Using the shortcut means you'll multiply the drip rate x 6 to get ml / hr.
100 x 6 = 600. The IV is now running at 600 ml / hr.

REVIEWING DRUG DOSES

There are many ways to figure drug dosages, but they are just different expressions of this equation:

$$\text{Volume to be administered} = \frac{\text{Desired dose}}{\text{Concentration on hand}}$$

Dosages are usually expressed in mgs or other units of mass (weight) but cannot easily be measured in this way. They are measured out in mls or other units of volume. So you must know the concentration in order to go from units of mass to units of volume.

Concentration is just an expression of how much of a drug (or anything else) is dissolved in a solution. Pour a half cup of sugar into the quart pitcher of lemonade and you have one concentration. Pour in three cups of sugar, and you have a different (and much higher) concentration: 0.5 c / qt versus 3 c / qt .

If you wish to administer 20 mgs of a drug that comes in a concentration of 10 mg/ml you would figure out how many mls to give by dividing 20 (desired dose) by 10 (conc. on hand) and coming up with 2 mls.

The concentration is almost always specified on the medication's label. Occasionally, however, it is not written as such, and the person giving the medication must be able to calculate it. For instance if a medication comes in a 5-ml vial that was marked as containing 30 mg of drug, then the concentration is (30 divided by 5) 6 mg/ml.

DOSAGE PROBLEMS

1) Let us assume that your patient is to be given 3 mgs of the fictional drug above. Since it come in a concentration of 6 mgs/ml. How many mls do you want to draw up?

2) On the next response, you are asked to administer 20 mgs of a drug that comes in a concentrated form: 50 mgs in a 5-ml vial. How many mls. should you inject into the I.V. port?

3) You prepare a particularly bizarre drug by dropping a 10-mg crystal into 2 mls. of fluid and stirring until it's dissolved. What will be the concentration of this solution?

If you are asked to give a dose 2-and-a-half mgs. poured into the patient's ear while sleeping, how many mls. will have to go into the ear? How will you keep him from waking up? What Shakespeare character was murdered in this way?

4) Your young patient weighs about 56 lbs and requires a dose of 0.1 mg/kg of I.V. medication. It comes in a 10-ml preload that contains one mg.

How many kgs does the kid weigh?

So what's the desired dose?

What's the concentration?

What will be the number of mls you draw up?

How many vials is this?

What volume would you give if you could get some of this medication in a concentration of 1 mg/ml? (And do these concentrations sound familiar?)

5) How many mls of solution must you give if the patient needs a dose of 1 mg/kg, and the medication comes in a 50-ml vial containing 100 mg ? Looking at the patient, you guess he weighs about 175 lbs.

6) Another medic is trying to help you out with a critical patient and draws up a 12-cc syringe full of medication. You know that this drug comes only in a concentration of 0.5 mg/ml but you double-check the box anyway and confirm this. The maximum safe dose for this drug is 4 mg for an adult. How many mls. do you have in this syringe? How many can you give?

7) An E.R. physician orders you to provide a dose of 1/2 mg of a drug that comes in a 20-ml vial that contains 5 mgs. How many mls. do you wish to inject?

8) "Hurry and give this patient 12 mgs of Dammitol I.V.," says the physician on the other end of the phone. You note that Dammitol comes in a preloaded syringe that contains 30 mg. of drug. It's a 50-ml syringe. How many mls do you want to squirt out of the syringe (Into the wastebasket, not onto the floor. Dammitol is slippery.) so that what remains in the syringe is the appropriate dose?

DOSAGE PROBLEM 1 - ANSWER
Remember: volume to be administered = desired dose/concentration,
so 3/6 = .5 and you'll therefore draw up **0.5 ml**. of the medication.

PROBLEM 2 - ANSWER
50 mgs in 5 ml = how many mg/ml? Answer: divide 50 by 5 and you get 10, so the concentration is 10 mg/ml.

You want to give 20 mgs, so that's the desired dose.

Desired dose / concentration on hand = volume to be administered.

So 20/10 = 2, and you therefore want to draw up **2 ml**.

PROBLEM 3 - ANSWER
10 mg of drug in 2 ml of solution gives a concentration of (10/2 = 5) **5 mg/ml.**

Desired dose = 2.5 mg. and concentration = 5 mg/ml. Then 2.5/5 = .5 So the volume to be administered is **0.5 ml.**

Hamlet's father was killed with a drug poured into his ear. The Elizabethans had some rather quaint ideas about anatomy and physiology.

PROBLEM 4 - ANSWER
A kid who weighs 56 pounds weighs (56 - 10% = ca. 50 and 50/2 =25) about **25 kgs**.

So the desired dose is 25 x 0.1, which equals **2.5 mg**.

The concentration of a drug that's 1 mg. in 10 ml. is 1/10, which equals **0.1 mg/ml**.

Number of mls. to draw up (volume to be administered) is dose divided by concentration, which is 2.5 divided by 0.1, which equals **25 mls**. Since they're 10-ml. vials, that means you'll use two whole vials and half of a third one.

If you could get it in a concentration of 1 mg/ml. then there'd be 2.5 mg in 2.5 ml and **2.5 ml**. would be all you'd have to use.

(By the way, these are the concentrations we have available for epinephrine, but 0.1 mg/kg is NOT the usual pediatric dose of epi.)

PROBLEM 5 - ANSWER
If the patient is 175 pounds, he or she is approximately 79 kg. Call it 80 kg to make the math easier (We won't fudge the math in all situations, but remember, the weight was approximate in the first place.) So the desired dose is 80 mg.

100 mg. in 50 ml means the concentration is 2 mg/ml.

Dose/ conc. = vol.   So 80/2 = 40. You want to draw up **40 ml**.

PROBLEM 6 - ANSWER

Dose is 4 mg. (specified in the problem). Concentration (also specified) is 0.5

4 divided by 0.5 = 8

The volume to be administered is **8 mls**. out of the 12 with which he filled the syringe

PROBLEM 7 - ANSWER
Concentration, if there are 5 mgs. in a 20-ml. vial is 0.25 mg/ml (since 5/20 equals 0.25)

Volume to be administered equals the dose divided by the concentration
That is: Volume = 0.5 divided by 0.25 (which equals 2.)

Answer: **2 mls**.

PROBLEM 8 - ANSWER
30 mg. of drug in a 50 ml. preloaded syringe means a concentration of 0.6 mg/ml. (since 30 divided by 50 = 0.6)

Then divide desired dose by concentration on hand

12 divided by 0.6 = 20

Volume to be administered is 20 ml.

Since you want to give 20 mls. out of that 50-ml. syringe, you should squirt **30 mls**. out into the trash, and what remains will be the appropriate dose. However, most medics, in most situations, would probably not operate that way; they'd simply give the 20 mls. and dispose of the remaining 30 mls. when they trash the syringe.