SELECTED MATH PROBLEMS FOR WASTEWATER

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Math Problem Solving Strategy

1. Read the question carefully and underline what they are asking you to find.
2. Write down the formula you need to solve the problem. Look in the front of the test booklet if necessary.
3. Fill in everything you know. Sometimes filling in what you know might require you to find something else first like area or volume.
4. Check your units! Make sure they are correct for the formula and agree with each other.
5. Convert units where needed.
6. Put the new units into the formula.
7. Solve.
8. Check the units of your answer. Are they what the question asked for?
9. Convert units if necessary.

THE RULES FOR BASIC ALGEBRA

1. For Unit Conversions
   a. Only tops and bottoms can cancel
   b. Everything on the top gets multiplied
   c. Everything on the bottom gets divided
2. You can rearrange any equation by following these simple rules:
   a. Do anything you want.
   b. Do the opposite.
   c. Do it to both sides.
3. Simplify any equation correctly by following the Order of Operations. Whenever you CAN do things in this order, you MUST do them in this order.
   a. **P**arenthesis, **P**owers or **E**xponents (x^2), **M**ultiply, **D**ivide, **A**dd, and **S**ubtract
   b. **PMDAS** or **PEMDAS**
   c. **P**olly **M**akes **D**onuts **A**fter **S**chool
   d. **P**lease **E**xcuse **M**y **D**ear **A**unt **S**ally

UNIT CONVERSIONS

1. Convert 6000 gallons to cubic feet.
2. Convert 4000 cubic feet to gallons.
3. Convert 7 days into seconds.
4. Convert 85 mph into feet per second
5. Convert 20 gpm to MGD.
6. Convert 300 gpm to cfs.
7. Convert 20 cfs to MGD.
8. Convert 400 psi into feet of head.
9. Convert 20 gallons per square foot per day.
10. A 30 HP pump runs for 80 hours. Electricity costs $0.085 per Kwh. What will it cost to run the pump?

TANK GEOMETRY

1. It's a big night out for pizza, but you can't decide if you should order the 12-inch pizza for $14.50 or spend a few more bucks and get the 16-inch pizza for $18.00. What is the better deal? Find dollars spent per square inch of pizza.

2. There is a 6-inch pipe and a 12-inch pipe. Assuming that the water is moving at the same speed through both AND both pipes are running full, how much more flow will the 12-inch pipe hold?

3. The diameter of a wet well is 15 feet. It is filled to a depth of 12 feet. How many gallons of water does it contain?

4. How many gallons of liquid can be held in a tank that is 120 feet long by 40 feet wide by 14 feet deep?

5. Approximately how many gallons would 450 feet of 6-inch diameter pipe hold?

6. A chemical storage tank is 15 feet in diameter and 10 feet deep. A pressure indicator at the bottom of the tank reads 3.8 psi. How many gallons of water are in it?

7. Find the perimeter or circumference of a tank that is 80 feet in diameter.

8. A covered cylindrical tank must be painted both inside and out. All surfaces, except the bottom of the tank, must be painted. If the tank is 25 feet tall and 50 feet in diameter, how many square feet must be painted?

HYDRAULIC RETENTION TIME

1. A tank holds 500 gallons. A pump is used to fill the tank at a rate of 25 gpm. How long will it take to fill the tank?

2. A sludge storage tank is being fed feed sludge at a rate of 300 gpm. At the same time, sludge is being taken out of the tank for land application at an average rate of 200 gpm. If the tank holds 1.2 MG, what is the hydraulic retention time in hours?

3. A wet well is 35 feet in diameter and 65 feet deep. With no water entering the tank, the water level dropped 14 feet in 5 hours. Find the average flow rate for water being pumped from the wet well in gpm.

4. A 250 gpm is able to completely empty an aeration basin in 6 hours and 15 minutes. How much MLSS was in the basin?

VELOCITY

1. A 42-inch diameter pipe transfers 35 cfs of water. Find the velocity in cfs if the pipe is running full.

2. A plastic float is dropped into a manhole. It appears in the downstream manhole, 450 feet away, after 68 seconds. Find the velocity of water in the sewer.

3. A wastewater plant has four grit basins that operate in parallel. Each grit basin is 2 feet wide, 10 feet long, and 1.5 feet deep. If the average influent flow is 3.5 MGD, what is the minimum number of grit basins to have on-line to achieve an average velocity through the grit basins of less than 1.0 fps?

DISINFECTION AND CHEMICAL DOSING

1. Find the chlorinator setting in pounds per day for a wastewater plant disinfecting with gaseous chlorine when the influent flow is 2.5 MGD. The desired dose is 5 mg/L.

2. A wastewater plant treating 3.5 MGD uses seven 150 pound chlorine cylinders each week. What was the average chlorine dose in mg/L?

3. The chlorine dose at the beginning of the chlorine contact chamber was 5.2 mg/L. The measured total chlorine result at the end of the chlorine contact chamber was 0.5 mg/L. What was the demand?

4. A wastewater plant disinfects with a sodium hypochlorite solution that contains 15% available chlorine. If the effluent flow rate is 600 gpm, how many gallons of sodium hypochlorite solution will be needed each day at a dose of 4.5 mg/L?

5. From experience, the operator knows that the chlorine demand will be about 1.2 mg/L in the treated effluent. She would like to maintain a total chlorine residual of 3.0 mg/L for disinfection. If the plant is treating 800 gpm and is using HTH tablets for disinfection (70% available chlorine), how many pounds of HTH tablets will be needed each day?

PUMPS

1. Water is being pumped from a wet well through a force main to the next gravity line which is 225 feet higher at the top of the ridge. Find the pump size required to transfer the wastewater at a rate of 80 gpm. The pump is 85% efficient and the motor is 90% efficient.

2. A 25 HP pump is being used for a dewatering operation. If the pump runs for 8 hours a day, 7 days a week, how much will it cost to run the pump for one week? Assume energy costs of $0.085 a Kwh.

3. A chemical feed pump with a 6-inch bore and a 6-inch stroke pumps at 75 cycles per minute. What is the pumping rate in gpm?

4. A pump station with two pumps (lead and lag) is pushing wastewater uphill 50 feet at a rate of 150 gpm. The pumps are consuming 1.865 Kwh of electricity each hour of run time. How efficient is this pump and motor combination overall?

1. $\frac{6000\ \text{gal}}{} \Big| \frac{1\ \text{cf}}{7.48\ \text{gal}} = 802\ \text{cf}$

ON THE BOTTOM, SO DIVIDE

2. $\frac{4000\ \text{cf}}{} \Big| \frac{7.48\ \text{gal}}{1\ \text{cf}} = 29{,}920\ \text{cf}$

ON THE TOP, SO MULTIPLY

3. $\frac{7\ \text{days}}{} \Big| \frac{1440\ \text{min}}{1\ \text{day}} \Big| \frac{60\ \text{sec}}{1\ \text{min}} = 604{,}800\ \text{sec}$

$\frac{7\ \text{days}}{} \Big| \frac{24\ \text{hrs}}{1\ \text{day}} \Big| \frac{60\ \text{min}}{1\ \text{hr}} \Big| \frac{60\ \text{sec}}{1\ \text{min}} = 604{,}800\ \text{sec}$

4. $\frac{85\ \text{miles}}{\text{hr}} \Big| \frac{5280\ \text{ft}}{1\ \text{mile}} \Big| \frac{1\ \text{hr}}{60\ \text{min}} \Big| \frac{1\ \text{min}}{60\ \text{sec}} = 124.7\ \text{ft/sec}$

WHEN YOU SAY "PER", THE NEXT THING JUMPS OVER THE LINE

5. $\frac{20\ \text{gal}}{\text{min}} \Big| \frac{1440\ \text{min}}{1\ \text{day}} \Big| \frac{1\ \text{MG}}{1{,}000{,}000\ \text{gal}} = 0.0288\ \text{mgd}$

20 GALLONS "PER" MINUTE

6. $\frac{300\ \text{gal}}{\text{min}} \Big| \frac{1\ \text{cf}}{7.48\ \text{gal}} \Big| \frac{1\ \text{min}}{60\ \text{sec}} = 0.67\ \text{cf/s}$

7. easy way $\quad \frac{20\ \text{cfs}}{} \Big| \frac{1\ \text{MGD}}{1.55\ \text{cfs}} = 12.9\ \text{MGD}$

THIS CONVERSION FACTOR IS IN THE TEST BOOK

harder way

$\frac{20\ \text{cf}}{\text{s}} \Big| \frac{60\ \text{sec}}{1\ \text{min}} \Big| \frac{1440\ \text{min}}{1\ \text{day}} \Big| \frac{7.48\ \text{gal}}{1\ \text{cf}} \Big| \frac{1\ \text{MG}}{1{,}000{,}000\ \text{gal}} = 12.9\ \text{MGD}$

*HERE, THE CONVERSION FACTOR INCLUDES ALL THIS MATH – 1.55 cfs = 1 mgd SO WE CAN PUT ONE ON TOP + ONE ON THE BOTTOM

8. $400\ psi \left| \frac{1\ ft}{0.433\ psi} \right| = 923\ ft$

If I have a cubic foot of water, it weighs 62.4 lbs

$$1\ cf \left| \frac{7.48\ gal}{1\ cf} \right| \frac{8.34\ lbs}{1\ gal} \right| = 62.4\ lbs$$

Now, take the area on the bottom of that cube 1ft by 1ft and find square inches. 1 ft = 12 inches.

AREA = (LENGTH)(WIDTH)
AREA = (12 in)(12 in)
AREA = $144\ in^2$

Here's the magic: Find the pressure at the bottom of my cubic foot of water.

$$\frac{62.4\ lbs}{144\ in^2} = 0.433\ lb/in^2 \text{ or psi}$$

SO.... what we really mean when we say that there are 0.433 psi for every foot of depth, we mean feet of WATER or something that weighs the same as water: 8.34 lbs/gal

9. Convert to gal/min·sf

$$\frac{20\text{ gal}}{\text{sf}\cdot\text{day}} \Big| \frac{1\text{ day}}{1440\text{ min}} \Big| = 0.0138\text{ gal/d·sf}$$

10. $$30\text{ HP} \Big| \frac{0.746\text{ kW}}{1\text{ HP}} \Big| \frac{\$0.085}{1\text{ kwh}} \Big| 80\text{ hrs} \Big| = \$152.18$$

← power is sold in kw·hrs
so, we need kilowatts and we
need total hours of run time

GEOMETRY

1. Find the price per square inch of pizza

$A = 0.785 d^2$
$A = (0.785)(12in)(12in)$
$A = 113.04\ in^2$

$A = 0.785 d^2$
$A = (0.785)(16in)(16in)$
$A = 200.96\ in^2$

almost twice as
much pizza! ☺

FIRST PIZZA $\frac{\$14.50}{113.04 in^2}$ = $0.128/in² of pizza

SECOND PIZZA $\frac{\$18.00}{200.96}$ = $0.089/in² of pizza

*MORAL: ALWAYS GET THE LARGE PIZZA

2. Pipe capacity is also based on area.

$A = 0.785d^2$
$A = (0.785)(6in)(6in)$
$A = 28.26\ in^2$

$A = 0.785d^2$
$A = (0.785)(12in)(12in)$
$A = 113.04\ in^2$

$\frac{113.04}{28.26} = 4$

WHEN YOU DOUBLE THE DIAMETER; AREA GOES UP BY A FACTOR OF 4

3. $Volume = 0.785d^2h$
$= (0.785)(15\ ft)(15\ ft)(12\ ft)$
$= 2119.5\ ft^3$

$2119.5\ ft^3 \left| \frac{7.48\ gal}{1\ ft^3} \right| = 15843.86$ gallons

4. VOLUME = (LENGTH)(WIDTH)(HEIGT OR DEPTH)
VOLUME = (120 ft)(40 ft)(14 ft)
VOLUME = 67,200 cf

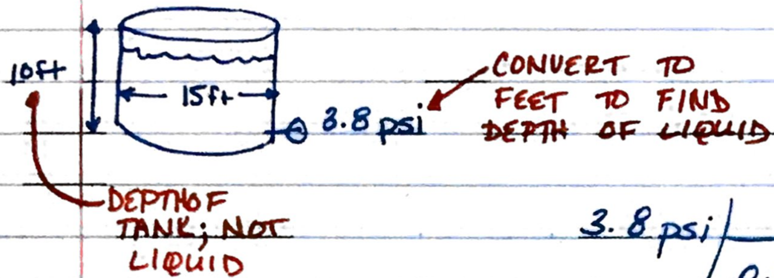
$67{,}200\ ft^3 \left| \frac{7.48\ gal}{1\ ft^3} \right| = 502{,}656$ gallons

5. Be careful – all the units need to go together.
$6\ inches \left| \frac{1\ ft}{12\ in} \right| = 0.5\ ft$

$Volume = 0.785d^2h$
$Volume = (0.785)(0.5\ ft)(0.5\ ft)(450\ ft)$
$Volume = 88.3125\ ft^3$

5. (cont.) $88.3125\ ft^3 \left| \frac{7.48\ gal}{1\ ft^3} \right| = 660$ gallons

6. WHEN IN DOUBT, DRAW A PICTURE.



$3.8\ psi \left| \frac{1\ ft}{0.433\ psi} \right| = 8.78\ ft$

$Volume = 0.785 d^2 h$

$Volume = (0.785)(15\ ft)(15\ ft)(8.78\ ft)$

$Volume = 1550.7675\ cf$

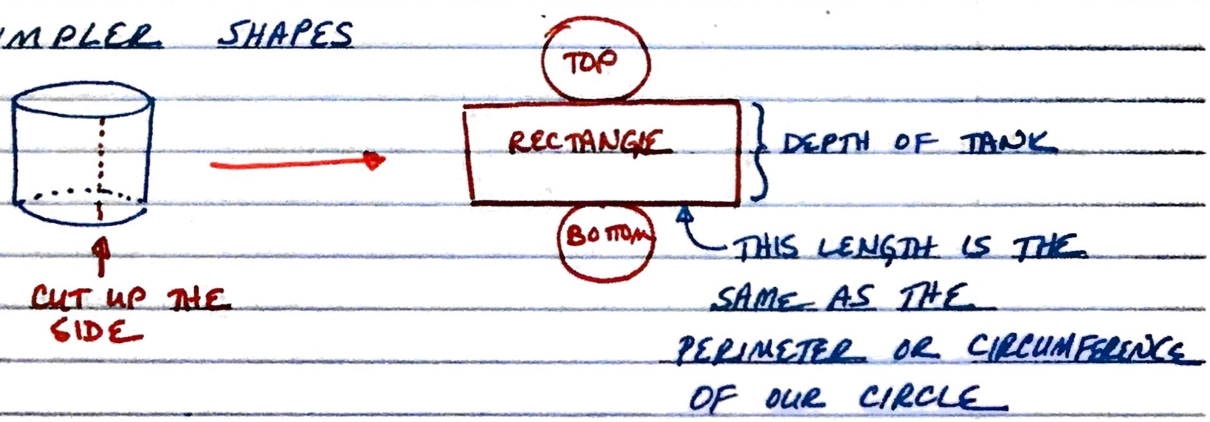
$1550.7675\ cf \left| \frac{7.48\ gal}{1\ cf} \right| = 11600$ gallons

7. $Circumference = \pi d$

$= (3.14)(80\ ft)$

$= 251.2\ ft$

8. STEP ONE IS TO OPEN THE TANK INTO SIMPLER SHAPES



B CONT. AREA OF RECTANGLE = (LENGTH)(WIDTH)

AREA OF RECTANGLE = (πd)(WIDTH)

↑ CIRCUMFERENCE

AREA OF RECTANGLE = (3.14)(50 FT)(25 FT)

= 3925 ft^2

BUT, I NEED THE INSIDE + THE OUTSIDE, SO MULTIPLY BY 2 = 7850 ft^2

AREA OF CIRCLE = $0.785\, d^2$

= (0.785)(50 FT)(50 FT)

= ~~7850~~ FT^2 This should be 1962.5 ft2.

BUT, I NEED THE INSIDE + OUTSIDE OF THE TOP AND THE INSIDE OF THE BOTTOM, SO MULTIPLY BY 3 = ~~23,550 ft~~ 5887.5 ft2.

Last, add the pieces together.

7850 ft^2

+ ~~23,550~~ 5887.5 ft2 ft^2

~~31,400~~ ft^2 13737.5 ft2

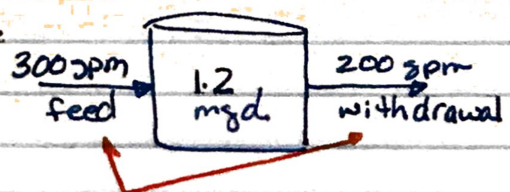
HYDRAULIC RETENTION TIME

1. $t = \frac{\text{Volume}}{\text{Flow}}$

$t = \frac{500 \text{ gallons}}{25 \text{ gal/min}}$

t = 20 minutes

2.



USE THE DIFFERENCE; 100gpm

here, detention time is the average time spent in the tank.

2. $time = \frac{Volume}{Flow}$

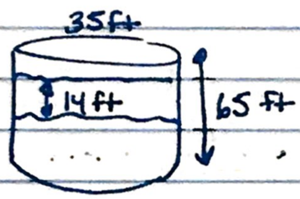
$time = \frac{1.2\ MG}{100\ gpm}$ ← UNITS DON'T MATCH

$time = \frac{1{,}200{,}000\ gallons}{100\ gpm}$

time = 12000 minutes ← THEY ASKED FOR HOURS

$12000\ minutes \times \frac{1\ hr}{60\ min} = 200$ HOURS

3.



dropped 14 ft in 5 hrs. This is the volume we are interested in.

$Volume = 0.785 d^2 h$

$Volume = (0.785)(35\ ft)(35\ ft)(14\ ft)$

$Volume = 13462.75\ cf$

$time = \frac{volume}{flow}$ ← we want flow in gpm, so volume needs to be in gallons

time needs to be in minutes

$13462.75\ ft^3 \times \frac{7.48\ gal}{1\ ft^3} = 100{,}701.37$ gallons

$5\ hrs \times \frac{60\ min}{1\ hr} = 300$ minutes

3 (cont.) $\text{time} = \frac{\text{Volume}}{\text{Flow}}$ AND $\text{Flow (gpm)} = \frac{\text{Volume}}{\text{time}}$ $\frac{\text{GAL}}{\text{MIN}}$

yes?

$\text{FLOW} = \frac{100{,}701.37 \text{ gallons}}{300 \text{ min}}$

FLOW = 336 gpm

4. $\text{time} = \frac{\text{Volume}}{\text{Flow gpm}}$ ← must be in gallons

(time) ↑ must be in minutes

$6 \text{ hrs} \left| \frac{60 \text{ min}}{1 \text{ hr}} \right| = 360 \text{ min}$

plus the extra 15 min = 375 min

$\text{time} = \frac{\text{Volume}}{\text{Flow}}$

$(250 \text{ gpm})(375 \text{ minutes}) = \left[\frac{\text{Volume}}{250 \text{ gpm}}\right] 250 \text{ gpm}$

move the 250 gpm to the other side by multiplying both sides by 250 gpm

these will cancel out + go away

93,750 gallons = Volume

VELOCITY

1. $\frac{ft}{s}$ $\text{Velocity} = \frac{\text{Flow (cfs)}}{\text{Area } (ft^2)}$

first, find area in ft^2

$42 \text{ inches} \left| \frac{1 \text{ ft}}{12 \text{ in}} \right| = 3.5 \text{ ft}$

1. (cont) AREA = $0.785\, d^2$

$= (0.785)(3.5\text{ ft})(3.5\text{ ft})$

$= 9.61625\text{ ft}^2$

$$\text{velocity} = \frac{\text{flow}}{\text{area}}$$

$$= \frac{35\text{ cfs}}{9.61625\text{ ft}^2}$$

$= 3.64$ ft/second

* note: you end up with cfs on top and ft^2 on the bottom. Here is what happens to the units.

these cancel to leave ft/s → $\frac{ft \cdot ft \cdot ft/sec}{ft \cdot ft}$

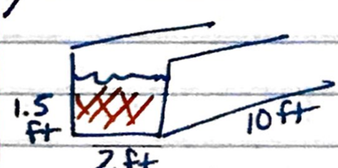
2. $$\text{Velocity} = \frac{\text{DISTANCE}}{\text{TIME}}$$

$$\text{Velocity} = \frac{450\text{ ft}}{68\text{ sec}}$$

Velocity = 6.6 ft/s

* two different formulas for velocity

3. The easy way to do this problem is to put all the flow through 1 grit basin.



WE NEED THE CROSS-SECTIONAL AREA SO:

THEN; CONVERT MGD TO CFS

$$3.5\text{ MGD} \left| \frac{1.55\text{ cfs}}{1\text{ MGD}} \right| = 5.425\text{ cfs}$$

AREA = (LENGTH)(WIDTH)

AREA = (2 FT)(1.5 FT)

AREA = 3 ft^2

3. velocity = $\frac{\text{flow}}{\text{area}}$

velocity = $\frac{5.425 \text{ cfs}}{3 \text{ ft}^2}$

velocity = 1.8 ft/s

velocity w/ 4L 1 grit basin on-line, so we need (2)

DISINFECTION

1. lb/d = (mg/L)(MGD)(8.34)

lb/d = (5 mg/L)(2.5 MGD)(8.34)

lb/d = 104.25

2. lb/d = (mg/L)(MGD)(8.34)

150 lb/d = (mg/L)(3.5 mgd)(8.34)

$\frac{150 \text{ lb/d}}{29.19} = \frac{(\text{mg/L})(29.19)}{29.19}$

5.14 = mg/L

① SIMPLIFY
② MOVE TO GET mg/L ALONE

3. DOSE = DEMAND + RESIDUAL

PUT IN OTHER WORDS

ADDED = USED + LEFT OVER

5.2 mg/L = USED + 0.5 mg/L

5.2 − 0.5 = USED + 0.5 − 0.5

4.7 mg/L = USED OR DEMAND

* NOW, SUBTRACT 0.5 mg/L FROM BOTH SIDES

4. MUST HAVE MGD, SO CONVERT FIRST

$\frac{600 \text{ gal}}{\text{min}} \times \frac{1440 \text{ min}}{1 \text{ day}} \times \frac{1 \text{ MG}}{1000000 \text{ gal}} = 0.864 \text{ mgd}$

4. (CONT) $lb/d = \frac{(mg/L)(MGD)(8.34)}{\% PURITY}$

$lb/d = \frac{(4.5 mg/L)(0.864 MGD)(8.34)}{0.15}$

$lb/d = 216.1728$

$216.1728 \text{ lbs} \left| \frac{1 \text{ gal}}{8.34 \text{ lbs}} \right| = 26 \text{ gallons}$

5. (A) DOSE = DEMAND + RESIDUAL

DOSE = 1.2 mg/L + 3.0 mg/L

DOSE = 4.2 mg/L

(B) $\frac{800 \text{ gal}}{\text{min}} \left| \frac{1440 \text{ min}}{1 \text{ day}} \right| \frac{1 \text{ MG}}{1000000 \text{ gal}} \right| = 1.152 \text{ mgd}$

(C) $lb/d = \frac{(mg/L)(mgd)(8.34)}{\% PURE}$

$lb/d = \frac{(4.2 mg/L)(1.152 mgd)(8.34)}{0.7}$

$lb/d = 57.6$

PUMPS

1. $HP_{MOTOR} = \frac{(gpm)(TDH, ft)}{(3960)(E_p)(E_m)}$ ← efficiency terms

$HP_{MOTOR} = \frac{(80 gpm)(225 ft)}{(3960)(0.85)(0.90)}$

$HP_{MOTOR} = 5.94$

↑ in practice, this would end up being a 7.5 HP PUMP

2. TOTAL RUN TIME = (8 hrs)(7 days)
= 56 hrs per week

$$25\text{ HP} \left| \frac{0.746\text{ kw}}{1\text{ HP}} \right| \frac{\$0.085}{1\text{ kwh}} \left| \frac{56\text{ hrs}}{} \right| = \$88.77$$

3. This is a geometry problem in disguise. Find the volume of the piston cavity.

Volume $= 0.785 d^2 h$ — 6 inches = 0.5 ft

Volume = (0.785)(0.5 ft)(0.5 ft)(0.5 ft)

Volume = 0.098125 ft^3

$$\frac{0.098125\text{ ft}^3}{\text{cycle}} \left| \frac{7.48\text{ gal}}{1\text{ ft}^3} \right| \frac{75\text{ cycles}}{1\text{ min}} \Big| = 55\ \frac{\text{gal}}{\text{min}}$$

4. $HP_{MOTOR} = \frac{(\text{gpm})(\text{TDH, ft})}{(3960)(E_p)(E_m)}$

$$1.865\text{ kw} \left| \frac{1\text{ HP}}{0.746\text{ kw}} \right| = 2.5\text{ HP}$$

$2.5\text{ HP} = \frac{(150\text{ gpm})(50\text{ ft})}{(3960)(E_p)(E_m)}$ — * simplify

$2.5\text{ HP} = \frac{1.893}{(E_p)(E_m)}$ — * rearrange

$(2.5\text{ HP})(E_p)(E_m) = \frac{(1.893)(E_p)(E_m)}{(E_p)(E_m)}$

$\frac{(2.5\text{ HP})(E_p)(E_m)}{2.5} = \frac{1.893}{2.5}$

$(E_p)(E_m) = 0.758$

75.8% overall efficiency