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FABE 5820 SECOND EXAM
Open book, open notes

Work rapidly. Present fundamental equations used. Show all work and units. Cite all assumptions and references. The point value of each question is shown in the margin (Total = 100 pts).

1. Design a mechanical ventilation system for a community theater house located in Bakersfield, California. Assume an exhaust ventilation system and 99% heating season design conditions. Given the following:

   A/R_t value for the building = 127 btu/hr °F
   t_i (design) = 70°F (winter) to 76 °F (summer)
   RH_i all-season design = 50%
   RH_o winter design = 70%
   q_S = 12,000 BTU/hr at all T_i of interest
   q_L = 5,056 BTU/hr at all T_i of interest

100% PERFECT SCORE!

A. (15 pts) What winter ventilation rate would you specify (CFM)?
Sketch your psych chart and show all work and logic.

$t_o = 35.0$°F

Humidity control

$Q = \dfrac{V q_L}{h_{fg}(60)(\omega_2-\omega_1)}$

From psych chart @ indoor conditions (1)
(70°F and 50%)

$\omega_2 = 0.0078 \frac{lb}{lb\,da}$

From psych chart @ outdoor conditions (2)
(35°F and 70%)

$\omega_1 = 21 \frac{grains}{lb\,da}\left(\frac{1\ lb\,da}{7000\ grains}\right) = 0.003 \frac{lb}{lb\,da}$

Exhaust ventilation system, so must use V_{indoor}
→ From psych chart @ indoor conditions
(70°F and 50%)

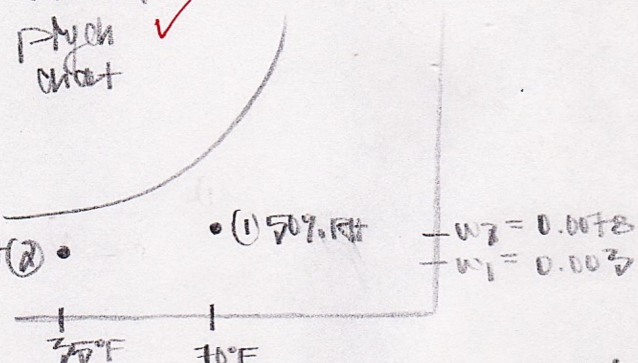
$V = 13.5 \frac{ft^3}{lb\,da}$

From ASHRAE 2013, p. 1.9, Table 3, @ t_i = 70°F,

$h_{fg} = 1053.7 \frac{BTU}{lb}$

$Q = \dfrac{\left(13.5 \frac{ft^3}{lb\,da}\right)\left(5{,}056 \frac{BTU}{hr}\right)}{\left(1053.7 \frac{BTU}{lb}\right)(60)(0.0078-0.003)\frac{lb}{lb\,da}}$

$Q = 224.9$ cfm



temperature control

$Q = \dfrac{V}{(60)(c_p)(t_i-t_o)}\left[q_s - \frac{A}{R_t}(t_i-t_o)\right]$

$Q = \dfrac{13.5 \frac{ft^3}{lb\,da}}{(60)\left(0.24 \frac{BTU}{lb\,°F}\right)(70-35)°F}\left[12{,}000 \frac{BTU}{hr} - \left(127 \frac{BTU}{hr\,°F}\right)(70-35)°F\right]$

$Q = 202.4$ cfm < 224.9 cfm

therefore,

$\boxed{Q = 224.9 \text{ CFM}}$

round up to closest 50 cfm:

$\boxed{Q = 250 \text{ CFM}}$

* use room V of 1st page! *

(5 pts) B. Assuming Δt = 10°F, what fall-spring ventilation rate would you recommend for temperature control (CFM)?

$$Q = \frac{13.5\ \frac{ft^3}{lb_{da}}}{(60)(0.24\ \frac{BTU}{lb°F})(10°F)}\left[12{,}000\ \frac{BTU}{hr} - \left(127\ \frac{BTU}{hr°F}\right)(10°F)\right] = \boxed{1005.9\ cfm}$$

round up to nearest 50 cfm; $\boxed{1050\ CFM}$

(5 pts) C. Assuming Δt = 5°F, what summer ventilation rate would you recommend (CFM)?

$$Q = \frac{13.5\ \frac{ft^3}{lb_{da}}}{(60)(0.24\ \frac{BTU}{lb°F})(5F)}\left[12{,}000\ \frac{BTU}{hr} - \left(127\ \frac{BTU}{hr°F}\right)(5°F)\right] = \boxed{2130.9\ CFM}$$

round up to nearest 50 cfm; $\boxed{2150\ CFM}$

(15 pts) D. Assume that you can specify fans of any size and that you must use four fans. What fan sizes would you recommend and when would they turn on? Assume that the first three fans are for fall-spring conditions and colder and that all four fans will run for maximum summer conditions. None of the fans can provide variable output flow rates.

t_i = 70°F to 74°F

350 CFM to run continuously (for fall-spring conditions)$\left(=\frac{1050\ cfm}{3}\right)$

350 CFM to turn on when $t_i \geq$ 71 °F (= 1050 cfm/3)

350 CFM to turn on when $t_i \geq$ 73 °F (= 1050 cfm/3)

1100 CFM to turn on when $t_i \geq$ 75 °F (= 2150 CFM − 1050 cfm)

2. Calculate the temperature in an attic in Dublin, Ireland, at 99.6% winter design conditions where the temperature in the room below the attic is 70°F. Assume the attic is sealed tightly and has no natural or mechanical ventilation. The AU-values are as follows:

AU_{roof} = 113 BTU/hr°F

AU_{gables} = 345 BTU/hr°F

$AU_{ceiling}$ = 733 BTU/hr°F

(10 pts)

t_o = 27.2°F

No natural or mechanical ventilation

$\cancel{q_{ventilation}} = q_f - q_b$

$q_b = q_f$

$AU_{roof}\,\Delta t + AU_{gables}\,\Delta t = AU_{ceiling}\,\Delta t$

$\left(113\ \frac{BTU}{hr°F} + 345\ \frac{BTU}{hr°F}\right)(t_i - 27.2°F) = \left(733\ \frac{BTU}{hr°F}\right)(70°F - t_i)$

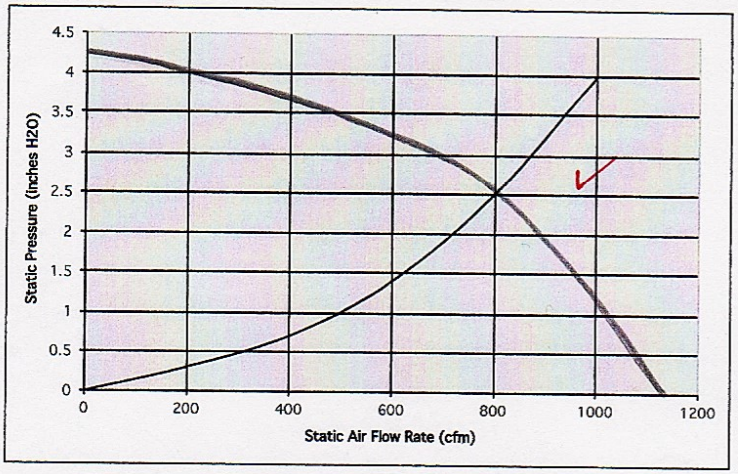
$458t - 12457.4 = 51310 - 733t$

$\frac{1191t}{1191} = \frac{63767.4}{1191}$

$\boxed{t_i = 53.5°F}$

3. The characteristic curve for a duct system is presented below. Sketch in a hypothetical fan curve that would operate at the farmer's desired airflow rate of 800 CFM. Identify the operating point values (Q, P_s) in the blanks below the graph.

(10 pts)



Operating Point = 800 CFM at 2.5 inches H_2O static pressure

4. Using the appropriate fan laws (show your work and document all equations used), fill in the table below with four values showing how air flow rate and static pressure will change when an original fan is modified to increase fan diameter or speed.:

(15 pts)

ORIGINAL FAN		effect of changing diameter		effect of changing speed	
D = 12 inches, N = 2000rpm		**D = 20 inches,** N = 2000rpm		D = 12 inches, **N = 3000 rpm**	
Q (cfm)	**Static P (in)**	**Q (cfm)**	**Static P (in)**	**Q (cfm)**	**Static P (in)**
400	0.5	1852	1.39	600	1.13

changing diameter, D

$$P_2 = P_1\left(\frac{D_2}{D_1}\right)^2$$

$$Q_2 = Q_1\left(\frac{D_2}{D_1}\right)^3$$

$$P_2 = 0.5\,in\left(\frac{20\,in}{12\,in}\right)^2 = 1.39\,in$$

$$Q_2 = 400\,cfm\left(\frac{20\,in}{12\,in}\right)^3 = 1852\,cfm$$

changing speed, N

$$P_2 = P_1\left(\frac{N_2}{N_1}\right)^2$$

$$Q_2 = Q_1\left(\frac{N_2}{N_1}\right)$$

$$P_2 = 0.5\,in\left(\frac{3000\,rpm}{2000\,rpm}\right)^2 = 1.125\,in$$

$$Q_2 = 400\,cfm\left(\frac{3000\,rpm}{2000\,rpm}\right) = 600\,cfm$$

5. An Arabian horse stable outside of Dallas, Texas, has an internal sensible heat production of 33,740 BTU/hr, an AU-value of 715 BTU/hr°F, and a ventilation rate of 900 cfm. Indoor design temperature, $T_i = 65°F$. Using the bin method, answer the following questions:

$Q = 900$ cfm

$q_s = 33{,}740 \frac{BTU}{hr}$

$t_i = 65°F$

$AU = 715 \frac{BTU}{hr°F}$

(5 pts) A. What is the balance point temperature, $T_{o\,(bal)}$?

$$T_{o(bal)} = t_i - \left[\frac{q_s}{AU + 1.08\,Q}\right] = 65°F - \left[\frac{33{,}740 \frac{BTU}{hr}}{715\frac{BTU}{hr°F} + 1.08(900\,cfm)}\right] = \boxed{45°F}$$

(10 pts) B. How many actual hours would be used for the bin containing the balance point temperature?

1st partial bin → highest bin that includes the balance temp. → 45/49°F bin

$$hours = bin(hrs)\left(\frac{t_{bal} - t_{binmin}}{5°F}\right) = 615\,hrs\left(\frac{45 - 44.5°F}{5°F}\right) = 61.5\,hours$$

$$\boxed{61.5\ hours}$$

(10 pts) C. How much energy (MBTU, million BTUs) is required for the 32°F (30/34°F) bin?

30/34 $t_{avg} = 32°F$ 289 hours

$\Delta t = t_i - t_{avg}$

$= 65 - 32 = 33°F$

$q_{vent} = 1.08\,Q\,\Delta t$

$= 1.08(900\,cfm)(33°F)$

$= 32{,}076 \frac{BTU}{hr}$

$q_{bldg} = AU\,\Delta t$

$= (715 \frac{BTU}{hr°F})(33°F)$

$= 23{,}595 \frac{BTU}{hr}$

$q_{NR} = q_{vent} + q_{bldg} - q_s$

$= (32{,}076 + 23{,}595 - 33{,}740) \frac{BTU}{hr}$

$= 21{,}931 \frac{BTU}{hr}$

$E = q_{NR} \times hours$

$= (21{,}931 \frac{BTU}{hr})(289\,hours)$

$= 6338059\,BTU$

$= \boxed{6.34\,MBTU}$