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# UNIVERSITI TUN HUSSEIN ONN MALAYSIA

## FINAL EXAMINATION

## SEMESTER I
## SESSION 2021/2022

| | | |
|---|---|---|
| COURSE NAME | : | AIR CONDITIONING SYSTEM DESIGN |
| COURSE CODE | : | BBA40603 |
| PROGRAMME CODE | : | BBG |
| EXAMINATION DATE | : | JANUARY / FEBRUARY 2022 |
| DURATION | : | 3 HOURS |
| INSTRUCTION | : | 1. ANSWER **ALL** QUESTIONS<br>2. THIS FINAL EXAMINATION IS A **ONLINE** ASSESSMENT AND CONDUCTED VIA **CLOSE BOOK.** |

THIS QUESTION PAPER CONSISTS OF **TWENTY-ONE (21)** PAGES

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**SECTION A (20 marks)**

**Q1.** Why is it necessary to calculate the cooling load of a room?

A. It defines the shape and volume of the room.
B. It is unnecessary, as rooms are only calculated in terms of area
C. To estimate the capacity that is required for cooling the room.
D. None above

**Q2.** What is the Cooling Load?

A. It is the amount of heat that must be added or be removed from a place so that we able to control its pressure
B. It is the amount of heat that must be added or be removed from a place so that we able to control its temperature
C. It is the amount of heat that must be added or be removed from a place so that we able to control its humidity
D. It is the amount of heat that must be added or be removed from a place so that we able to control its pressure & temperature

**Q3.** Select the main types of heat loads included in space load calculation.

I. Transmission loads
II. Solar radiation
III. People
IV. Infiltration
V. Ventilation

A. I, II, III, & IV
B. I, II, III, & V
C. I, III, IV, & V
D. II, III, IV, & V

**Q4.** What is transmission load?

A. Transmission load is the total heat load calculation through the roof, and we also need to consider the effect of solar radiation.
B. Transmission load is the total heat load calculation through the walls, and we also need to consider the effect of solar radiation.
C. Transmission load is the total heat load calculation through the walls, roof, and floor, and we also need to consider the effect of solar radiation.
D. Transmission load is the total heat load calculation through the floor, and we also need to consider the effect of solar radiation.

**Q5.** When specifying how many tons of cooling capacity for a building's chiller, you should look at what cooling load?

A. Overall building sensible cooling load
B. Space sensible plus latent cooling load
C. Overall building sensible plus latent cooling load
D. Space sensible cooling load only

**Q6.** As shown below, increasing the number of people in space, impacts the cooling load estimate with…

A. no effect
B. increase the inside design temperature
C. increasing the cooling load
D. decreasing the cooling load

**Q7.** Assume you calculated the sensible and latent cooling loads for a dance studio and discovered that the sensible cooling load is 64,000 BTU/hr and the latent cooling load is 12,500 BTU/hr. What is the sensible heat ratio?

A. 0.16
B. 0.55
C. 0.84
D. 1.20

**Q8.** To determine the design CFM for an air handler serving several zones using a variable air volume (VAV) system…

A. one needs to determine the time that the maximum cooling load occurs for all the zones that the air handler serves and then use that value to calculate the CFM required.
B. It is done the same way as selecting the design cooling load for a constant air volume (CAV) system handler.
C. One needs to determine the max cooling load for each zone served by the air handler, add these values to get a total cooling load, and then use the total cooling load to calculate the CFM.
D. None of the above answers

**Q9.** What is the U-A value for a glass window unit (see **Table Q9**) with the condition as below?

*Size $5ft \times 7ft$ vertical window*
*Winter condition*
*Insulating glass unit with a 1/4 in glass and 1/2 in. air space.*
*Interior shading*

**Table Q9: Overall Coefficients of Heat Transmission (U-Factor) of Windows and Skylights, Btu/(hr.ft2.F)**

| Description | Exterior Vertical Panels | | | | Exterior Horizontal Panels (Skylights) | |
|---|---|---|---|---|---|---|
| | Summer | | Winter | | | |
| | No Indoor Shade | Indoor Shade | No Indoor Shade | Indoor Shade | Summer | Winter |
| Flat glass | | | | | | |
| Single Glass | 1.04 | 0.81 | 1.1 | 0.83 | 0.83 | 1.23 |
| Insulating Glass, Double | | | | | | |
| 3/16 in. air space (0.125 in. glass) | 0.65 | 0.58 | 0.62 | 0.52 | 0.57 | 0.70 |
| 1/4 in. air space (0.125 in. glass) | 0.61 | 0.55 | 0.58 | 0.48 | 0.54 | 0.65 |
| 1/2 in. air space (0.25 in. glass) | 0.56 | 0.52 | 0.49 | 0.42 | 0.49 | 0.59 |
| 1/2 in. air space | | | | | | |
| low emittance coating | | | | | | |
| e = 0.20 | 0.38 | 0.37 | 0.32 | 0.30 | 0.36 | 0.48 |
| e = 0.40 | 0.45 | 0.44 | 0.38 | 0.35 | 0.42 | 0.52 |
| e = 0.60 | 0.51 | 0.48 | 0.43 | 0.38 | 0.46 | 0.56 |
| Insulating Glass, Triple | | | | | | |
| 1/4 in. air space | 0.44 | 0.40 | 0.39 | 0.31 | | |
| 1/2 in. air space | 0.39 | 0.36 | 0.31 | 0.26 | | |
| Storm Windows | | | | | | |
| 1 in. to 4 in. air spaces | 0.50 | 0.48 | 0.50 | 0.42 | | |
| Plastic Bubbles | | | | | | |
| Single | | | | | 0.80 | 1.15 |
| Double | | | | | 0.46 | 0.70 |

A. 0.56
B. 14.70
C. 17.92
D. 19.52

**Q10.** What is the CLTD value for a wall (see **Table Q10**) with the condition as below?

*Wall type A*
*Wall surface: Light-colored exterior surface south façade*
*Time & Month: 1600 in July*

**Table Q10: CLTDs for Sunlit Walls**

| | Group A Walls | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Solar Time, hr | | | | | | | | | | | | | | | | | | | |
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** |
| **N** | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 2 | 2 | 3 | 4 | 4 | 6 | 7 | 8 | 9 | 11 | 12 | 12 |
| **NE** | 10 | 8 | 7 | 6 | 5 | 4 | 3 | 3 | 3 | 6 | 9 | 11 | 13 | 14 | 14 | 15 | 15 | 16 | 16 | 15 |
| **E** | 11 | 9 | 8 | 7 | 6 | 4 | 3 | 3 | 4 | 7 | 11 | 14 | 18 | 20 | 21 | 21 | 21 | 20 | 19 | 18 |
| **SE** | 11 | 9 | 8 | 7 | 6 | 4 | 3 | 3 | 3 | 5 | 7 | 11 | 14 | 17 | 19 | 20 | 21 | 20 | 19 | 19 |
| **S** | 12 | 10 | 8 | 7 | 6 | 4 | 3 | 3 | 2 | 2 | 2 | 3 | 6 | 8 | 11 | 14 | 16 | 18 | 19 | 19 |
| **SW** | 17 | 14 | 12 | 10 | 8 | 7 | 5 | 4 | 3 | 3 | 3 | 3 | 4 | 6 | 8 | 11 | 14 | 18 | 22 | 24 |
| **W** | 19 | 17 | 14 | 12 | 9 | 8 | 6 | 4 | 4 | 3 | 3 | 4 | 4 | 6 | 7 | 9 | 12 | 17 | 21 | 24 |
| **NW** | 16 | 14 | 12 | 9 | 8 | 6 | 5 | 4 | 3 | 3 | 3 | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 16 | 19 |

A. 9
B. 21
C. 14
D. 16

**Q11.** What is the Solar Heat Gain Factor (SHGF) value for window glass (see **Table Q11**) with the condition as below?

*Glass facing west*
*December 21 at 0 deg N lat*

**Table Q11: Maximum Solar Heat Gain Factor (SHGF) for Sunlit Glass**

**0 Deg**

| | N | NNE/ NNW | NE/ NW | ENE/ WNW | E/ W | ESE/ WSW | SE/ SW | SSE/ SSW | S | HOR |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 34 | 34 | 88 | 177 | 234 | 254 | 235 | 182 | 118 | 296 |
| Feb | 36 | 39 | 132 | 205 | 245 | 247 | 210 | 141 | 67 | 306 |
| Mar. | 38 | 87 | 170 | 223 | 242 | 223 | 170 | 87 | 38 | 303 |
| Apr. | 71 | 134 | 193 | 224 | 221 | 184 | 118 | 38 | 37 | 284 |
| May | 113 | 164 | 203 | 218 | 201 | 154 | 80 | 37 | 37 | 265 |
| June | 129 | 173 | 206 | 212 | 191 | 140 | 66 | 37 | 37 | 255 |
| July | 115 | 164 | 201 | 213 | 195 | 149 | 77 | 38 | 38 | 260 |
| Aug. | 75 | 134 | 187 | 216 | 212 | 175 | 112 | 39 | 38 | 276 |
| Sep | 40 | 84 | 163 | 213 | 231 | 213 | 163 | 84 | 40 | 293 |
| Oct. | 37 | 40 | 129 | 199 | 236 | 238 | 202 | 135 | 66 | 299 |
| Nov. | 35 | 35 | 88 | 175 | 230 | 250 | 230 | 179 | 117 | 293 |
| Dec. | 34 | 34 | 71 | 164 | 226 | 253 | 240 | 196 | 138 | 288 |

**16 Deg**

| | N | NNE/ NNW | NE/ NW | ENE/ WNW | E/ W | ESE/ WSW | SE/ SW | SSE/ SSW | S | HOR |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 30 | 30 | 55 | 147 | 210 | 244 | 251 | 223 | 199 | 248 |
| Feb. | 33 | 33 | 96 | 180 | 231 | 247 | 233 | 188 | 154 | 275 |
| Mar. | 35 | 53 | 140 | 205 | 239 | 235 | 197 | 138 | 93 | 291 |
| Apr. | 39 | 99 | 172 | 216 | 227 | 204 | 150 | 77 | 45 | 289 |
| May | 52 | 132 | 189 | 218 | 215 | 179 | 115 | 45 | 41 | 282 |
| June | 66 | 142 | 194 | 217 | 207 | 167 | 99 | 41 | 41 | 277 |
| July | 55 | 132 | 187 | 214 | 210 | 174 | 111 | 44 | 42 | 277 |
| Aug. | 41 | 100 | 168 | 209 | 219 | 196 | 143 | 74 | 46 | 282 |
| Sep. | 36 | 50 | 134 | 196 | 227 | 224 | 191 | 134 | 93 | 282 |
| Oct. | 33 | 33 | 95 | 174 | 223 | 237 | 225 | 183 | 150 | 270 |
| Nov. | 30 | 30 | 55 | 145 | 206 | 241 | 247 | 220 | 196 | 246 |
| Dec. | 29 | 29 | 41 | 132 | 198 | 241 | 254 | 233 | 212 | 234 |

**4 Deg**

| | N | NNE/ NNW | NE/ NW | ENE/ WNW | E/ W | ESE/ WSW | SE/ SW | SSE/ SSW | S | HOR |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 33 | 33 | 79 | 170 | 229 | 252 | 237 | 193 | 141 | 286 |
| Feb. | 35 | 35 | 123 | 199 | 242 | 248 | 215 | 152 | 88 | 301 |
| Mar. | 38 | 77 | 163 | 219 | 242 | 227 | 177 | 96 | 43 | 302 |
| Apr. | 55 | 125 | 189 | 223 | 223 | 190 | 126 | 43 | 38 | 287 |
| May | 93 | 154 | 200 | 220 | 206 | 161 | 89 | 38 | 38 | 272 |
| June | 110 | 164 | 202 | 215 | 196 | 147 | 73 | 38 | 38 | 263 |
| July | 96 | 154 | 197 | 215 | 200 | 156 | 85 | 39 | 38 | 267 |
| Aug. | 59 | 124 | 184 | 215 | 214 | 181 | 120 | 42 | 40 | 279 |
| Sep. | 39 | 75 | 156 | 209 | 231 | 216 | 170 | 93 | 44 | 293 |
| Oct. | 36 | 36 | 120 | 193 | 234 | 239 | 207 | 148 | 86 | 294 |
| Nov. | 34 | 34 | 79 | 168 | 226 | 248 | 232 | 190 | 139 | 284 |
| Dec. | 33 | 33 | 62 | 157 | 221 | 250 | 242 | 206 | 160 | 277 |

**20 Deg**

| | N | NNE/ NNW | NE/ NW | ENE/ WNW | E/ W | ESE/ WSW | SE/ SW | SSE/ SSW | S | HOR |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 29 | 29 | 48 | 138 | 201 | 243 | 253 | 233 | 214 | 232 |
| Feb. | 31 | 31 | 88 | 173 | 226 | 244 | 238 | 201 | 174 | 263 |
| Mar. | 34 | 49 | 132 | 200 | 237 | 236 | 206 | 152 | 115 | 284 |
| Apr. | 38 | 92 | 166 | 213 | 228 | 208 | 158 | 91 | 58 | 287 |
| May | 47 | 123 | 184 | 217 | 217 | 184 | 124 | 54 | 42 | 283 |
| June | 59 | 135 | 189 | 216 | 210 | 173 | 108 | 45 | 42 | 279 |
| July | 48 | 124 | 182 | 213 | 212 | 179 | 119 | 53 | 43 | 278 |
| Aug. | 40 | 91 | 162 | 206 | 220 | 200 | 152 | .88 | 57 | 280 |
| Sep. | 36 | 46 | 127 | 191 | 225 | 225 | 199 | 148 | 114 | 275 |
| Oct. | 32 | 32 | 87 | 167 | 217 | 236 | 231 | 196 | 170 | 258 |
| Nov. | 29 | 29 | 48 | 136 | 197 | 239 | 249 | 229 | 211 | 230 |
| Dec. | 27 | 27 | 35 | 122 | 187 | 238 | 254 | 241 | 226 | 217 |

A. 187
B. 198
C. 226
D. 221

**Q12.** What is the Shading Coefficient (SC) value for window glass (see **Table Q12**) with the condition as below?

*Sunlit double insulating glass window*
*Heat absorbing gray-tinted outer glass (1/4 in.)*
*3/16 in. air space*
*Clear inner glass (1/4 in.)*
*Unshaded outside & inside ($h_o$ = 3.0)*

**Table Q12: Shading Coefficients for Glass without or with Interior shading.**

| | Types of Glass | Nominal Thickness each Light | No Interior Shading | | Types of Interior Shading | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Venetian Blinds | | Roller Shades | | |
| | | | | | | | Opaque | | Translucent |
| | | | $h_o = 4.0$ | $h_o = 3.0$ | Medium | Light | Dark | Light | Light |
| SINGLE GLASS | Single | | | | | | | | |
| | Clear | 3/32 to 1/4 | 1.00 | 1.00 | | | | | |
| | Clear | 1/4 to 1/2 | 0.94 | 0.95 | | | | | |
| | Clear | 3/8 | 0.90 | 0.99 | 0.64 | 0.55 | 0.59 | 0.25 | 0.39 |
| | Clear | 1/2 | 0.87 | 0.88 | | | | | |
| | Clear Pattern | 1/8 to 9/32 | 0.83 | 0.85 | | | | | |
| | Heat Absorbing Pattern | 1/8 | 0.83 | 0.85 | | | | | |
| | Heat Absorbing | 3/16 to 1/4 | 0.69 | 0.73 | | | | | |
| | Heat Absorbing Pattern | 3/16 to 1/4 | 0.69 | 0.73 | 0.57 | 0.53 | 0.45 | 0.30 | 0.36 |
| | Tinted | 1/8 to 7/32 | 0.69 | 0.73 | | | | | |
| | Heat Absorbing or Pattern | | 0.60 | 0.64 | 0.54 | 0.52 | 0.40 | 0.28 | 0.32 |
| | Heat Absorbing | 3/8 | 0.60 | 0.64 | | | | | |
| INSULATING GLASS | Double | | | | | | | | |
| | Clear Out / Clear In | 3/32, 1/8 | 0.88 | 0.88 | 0.57 | 0.51 | 0.60 | 0.25 | 0.37 |
| | Clear Out / Clear In | 1/4 | 0.81 | 0.82 | | | | | |
| | Heat Absorbing Out / Clear In | 1/4 | 0.55 | 0.58 | | | | | |
| | Triple | | | | | | | | |
| | Clear | 1/4 | 0.71 | | | | | | |
| | Clear | 1/8 | 0.80 | | | | | | |

A. 0.73
B. 0.69
C. 0.55
D. 0.58

**Q13.** Given the following design conditions, determine the cooling load at 1200 hours due to lighting within the space:

- Lights on from 8.00 am until 6.00 pm
- Two (2) 40-W lamps per fixture, 12 fixtures with only 9 on at a time
- Ballast factor = 1.20
- CLF = 0.72

A. 88 Btu/hr
B. 311 Btu/hr
C. 2122 Btu/hr
D. 2946 Btu/hr

**Q14.** Determine the total cooling load at 1200 hours due to 6 people in an office from 9.00 am to 5.00 pm based on the data given and referring to **Table Q14**. The office temperature is 78°F.

$Q_S$/person = 230 Btu/hr
$Q_L$/person = 190 Btu/hr

**Table Q14: Sensible heat cooling load factors for people**

| Total hours in space | Hours after people enter space | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 2 | 0.65 | 0.74 | 0.16 | 0.11 | 0.08 | 0.06 | 0.05 | 0.04 | 0.03 | 0.02 | 0.02 | 0.01 |
| 4 | 0.65 | 0.75 | 0.81 | 0.85 | 0.24 | 0.17 | 0.13 | 0.10 | 0.07 | 0.06 | 0.04 | 0.03 |
| 6 | 0.65 | 0.75 | 0.81 | 0.85 | 0.89 | 0.91 | 0.29 | 0.20 | 0.15 | 0.12 | 0.09 | 0.07 |
| 8 | 0.65 | 0.75 | 0.81 | 0.85 | 0.89 | 0.91 | 0.93 | 0.95 | 0.31 | 0.22 | 0.17 | 0.13 |
| 10 | 0.65 | 0.75 | 0.81 | 0.85 | 0.89 | 0.91 | 0.93 | 0.95 | 0.96 | 0.97 | 0.33 | 0.24 |

A. 1140 Btu
B. 1380 Btu
C. 2280 Btu
D. 2520 Btu

**Q15.** Which of the following is not one of the three methods used to size duct systems?

A. static gain
B. equal friction
C. equal freedom of flow
D. equal velocity

**Q16.** Typical duct velocities for low-velocity systems are shown in **Table Q16**. What is the airflow of the main duct supply for hospital bedrooms in feet per minute?

**Table Q16: Suggested duct velocities for a low-velocity duct system, ft/min (m/s)**

| | Main ducts | | Branch ducts | |
|---|---|---|---|---|
| Application | Supply | Return | Supply | Return |
| Residences | 1,000 (5.1) | 800 (4.1) | 600 (3) | 600 (3) |
| Apartments<br>Hotel bedrooms<br>Hospital bedrooms | 1,500 (7.6) | 1,300 (6.6) | 1,200 (6.1) | 1,000 (5.1) |
| Private offices<br>Director's rooms<br>Libraries | 1,800 (9.1) | 1,400 (7.1) | 1,400 (7.1) | 1,200 (6.1) |
| Theaters<br>Auditoriums | 1,300 (6.6) | 1,100 (5.6) | 1,000 (5.1) | 800 (4.1) |
| General offices<br>Expensive restaurants<br>Expensive stores<br>Banks | 2,000 (10.2) | 1,500 (7.6) | 1,600 (8.1) | 1,200 (6.1) |
| Average stores<br>Cafeterias | 2,000 (10.2) | 1,500 (7.6) | 1,600 (8.1) | 1,200 (6.1) |
| Industrial | 2,500 (12.7) | 1,800 (9.1) | 2,200 (11.2) | 1,600 (8.1) |

A. 1000
B. 1200
C. 1300
D. 1500

**Q17.** What does it indicate by equal friction in a duct system?

A. this method of sizing supply duct systems figures constant pressure loss per unit length
B. this method of sizing return duct systems figures constant pressure loss per unit length
C. this method of design is computer-operated
D. this describes the unit of measure in which airflow is gauged

**Q18.** Which of the following is how the duct sizes on the air friction chart are expressed?
A. Square
B. Round
C. Oval
D. Rectangular

**Q19.** The average velocity of a 20-in round duct is 85fpm. What is the airflow (cfm) in the duct?

A. 112
B. 152
C. 171
D. 185

**Q20.** With no shading, a room has a total window area of $100ft^2$. The temperature in the room is 80°F, and the daily average temperature outside is 84°F. At 4 pm solar time, what is the cooling load from conduction heat gain through the glass?
Note: This window features a single pane of glass and an aluminum sash with a thermal break (U = 0.81 Btu / (hr.ft.F)

A. 324 Btu/hr
B. 400 Btu/hr
C. 64,800 Btu/hr
D. 80,000 Btu/hr

**SECTION B (80 marks)**

**Q21** (a) According to ASHRAE (2013), what is the definition of thermal comfort?

(2 marks)

(b) Describe four (4) of the environmental and human-related characteristics that can impact the thermal comfort of building occupants.

(8 marks)

(c) You intended to move to a new apartment flat and have shortlisted 3 units as indicated (A, B and C) in **Figure Q21(c)**. Which of the three units will be the worst choice in terms of thermal comfort? State your reasons.

(5 marks)

(d) Calculate the winter U-factor for a wall made up of 4 inch (100 mm) face brick (K = 1.1 W/m K), 4 inch (100 mm) common brick (K=0.6 W/m K), and 1/2 inch (13 mm) gypsum plaster (K=0.11 W/m K).

(3 marks)

**Q22** (a) Referring to the following information, **Figure Q22 (a), Table Q22 (a-i)**, and **Table Q22 (a-ii)** calculate the heat gain by conduction through an east-facing wall at Hour 12 in July for Room 102 located at Kuala Lumpur (3.1390° N, 101.6869° E) which is a new building (K=0.83).

- Group D walls
- Floor-to-ceiling height = 12.14 ft
- U-factor of the wall = 0.284 $Btu/(hr \cdot ft^2 \cdot °F)$
- Indoor dry-bulb temperature = 78 $°F$
- Outdoor dry-bulb temperature = 95 °F

(5 marks)

(b) Referring to the following information, **Figure Q22 (a), Figure Q22 (b), Table Q22 (b-i), Table Q22 (b-ii),** and **Table Q22 (b-iii),** calculate the heat gain by solar radiation through the windows on a west-facing wall at Hour 14 in July for Room 101 at Kuala Lumpur (3.1390° N, 101.6869° E).

- Eight (8) single-layer clear windows with interior shading light roller type. Each window is 3.94ft wide x 4.92ft high.

(5 marks)

(c) Referring to the following information, calculate both the sensible and latent heat gains due to air infiltration from outdoors for Room 101.

- Area of floor = 247.57 $ft^2$
- Floor-to-ceiling height = 12.14 ft
- Amount of infiltration = 0.76 air change/hour
- Indoor conditions = 75 °F dry-bulb temperature and 0.009 specific humidity
- Outdoor conditions = 100 °F dry-bulb temperature and 0.02 specific humidity

(7 marks)

(d) Referring to the following information, **Table Q22 (d-i)** and **Table Q22 (d-ii)** calculate the internal heat gains from people and lighting.

- Number of people = 10 with peoples participating in moderately active office work. CLF = 0.84
- Only 8 lamps were used from 10 lamps.
- Working hours = 8 hours
- a classification = 0.55
- b classification = C
- Designing time = 16
- Amount of lighting in space = 1.1watt/ft$^2$
- Area of floor = 247.57 ft$^2$
- Ballast factor = 1.3 (fluorescent lights)

(7 marks)

**Q23** (a) Given the following components of cooling load in **Table Q23(a):**

**Table Q23(a)**

| | Sensible heat gain (W) | Latent heat gain (W) |
|---|---|---|
| Conduction through roof | 2050 | |
| Conduction through exterior walls | 200 | |
| Conduction through windows | 400 | |
| Solar radiation through windows or skylights | 5000 | |
| Heat gain from people | 2000 | 950 |
| Heat gain from lights | 6500 | |
| Heat gain from office equipment's | 2500 | |
| Air infiltration through cracks from outdoors | 800 | 650 |
| Cooling load due to ventilation brought in by the central HVAC system | 1850 | 1900 |
| Heat gains from the supply fan | 1000 | |

i. Calculate the sensible heat ratio for the space?

(4 marks)

ii. Assuming the air is supplied to the space at 13°C dry-bulb and the space dry-bulb temperature is 25°C, calculate the quantity of air must be supplied to the space?

(5 marks)

(b) The following sensible heat gains exist for three spaces being served by the same centralized HVAC systems are shown in **Table Q23(b)**;

**Table Q23(b)**

| | **Total space sensible heat gain (W)** | |
|---|---|---|
| | **9.00 am** | **4.00 pm** |
| Room 201 | 20,500 | 6,000 |
| Room 202 | 10,000 | 25,000 |
| Room 203 | 24,500 | 6,000 |

i. Explain when does the block load occurs?

(4 marks)

ii. Calculate the block space sensible load?

(2 marks)

iii. Suppose that you are sizing a constant-volume supply fan. Calculate the "sum-of-peaks" space sensible load?

(2 marks)

**Q24** (a) Calculate the aspect ratio using the rectangular air duct dimensions shown in Figure Q24(a). Explain why this rectangular duct's capital and operating cost is higher than a square duct of the same flow area.

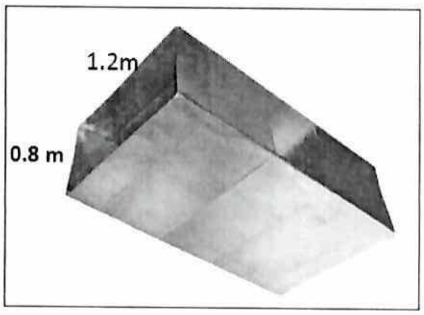


**Figure Q24(a)**

(5 marks)

(b) Explain why rectangular ducts are still commonly used in buildings despite the higher capital and operating cost.

(4 marks)

(c) The following **Figure Q24 (c)** shows a typical duct layout.

i. Using the equal friction method and friction chart in **Figure Q24 (c-i)**, determine the size of each ducting (A – I) and duct lost in each ducting if using round ducts with the maximum velocity of air allowed in the system as 5 m/s. You also need to fill the **Table Q24(c)**:

**Table Q24(c)**

| ID | TYPE | Volume flow rate ($m^3/s$) | $\Delta P$ (Pa/m) | Velocity (m/s) | Diameter (m) | Length (m) | Duct loss (Pa) |
|---|---|---|---|---|---|---|---|
| A | Duct | | | | | | |
| B | Tee | | | | | | |
| C | Branch | | | | | | |
| D | Duct | | | | | | |
| E | Tee | | | | | | |
| F | Branch | | | | | | |
| G | Branch | | | | | | |
| H | 90 Bend | | | | | | |
| I | Branch | | | | | | |

ii. Based on the complete **Table Q24(c)**, determine the index run on the system.

(12 marks)

**- END OF QUESTIONS -**

## FINAL EXAMINATION

SEMESTER / SESSION: SEM I / 2021/2022 PROGRAMME CODE : BBG
COURSE NAME : AIR CONDITIONING SYTEM DESIGN
COURSE CODE : BBA 40603

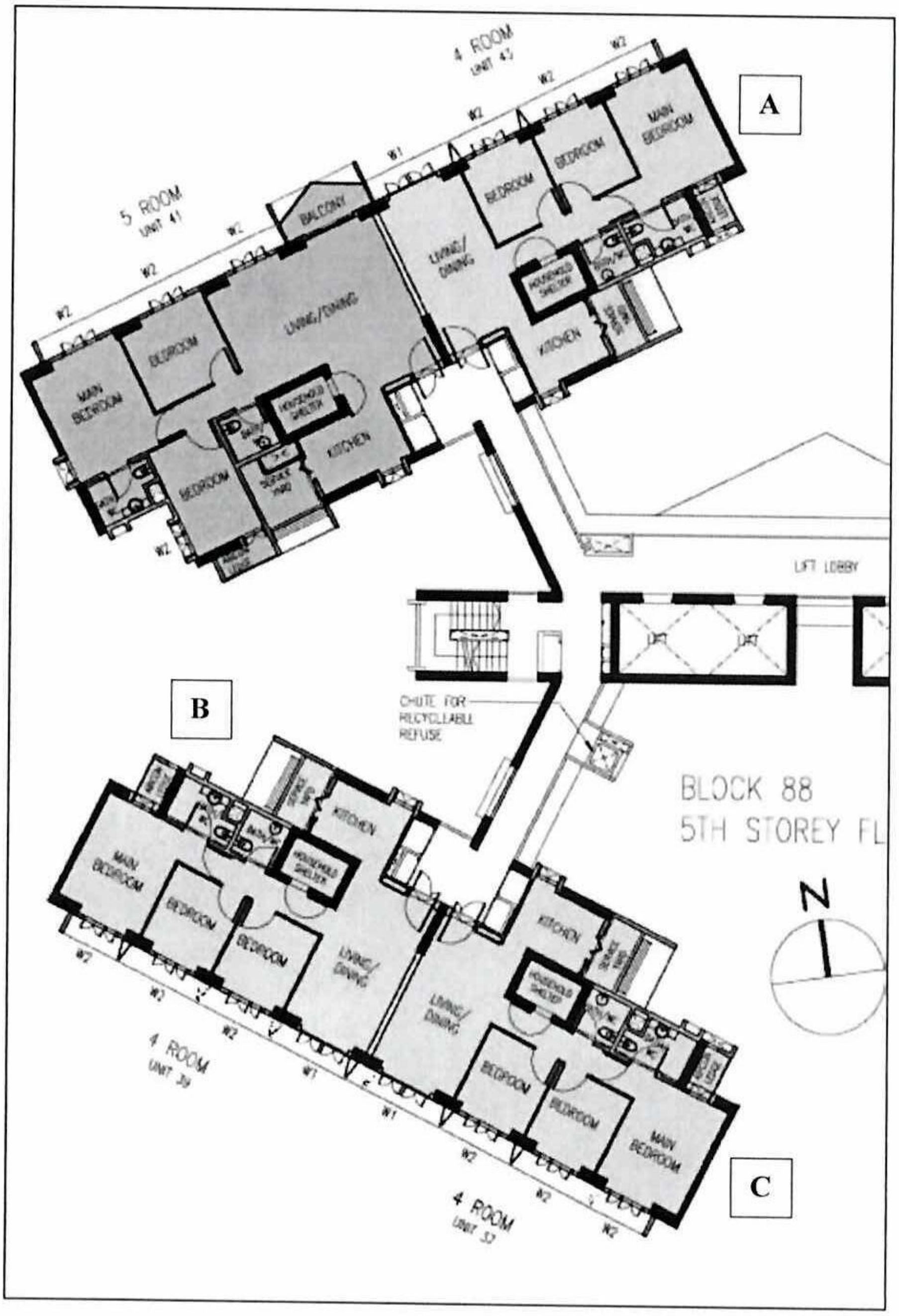


**Figure Q21 (c)**

**FINAL EXAMINATION**

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COURSE CODE : BBA 40603

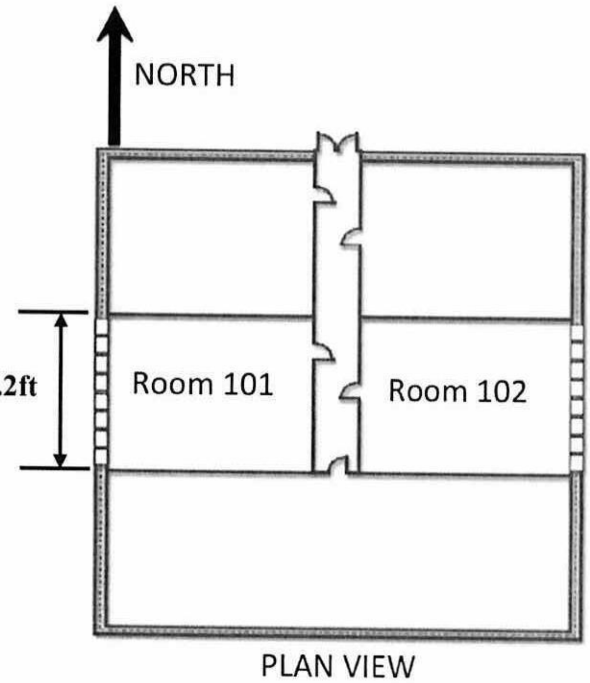


**Figure Q22 (a)**

**Table Q22 (a-i): Cooling Load Temperature Differences for Calculating Cooling Load from Sunlit Walls**

| North Latitude Wall Facing | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | Hr of Maximum CLTD | Minimum CLTD | Maximum CLTD | Difference CLTD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Solar Time, hr | | | | | | | | | | | | | | | | | |
| **Group A Walls** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 14 | 14 | 14 | 13 | 13 | 13 | 12 | 12 | 11 | 11 | 10 | 10 | 10 | 10 | 10 | 10 | 11 | 11 | 12 | 12 | 13 | 13 | 14 | 14 | 2 | 10 | 14 | 4 |
| NE | 19 | 19 | 19 | 18 | 17 | 17 | 16 | 15 | 15 | 15 | 15 | 15 | 16 | 16 | 17 | 18 | 18 | 18 | 19 | 19 | 20 | 20 | 20 | 20 | 22 | 15 | 20 | 5 |
| E | 24 | 24 | 23 | 23 | 22 | 21 | 20 | 19 | 19 | 18 | 19 | 19 | 20 | 21 | 22 | 23 | 24 | 24 | 25 | 25 | 25 | 25 | 25 | 25 | 22 | 18 | 25 | 7 |
| SE | 24 | 23 | 23 | 22 | 21 | 20 | 20 | 19 | 18 | 18 | 18 | 18 | 18 | 19 | 20 | 21 | 22 | 23 | 23 | 24 | 24 | 24 | 24 | 24 | 22 | 18 | 24 | 6 |
| S | 20 | 20 | 19 | 19 | 18 | 18 | 17 | 16 | 16 | 15 | 14 | 14 | 14 | 14 | 14 | 15 | 16 | 17 | 18 | 19 | 19 | 20 | 20 | 20 | 23 | 14 | 20 | 6 |
| SW | 25 | 25 | 25 | 24 | 24 | 23 | 22 | 21 | 20 | 19 | 19 | 18 | 17 | 17 | 17 | 17 | 18 | 19 | 20 | 22 | 23 | 24 | 25 | 25 | 24 | 17 | 25 | 8 |
| W | 27 | 27 | 26 | 26 | 25 | 24 | 24 | 23 | 22 | 21 | 20 | 19 | 19 | 18 | 18 | 18 | 18 | 19 | 20 | 22 | 23 | 25 | 26 | 26 | 1 | 18 | 27 | 9 |
| NW | 21 | 21 | 21 | 20 | 20 | 19 | 19 | 18 | 17 | 16 | 16 | 15 | 15 | 14 | 14 | 14 | 15 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 1 | 14 | 21 | 7 |
| **Group B Walls** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 15 | 14 | 14 | 13 | 12 | 11 | 11 | 10 | 9 | 9 | 9 | 8 | 9 | 9 | 9 | 10 | 11 | 12 | 13 | 14 | 14 | 15 | 15 | 15 | 24 | 8 | 15 | 7 |
| NE | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 19 | 20 | 20 | 21 | 21 | 21 | 20 | 20 | 21 | 12 | 21 | 9 |
| E | 23 | 22 | 21 | 20 | 18 | 17 | 16 | 15 | 15 | 15 | 17 | 19 | 21 | 22 | 24 | 25 | 26 | 26 | 27 | 27 | 26 | 26 | 25 | 24 | 20 | 15 | 27 | 12 |
| SE | 23 | 22 | 21 | 20 | 18 | 17 | 16 | 15 | 14 | 14 | 15 | 16 | 18 | 20 | 21 | 23 | 24 | 25 | 26 | 26 | 26 | 26 | 25 | 24 | 21 | 14 | 26 | 12 |
| S | 21 | 20 | 19 | 18 | 17 | 15 | 14 | 13 | 12 | 11 | 11 | 11 | 11 | 12 | 14 | 15 | 17 | 19 | 20 | 21 | 22 | 22 | 22 | 21 | 23 | 11 | 22 | 11 |
| SW | 27 | 26 | 25 | 24 | 22 | 21 | 19 | 18 | 16 | 15 | 14 | 14 | 13 | 13 | 14 | 15 | 17 | 20 | 22 | 25 | 27 | 28 | 28 | 28 | 24 | 13 | 28 | 15 |
| W | 29 | 28 | 27 | 26 | 24 | 23 | 21 | 19 | 18 | 17 | 16 | 15 | 14 | 14 | 14 | 15 | 17 | 19 | 22 | 25 | 27 | 29 | 29 | 30 | 24 | 14 | 30 | 16 |
| NW | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 15 | 14 | 13 | 12 | 12 | 12 | 11 | 12 | 12 | 13 | 15 | 17 | 19 | 21 | 22 | 23 | 23 | 24 | 11 | 23 | 9 |
| **Group C Walls** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 8 | 7 | 7 | 8 | 8 | 9 | 10 | 12 | 13 | 14 | 15 | 16 | 17 | 17 | 17 | 16 | 22 | 7 | 17 | 10 |
| NE | 19 | 17 | 16 | 14 | 13 | 11 | 10 | 10 | 11 | 13 | 15 | 17 | 19 | 20 | 21 | 22 | 22 | 23 | 23 | 23 | 23 | 22 | 21 | 20 | 20 | 10 | 23 | 13 |
| E | 22 | 21 | 19 | 17 | 15 | 14 | 12 | 12 | 14 | 16 | 19 | 22 | 25 | 27 | 29 | 29 | 30 | 30 | 30 | 29 | 28 | 27 | 26 | 24 | 18 | 12 | 30 | 18 |
| SE | 22 | 21 | 19 | 17 | 15 | 14 | 12 | 12 | 12 | 13 | 16 | 19 | 22 | 24 | 26 | 28 | 29 | 29 | 29 | 29 | 28 | 27 | 26 | 24 | 19 | 12 | 29 | 17 |
| S | 21 | 19 | 18 | 16 | 15 | 13 | 12 | 10 | 9 | 9 | 9 | 10 | 11 | 14 | 17 | 20 | 22 | 24 | 25 | 26 | 25 | 25 | 24 | 22 | 20 | 9 | 26 | 17 |
| SW | 29 | 27 | 25 | 22 | 20 | 18 | 16 | 15 | 13 | 12 | 11 | 11 | 11 | 13 | 15 | 18 | 22 | 26 | 29 | 32 | 33 | 33 | 32 | 31 | 22 | 11 | 33 | 22 |
| W | 31 | 29 | 27 | 25 | 22 | 20 | 18 | 16 | 14 | 13 | 12 | 12 | 12 | 13 | 14 | 16 | 20 | 24 | 29 | 32 | 35 | 35 | 35 | 33 | 22 | 12 | 35 | 23 |
| NW | 25 | 23 | 21 | 20 | 18 | 16 | 14 | 13 | 11 | 10 | 10 | 10 | 10 | 11 | 12 | 13 | 15 | 18 | 22 | 25 | 27 | 27 | 27 | 26 | 22 | 10 | 27 | 17 |
| **Group D Walls** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N | 15 | 13 | 12 | 10 | 9 | 7 | 6 | 6 | 6 | 6 | 6 | 7 | 8 | 10 | 12 | 13 | 15 | 17 | 18 | 19 | 19 | 19 | 18 | 16 | 21 | 6 | 19 | 13 |
| NE | 17 | 15 | 13 | 11 | 10 | 8 | 7 | 8 | 10 | 14 | 17 | 20 | 22 | 23 | 23 | 24 | 24 | 25 | 25 | 24 | 23 | 22 | 20 | 18 | 19 | 7 | 25 | 18 |
| E | 19 | 17 | 15 | 13 | 11 | 9 | 8 | 9 | 12 | 17 | 22 | 27 | 30 | 32 | 33 | 33 | 32 | 32 | 31 | 30 | 28 | 26 | 24 | 22 | 16 | 8 | 33 | 25 |
| SE | 20 | 17 | 15 | 13 | 11 | 10 | 8 | 8 | 10 | 13 | 17 | 22 | 26 | 29 | 31 | 32 | 32 | 32 | 31 | 30 | 28 | 26 | 24 | 22 | 17 | 8 | 32 | 24 |
| S | 19 | 17 | 15 | 13 | 11 | 9 | 8 | 7 | 6 | 6 | 7 | 9 | 12 | 16 | 20 | 24 | 27 | 29 | 29 | 29 | 27 | 26 | 24 | 22 | 19 | 6 | 29 | 23 |
| SW | 28 | 25 | 22 | 19 | 16 | 14 | 12 | 10 | 9 | 8 | 8 | 8 | 10 | 12 | 16 | 21 | 27 | 32 | 36 | 38 | 38 | 37 | 34 | 31 | 21 | 8 | 38 | 30 |
| W | 31 | 27 | 24 | 21 | 18 | 15 | 13 | 11 | 10 | 9 | 9 | 9 | 10 | 11 | 14 | 18 | 24 | 30 | 36 | 40 | 41 | 40 | 38 | 34 | 21 | 9 | 41 | 32 |
| NW | 25 | 22 | 19 | 17 | 14 | 12 | 10 | 9 | 8 | 7 | 7 | 8 | 9 | 10 | 12 | 14 | 18 | 22 | 27 | 31 | 32 | 32 | 30 | 27 | 22 | 7 | 32 | 25 |

**FINAL EXAMINATION**

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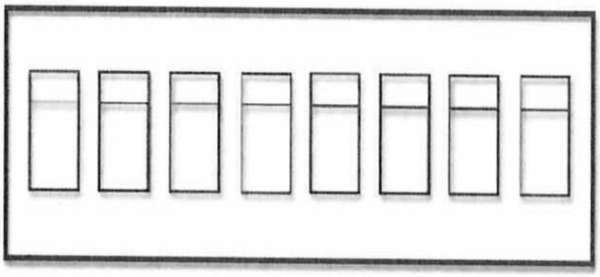
**Table Q22 (a-ii): CLTD Correction for Latitude and Month Applied to Walls and Roofs, North Latitudes.**

Table 3.12 CLTD Correction For Latitude and Month Applied to Walls and Roofs, North Latitudes

| Lat. | Month | N | NNE NNW | NE NW | ENE WNW | E W | ESE WSW | SE SW | SSE SSW | S | HOR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | Dec | −3 | −5 | −5 | −5 | −2 | 0 | 3 | 6 | 9 | −1 |
| | Jan/Nov | −3 | −5 | −4 | −4 | −1 | 0 | 2 | 4 | 7 | −1 |
| | Feb/Oct | −3 | −2 | −2 | −2 | −1 | −1 | 0 | −1 | 0 | 0 |
| | Mar/Sept | −3 | 0 | 1 | −1 | −1 | −3 | −3 | −5 | −8 | 0 |
| | Apr/Aug | 5 | 4 | 3 | 0 | −2 | −5 | −6 | −8 | −8 | −2 |
| | May/Jul | 10 | 7 | 5 | 0 | −3 | −7 | −8 | −9 | −8 | −4 |
| | Jun | 12 | 9 | 5 | 0 | −3 | −7 | −9 | −10 | −8 | −5 |
| 8 | Dec | −4 | −6 | −6 | −6 | −3 | 0 | 4 | 8 | 12 | −5 |
| | Jan/Nov | −3 | −5 | −6 | −5 | −2 | 0 | 3 | 6 | 10 | −4 |
| | Feb/Oct | −3 | −4 | −3 | −3 | −1 | −1 | 1 | 2 | 4 | −1 |
| | Mar/Sept | −3 | −2 | −1 | −1 | −1 | −2 | −2 | −3 | −4 | 0 |
| | Apr/Aug | 2 | 2 | 2 | 0 | −1 | −4 | −5 | −7 | −7 | −1 |
| | May/Jul | 7 | 5 | 4 | 0 | −2 | −5 | −7 | −9 | −7 | −2 |
| | Jun | 9 | 6 | 4 | 0 | −2 | −6 | −8 | −9 | −7 | −2 |
| 16 | Dec | −4 | −6 | −8 | −8 | −4 | −1 | 4 | 9 | 13 | −9 |
| | Jan/Nov | −4 | −6 | −7 | −7 | −4 | −1 | 4 | 8 | 12 | −7 |
| | Feb/Oct | −3 | −5 | −5 | −4 | −2 | 0 | 2 | 5 | 7 | −4 |
| | Mar/Sept | −3 | −3 | −2 | −2 | −1 | −1 | 0 | 0 | 0 | −1 |
| | Apr/Aug | −1 | 0 | −1 | −1 | −1 | −3 | −3 | −5 | −6 | 0 |
| | May/Jul | 4 | 3 | 3 | 0 | −1 | −4 | −5 | −7 | −7 | 0 |
| | Jun | 6 | 4 | 4 | 1 | −1 | −4 | −6 | −8 | −7 | 0 |



Elevation view (Room 101)

**Figure Q22 (b)**

**FINAL EXAMINATION**

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**Table Q22 (b-i): Shading coefficient for glass without or with interior shading by venetian blinds or roller shades.**

| | Type of Glass | Nominal Thickness Each Light[a] | Solar Trans.[b] | No Interior Shading | | Type of Interior Shading | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Venetian Blinds | | Roller Shades | | |
| | | | | | | | | Opaque | | Translucent |
| | | | | $h_o = 4.0$ | $h_o = 3.0$ | Medium | Light | Dark | Light | Light |
| SINGLE GLASS | Single | | | | | | | | | |
| | Clear | 3/32 to 1/4 | 0.87-0.80 | 1.00 | 1.00 | | | | | |
| | Clear | 1/4 to 1/2 | 0.80-0.71 | 0.94 | 0.95 | | | | | |
| | Clear | 3/8 | 0.72 | 0.90 | 0.92 | | | | | |
| | Clear | 1/2 | 0.67 | 0.87 | 0.88 | 0.64 | 0.55 | 0.59 | 0.25 | 0.39 |
| | Clear Pattern | 1/8 to 9/32 | 0.87-0.79 | 0.83 | 0.85 | | | | | |
| | Heat Absorbing Pattern | 1/8 | | 0.83 | 0.85 | | | | | |
| | Heat Absorbing[c] | 3/16 to 1/4 | 0.46 | 0.69 | 0.73 | | | | | |
| | Heat Absorbing Pattern | 3/16 to 1/4 | | 0.69 | 0.73 | 0.57 | 0.53 | 0.45 | 0.30 | 0.36 |
| | Tinted | 1/8 to 7/32 | 0.59-0.45 | 0.69 | 0.73 | | | | | |
| | Heat Absorbing or Pattern | | 0.44-0.30 | 0.60 | 0.64 | | | | | |
| | Heat Absorbing[c] | 3/8 | 0.34 | 0.60 | 0.64 | 0.54 | 0.52 | 0.40 | 0.28 | 0.32 |
| | Heat Absorbing | | 0.44-0.30 | | | | | | | |
| | or Pattern | 1/2 | 0.24 | 0.53 | 0.58 | 0.42 | 0.40 | 0.36 | 0.28 | 0.31 |
| | Reflective Coated Glass | | | 0.30 | | 0.25 | 0.23 | | | |
| | | | | 0.40 | | 0.33 | 0.29 | | | |
| | | | | 0.50 | | 0.42 | 0.38 | | | |
| | | | | 0.60 | | 0.50 | 0.44 | | | |
| INSULATING GLASS | Double[d] | | | | | | | | | |
| | Clear Out | | | | | | | | | |
| | Clear In | 3/32, 1/8 | 0.71[a] | 0.88 | 0.88 | 0.57 | 0.51 | 0.60 | 0.25 | 0.37 |
| | Clear Out | | | | | | | | | |
| | Clear In | 1/4 | 0.61[a] | 0.81 | 0.82 | | | | | |
| | Heat Absorbing Out | 1/4 | 0.36[a] | 0.55 | 0.58 | | | | | |
| | Clear In | | | | | 0.39 | 0.36 | 0.40 | 0.22 | 0.30 |
| | Reflective Coated Glass | | | 0.20 | | 0.19 | 0.18 | | | |
| | | | | 0.30 | | 0.27 | 0.26 | | | |
| | | | | 0.40 | | 0.34 | 0.33 | | | |
| | Triple | | | | | | | | | |
| | Clear | 1/4 | | 0.71 | | | | | | |
| | Clear | 1/8 | | 0.80 | | | | | | |

**Table Q22 (b-ii): Maximum SHGF for Sunlit Glass (0° North Latitude), $Btu/(hr \cdot ft^2)$**

| 0 Deg | N | NNE/ NNW | NE/ NW | ENE/ WNW | E/ W | ESE/ WSW | SE/ SW | SSE/ SSW | S | HOR |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 34 | 34 | 88 | 177 | 234 | 254 | 235 | 182 | 118 | 296 |
| Feb. | 36 | 39 | 132 | 205 | 245 | 247 | 210 | 141 | 67 | 306 |
| Mar. | 38 | 87 | 170 | 223 | 242 | 223 | 170 | 87 | 38 | 303 |
| Apr. | 71 | 134 | 193 | 224 | 221 | 184 | 118 | 38 | 37 | 284 |
| May | 113 | 164 | 203 | 218 | 201 | 154 | 80 | 37 | 37 | 265 |
| June | 129 | 173 | 206 | 212 | 191 | 140 | 66 | 37 | 37 | 255 |
| July | 115 | 164 | 201 | 213 | 195 | 149 | 77 | 38 | 38 | 260 |
| Aug. | 75 | 134 | 187 | 216 | 212 | 175 | 112 | 39 | 38 | 276 |
| Sep. | 40 | 84 | 163 | 213 | 231 | 213 | 163 | 84 | 40 | 293 |
| Oct. | 37 | 40 | 129 | 199 | 236 | 238 | 202 | 135 | 66 | 299 |
| Nov. | 35 | 35 | 88 | 175 | 230 | 250 | 230 | 179 | 117 | 293 |
| Dec. | 34 | 34 | 71 | 164 | 226 | 253 | 240 | 196 | 138 | 288 |

## FINAL EXAMINATION

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### Table Q22 (b-iii): Cooling Load Factors for Glass with Interior Shading, North Latitude (All Room Construction)

| Fenes-stration Facing | Solar Time, hr | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| N | 0.08 | 0.07 | 0.06 | 0.06 | 0.07 | 0.73 | 0.66 | 0.65 | 0.73 | 0.80 | 0.86 | 0.89 | 0.89 | 0.86 | 0.82 | 0.75 | 0.78 | 0.91 | 0.24 | 0.18 | 0.15 | 0.13 | 0.11 | 0.10 |
| NNE | 0.03 | 0.03 | 0.02 | 0.02 | 0.03 | 0.64 | 0.77 | 0.62 | 0.42 | 0.37 | 0.37 | 0.37 | 0.36 | 0.35 | 0.32 | 0.28 | 0.23 | 0.17 | 0.08 | 0.07 | 0.06 | 0.05 | 0.04 | 0.04 |
| NE | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.56 | 0.76 | 0.74 | 0.58 | 0.37 | 0.29 | 0.27 | 0.26 | 0.24 | 0.22 | 0.20 | 0.16 | 0.12 | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 |
| ENE | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.52 | 0.76 | 0.80 | 0.71 | 0.52 | 0.31 | 0.26 | 0.24 | 0.22 | 0.20 | 0.18 | 0.15 | 0.11 | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 |
| E | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.47 | 0.72 | 0.80 | 0.76 | 0.62 | 0.41 | 0.27 | 0.24 | 0.22 | 0.20 | 0.17 | 0.14 | 0.11 | 0.06 | 0.05 | 0.05 | 0.04 | 0.03 | 0.03 |
| ESE | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.41 | 0.67 | 0.79 | 0.80 | 0.72 | 0.54 | 0.34 | 0.27 | 0.24 | 0.21 | 0.19 | 0.15 | 0.12 | 0.07 | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 |
| SE | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.30 | 0.57 | 0.74 | 0.81 | 0.79 | 0.68 | 0.49 | 0.33 | 0.28 | 0.25 | 0.22 | 0.18 | 0.13 | 0.08 | 0.07 | 0.06 | 0.05 | 0.04 | 0.04 |
| SSE | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 | 0.12 | 0.31 | 0.54 | 0.72 | 0.81 | 0.81 | 0.71 | 0.54 | 0.38 | 0.32 | 0.27 | 0.22 | 0.16 | 0.09 | 0.08 | 0.07 | 0.06 | 0.05 | 0.04 |
| S | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.09 | 0.16 | 0.23 | 0.38 | 0.58 | 0.75 | 0.83 | 0.80 | 0.68 | 0.50 | 0.35 | 0.27 | 0.19 | 0.11 | 0.09 | 0.08 | 0.07 | 0.06 | 0.05 |
| SSW | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.09 | 0.14 | 0.18 | 0.22 | 0.27 | 0.43 | 0.63 | 0.78 | 0.84 | 0.80 | 0.66 | 0.46 | 0.25 | 0.13 | 0.11 | 0.09 | 0.08 | 0.07 | 0.06 |
| SW | 0.05 | 0.05 | 0.04 | 0.04 | 0.03 | 0.07 | 0.11 | 0.14 | 0.16 | 0.19 | 0.22 | 0.38 | 0.59 | 0.75 | 0.83 | 0.81 | 0.69 | 0.45 | 0.16 | 0.12 | 0.10 | 0.09 | 0.07 | 0.06 |
| WSW | 0.05 | 0.05 | 0.04 | 0.04 | 0.03 | 0.07 | 0.10 | 0.12 | 0.14 | 0.16 | 0.17 | 0.23 | 0.44 | 0.64 | 0.78 | 0.84 | 0.78 | 0.55 | 0.16 | 0.12 | 0.10 | 0.09 | 0.07 | 0.06 |
| W | 0.05 | 0.05 | 0.04 | 0.04 | 0.03 | 0.06 | 0.09 | 0.11 | 0.13 | 0.15 | 0.16 | 0.17 | 0.31 | 0.53 | 0.72 | 0.82 | 0.81 | 0.61 | 0.16 | 0.12 | 0.10 | 0.08 | 0.07 | 0.06 |
| WNW | 0.05 | 0.05 | 0.04 | 0.03 | 0.03 | 0.07 | 0.10 | 0.12 | 0.14 | 0.16 | 0.17 | 0.18 | 0.22 | 0.43 | 0.65 | 0.80 | 0.84 | 0.66 | 0.16 | 0.12 | 0.10 | 0.08 | 0.07 | 0.06 |
| NW | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.07 | 0.11 | 0.14 | 0.17 | 0.19 | 0.20 | 0.21 | 0.22 | 0.30 | 0.52 | 0.73 | 0.82 | 0.69 | 0.16 | 0.12 | 0.10 | 0.08 | 0.07 | 0.06 |
| NNW | 0.05 | 0.05 | 0.04 | 0.03 | 0.03 | 0.11 | 0.17 | 0.22 | 0.26 | 0.30 | 0.32 | 0.33 | 0.34 | 0.34 | 0.39 | 0.61 | 0.82 | 0.76 | 0.17 | 0.12 | 0.10 | 0.08 | 0.07 | 0.06 |
| HOR. | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 | 0.12 | 0.27 | 0.44 | 0.59 | 0.72 | 0.81 | 0.85 | 0.85 | 0.81 | 0.71 | 0.58 | 0.42 | 0.25 | 0.14 | 0.12 | 0.10 | 0.08 | 0.07 | 0.06 |

### Table Q22 (d-i): Cooling Load Factors when Lights are on for 8 Hours

| "a" Classification | "b" Classification | Number of hours after lights are turned on | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 0.45 | A | 0.02 | 0.46 | 0.57 | 0.65 | 0.72 | 0.77 | 0.82 | 0.85 | 0.88 | 0.46 | 0.37 | 0.30 | 0.24 | 0.19 | 0.15 | 0.12 | 0.10 | 0.08 | 0.06 | 0.05 | 0.04 | 0.03 | 0.03 | 0.02 |
| | B | 0.07 | 0.51 | 0.56 | 0.61 | 0.65 | 0.68 | 0.71 | 0.74 | 0.77 | 0.34 | 0.31 | 0.28 | 0.25 | 0.22 | 0.20 | 0.18 | 0.16 | 0.15 | 0.13 | 0.12 | 0.11 | 0.10 | 0.09 | 0.08 |
| | C | 0.11 | 0.55 | 0.58 | 0.60 | 0.63 | 0.65 | 0.67 | 0.69 | 0.71 | 0.28 | 0.26 | 0.25 | 0.23 | 0.22 | 0.20 | 0.19 | 0.18 | 0.17 | 0.16 | 0.15 | 0.14 | 0.13 | 0.12 | 0.12 |
| | D | 0.14 | 0.58 | 0.60 | 0.61 | 0.62 | 0.63 | 0.64 | 0.65 | 0.66 | 0.22 | 0.22 | 0.21 | 0.20 | 0.20 | 0.19 | 0.19 | 0.18 | 0.18 | 0.17 | 0.16 | 0.16 | 0.16 | 0.15 | 0.15 |
| 0.55 | A | 0.01 | 0.56 | 0.65 | 0.72 | 0.77 | 0.82 | 0.85 | 0.88 | 0.90 | 0.37 | 0.30 | 0.24 | 0.19 | 0.16 | 0.13 | 0.10 | 0.08 | 0.07 | 0.05 | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 |
| | B | 0.06 | 0.60 | 0.64 | 0.68 | 0.71 | 0.74 | 0.76 | 0.79 | 0.81 | 0.28 | 0.25 | 0.23 | 0.20 | 0.18 | 0.16 | 0.15 | 0.13 | 0.12 | 0.11 | 0.10 | 0.09 | 0.08 | 0.07 | 0.06 |
| | C | 0.09 | 0.63 | 0.66 | 0.68 | 0.70 | 0.71 | 0.73 | 0.75 | 0.76 | 0.23 | 0.21 | 0.20 | 0.19 | 0.18 | 0.17 | 0.16 | 0.15 | 0.14 | 0.13 | 0.12 | 0.11 | 0.11 | 0.10 | 0.10 |
| | D | 0.11 | 0.66 | 0.67 | 0.68 | 0.69 | 0.70 | 0.71 | 0.72 | 0.72 | 0.18 | 0.18 | 0.17 | 0.17 | 0.16 | 0.16 | 0.15 | 0.15 | 0.14 | 0.14 | 0.13 | 0.13 | 0.13 | 0.12 | 0.12 |
| 0.65 | A | 0.01 | 0.66 | 0.73 | 0.78 | 0.82 | 0.86 | 0.88 | 0.91 | 0.93 | 0.29 | 0.23 | 0.19 | 0.15 | 0.12 | 0.10 | 0.08 | 0.06 | 0.05 | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | 0.01 |
| | B | 0.04 | 0.69 | 0.72 | 0.75 | 0.77 | 0.80 | 0.82 | 0.84 | 0.85 | 0.22 | 0.19 | 0.18 | 0.16 | 0.14 | 0.13 | 0.12 | 0.10 | 0.09 | 0.08 | 0.08 | 0.07 | 0.06 | 0.06 | 0.05 |
| | C | 0.07 | 0.72 | 0.73 | 0.75 | 0.76 | 0.78 | 0.79 | 0.80 | 0.82 | 0.18 | 0.17 | 0.16 | 0.15 | 0.14 | 0.13 | 0.12 | 0.11 | 0.11 | 0.10 | 0.10 | 0.09 | 0.08 | 0.08 | 0.07 |
| | D | 0.09 | 0.73 | 0.74 | 0.75 | 0.76 | 0.77 | 0.77 | 0.78 | 0.79 | 0.14 | 0.14 | 0.13 | 0.13 | 0.13 | 0.12 | 0.12 | 0.11 | 0.11 | 0.11 | 0.10 | 0.10 | 0.10 | 0.10 | 0.09 |
| 0.75 | A | 0.01 | 0.76 | 0.80 | 0.84 | 0.87 | 0.90 | 0.92 | 0.93 | 0.95 | 0.21 | 0.17 | 0.13 | 0.11 | 0.09 | 0.07 | 0.06 | 0.05 | 0.04 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 |
| | B | 0.03 | 0.78 | 0.80 | 0.82 | 0.84 | 0.85 | 0.87 | 0.88 | 0.89 | 0.15 | 0.14 | 0.13 | 0.11 | 0.10 | 0.09 | 0.08 | 0.07 | 0.07 | 0.06 | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 |
| | C | 0.05 | 0.80 | 0.81 | 0.82 | 0.83 | 0.84 | 0.85 | 0.86 | 0.87 | 0.13 | 0.12 | 0.11 | 0.10 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.07 | 0.07 | 0.06 | 0.06 | 0.06 | 0.05 |
| | D | 0.06 | 0.81 | 0.82 | 0.82 | 0.83 | 0.83 | 0.84 | 0.84 | 0.85 | 0.10 | 0.10 | 0.10 | 0.09 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 | 0.08 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |

**FINAL EXAMINATION**

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COURSE NAME : AIR CONDITIONING SYTEM DESIGN
COURSE CODE : BBA 40603

**Table Q22 (d-ii): Heat Generated by People**

| Level of Activity | Sensible Heat Gain (Btu/h) | Latent Heat Gain (Btu/h) |
|---|---|---|
| Moderately active work (Office) | 256 | 188 |
| Standing, light work, walking (Store) | 256 | 188 |
| Light bench work (Factory) | 273 | 477 |
| Heavy work (Factory) | 580 | 870 |
| Exercise (Gymnasium) | 716 | 1075 |

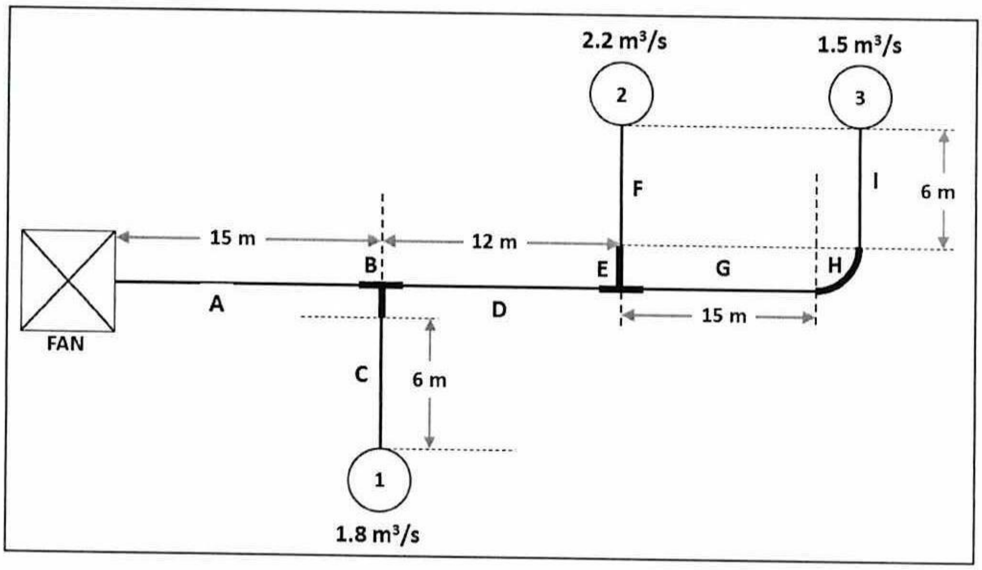


**Figure Q24 (c)**

## FINAL EXAMINATION

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COURSE CODE : BBA 40603

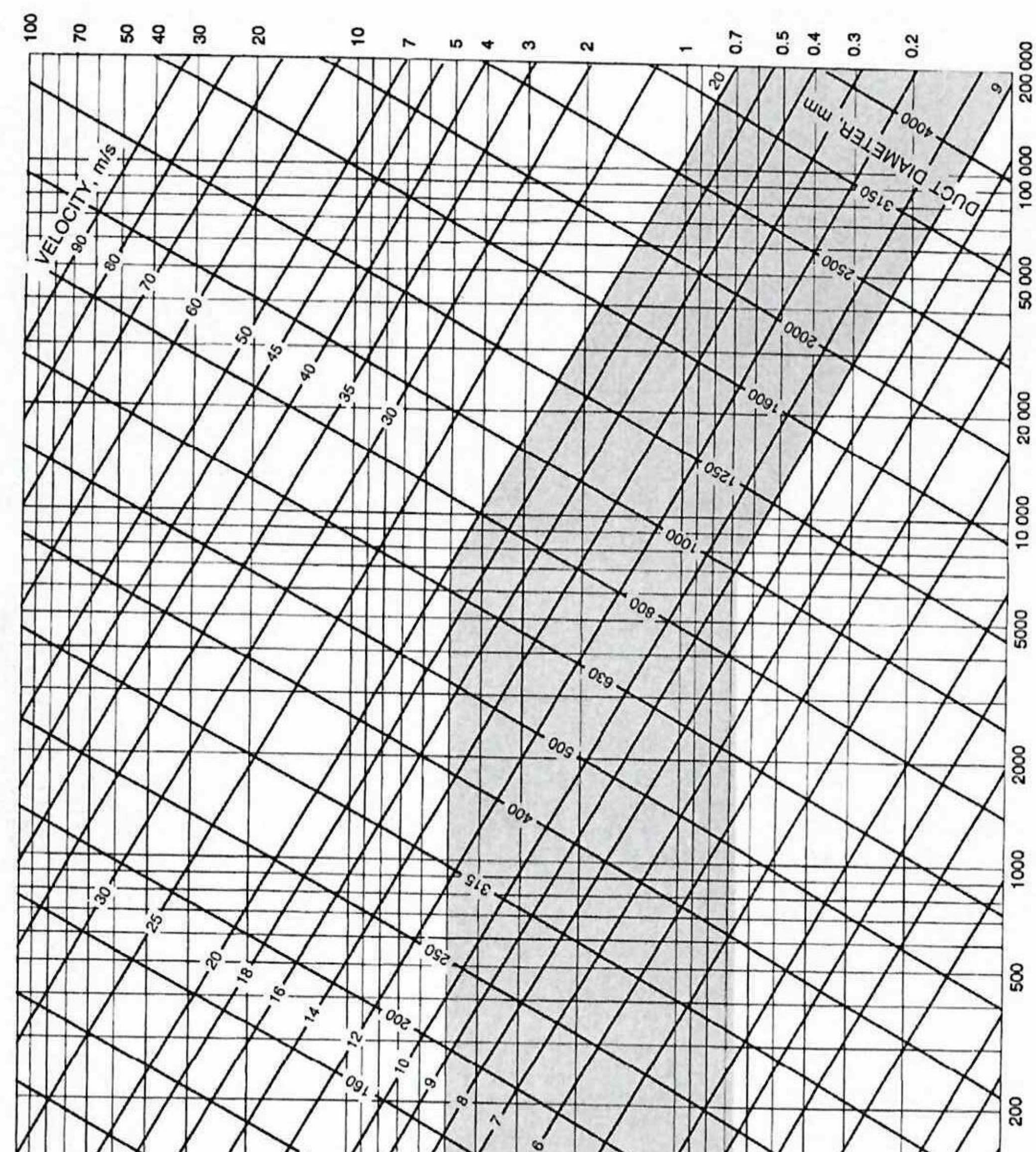


Figure Q24 (c-i)

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**LIST OF FORMULA**

**COOLING LOAD CALCULATION**

$U = 1/R_{total}$

$Q = U \times A \times CLTD$

*CLTD correction:* $= (CLTD + LM) \times K + ((78 - Tr) + (To - 80))$

$Q_{solar} = A \times SC \times SHGF \times CLF$

$Q_{sensible}$ = *No. of people x sensible heat gain per person x CLF*

$Q_{latent}$ = *No. of people x latent heat gain per person*

*Lighting load:*

$Q = qi \times 3.41 \times Fa \times Fs \times CLF$

*Heat gain from infiltration;*

$Qs = 1.1 \times \Delta T \times CFM$

$QL = 4840 \times \Delta\omega \times CFM$

$CFM = volume + Na/60$

*Supply airflow = sensible heat gain / [1210 x (room DB – supply DB)]*

**AIR DUCTING DESIGN**

$\Delta P_{A\text{-}B} = \Delta P_{A,f} + \Delta P_{B,f} + \Delta P_{u\text{-}b} + \Delta P_{exit}$

$\Delta P_{A,f} = (0.022243 \times \bar{Q}^{1.852}_{air} \times L_A) / D^{4.973}_A$ ; L = length, D = diameter, $\bar{Q}$ = flow rate

$\Delta P_{u\text{-}b} = C_{u\text{-}b} (\rho V^2_d /2)$; C = dynamic loss coefficient, $\rho = 1.2$, V = velocity

$\Delta P_{exit} = C_{exit} (\rho V^2_1 /2)$