L-3/T-2/ME **Date : 08/12/2014**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2012-2013

Sub : **IPE 331** (Production Processes)

Full Marks : 280 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this Section. Answer any **THREE**.

1\. (a) Write short notes on the following: **(12)**

(i) Skin dry molding

(ii) Gated pattern

(iii) Follow board pattern

(b) Briefly describe the properties required in good molding sand. How does this sand differ from that used for cores? Explain. **(12)**

(c) With the help of suitable diagrams, describe the following: **(12)**

(i) Squeeze casting

(ii) Centrifugal casting

(d) What are the functions of a chill? Discuss the considerations that must be taken into account for designing risers in molds. **(10⅔)**

2\. (a) Draw a single point turning tool and visualize its different rake angles, clearance angles and cutting edge angles. Also state why those angles are provided. **(12)**

(b) Based on the relevant machining condition and type of material, deduce the following expression: **(12)**

$P_z = 2\tau_s S_0 t \cot\beta$, where the notations indicate their usual meaning.

(c) SAE 133 cold rolled steel rod of 200 mm diameter is turned at a speed of 650 rpm, feed of 0.25 mm/rev. and 6.00 mm depth of cut by a tool having rake angle 20° and principal cutting edge angle 60°. It was noted that the magnitudes of the tangential component and the axial component of the cutting force is 1000 N and 347 N respectively and the value of chip reduction coefficient is 1.732. Using Merchant's analysis, calculate: **(12)**

(i) direction and magnitude of resultant force

(ii) shear plane angle

(iii) friction force and friction angle and

(iv) cutting power consumption

(d) What are the necessary characteristics of cutting fluids? List the different cutting tool material and enumerate the advantages, limitations and applications of each. **(10⅔)**

26

Contd P/2

IPE 331

3. (a) Differentiate among autogenous, homogenous and heterogenous welding processes. Sketch the various types of weld joints and welds used in making a joint. **(12)**

(b) With the help of neat sketch, describe briefly the principles of operation of submersed arc welding. For what types of applications might thermit welding be attractive? **(12)**

(c) With the help of suitable diagrams, describe the following: **(12)**

(i) Resistance projection welding

(ii) Percussion welding

(d) Explain the similarities and differences between Electron-beam and Laser-beam welding. Give typical applications for each. **(10⅔)**

4. (a) Why is it important to design the geometry of the gating system to control the rate of metal flow from the pouring ladle into the mold cavity? Why is it important to provide a means of venting gases from the mold cavity? **(12)**

(b) What factors restrain increase in cutting velocity, feed and depth of cut in turning operation and how? Explain. State the causes and effects of high cutting temperature in machining. **(12)**

(c) What are some of the process variable that must be specified when setting up an arc welding process? What are the differences between the seams produced by roll-spot welding and continuous seam welding? Explain. **(12)**

(d)Use sketches to illustrate the different types of machining chips and explain when and why you can expect to have each of these types. Explain the stages involved in the formation of the built-up-edge (BUE). **(10⅔)**

SECTION – B

There are **FOUR** questions in this Section. Answer any **THREE**.

5. (a) Differentiate generating and forming process of machining. Explain different machining operations in which generating and forming are combined to create shapes. **(11)**

(b) State the various methods for cutting tapers in a lathe. With the help of neat sketch, describe the method of taper turning using 'taper turning attachment' in a lathe machine. **(12)**

(c) What are the different operations that can be performed on a lathe? Explain any five in detail. **(10)**

(d) Describe the quick return motion mechanism of hydraulic shaper with sketches. Write down the advantages and disadvantages of hydraulic shaper. **(13⅔)**

Contd P/3

IPE 331

6. (a) Briefly describe the parameters, which influence the performance of a grinding wheel. **(15)**

(b) Classify grinding operation based on the type of surface produced and describe each type with necessary sketches. **(9)**

(c) What is the metal removal rate when a 25 mm diameter hole, 60 mm deep, is drilled in 1020 steel at a cutting speed of 44 m/min with a feed rate of 0.25 mm/rev? Calculate the machining time required for making 15 holes. [Here, the drill point angle is 120°] **(10)**

(d) With neat sketches show the constructional features of a twist drill and label the important features. **(12⅔)**

7. (a) Briefly describe the principle parts and movements of a Column and Knee type milling machine. **(11)**

(b) Calculate the indexing requirement for 319 divisions on a milling machine equipped with a differential indexing head. The available index plates are: **(12)**

Plate 1: 15, 16, 17, 18, 19, 20 holes
Plate 2: 21, 23, 27, 29, 31, 33 holes
Plate 3: 37, 39, 41, 43, 47, 49 holes

The change gear set available is 24, 24, 28, 32, 40, 44, 48, 56, 64, 72, 86, 100. In the available dividing head the number of worm start is 1 and the number of worm-wheel teeth is 40.

(c) What do you mean by extrusion? Describe various extrusion processes with appropriate sketches. **(8)**

(d) What is flat rolling? How roll force can be reduced in flat rolling? List the defects commonly observed after flat rolling. **(15⅔)**

8. (a) With the help of diagram, discuss the following: **(12)**

(i) Precision forging
(ii) Cogging operation
(iii) Coining operation
(iv) Roll forging

(b) What are the steps involved in closed-die forging? Explain with sketch the various features of a typical forging die. **(12)**

(c) How will you manufacture an aluminum beverage can using metal forming processes? Explain each process with neat sketch. **(12)**

(d) Briefly describe some shearing operations used in sheet metal cutting. **(10⅔)**

L-3/T-2/ME **Date : 06/01/2015**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B.Sc. Engineering Examinations 2012-2013

Sub : **ME 343** (Machine Design II)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

Mechanical Engineering Design textbook will be supplied for use.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this Section. Answer any **THREE**.

1. An inlet valve spring is to be designed for an automobile engine as shown in Figure Q. 1. The spring is required to keep the inlet valve port closed by pushing the valve stem upwards with a force of 30 N. The length of the spring at this position is 60 mm. The valve stem diameter is 10 mm. Allow a diametral clearance of 1.25 mm between the stem and the uncompressed spring to avoid interference. It is further specified that the free length of the spring should be 70 mm and solid length should be less than 49 mm. The factor of safety for the spring when closed solid should be more than 2.0. The spring should have squared and ground ends for accurate load transfer. The specific weight of the spring material is 80 kN/m^3. **(35)**

   (i) Perform a design assessment for a 2 mm wire diameter helical compression spring of Chrome-vanadium A232 material for the valve.

   (ii) Estimate the critical frequency of the spring.

   (iii) If the load applied on the spring during operation ranges between a minimum of 30 N to a maximum of 50 N, estimate the factor of safety guarding against fatigue failure using the Sines torsional fatigue criterion with Zimmerli data.

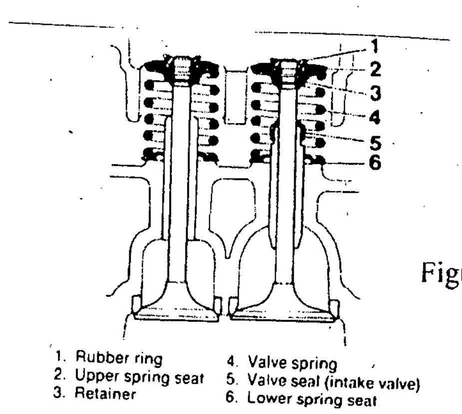

Figure for Q1

2. (a) A pressure-fed bearing has a journal diameter of 50.00 mm with a unilateral tolerance of −0.05 mm. The bushing bore diameter is 50.084 mm with a unilateral tolerance of 0.10 mm. The length of the busing is 55 mm. Its central annular groove is 5 mm wide and is fed by SAE 30 oil is 55°C at 200 kPa supply gauge pressure. The journal speed is 2880 rev/min carrying a load of 10 kN. The sump can dissipate 300 watts per bearing if necessary. For minimum radial clearances, perform a design assessment using Trumpler's criteria. **(25)**

Contd P/2

ME 343

Contd ... Q. No. 2

(b) A full journal bearing with shaft diameter of 25 mm and bore diameter of 25.04 mm, has l/d ratio of unity. The journal rotates at 1200 rev/min supporting a bushing load of 1.25 kN. The average viscosity of the oil is 50 mPa.s. Find the power loss, and the percentage of side flow. **(10)**

3. (a) Two tapered roller bearings support a rotating outer outer hub around a stationary shaft shown in Figure 3a. The device is to operate at 250 rev/min, 8 hours per day, 5 days per week, for 5 years, before bearing replacement is necessary. The radial force carried by the bearing on the left side is 12 kN and the radial force at the right-side bearing is 25 kN. In addition, the outer hub applies a rightward force of 5 kN. Assuming bearings are available with K = 1.5, find the required radial rating for each bearing. The required reliability is 90% on each bearing and application factor is 1.2. Use Timken data for Weibull parameters if necessary. **(20)**

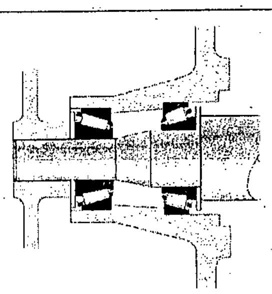

Figure for Q 3 (a)

(b) An angular contact ball bearing with the inner ring rotating is to be selected for an application with a design life of 25 kh at a speed of 350 rev/min. The radial load is 3.5 kN and an application factor of 1.2 is required. The reliability goal is 0.90. Find the multiple of rating life x_p required, and the catalog rating C_{10} with which to enter a bearing table. Choose a 02-series bearing, and estimate the reliability in use. The Weibull parameters are $x_o = 0.02$, $(\theta - x_o) = 4.439$ and $b = 1.483$. **(15)**

4. (a) The brake shown in figure 4(a) has a coefficient of friction of 0.3, a face width of 50 mm and a limiting shoe lining pressure of 1 MPa. Find the limiting actuating force F and the braking capacity. **(25)**

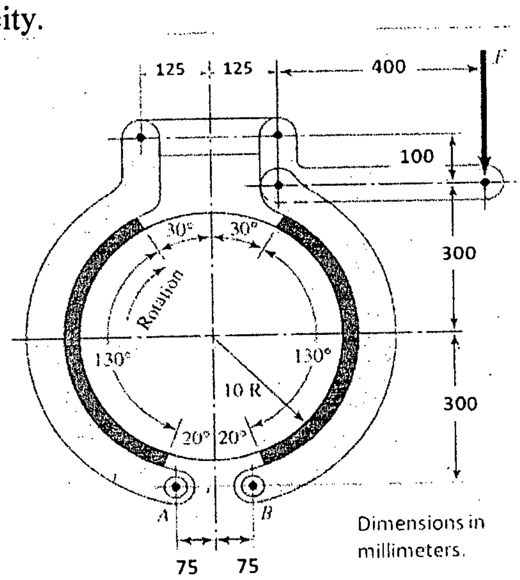

Figure for Q 4(a)

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ME 343

Contd ... Q. No. 4

(b) A plate clutch has a single pair of mating friction surface 250-mm OD by 175-mm ID. The mean value of the coefficient of friction is 0.30, and the actuating force is 4 kN. Find the maximum pressure and the torque capacity using the uniform-wear model. Also find the maximum pressure and the torque capacity using the uniform-pressure model. **(10)**

SECTION – B

There are **FOUR** questions in this Section. Answer any **THREE**.

Assume reasonably any missing data. Symbols carry their usual meaning.

5. (a) (i) Why is involute profile used for gear teeth? **(10)**

   (ii) List two advantages of helical gears over spur gears from design point of view.

   (iii) When is a worm gear set specially needed? What is its major drawback from practical point of view?

   (b) Following data are for a pair of spur gears:

   $\phi = 14.5°$, $m = 12$ mm, $N_p = 25$, $m_G = 3$, $W^t = 1$ kN, $b = 4p$. Calculate the separating force, y_g and Lewis bending stress for the pinion. **(15)**

   (c) A pair of straight bevel gears have following particulars: the gears are of equal size, the driver gear (50 teeth) runs at 480 rpm and transmits 1 kW which increases by 10% due to mild shock. $\phi = 20°$ and average pitch radius = 75 mm. Calculate the radial and axial forces on the driven bevel gear. **(10)**

6. An 18-tooth ($\phi_n = 20°$ FD) helical pinion with a right-hand helix angle of 30° runs at 1120 rpm and drivers a 72-teeth helical gear and transmits 75 kW. Find safety factor using AGMA equations and following data: **(35)**

   normal module = 10 mm, $b = 4p_t$, power source has light shock but driven machine has moderate shock, both gears are made of ASTM A48 Grey C.I. class40, transmission accuracy level no. 7, pinion life = 10^7 cycles with 50% reliability, gears are straddle mounted with bearings immediately adjacent, teeth are crowned.

7. Directly connected to a 2.5 hp (1 hp = 33000 ft-lb/min) electric motor that runs at 1450 rpm, a double treated C.I. worm transmits power to a machine through a 50 teeth chilled-cast bronze gear. Given: **(35)**

   $\phi_n = 25°$, $p_t = 5$ teeth/inch, $F_e = 1$ inch, $d_w = 2"$ load application factor = 1.4, a cooling air fan is attached on worm shaft, lateral area of case is twice the minimum lateral area recommended by AGMA.

   Calculate: f, n_G, efficiency of the drive, safety factor according to AGMA equations and safety factor according to Buckingham wear load. Also find temperature rise of the sump oil.

Contd P/4

ME 343

8. (a) A skip for a mine shaft weighs 1000 kg and lifts a load of 1250 kg from a depth of 300 m. The maximum speed 6 m/s is attained in 5 seconds. Given: **(20)**

$\frac{F_f}{Maximum F_t} = 2$, D = 68 d, E_r = 83 GPa, indefinite life.

(i) Specify sizes of 6 × 10 IPS regular lay rope and pulley. Also specify the sheave material.

(ii) Find static and fatigue safety factors considering rope bending at the pulley, and find the maximum static and dynamic elastic deflections of the rope.

(b) Smaller pulley (d = 200 mm) of a V-belt drive is connected to a 9 kW motor running at 1450 rpm. Five B3000 belts are proposed with K_s = 1.4 and n_d = 1.1 and driven pulley dia D = 300 mm. Calculate: **(15)**

n_{sf} and life of the belts in no. of pass. Take: $F_{b1} = 1.1\ F_1$ and $F_{b2} = 0.8\ F_1$.

L-3/T-2/ME **Date : 11/01/2015**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2012-2013

Sub : **ME 303** (Convection, Boiling, Condensation and Mass Transfer)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

Assume reasonable value for any missing data. The symbols have their usual meanings.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this Section. Answer any **THREE**.

The necessary chart, table, equations etc. have been attached.

1. (a) Air at 1 atm and 300 K flows across a 20-cm-square plate at a free-stream velocity of 20 m/s. The last half of the plate is heated to a constant temperature of 350 K. Calculate the heat lost by the plate. **(18)**

   (b) Atmospheric air at T_∞ = 5°C and a free-stream velocity u_∞ = 6 m/s flows across a single tube of outside diameter D = 25 cm. The tube's surface is kept at a uniform temperature T_w = 180°C. Determine the average heat transfer coefficient. **(17)**

2. (a) Derive the expression of two-dimensional conservation of momentum in x-direction (i.e. x-momentum equation). **(20)**

   (b) Air at 300 K and 1 atm enters a smooth tube having a diameter of 2 cm and length of 10 cm. The air velocity is 40 m/s. What constant heat flux must be applied at the tube surface to result in an air temperature rise of 5°C? What average wall temperature would be necessary for this case? **(15)**

3. (a) Derive the expression of heat transfer in a parallel-flow double-pipe heat exchanger by using log mean temperature difference. **(18)**

   (b) Describe with neat sketch the working principle of a plate type liquid-to-liquid heat exchanger. **(17)**

4. (a) How is thermal resistance due to fouling in a heat exchanger accounted for? How do the fluid velocity and temperature affect fouling? **(15)**

   (b) A two-shell-pass, four-tube-pass heat exchanger with the flow arrangement shown in Fig. 4(b) is used to cool processed water flowing at a rate m_h = 5 kg/s from t_1 = 75°C to t_2 = 25°C on the tube side, with cold water entering the shell side at T_1 = 10°C at a rate m_c = 6 kg/s. The overall heat transfer coefficient is U_m = 750 W/m^2.°C. Calculate (i) the heat transfer surface area, and (b) the outlet temperature of the coolant water. **(20)**

Contd P/2

ME 303

SECTION – B

There are **FOUR** questions in this Section. Answer any **THREE**.

5. (a) Describe the mechanism of condensation heat transfer on a vertical plate. Derive an expression for the film thickness over a vertical flat plate and discuss. **(15)**

(b) Calculate the average heat transfer coefficient for filmwise condensation of pure stream at atmospheric pressure for **(20)**

(i) a vertical plate of 1.5 meter in length

(ii) an inclined plate of 1.5 meter in length (angle of inclination 30°)

(iii) the outside surface of a vertical tube 1.5 cm OD and 1.5 meter in length

(iv) the outside surface of a horizontal tube 1.5 cm OD and 1.5 meter in length.

(v) Discuss your findings. Assume the following:

Plate temperature 70°C, k_e = 0.70 w/m°C, ρ_e : 1000 kg/m^3 h_{fg} : = 2500 kJ/kg μ_e : 0.56×10^{-3} kg/m sec.

6. (a) Describe the different flow regimes encountered in flow boiling in a tube with a neat sketch. How does heat transfer coefficient vary along the tube? Discuss. **(15)**

(b) What do you mean by critical heat flux? Describe its physical meaning. Why is the critical heat-flux avoided in the design of boilers? **(7)**

(c) Discuss some methods of enhancing boiling heat transfer. **(8)**

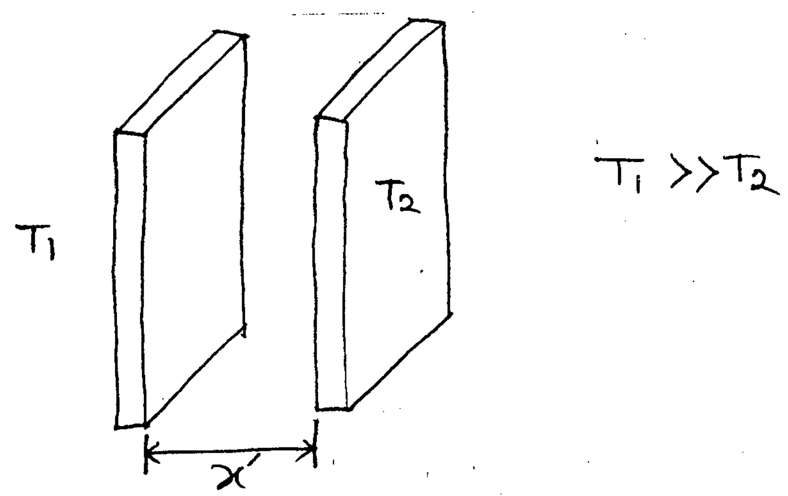
(d) Write short note on 'nanofluids' **(5)**

7. (a) A horizontal pipe 2 cm OD is at 130°C, calculate the heat transfer coefficient and rate of heat transfer per meter length to the surrounding medium when the pipe is surrounded by, (i) air at 25°C, (ii) Water at 25°C **(18)**

Make any assumption you may think appropriate. Assume $N_u = 0.53(Ra)^{0.25}$

(b) A hot plate and a cold plate are placed vertically near to one another as shown in figure for Q 7(b). Show and discuss the velocity and temperature profile of air in between. **(10)**

(c) Discuss the physical meaning of Grashof and Prandtl number. **(7)**



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for Fig. 7b

8. (a) Surface of a mild steel component is generally hardened by packing the component in a carbonaceous material in a furnace at high temperature for a predetermined time. Consider such a component with uniform initial carbon concentration of 0.15 percent by mass. The mild steel component is now packed in a carbonaceous material and is placed in a high temperature furnace. The diffusion coefficient of carbon in steel at the furnace temperature is 4.8×10^{-4} m^2/sec and the equilibrium concentration of carbon in the iron at the interfaces determined from equilibrium data to be 1-2 percent by mass. Calculate how long the component should be kept in the furnace for the mass concentration of carbon 0.5 mm below the surface to reach 1 percent. **(16)**

(b) In order to avoid over pressurization as well as maintain a pressure close to one atmosphere, an industrial pipe line containing ammonia gas is vented to ambient air. Venting is achieved by tapping the pipe line and inserting a 4 mm diameter tube, which extends upto 25 meter into the atmosphere. With the entire system operating at 20°C, calculate: **(14)**

(i) the mass rate of contamination of the atmospheric air with ammonia in kg/hr

(ii) the mass rate of air diffused with ammonia in the pipe line in kg/hr

Assume the following: mass diffusivity of ammonia in air = 0.28×10^{-4} m^2/sec molecular weight of ammonia: 17 kg/kmol, molecular weight of air: 29 kg/kmol, R: 8.3×10^{-2} m^3·atm/kmol K

(c) Discuss the relation $sh = f\,(R_e S_c)$ where the symbols have their usual meanings. **(5)**

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ble 5.2 *Summary of equations for flow over flat plates Properties evaluated at $T_f = (T_w + T_\infty)/2$ unless otherwise noted.*

Flow regime	Restrictions	Equation	Equation number
		Heat transfer	
Laminar, local	$T_w =$ const, $\mathrm{Re}_x < 5 \times 10^5$ $0.6 < \mathrm{Pr} < 50$	$\mathrm{Nu}_x = 0.332\, \mathrm{Re}_x^{1/2}\mathrm{Pr}^{1/3}$	(5-44)
Laminar, local	$T_w =$ const, $\mathrm{Re}_x < 5 \times 10^5$ $\mathrm{Re}_x\,\mathrm{Pr} > 100$	$\mathrm{Nu}_x = \dfrac{0.3387\, \mathrm{Re}_x^{1/2}\, \mathrm{Pr}^{1/3}}{\left[1 + \left(\dfrac{0.0468}{\mathrm{Pr}}\right)^{2/3}\right]^{1/4}}$	(5-51)
Laminar, local	$q_w =$ const, $\mathrm{Re}_x < 5 \times 10^5$ $0.6 < \mathrm{Pr} < 50$	$\mathrm{Nu}_x = 0.453\, \mathrm{Re}_x^{1/2}\, \mathrm{Pr}^{1/3}$	(5-48)
Laminar, local	$q_w =$ const, $\mathrm{Re}_x < 5 \times 10^5$	$\mathrm{Nu}_x = \dfrac{0.4637\, \mathrm{Re}_x^{1/2}\, \mathrm{Pr}^{1/3}}{\left[1 + \left(\dfrac{0.0207}{\mathrm{Pr}}\right)^{2/3}\right]^{1/4}}$	(5-51)
Laminar, average	$\mathrm{Re}_L < 5 \times 10^5$, $T_w =$ const	$\overline{\mathrm{Nu}}_L = 2\, \mathrm{Nu}_{x=L} = 0.664\, \mathrm{Re}_L^{1/2}\, \mathrm{Pr}^{1/3}$	(5-46)
Laminar, local	$T_w =$ const, $\mathrm{Re}_x < 5 \times 10^5$ $\mathrm{Pr} \ll 1$ (liquid metals)	$\mathrm{Nu}_x = 0.564(\mathrm{Re}_x\, \mathrm{Pr})^{1/3}$	
Laminar, local	$T_w =$ const, starting at $x = x_0$, $\mathrm{Re}_x < 5 \times 10^5$, $0.6 < \mathrm{Pr} < 50$	$\mathrm{Nu}_x = 0.332\, \mathrm{Re}_x^{1/2}\, \mathrm{Pr}^{1/3}\left[1 - \left(\frac{x_0}{x}\right)^{3/4}\right]^{-1/3}$	(5-43)
Turbulent, local	$T_w =$ const, $5 \times 10^5 < \mathrm{Re}_x < 10^7$	$\mathrm{St}_x\, \mathrm{Pr}^{2/3} = 0.0296\, \mathrm{Re}_x^{-0.2}$	(5-81)
Turbulent, local	$T_w =$ const, $10^7 < \mathrm{Re}_x < 10^9$	$\mathrm{St}_x\, \mathrm{Pr}^{2/3} = 0.185(\log \mathrm{Re}_x)^{-2.584}$	(5-82)
Turbulent, local	$q_w =$ const, $5 \times 10^5 < \mathrm{Re}_x < 10^7$	$\mathrm{Nu}_x = 1.04\, \mathrm{Nu}_{x\,T_w=\mathrm{const}}$	(5-87)
Laminar-turbulent, average	$T_w =$ const, $\mathrm{Re}_x < 10^7$ $\mathrm{Re}_{\mathrm{crit}} = 5 \times 10^5$	$\overline{\mathrm{St}}\mathrm{PR}^{2/3} = 0.037\, \mathrm{Re}_L^{-0.2} - 871\, \mathrm{Re}_L^{-1}$ $\overline{\mathrm{Nu}}_L = \mathrm{Pr}^{1/3}(0.037\, \mathrm{Re}_L^{0.8} - 871)$	(5-84) (5-85)
Laminar-turbulent, average	$T_w =$ const, $\mathrm{Re}_x < 10^7$ liquids, μ at T_∞ μ_w at T_w	$\overline{\mathrm{Nu}}_L = 0.036\, \mathrm{Pr}^{0.43}(\mathrm{Re}_L^{0.8} - 9200)\left(\frac{\mu_\infty}{\mu_w}\right)^{1/4}$	(5-86)
High-speed flow	$T_w =$ const, $q = hA(T_w - T_{aw})$ $r = (T_{aw} - T_\infty)/(T_o - T_\infty)$ $=$ recovery factor $= \mathrm{Pr}^{1/2}$ (laminar) $= \mathrm{Pr}^{1/3}$ (turbulent)	Same as for low-speed flow with properties evaluated at $T^* = T_\infty + 0.5(T_w - T_\infty) + 0.22(T_{aw} - T_\infty)$	

$$\mathrm{Nu}_m = 0.3 + \frac{0.62\, \mathrm{Re}^{1/2}\, \mathrm{Pr}^{1/3}}{[1 + (0.4/\mathrm{Pr})^{2/3}]^{1/4}}\left[1 + \left(\frac{\mathrm{Re}}{282{,}000}\right)^{1/2}\right]$$

→ Flow across a tube

for $20{,}000 < \mathrm{Re} < 400{,}000$

(2)

(4)

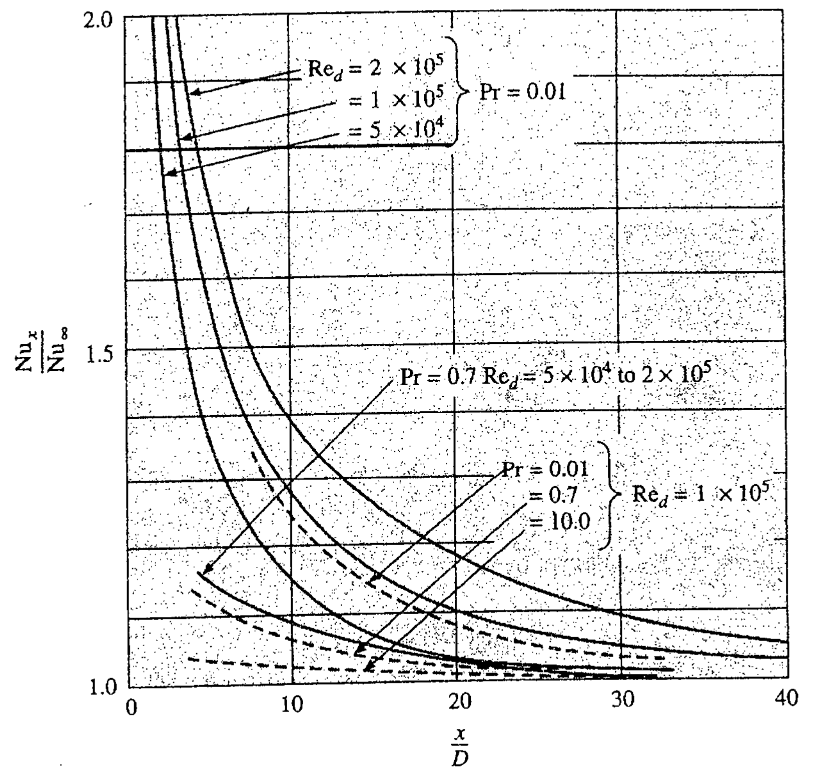


Fig. *Turbulent thermal entry Nusselt numbers for circular tubes with q_w = constant.*

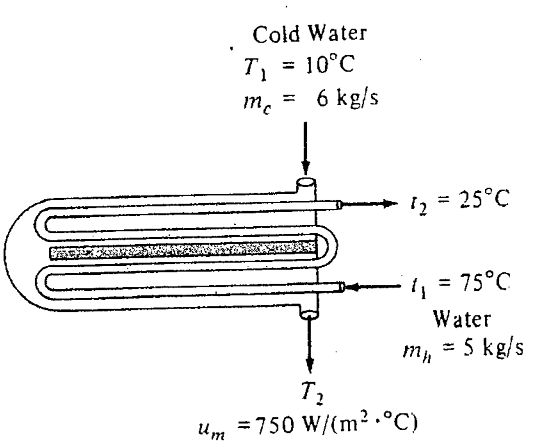
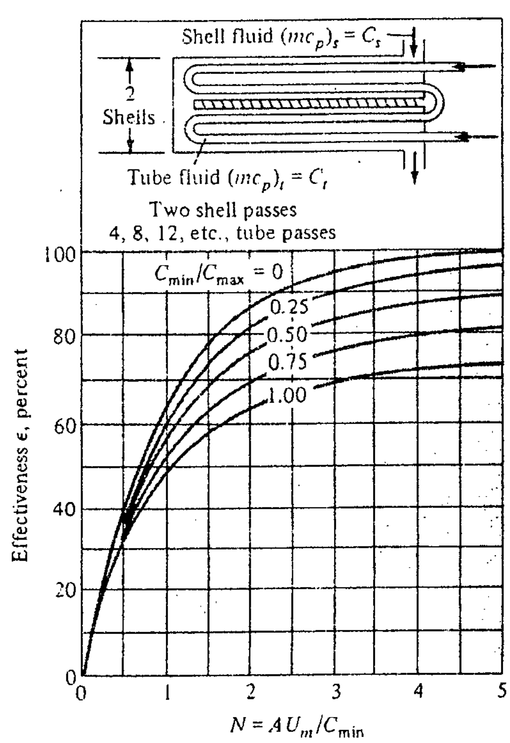


Fig. for Question 4 (b)



The complementary error function

η	erfc (η)	η	erfc (η)	η	erfc (η)	η	erfc (η)	η	erfc (η)	η	erfc (η)
0.00	1.00000	0.38	0.5910	0.76	0.2825	1.14	0.1069	1.52	0.03159	1.90	0.00721
0.02	0.9774	0.40	0.5716	0.78	0.2700	1.16	0.10090	1.54	0.02941	1.92	0.00562
0.04	0.9549	0.42	0.5525	0.80	0.2579	1.18	0.09516	1.56	0.02737	1.94	0.00608
0.06	0.9324	0.44	0.5338	0.82	0.2462	1.20	0.08969	1.58	0.02545	1.96	0.00557
0.08	0.9099	0.46	0.5153	0.84	0.2349	1.22	0.08447	1.60	0.02365	1.98	0.00511
0.10	0.8875	0.48	0.4973	0.86	0.2239	1.24	0.07950	1.62	0.02196	2.00	0.00468
0.12	0.8652	0.50	0.4795	0.88	0.2133	1.26	0.07476	1.64	0.02038	2.10	0.00298
0.14	0.8431	0.52	0.4621	0.90	0.2031	1.28	0.07027	1.66	0.01890	2.20	0.00186
0.16	0.8210	0.54	0.4451	0.92	0.1932	1.30	0.06599	1.68	0.01751	2.30	0.00114
0.18	0.7991	0.56	0.4284	0.94	0.1837	1.32	0.06194	1.70	0.01612	2.40	0.00069
0.20	0.7773	0.58	0.4121	0.96	0.1746	1.34	0.05809	1.72	0.01500	2.50	0.00041
0.22	0.7557	0.60	0.3961	0.98	0.1658	1.36	0.05444	1.74	0.01387	2.60	0.00024
0.24	0.7343	0.62	0.3806	1.00	0.1573	1.38	0.05098	1.76	0.01281	2.70	0.00013
0.26	0.7131	0.64	0.3654	1.02	0.1492	1.40	0.04772	1.78	0.01183	2.80	0.00008
0.28	0.6921	0.66	0.3506	1.04	0.1413	1.42	0.04462	1.80	0.01091	2.90	0.00004
0.30	0.6714	0.68	0.3362	1.06	0.1339	1.44	0.04170	1.82	0.01006	3.00	0.00002
0.32	0.6509	0.70	0.3222	1.08	0.1267	1.46	0.03895	1.84	0.00926	3.20	0.00001
0.34	0.6306	0.72	0.3086	1.10	0.1198	1.48	0.03635	1.86	0.00853	3.40	0.00000
0.36	0.6107	0.74	0.2953	1.12	0.1132	1.50	0.03390	1.88	0.00784	3.60	0.00000

Table 6.8 *Summary of forced-convection relations (See text for property evaluation).*

Subscripts: b = bulk temperature, f = film temperature, ∞ = free stream temperature, w = wall temperature

Geometry	Equation	Restrictions	Equation number
Tube flow	$Nu_d = 0.023\, Re_d^{0.8} Pr^n$	Fully developed turbulent flow, $n = 0.4$ for heating, $n = 0.3$ for cooling, $0.6 < Pr < 100$, $2500 < Re_d < 1.25 \times 10^5$	(6-4*a*)
Tube flow	$Nu_d = 0.0214(Re_d^{0.8} - 100)Pr^{0.4}$	$0.5 < Pr < 1.5$, $10^4 < Re_d < 5 \times 10^6$	(6-4*b*)
	$Nu_d = 0.012(Re_d^{0.87} - 280)Pr^{0.4}$	$1.5 < Pr < 500$, $3000 < Re_d < 10^6$	(6-4*c*)
Tube flow	$Nu_d = 0.027\, Re_d^{0.8}\, Pr^{1/3} \left(\frac{\mu}{\mu_w}\right)^{(0.14)}$	Fully developed turbulent flow	(6-5)
Tube flow, entrance region	$Nu_d = 0.036\, Re_d^{0.8}\, Pr^{1/3} \left(\frac{d}{L}\right)^{0.055}$	Turbulent flow	(6-6)
	See also Figures 6.5 and 6.6	$10 < \frac{L}{d} < 400$	
Tube flow	Petukov relation	Fully developed turbulent flow, $0.5 < Pr < 2000$, $10^4 < Re_d < 5 \times 10^6$, $0 < \frac{\mu_b}{\mu_w} < 40$	(6-7)
Tube flow	$Nu_d = 3.66 + \frac{0.0668(d/L)\, Re_d\, Pr}{1 + 0.04[(d/L)\, Re_d\, Pr]^{2/3}}$	Laminar, T_w =const	(6-9)
Tube flow	$Nu_d = 1.86\, (Re_d\, Pr)^{1/3} \left(\frac{d}{L}\right)^{1/3} \left(\frac{\mu}{\mu_w}\right)^{0.14}$	Fully developed laminar flow, T_w = constant, $Re_d\, Pr \frac{d}{L} > 10$	(6-10)
Rough tubes	$St_b\, Pr_f^{2/3} = \frac{f}{8}$ or Equation (6-7)	Fully developed turbulent flow	(6-12)
Noncircular ducts	Reynolds number evaluated on basis of hydraulic diameter $D_H = \frac{4A}{P}$, A = flow cross-section area, P = wetted perimeter	Same as particular equation for tube flow	(6-14)

Continued

(4)

(6)

ME 303

The heat-transfer coefficient is now written

$$h\,dx\,(T_w - T_g) = -k\,dx\,\frac{T_g - T_w}{\delta}$$

or

$$h = \frac{k}{\delta}$$

so that

$$h_x = \left[\frac{\rho(\rho - \rho_v) g h_{fg} k^3}{4\mu x (T_g - T_w)}\right]^{1/4} \tag{9-7}$$

Expressed in dimensionless form in terms of the Nusselt number, this is

$$\mathrm{Nu}_x = \frac{hx}{k} = \left[\frac{\rho(\rho - \rho_v) g h_{fg} x^3}{4\mu k (T_g - T_w)}\right]^{1/4} \tag{9-8}$$

The average value of the heat-transfer coefficient is obtained by integrating over the length of the plate:

$$\bar{h} = \frac{1}{L}\int_0^L h_x\,dx = \tfrac{4}{3} h_{x=L} \tag{9-9}$$

or

$$\bar{h} = 0.943\left[\frac{\rho(\rho - \rho_v) g h_{fg} k_f^3}{L \mu_f (T_g - T_w)}\right]^{1/4} \tag{9-10}$$

More refined analyses of film condensation are presented in detail by Rohsenow [37]. The most significant refinements take into account a nonlinear temperature profile in the film and modifications to the energy balance to include additional energy to cool the film below the saturation temperature. Both effects can be handled by replacing h_{fg} with h'_{fg}, defined by

$$h'_{fg} = h_{fg} + 0.68c(T_g - T_w) \tag{9-11}$$

where c is the specific heat of the liquid. Otherwise, properties in Eqs. (9-7) and (9-10) should be evaluated at the film temperature

$$T_f = \frac{T_g + T_w}{2}$$

With these substitutions Eq. (9-10) may be used for vertical plates and cylinders and fluids with $\mathrm{Pr} > 0.5$ and $cT/h_{fg} \le 1.0$.

For laminar film condensation on horizontal tubes Nusselt obtained the relation

$$\bar{h} = 0.725\left[\frac{\rho(\rho - \rho_v) g h_{fg} k_f^3}{\mu_f d (T_g - T_w)}\right]^{1/4} \tag{9-12}$$

where d is the diameter of the tube. When condensation occurs on a horizontal tube bank with n tubes placed directly over one another in the vertical direction, the heat-transfer coefficient may be calculated by replacing the diameter in Eq. (9-12) with nd.

When a plate on which condensation occurs is sufficiently large or there is a sufficient amount of condensate flow, turbulence may appear in the

7

Table A.5 Properties of air at atmospheric pressure.†

The values of μ, k, c_p, and Pr are not strongly pressure-dependent and may be used over a fairly wide range of pressures

T, K	ρ kg/m^3	c_p kJ/kg · °C	$\mu \times 10^5$ kg/m · s	$\nu \times 10^6$ m^2/s	k W/m · °C	$\alpha \times 10^4$ m^2/s	pr
100	3.6010	1.0266	0.6924	1.923	0.009246	0.02501	0.770
150	2.3675	1.0099	1.0283	4.343	0.013735	0.05745	0.753
200	1.7684	1.0061	1.3289	7.490	0.01809	0.10165	0.739
250	1.4128	1.0053	1.5990	11.31	0.02227	0.15675	0.722
300	1.1774	1.0057	1.8462	15.69	0.02624	0.22160	0.708
350	0.9980	1.0090	2.075	20.76	0.03003	0.2983	0.697
400	0.8826	1.0140	2.286	25.90	0.03365	0.3760	0.689
450	0.7833	1.0207	2.484	31.71	0.03707	0.4222	0.683
500	0.7048	1.0295	2.671	37.90	0.04038	0.5564	0.680
550	0.6423	1.0392	2.848	44.34	0.04360	0.6532	0.680
600	0.5879	1.0551	3.018	51.34	0.04659	0.7512	0.680
650	0.5430	1.0635	3.177	58.51	0.04953	0.8578	0.682
700	0.5030	1.0752	3.332	66.25	0.05230	0.9672	0.684
750	0.4709	1.0856	3.481	73.91	0.05509	1.0774	0.686
800	0.4405	1.0978	3.625	82.29	0.05779	1.1951	0.689
850	0.4149	1.1095	3.765	90.75	0.06028	1.3097	0.692
900	0.3925	1.1212	3.899	99.3	0.06279	1.4271	0.696
950	0.3716	1.1321	4.023	108.2	0.06525	1.5510	0.699
1000	0.3524	1.1417	4.152	117.8	0.06752	1.6779	0.702
1100	0.3204	1.160	4.44	138.6	0.0732	1.969	0.704
1200	0.2947	1.179	4.69	159.1	0.0782	2.251	0.707
1300	0.2707	1.197	4.93	182.1	0.0837	2.583	0.705
1400	0.2515	1.214	5.17	205.5	0.0891	2.920	0.705
1500	0.2355	1.230	5.40	229.1	0.0946	3.262	0.705
1600	0.2211	1.248	5.63	254.5	0.100	3.609	0.705
1700	0.2082	1.267	5.85	280.5	0.105	3.977	0.705
1800	0.1970	1.287	6.07	308.1	0.111	4.379	0.704
1900	0.1858	1.309	6.29	338.5	0.117	4.811	0.704
2000	0.1762	1.338	6.50	369.0	0.124	5.260	0.702
2100	0.1682	1.372	6.72	399.6	0.131	5.715	0.700
2200	0.1602	1.419	6.93	432.6	0.139	6.120	0.707
2300	0.1538	1.482	7.14	464.0	0.149	6.540	0.710
2400	0.1458	1.574	7.35	504.0	0.161	7.020	0.718
2500	0.1394	1.688	7.57	543.5	0.175	7.441	0.730

† From Natl. Bur. Stand. (U.S.) Circ. 564, 1955.

Table A-9 Properties of Water (Saturated Liquid)†

Note: $Gr_x Pr = \left(\frac{g\beta\rho^2 c_p}{\mu k}\right) x^3 \Delta T$

°F	°C	c_p, kJ/kg · °C	ρ, kg/m^3	μ, kg/m · s	k, W/m · °C	Pr	$\frac{g\beta\rho^2 c_p}{\mu k}$, 1/m^3 · °C
32	0	4.225	999.8	1.79×10^{-3}	0.566	13.25	
40	4.44	4.208	999.8	1.55	0.575	11.35	1.91×10^9
50	10	4.195	999.2	1.31	0.585	9.40	6.34×10^9
60	15.56	4.186	998.6	1.12	0.595	7.88	1.08×10^{10}
70	21.11	4.179	997.4	9.8×10^{-4}	0.604	6.78	1.46×10^{10}
80	26.67	4.179	995.8	8.6	0.614	5.85	1.91×10^{10}
90	32.22	4.174	994.9	7.65	0.623	5.12	2.48×10^{10}
100	37.78	4.174	993.0	6.82	0.630	4.53	3.3×10^{10}
110	43.33	4.174	990.6	6.16	0.637	4.04	4.19×10^{10}
120	48.89	4.174	988.8	5.62	0.644	3.64	4.89×10^{10}
130	54.44	4.179	985.7	5.13	0.649	3.30	5.66×10^{10}
140	60	4.179	983.3	4.71	0.654	3.01	6.48×10^{10}
150	65.55	4.183	980.3	4.3	0.659	2.73	7.62×10^{10}
160	71.11	4.186	977.3	4.01	0.665	2.53	8.84×10^{10}
170	76.67	4.191	973.7	3.72	0.668	2.33	9.85×10^{10}
180	82.22	4.195	970.2	3.47	0.673	2.16	1.09×10^{11}
190	87.78	4.199	966.7	3.27	0.675	2.03	
200	93.33	4.204	963.2	3.06	0.678	1.90	
220	104.4	4.216	955.1	2.67	0.684	1.66	
240	115.6	4.229	946.7	2.44	0.685	1.51	
260	126.7	4.250	937.2	2.19	0.685	1.36	
280	137.8	4.271	928.1	1.98	0.685	1.24	
300	148.9	4.296	918.0	1.86	0.684	1.17	
350	176.7	4.371	890.4	1.57	0.677	1.02	
400	204.4	4.467	859.4	1.36	0.665	1.00	
450	232.2	4.585	825.7	1.20	0.646	0.85	
500	260	4.731	785.2	1.07	0.616	0.83	
550	287.7	5.024	735.5	9.51×10^{-5}			
600	315.6	5.703	678.7	8.68			

†Adapted from A. I. Brown and S. M. Marco. "Introduction to Heat Transfer," 3d ed., McGraw-Hill Book Company, New York, 1958.

L-3/T-2/ME Date : 16/01/2015

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B. Sc. Engineering Examinations 2012-2013

Sub : **ME 323** (Fluid Mechanics II)

Full Marks : 210 Time : 3 Hours

Assume reasonable data if necessary. Symbols carry their usual meaning.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this Section. Answer any **TRHEE**.

The questions are of equal value.

Moody diagram is supplied.

1. (a) Explain hydraulic jump in reference to open channel. Derive the conditions for maximum velocity and maximum discharge through a circular open channel.

   (b) Water is flowing at the rate of 0.20 m^3/s through a circular open channel of 0.7 m diameter. Calculate the slope of the bed of the channel considering maximum velocity of flow. Take Chezy's constant C = 65.

2. (a) Explain boundary layer thickness with diagram. Derive the expressions of displacement thickness and momentum thickness.

   (b) Find the power requires to deliver crude oil of specific gravity 0.86 and kinematic viscosity of 9.32×10^{-6} m^2/s through a horizontal pipe of 500 mm diameter. The length of pipe is 1200 m and the flow rate of oil is 0.25 m^3/s. Neglect minor losses. The wall roughness of pipe is 0.00005 m.

3. (a) Show that friction factor is $64/N_{Re}$ for laminar flow through a smooth circular pipe. Here, N_{Re} is the Reynolds number based on diameter of the pipe.

   (b) Mercury is flowing through a 5 m long and 5 mm diameter smooth tube at an average of 3 m/s. Calculate the head loss and the pressure drop. Absolute viscosity of mercury is equal to 1.56×10^{-3} Ns/m^2.

4. Write short notes on the following:

   (i) Minor losses

   (ii) Laminar and turbulent flows

   (iii) Most economical section of open channel.

SECTION – B

There are **FOUR** questions in this Section. Answer any **THREE**.

The figures in the margin indicate full marks.

5. (a) Define Mach number and classify the flow regimes based on this number. Mention at least one example of each of the classified flows. **(10)**

(b) What do you mean by stagnation condition in context to fluid flow? Deduce an expression of stagnation pressure for isentropic compressible flow starting from the Euler equation of motion. **(17)**

(c) A bicycle tire is filled with air at a pressure of 170 kPa abs. In a certain case, the valve breaks and air starts to exhaust out of the tire into the atmosphere (p_a = 100 kPa abs. and T_a = 20°C). Frictional losses can be ignored here. Find the Mach number and velocity of air at the exit plane of the valve (initially). **(8)**

6. (a) Derive an expression of local Mach number with respect to the ratio of critical area to local area for isentropic flow of compressible fluid through a variable area duct. Simplify this expression for the case of air flow (k = 1.40). **(15)**

(b) A converging-diverging nozzle is used for supersonic air jet from a large reservoir as shown in Fig. for Q. No. 6(b). The reservoir pressure is kept at 500 kPa. Determine the Mach number and static pressure at the points shown in the figure for Q. No. 6(b). Consider 1D isentropic flow in your calculation. Plot your results.

(c) Explain in brief the "Chocking Phenomena" in context of nozzle flows. **(15)**

The locations of the points are given in the following table:

Point	1	2*	3	4	5	6
r (mm)	25	20	22	25	28	31

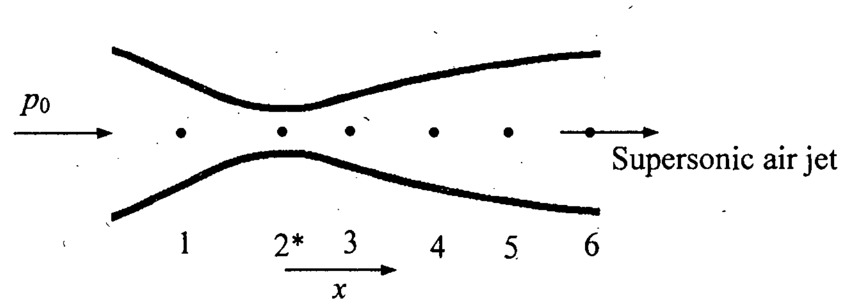


Fig. for Q. 6(b)

7. (a) Show that the strength of normal shock wave which occurs in the diverging section in case of overexpanded nozzle flows can be expressed by the following relation **(20)**

$$\frac{\Delta p}{p_1} = \frac{2k}{k+1}\left(M_1^2 - 1\right);$$ where the symbols have their usual meaning.

ME 323

Contd ... Q. No. 7

(b) Consider a converging-diverging nozzle feeding air from a reservoir in which the pressure is 400 kPa as shown in Fig. for Q. No. 7(b). At a particular off-design operation, a normal shock wave appears with $M_1 = 2.2$. If the throat area is 20.3 cm^2. then determine- **(15)**

(i) Sectional area of the nozzle where shock wave appears

(ii) Mach number and pressure downstream of the shock

(iii) Percent loss of total pressure due to shock wave.

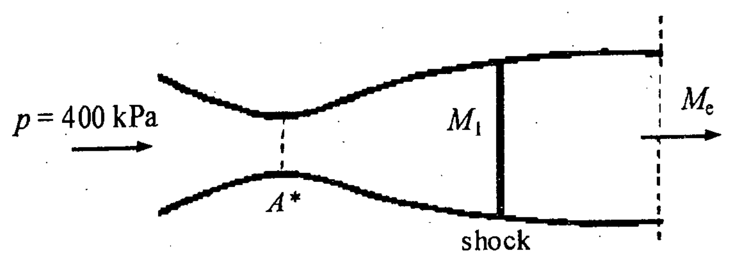


Fig. for Q. 7(b)

8. (a) Explain nozzle flows in under-expanded condition. **(10)**

(b) Mention the advantages and disadvantages of dimensional analysis. **(10)**

(c) Sonic velocity in a assumed to be a function of gas density ρ, pressure p, and dynamic viscosity μ. Determine a functional relationship using dimensional analysis. **(15)**

4

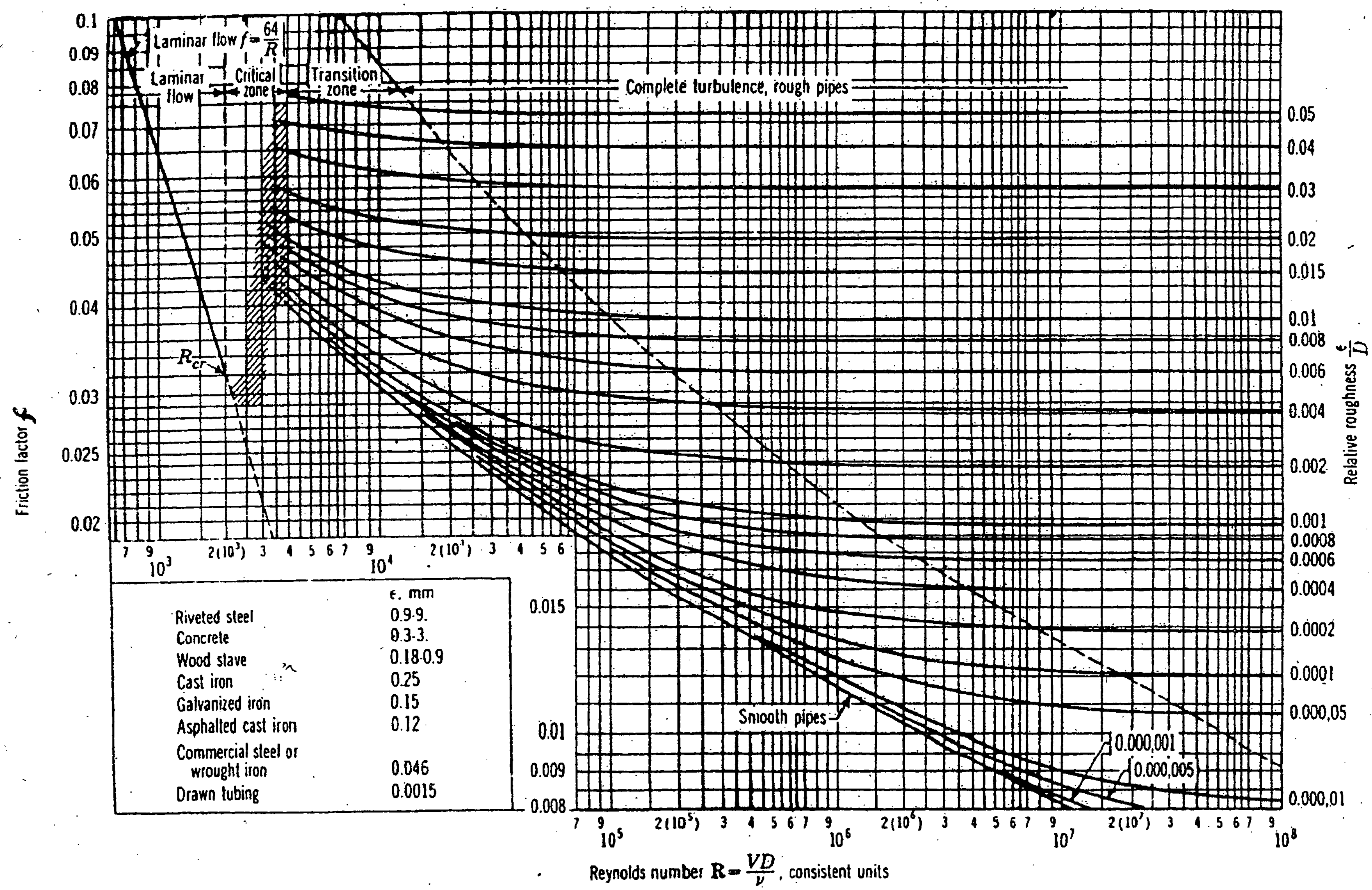


Figure Moody diagram.

L-3/T-2/ME **Date : 15/12/2014**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-2 B.Sc. Engineering Examinations 2012-2013

Sub : **IPE 381** (Measurement and Quality Control)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this Section. Answer any **THREE**.

1. (a) Define frequency distribution. What are the differences between frequency distribution and cumulative frequency distribution? A data set consists of 145 observations that range from 56 to 490. What size class interval do you recommend? **(8)**

   (b) How does probabilistic reasoning differ from statistical reasoning? In a game of Yahtzee, where 5 dice are tossed simultaneously. Find the probability of getting 4 of a kind. **(2+5)**

   (c) A producer of a certain type of electronic component ships to suppliers in lots of twenty. Suppose that 60% of all such lots contain no defective components, 30% contain one defective component, and 10% contain two defective components. A lot is picked, two components from the lot are randomly selected and tested, and neither is defective. **(8)**

   (i) What is the probability that zero defective components exist in the lot?

   (ii) What is the probability that one defective exists in the lot?

   (d) Write short notes on the following topics, **(12)**

   (i) Stem and leaf plot (ii) Tree diagram (iii) The law of total probability

2. (a) What do you understand by probability distribution? From a box containing 4 black balls and 2 green balls, 3 balls are drawn in succession, each ball being replaced in the box before the next draw is made. Find the probability distribution for the number of green balls. **(4+8)**

   (b) What are the similarities and dissimilarities between Bernoulli's experiment and Poisson experiment? The acceptance scheme for purchasing lots containing a large number of batteries is to test no more than 75 randomly selected batteries and to reject a lot if a single battery fails. Suppose the probability of a failure is 0.001. **(6+8)**

   (i) What is the probability that a lot is accepted?

   (ii) What is the probability that a lot is rejected on the 20th test?

   (iii) What is the probability that it is rejected in 10 or fewer trials?

   (c) Write down the conditions for approximating normal distribution to binomial distribution. Using approximation solve the following problem. A multiple-choice quiz has 200 questions, each with 4 possible answers of which only 1 is correct. What is the probability that sheer guesswork yields from 25 to 30 correct answers for the 80 of the 200 problems about which the student has no knowledge? **(3+6)**

IPE 381

3. (a) List the advantages of acceptance sampling plan. **(5)**

(b) A company and its customer have agreed to follow a double sampling plan. The first sample size n_1 = 40 and maximum allowable no. of nonconforming products for first sample c_1 = 2. For second sample, n_2 = 80 and c_2 = 4. Lot size for this sampling plan, N = 3000. Calculate the probability of acceptance if company follows 2-sigma control limit for the process and products' quality measures follow normal distribution. **(18)**

(c) Write short notes on the following topics. **(12)**

(i) Average Outgoing Quality

(ii) Centre, Limit theorem

(iii) Measures of central tendency

4. (a) Briefly describe the Ishikawa diagram. **(5)**

(b) Why is it difficult to eliminate natural causes than assignable causes? Explain. Also discuss some patterns that would be considered as indication of out of control. **(10)**

(c) A taxi company manager is trying to decide whether the use of radial tires instead of regular belted tires improves fuel economy. Twelve cars were equipped with radial tires and driven over a prescribed test course. Without changing drivers, the same cars were then equipped with regular belted tires and driven once again over the test course. The gasoline consumption, in kilometers per liter, was recorded as follows: **(20)**

	Kilometers per Liter	
Car	Radial Tires	Belted Tires
1	4.2	4.1
2	4.7	4.9
3	6.6	6.2
4	7.0	6.9
5	6.7	6.8
6	4.5	4.4
7	5.7	5.7
8	6.0	5.8
9	7.4	6.9
10	4.9	4.7
11	6.1	6.0
12	5.2	4.9

Can we conclude that cars equipped with radial tires give better fuel economy than those equipped with belted tires? Assume the populations to be normally distributed.

SECTION – B

There are **FOUR** questions in this Section. Answer any **THREE**.

5. (a) What do you understand by type I error and type II error in test of hypothesis? A soft drink machine at a steak house is regulated so that the amount of drink dispensed is approximately normally distributed with a mean of 200 milliliters and a standard deviation of 15 milliliters. **(18)**

IPE 381

The machine is checked periodically by taking a sample of 9 drinks and computing the average content. If $\bar{x}$ falls in the interval $191 < \bar{x} < 209$, the machine is thought to be operating satisfactory; otherwise, we conclude that $\mu \neq 200$ milliliters.

(i) Find the probability of committing a type I error when $\mu = 200$ milliliters.

(ii) Find the probability of committing a type II error when $\mu = 215$ milliliters.

(b) Show that the mean square error

$$s^2 = \frac{SSE}{k(n-1)}$$

for the analysis of variance in a one-way classification is an unbiased estimate of σ^2. **(10)**

(c) What is P-Value? Briefly discuss its significance with example. **(7)**

6. (a) What are the objectives of quality circle? State the steps the team member of QC follow to achieve these objectives. **(8)**

(b) According to Deming's Quality Principles what do you understand by eliminating exhortations? What can an organization do to follow the principle? **(7)**

(c) Calculate the dimensions of plug and ring gauges to control the production of 50 mm shaft and hole pair of H_7/d_8 as per IS specification. Given, 50 mm lies in diameter step of 30 and 50 mm and tolerance factor i (in microns) = $0.45\sqrt[3]{D} + 0.001D$. Also consider gauge maker's tolerance to be 10% and wear allowance to be 5% of the work tolerance. **(20)**

7. (a) Explain the various instruments used for linear measurements. **(10)**

(b) Describe the working principle of 'Autocollimator'. **(9)**

(c) Describe a method to measure the effective pitch diameter of a screw plug gauge. Also explain how the errors in pitch and angle affect the virtual effective diameter. **(10)**

(d) Derive an expression for the best size wire. **(6)**

8. (a) Write down the uses of non-destructive testing. Briefly describe the 'Ultrasonic Inspection method' with neat sketch. **(12)**

(b) What is meant by roughness and waviness of machined surface? How does the 'Tomlinson surface recorder' work? Explain with necessary sketch. **(15)**

(c) Explain the 'constant chord method' of measuring tooth thickness. **(8)**

Table 1: Formulae for Fundamental Deviations for Shafts for sizes upto 500 mm

Upper Deviation (es)

Shaft Designation	In microns (for D in mm)
a	$= -(265+1.3D)$ for $D \le 120$ and $= -3.5D$ for $D > 120$
b	$= -(140+0.85D)$ for $D \le 160$ $= -1.8D$ for $D > 160$
c	$= -52D^{0.2}$ for $D \le 40$ $= -(95+0.8D)$ for $D > 40$
d	$= -16D^{0.44}$
e	$= -11D^{0.41}$
f	$= -5.5D^{0.41}$
g	$= -2.5D^{0.34}$
h	$= 0$

Lower Deviation (ei)

Shaft Designation	In microns (for D in mm)
$j5$ to $j8$	No formula
$k4$ to $k8$	$= +0.6\sqrt[3]{D}$
k for grade ≤ 3 and ≥ 4	$= 0$
m	$= +(IT7 - IT6)$
n	$= +5D^{0.34}$
p	$= +IT7 + 0$ to 5
r	= geometric mean of values ei for p and s
s	$= IT8 + 1$ to 4 for $D \le 50$ $= +IT7$ to $+0.4D$ for $D>50$
t	$= IT7 + 0.63D$
u	$= +IT7 + D$
v	$= +IT7 + 1.25D$
x	$= +IT7 + 1.6D$
y	$= +IT7 + 2d$
z	$= +IT7 + 2.5D$
za	$= IT8 + 3 + 3.15D$
zb	$= +IT9 + 4D$
zc	$= +IT10 + 5D$

For js : The deviation are equal to $\pm IT/2$

Table 2: Standard Tolerances

IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14	IT15	IT16
10i	16i	25i	40i	64i	100i	160i	250i	400i	640i	1000i

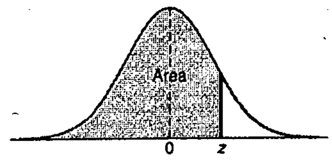


Table A.3 Areas under the Normal Curve

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
−3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002
−3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
−3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
−3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
−3.0	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
−2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
−2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
−2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
−2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
−2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
−2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
−2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
−2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
−2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
−2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
−1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
−1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
−1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
−1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
−1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
−1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
−1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
−1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
−1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
−1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
−0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
−0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
−0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
−0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
−0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
−0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
−0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
−0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
−0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
−0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641

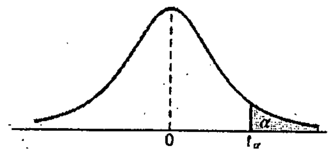


Table A.4 Critical Values of the t-Distribution

	α						
v	**0.40**	**0.30**	**0.20**	**0.15**	**0.10**	**0.05**	**0.025**
1	0.325	0.727	1.376	1.963	3.078	6.314	12.706
2	0.289	0.617	1.061	1.386	1.886	2.920	4.303
3	0.277	0.584	0.978	1.250	1.638	2.353	3.182
4	0.271	0.569	0.941	1.190	1.533	2.132	2.776
5	0.267	0.559	0.920	1.156	1.476	2.015	2.571
6	0.265	0.553	0.906	1.134	1.440	1.943	2.447
7	0.263	0.549	0.896	1.119	1.415	1.895	2.365
8	0.262	0.546	0.889	1.108	1.397	1.860	2.306
9	0.261	0.543	0.883	1.100	1.383	1.833	2.262
10	0.260	0.542	0.879	1.093	1.372	1.812	2.228
11	0.260	0.540	0.876	1.088	1.363	1.796	2.201
12	0.259	0.539	0.873	1.083	1.356	1.782	2.179
13	0.259	0.538	0.870	1.079	1.350	1.771	2.160
14	0.258	0.537	0.868	1.076	1.345	1.761	2.145
15	0.258	0.536	0.866	1.074	1.341	1.753	2.131
16	0.258	0.535	0.865	1.071	1.337	1.746	2.120
17	0.257	0.534	0.863	1.069	1.333	1.740	2.110
18	0.257	0.534	0.862	1.067	1.330	1.734	2.101
19	0.257	0.533	0.861	1.066	1.328	1.729	2.093
20	0.257	0.533	0.860	1.064	1.325	1.725	2.086
21	0.257	0.532	0.859	1.063	1.323	1.721	2.080
22	0.256	0.532	0.858	1.061	1.321	1.717	2.074
23	0.256	0.532	0.858	1.060	1.319	1.714	2.069
24	0.256	0.531	0.857	1.059	1.318	1.711	2.064
25	0.256	0.531	0.856	1.058	1.316	1.708	2.060
26	0.256	0.531	0.856	1.058	1.315	1.706	2.056
27	0.256	0.531	0.855	1.057	1.314	1.703	2.052
28	0.256	0.530	0.855	1.056	1.313	1.701	2.048
29	0.256	0.530	0.854	1.055	1.311	1.699	2.045
30	0.256	0.530	0.854	1.055	1.310	1.697	2.042
40	0.255	0.529	0.851	1.050	1.303	1.684	2.021
60	0.254	0.527	0.848	1.045	1.296	1.671	2.000
120	0.254	0.526	0.845	1.041	1.289	1.658	1.980
∞	0.253	0.524	0.842	1.036	1.282	1.645	1.960

Table A.4 (continued) Critical Values of the *t*-Distribution

	α						
v	**0.02**	**0.015**	**0.01**	**0.0075**	**0.005**	**0.0025**	**0.0005**
1	15.894	21.205	31.821	42.433	63.656	127.321	636.578
2	4.849	5.643	6.965	8.073	9.925	14.089	31.600
3	3.482	3.896	4.541	5.047	5.841	7.453	12.924
4	2.999	3.298	3.747	4.088	4.604	5.598	8.610
5	2.757	3.003	3.365	3.634	4.032	4.773	6.869
6	2.612	2.829	3.143	3.372	3.707	4.317	5.959
7	2.517	2.715	2.998	3.203	3.499	4.029	5.408
8	2.449	2.634	2.896	3.085	3.355	3.833	5.041
9	2.398	2.574	2.821	2.998	3.250	3.690	4.781
10	2.359	2.527	2.764	2.932	3.169	3.581	4.587
11	2.328	2.491	2.718	2.879	3.106	3.497	4.437
12	2.303	2.461	2.681	2.836	3.055	3.428	4.318
13	2.282	2.436	2.650	2.801	3.012	3.372	4.221
14	2.264	2.415	2.624	2.771	2.977	3.326	4.140
15	2.249	2.397	2.602	2.746	2.947	3.286	4.073
16	2.235	2.382	2.583	2.724	2.921	3.252	4.015
17	2.224	2.368	2.567	2.706	2.898	3.222	3.965
18	2.214	2.356	2.552	2.689	2.878	3.197	3.922
19	2.205	2.346	2.539	2.674	2.861	3.174	3.883
20	2.197	2.336	2.528	2.661	2.845	3.153	3.850
21	2.189	2.328	2.518	2.649	2.831	3.135	3.819
22	2.183	2.320	2.508	2.639	2.819	3.119	3.792
23	2.177	2.313	2.500	2.629	2.807	3.104	3.768
24	2.172	2.307	2.492	2.620	2.797	3.091	3.745
25	2.167	2.301	2.485	2.612	2.787	3.078	3.725
26	2.162	2.296	2.479	2.605	2.779	3.067	3.707
27	2.158	2.291	2.473	2.598	2.771	3.057	3.689
28	2.154	2.286	2.467	2.592	2.763	3.047	3.674
29	2.150	2.282	2.462	2.586	2.756	3.038	3.660
30	2.147	2.278	2.457	2.581	2.750	3.030	3.646
40	2.123	2.250	2.423	2.542	2.704	2.971	3.551
60	2.099	2.223	2.390	2.504	2.660	2.915	3.460
120	2.076	2.196	2.358	2.468	2.617	2.860	3.373
∞	2.054	2.170	2.326	2.432	2.576	2.807	3.290