Ministry of Higher Education & Scientific Research **Tikrit University** **College of Engineering** **Chemical Eng. Dept.**	**2026-2025**	وزارة التعليم العالي والبحث العلمي جامعةتكريت كلية الهندسة قسم الهندسة الكيمياوية

Subject: Reactor Design

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Q1: The rate of the formation of NO_2 in the reaction

$2NO+O_2$<----->$2NO_2$

If r_{NO2}= 4 mol/m^3.s. The rate of disappearance of O_2, $-r_{O2}$

A. -4 mole/m^3.s B. +8 mole/m^3.s

C. +2 moles/m^3.s D. -2 mole/m^3.s

Q2: For an irreversible second order reaction 50% conversion is currently achieved in one CSTR of 1000 L. It is proposed to use two 500 L CSTRs placed side by side with the feed equally divided. The exit conversion for the two CSTRs will be:

A. X >50% B. X <50%

C. X=50% D. Insufficient information to tell

Q3: the gas phase reversible is isomerization 2A<---->B+C Follows an elementary rate law and is to be carried out in a membrane reactor (IMRCF). Species B can diffuse out the walls of the membrane, while A and C cannot. The equilibrium constant for the reaction as written is Kc=1.0. An equimolar mixture of A and inert is fed to the conventional PFR. What is the equilibrium conversion in the conventional PFR?

A. 0.8 B. 0.66

C. 0.286 D. Insufficient information to tell

Q4 Consider the reaction network below: if the overall selectivity of W to P is 4.0, what is the overall yield of P?

A------>W

A------>P

A. 0.2 B. 0.8

C. 0.75 D. 4.0

Q5: A “reaction runaway” is possible in exothermic reaction process due to:

A. Poor catalyst activity B. High flow rate of coolant

C. Uncontrolled reaction temperature D. Having multiple steady state points of reaction

Q6: The reaction A----->D is carried out adiabatically. The heat capacities of A and D are approximately equal at 20J/mol.K. When a conversion of 50% is achieved in a PFR, the outlet temperature is 50K higher than the inlet. What is the heat of reaction?

A. 0.5 kJ/mol B. -0.5 kJ/mole

C. 2.0 kJ/mole D. -2.0 kJ/mole

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Q7: What is the main advantage of using a Packed Bed Rea

A. Uniform temperature distribution B. High-pressure drop

C. High surface area for reactions D. Easy to clean

Q8: Which of the following statements is true for reactors in series?

A. The total conversion is the sum of individual conversions.

B. The reactant concentration is the same in each reactor.

C. The total conversion is higher than in a single reactor of the same volume.

D. The total volume is less than the volume of a single reactor.

Q9: In non-isothermal reactors, the term "hot spot" refers to:

A. An area with high reactant concentration

B. A region with significantly higher temperature

C. A point of catalyst deactivation

D. A zone with low reaction rate

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Q10:. A liquid-phase first-order reaction A→B takes place in a CSTR. Feed concentration C_{A0}=2 mol/L, rate constant k=0.5 min−1, and flow rate =10 L/min. Find the reactor volume needed to achieve 75%

A. 15 L

B. 30

C. 40

D. 20

Q11:

A gas-phase reaction A→C follows first-order kinetics with $k=0.3\ min^{-1}$.
The inlet molar flow rate of A is 4 mol/min, and the feed concentration C_{A0}=1 mol/L.
Find the PFR volume needed to achieve 80% conversion.

A. 4.6 L

B. 5.4

C. 6.1

D. 2.5

Q12.

For A→B→C, with $k_1=2\ min^{-1}$, $k_2=1\ min^{-1}$. At what conversion of A is B at maximum concentration in a PFR?

A. 33%
B. 50%
C. 66%
D. 75%

Q13

For a CSTR with two competitive reactions:
A→B (k1=2 min^{-1})
A→D (k2=1 min^{-1}).
If the desired conversion is 60%, find the overall rate of disappearance of A.

A. 1.2
B. 1.8
C. 2.4
D. 0.6

Q14. A→B (k1=0.4 min^{-1}) and A→C (k2=0.2 min^{-1}) occur in a PFR.
If XA=0.7X_A = 0.7XA=0.7, find the yield of BBB based on A consumed.

A. 0.55
B. 0.65
C. 0.35
D. 0.45

Q15 Two identical CSTRs are connected in series for a first-order reaction with k=0.5 min^{-1}.
Overall desired conversion is 80%. What is the conversion per reactor approximately?

A. 64%
B. 40%
C. 50%
D. 60%

Q16: The packed bed reactor operates with a feed rate of 100 mol/h of A. If the reactor volume is 0.5 m^3, void fraction ϵ=0.4, and superficial velocity u_0=0.01 m/s, what is the residence time τ inside the reactor?

A. 40 s
B. 50 s
C. 60 s
D. 30 s

Q17:

An adiabatic PFR processes an exothermic reaction. If the inlet temperature is 500 K and conversion increases, what happens to the temperature?

A. Decreases
B. Remains constant

C. Increases
D. Decreases first then increases

Q18: The slope of the heat generation curve in a reactor stability diagram is determined by:

A) Reactor volume
B) Reaction kinetics
C) Coolant temperature
D) Catalyst particle size

Q19: A reactor is designed for a non-isothermal reversible exothermic reaction. To favor high conversion, the strategy should be:

A) Increase temperature throughout
B) Decrease temperature after partial conversion
C) Maintain constant high temperature
D) Use inert cooling gas injection

Q20: For a zero-order reaction in parallel CSTRs, the overall conversion is:

A) Higher than single CSTR
B) Lower than single CSTR
C) Same as single CSTR
D) Cannot be determined

Q21: Two equal volume CSTRs are placed in series for a second-order reaction. Compared to a single CSTR, the conversion is approximately:

A) Higher
B) Lower
C) Same
D) Depends on feed concentration

Q22: A single CSTR achieves 50% conversion. Using two equal CSTRs in series with same total volume, conversion becomes approximately:

A) 50%
B) 70%
C) 66%
D) 30%

Q23: In parallel operation of two PFRs, if one has twice the volume of the other, under identical kinetics, to maximize conversion:

A) Feed split equally
B) Feed split in proportion to volume
C) Feed to smaller reactor
D) All feed to bigger reactor

Q24: A PFR of volume 400 L gives 70% conversion for a first-order reaction. Two PFRs in series each of 200 L will give:

A) Less than 70%
B) 70%
C) More than 70%
D) Cannot determine

Q25: What is the activation energy (in kJ) of a reaction whose rate constant increases by a factor of 100 upon increasing the temperature from 300 K to 360 K?

A. 27 B. 35

C. 42 D. 69

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Q26: What is the main advantage of using a Packed Bed Reactor in catalytic processes?

A. Uniform temperature distribution B. High-pressure drop

C. High surface area for reactions D. Easy to clean

Q27 A gas phase isomerization reaction 2A<----->B+C follows an elementary rate law and it is carried out in a membrane reactor. In which of the following figures is the rate of transport of Bout of the reactor is the fastest?

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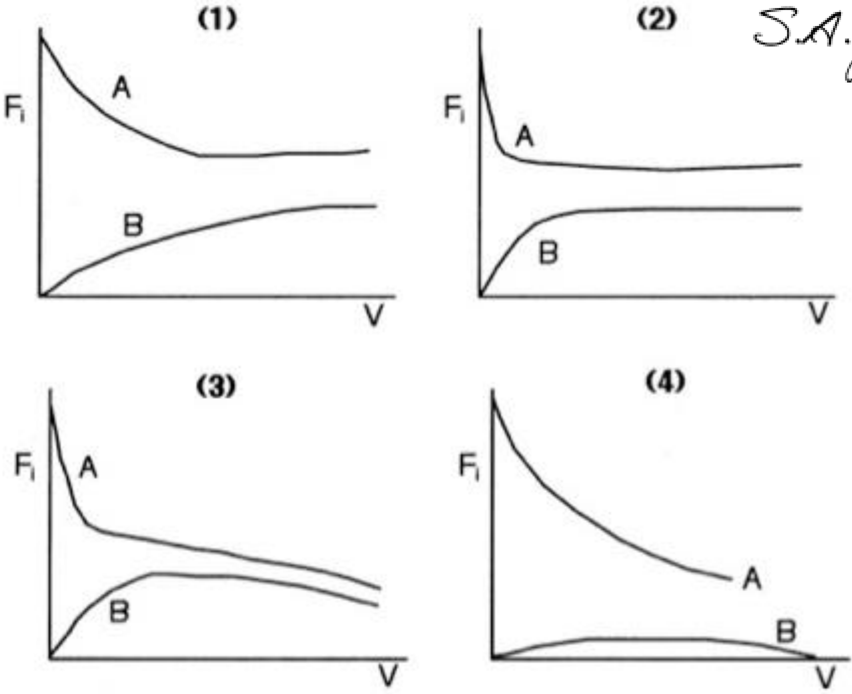

Q28:. A liquid-phase first-order reaction A→B takes place in a CSTR. Feed concentration C_{A0}=2 mol/L, rate constant k=0.5 min−1, and flow rate =10 L/min. Find the reactor volume needed to achieve 75%

A. 15 L

B. 30

C. 40

D. 20

Q29: A→B (k1=0.4 min^{-1}) and A→C (k2=0.2 min^{-1}) occur in a PFR.
If X_A=0.7, find the yield of BBB based on A consumed.

A. 0.55

B. 0.65

C. 0.35

D. 0.45

Q30:A packed bed reactor processes a gas-phase reaction with pressure drop according to y = 1 - αX, with α = 0.2. If X = 0.5, find the pressure ratio y.

A. 0.9

B. 0.8

C. 0.7

D. 0.6

Good Luck

Examination Committee

Unit Operations

Q1: Which of the following is a press filter?

A. Sand filter

B. Rotary drum filter

C. Plate and frame filter

D. Leaf filter

Q2: For a non-spherical particle, the sphericity

A. Is defined as the ratio of surface area of a sphere having the same volume as the particle to the actual surface area of the particle.

B. Is the ratio of volume of a sphere having the same surface area as the particle to the actual volume of the particle.

C. has the dimension of length.

D. is always less than 1.

Q3: In washing type plate and frame filter, the ratio of washing rate to the final filtrate rate is

A. 4

B. 1/4

C. 2

D. 1/2

Q4: What is the term used to describe the process of separating suspended particles from a liquid?

A. Evaporation

B. Sieving

C. Sedimentation

D. Centrifugation

Q5: Equivalent diameter of a particle is the diameter of the sphere having the same

A. Ratio of surface to volume as the actual volume

B. Volume as the particle.

C. Ratio of volume to surface as the particle.

D. None of these.

Q6: In a packed bed column, the packing material is typically used to:

A. Increase the contact area for the interaction between phases

B. Provide structural support to the column

C. Increase the flow rate of fluids

D. Remove heat from the system

Q7: Highly viscous liquids & pastes are agitated by

A. Multiple blade paddles

B. Propellers

C. Turbine agitators

D. None of these

Q8: The value of ‘angle of nip’ is generally about

A. 52°

B. 32°

C. 16°

D. 64°

Q9: Gravity settling process is not involved in the working of a

A. Classifier

B. Dorr-thickener

C. Hydro cyclone

D. Sedimentation tank

Q10: The energy required per unit mass to grind limestone particles of very large size to 100 μm is 12.7 kWh/ton. An estimate (using Bond's law) of the energy to grind the particles from a very large size to 50 μrn is

A. 9.0 kWh/ton

B. 18 kWh/ton

C. 25.4 kWh/ton

D. 6.35 kWh/ton

Q11: Filter aid is used to

A. Increase the rate of filtration.

B. Increase the porosity of the cake

C. Decreases the pressure drop.

D. Act as a support base for the septum.

Q12: The main size reduction operation in ultrafine grinders is

A. Cutting

B. Attrition

C. Compression

D. Impact

Q13: If a force greater than that of gravity is used to separate solids & fluids of different densities, the process is termed as the

A. Dispersion

B. Centrifugation

C. Sedimentation

D. fluidization

Q14: Where the density difference of the two liquid phase to be separated is very small (as in milk cream separator), the most suitable separator is a

A. sharpies super centrifuge

B. disc bowl centrifuge.

C. batch basket centrifuge

D. sparkler filter.

Q15: Maximum size reduction in a ball mill is done by the, __________ action.

A. Impact

B. Compression

C. Attrition

D. Cutting

Q16: Ball mill is used for

A. Cutting

B. Crushing

C. Grinding

D. Attrition

Q17: Which of the following is a vacuum filter?

A. Rotary disc filter

B. Filter press

C. Batch basket centrifuge

D. Tank filter (Nutsch filter)

Q18: In case of a hammer crusher, the

A. minimum product size is 3 mm.

B. maximum feed size may be 50 mm.

C. feed may be highly abrasive (Moh's scale >5)

D. rotor shaft carrying hammers can be vertical or horizontal.

Q19: Flow of filtrate through the cake in a plate and frame filter is best described by the __________ equation.

A. Fanning's

B. Hagen-Poiseulle's

C. Kozney-Carman

D. Carman

Q20: The porosity of a compressible cake is

A. Minimum at the filter medium.

B. Maximum at the filter medium.

C. Minimum at the upstream face.

D. Same throughout the thickness of cake.

Q21: The filtrate flow rate in constant pressure filtration

A. Continuously increases.

B. Remains constant throughout.

C. Continuously decreases.

D. May increase or decrease ; depends on the pressure.

Q22: A propeller agitator

A. Produces mainly axial flow

B. Runs at very slow speed (2 rpm)

C. Is used for mixing high viscosity pastes

D. All (a), (b) and (c)

Q23: Separation of a suspension or slurry into a supernatant clear liquid (free from particles) and a thick sludge containing a high concentration of solid is called

A. Classification

B. Sedimentation

C. Clarification

D. Decantation

Q24: Filtration rate does not depend upon the

A. Pressure drop & area of filtering surface

B. Resistance of the cake & the septum

C. Properties of the cake & the filtrate

D. None of these

Q25: With increase in drum speed, in a rotary drum filter, the filtration rate

A. Increases

B. Increases linearly

C. Decreases

D. Is not affected

Q26: The specific surface of spherical particles is given by (where D and ρ are diameter and density of particle).

A. 6/ D.ρ

B. 4/ D.ρ

C. 2/ D.ρ

D. 12/ D.ρ

Q27: Flooding in a column results due to

A. High pressure drop
B. Low pressure drop
C. Low velocity of the liquid
D. High temperature

Q28: Determine the Reynolds number for an agitated liquid with an impeller diameter of 3 feet, an agitator speed of 3,600 rph, fluid density of 64 lbs/cu. ft., and fluid viscosity of 2.12 lb/hr-ft.

A. 977,035
B. 900,045
C. 800,045
D. 877,035

Q29: What is the most important factor to be considered for designing a fluidized bed reactor?

A. Diameter of reactor
B. Size distribution of solids
C. Gas flow rate
D. Height of reactor

Q30: Fluid flow through a packed bed is represented by the

A. Fanning's equation
B. Ergun's equation
C. Hagen-Poiseuille's equation
D. None of these equation

Good Luck

Examination Committee

Subject: Petroleum Refining

Q1: A crude oil has an API of 35 and MeABP of 223 °C, the crude oil can be classified as

A. Naphthenic base crude
B. Intermediate base crude
C. Paraffinic base crude
D. Paraffinic Intermediate base crude

Q2 An Iraqi Oil having a specific gravity of 0.8975 at 60 ºF. The API of such oil is

A. 33.4
B. 9.5
C. 19.7
D. 26.2

Q3: One of the most typical diesel additives that should be added to improve the performance of gasoline fuel is

A. Solvents
B. Anti-oxidation
C. Heptane
D. Detergent

Q4: The main catalyst used in a fluidized catalytic cracking reactor is

A. Cobalt
B. Zeolite
C. Tungusten
D. Platinum

Q5: Two oil cuts have mixed together with a sp.gr of 0.861 and 0.856 for 1st and 2nd cut, respectively. The oil produced can be classified as

A. **N**
B. PIN
C. INP
D. P

Q6: An Australian diesel fuel at a specific gravity of 0.866 and aniline point of 159.8 °F. The diesel Index of such oil is evaluated to be

A. **50.97**
B. 61.23
C. 68.33
D. 74.87

Q7: The RVP of a blend LSR gasoline (5000 BPD, 11.1 psi (RVP)) and FCC gasoline (6000 BPD, 2.8 psi (RVP)) has estimated to be

A. **12.66 psi**
B. 13.87psi
C. 14.78
D. 16.18

Q8: One of the key product properties of kerosene that should be measured is

A. Metals content
B. Asphaltenes
C. Viscosity Index
D. Flash point

Q9: A gas oil product with boiling range of 260-350°C from Iraqi crude oil has an API gravity of 16 and T_{10} is 307°C. The flash point of this cut is determined to be

A. 152.5°C
B. 120°C
C. 79.88°C
D. 188.41°C

Q10: The Sulfur content of crude oils varies from less than 0.05 to more than 10 wt% but generally falls in the range of

A. 1-4 wt%
B. 0.8-3wt%
C. 2-5 wt%
D. 3 – 6 wt%

Q11: Which of the following is a major component of crude oil?

A. Alkanes
B. Alkenes
C. Aromatics
D. All of the above

Q12: What does API gravity measure?

A. Viscosity
B. Density
C. Sulfur Content
D. Boiling Point

Q13: Which fraction is typically collected at the top of a distillation column?

A. Residue
B. Gasoline
C. Diesel
D. lub oil

Q14: Which of the following processes is used to convert heavy hydrocarbons into lighter fractions?

A. Alkylation
B. Reforming
C. Cracking
D. Isomerization

Q15: What is the primary purpose of a distillation column in a refinery?

A. To chemically alter crude oil
B. To separate crude oil into different components
C. To remove impurities from crude oil

D. To mix various fuel additives

Q16: What type of cracking uses a catalyst to speed up the chemical reactions?

A. Thermal cracking
B. Fluid catalytic cracking (FCC)
C. Hydrocracking
D. Steam cracking

Q17: The main product obtained from catalytic reforming is:

A. Gasoline with high octane number
B. Diesel fuel
C. Asphalt
D. Lubricating oil

Q18: Which of the following is a sweetening process in petroleum refining?

A. Deasphalting
B. Hydrodesulfurization
C. Cracking
D. Polymerization

Q19: Which of these is not a product of crude oil refining?

A. Kerosene
B. Naphtha
C. Methanol
D. Diesel

Q20: Octane number is a measure of:

A. Viscosity
B. Ignition temperature
C. Knocking tendency of gasoline
D. Sulfur content

Q21: In the refining process, hydrotreating is primarily used to:

A. Increase octane number
B. Reduce sulfur content
C. Break large molecules
D. Improve viscosity

Q22: Estimate the flash point blending when experimental cut A (3000 BPD, BI_{FPA} =435.2) is blended with experimental cut B (5000 BPD, BI_{FPA} =122.5)

A. 254.15 K
B. 53.11 ˚C
C. 117.5 ˚F
D. 478.23 ˚R

Q23: What is the pour point when the following LVGO (3500 BPD, pour point = 38 ˚C) is blended with HVGO (1500 BPD, pour point = 44 ˚C)?

A. 316.7 K
B. 65.3 ˚C
C. 340.6 ˚F
D. 544.1 ˚R

Q24: Determine the acid make-up rate when the acid dilution ratio is 1.2. The alkylate unit having feed of 1500 BPD, $(I/O)_F$ =10 and the acid strength of 85.44.

A. 19556.4 lb/day
B. 20134.8 lb/day
C. 21632.5 lb/day
D. 22013.9 lb/day

<u>Q25:</u> What is the first step in petroleum refining?
A. Cracking
B. Alkylation
C. Distillation
D. Reforming

<u>Q26:</u> Which of the following is considered the lightest product in crude oil distillation?
A. Diesel
B. Kerosene
C. Fuel oil
D. LPG

<u>Q27:</u> Which process improves the octane number of gasoline?
A. Reforming
B. Deasphalting
C. Hydrocracking
D. Coking

<u>Q28:</u> Which of the following is a by-product of the cracking process?
A. Asphalt
B. Hydrogen
C. Residuum
D. Paraffin wax

<u>Q29:</u> Which of these processes is used to convert olefins and isobutane into high-octane gasoline components?

A. Polymerization
B. Alkylation
C. Desulfurization
D. Reforming

<u>Q30:</u> The API gravity of a crude oil sample indicates:

A. Sulfur content
B. Viscosity
C. Lightness or heaviness of the crude
D. Corrosiveness

Good Luck

Examination Committee

Heat Transfer

Q1: An insulation surrounded a pipe of 300ºC exposed to air 25ºC. If the radius of insulation at its critical value, the heat transfer rate will

A. be at the maximum value B. be equal to zero

C. be at the minimum value D. not change

``

Q2 Air at 1 atm and 300 K flows across a 20-cm-square plate at a free-stream velocity of 20 m/s. The plate is heated to a constant temperature of 350 K. The plate will lose heat from its surface by

A. conduction B. forced convection

C. radiation D. free convection

Q3: Clothes of……..colours absorb heat better than clothes of ……..colours

A. dark, light B. soft, dark

C. light, dark D. none of these

Q4: If a heated plate is exposed to ambient room air without an external source of motion, a movement of the air would be experienced as a result of the……………… near the plate.

A. specific heat change B. thermal conductivity change

C. density gradients D. none of these

Q5: If the outer radius of insulation is less than the critical value then the heat transfer will be ………..by adding more insulation

A. increased B. constant

C. zero D. decreased

Q6: Air at 1 atm and 300 K flows across a 20-cm-square plate at a free-stream velocity of 20 m/s. The plate is heated to a constant temperature of 350 K. the plate will be lost heat from its surface by

A. conduction
B. forced convection
C. radiation
D. free convection

Q7: In a shell and tube heat exchanger, baffles are provided on the shell side to

A. Improve the heat transfer
B. Provide support for tubes
C. Prevent stagnation of shell side fluid
D. All of these

Q8: The heat transfer rate is increased with an increase in

A. thermal potential difference
B. thermal conductivity of material
C. surface area
D. all of these

Q9: The heat transfer is carried out in solids due to

A. temperature difference
B. increasing in the thermal conductivity
C. changing in dimensions
D. none of these

Q10: The direction of heat transfer through the bodies is

A. normal to the surface area
B. parallel to the surface area
C. random
D. none of these

Q11: Boiled egg can be cooled at room temperature by

A. radiation
B. forced convection
C. conduction
D. natural convection

Q12: The heat transfer from bodies to surrounding using fins is carried out by

A. conduction-convection
B. convection-radiation
C. conduction
D. convection

Q13: The thermal conductivity of material is strongly depending on t Biot number is related to the

A. free convection heat transfer
B. lumped-heat capacity method
C. forced convection heat transfer
D. radiation

Q14: Nusselt number for forced convection heat transfer is a function of

A. Biot number and Reynolds number
B. Prandtl number and Grashof number
C. Reynolds and Prandtl number
D. Reynolds number and Grashof number

Q15: The lumped-heat-capacity analysis are based on the assumption that the internal resistance of the body is ……….. in comparison with the external resistance

A. high
B. constant
C. negligible
D. fluctuated

Q16: The ………… is a dimensionless fluid property defined by the ratio of the kinematic viscosity and the thermal diffusivity

A. Nusselt number
B. Reynolds number
C. Prandtl number
D. Biot number

Q17: …………. heat transfer is a process where heat waves are emitted that may be absorbed, reflected, or transmitted through a colder body.

A. Conduction
B. Radiation
C. Forced convection
D. Natural convection

Q18: A flat wall is exposed to an environmental temperature of 38^{o}C. The wall is covered with a layer of insulation 2.5 cm thick whose thermal conductivity is 1.4 W/m.^{o}C, and the temperature of the wall on the insulation is 315^{o}C. The wall loses heat to the environment by convection. Compute the value of the convection heat-transfer coefficient that must be maintained on the outer surface of the insulation to ensure that the outer- surface temperature does not exceed 41^{o}C.

A. 5114 W/m^2.^{o}C
B. 725 W/m^2.^{o}C
C. 3009 W/m^2.^{o}C
D. 28 W/m^2.^{o}C

Q19: Calculate the critical radius of insulation for asbestos (k =0.17 W/m.°C) surrounding a pipe and exposed to room air at 20°C with h = 3.0 W/m^2.°C.

A. 2.5 cm
B. 5.67 cm
C. 10 cm
D. 1.56 cm

Q20: A stainless-steel rod (ρ = 7817 kg/m^3, c = 460 J/kg °C) 6.4 mm in diameter is initially at a uniform temperature of 25°C and is suddenly immersed in a liquid at 150°C with h = 120 W/m^2 °C. By using lumped-capacity method of analysis, the time necessary for the rod temperature to reach 120°C is

A. 80.12 s
B. 10.33 s
C. 68.41 s
D. 120.55 s

Q21: A rod of 3 cm diameter and 20 cm length is maintained at 100°C at one end and 10°C at the other end. These temperature conditions are attained when there is heat flow rate of 6 W. If cylindrical surface of the rod is completely insulated, determine the thermal conductivity of the rod material

A. 21.54 W/m °C
B. 14.63 W/m °C
C. 18.86 W/m °C
D. 30.37 W/m °C

Q22: An electric current is passed through a wire 1 mm in diameter and 10 cm long. The wire is submerged in liquid water at atmospheric pressure, and the current is increased until the water boils. For this situation h = 5000 W/m^2.°C, and the water temperature will be 100°C. How much electric power must be supplied to the wire to maintain the wire surface at 114°C?

A. 78.72 W
B. 104.23 W
C. 230.30 W
D. 21.99 W

Q23: Two 3.0-cm-diameter 304 stainless-steel bars, 10 cm long, have ground surfaces and are exposed to air. If the contact resistance is 0.747°C/W and the axial heat transfer rate is 5.52 W, the temperature drop across the contact surface will be

A. 21.5°C
B. 11.2°C
C. 4.1°C
D. 3.6°C

Q24: A 5-cm layer of loosely packed asbestos (k = 0.161 W/m.°C) is placed between two plates at 100 and 200°C. Calculate the heat transfer across the layer.

A. 380 W/m^2
B. 115 W/m^2
C. 322 W/m^2
D. 843 W/m^2

Q25: If the radiant flux from the sun is 54 MW/m^2, what would be its equivalent blackbody temperature?

A. 2460 K
B. 5555 K
C. 300 K
D. 459 K

Q26: A 3.2-mm-diameter stainless-steel wire generates heat of 1587 MW/m^3 and the outer surface temperature of the wire is maintained at 93°C. Calculate the center temperature of the wire. Take the thermal conductivity of wire as 22.5 W/m·°C.

A. 138°C
B. 207°C
C. 61°C
D. 110°C

Q27: Avery long copper rod [k = 372 W/m.°C] 2.5 cm in diameter has one end maintained at 90°C. The rod is exposed to a fluid whose temperature is 40°C. The heat transfer coefficient is 3.5 W/m^2 °C. How much heat is lost by the rod?

A. 89.4 W B. 9.4 W

C. 11.2 W D. 3.955 W

Q28: A circumferential fin of rectangular profile has a thickness of 0.7 mm and is installed on a tube having a diameter of 3 cm that is maintained at a temperature of 200ºC. The length of the fin is 2 cm and the fin material is copper. Calculate the heat lost by the fin to a surrounding convection environment at 100ºC with a convection heat-transfer coefficient of 524 $W/m^2.^oC$. The fin efficiency is 55%.

A. 307 W B. 186 W

C. 402 W D. 78 W

Q29: A 12-mm-diameter aluminum sphere ((ρ = 2707 kg/m^3, Cp = 896 J/kg.ºC) is heated to a uniform temperature of 400◦C and then suddenly subjected to room air at 20ºC with a convection heat-transfer coefficient of 10 $W/m^2.^oC$. Using the lumped-capacity method of analysis, calculate the time for the center temperature of the sphere to reach 200ºC.

A. 158 s B. 312 s

C. 118 s D. 362 s

Q30: A 5-cm layer of loosely packed asbestos (k = 0.161 W/m.ºC) is placed between two plates at 100 and 200ºC. Calculate the heat transfer across the layer.

A. 100 W/m^2 B. 115 W/m^2

C. 322 W/m^2 D. 520 W/m^2

Good Luck

Examination Committee

Subject: Mass Balance

Q1: The extent of reaction (ξ) is defined as:

A) Number of moles reacted
B) Number of moles formed
C) A measure of how far the reaction has proceeded
D) Final moles

Q2: If 2 mol of A react according to A + B → C, how many moles of C are formed?

A) 1
B) 2
C) 3
D) 4

Q3: In stoichiometry, a reactant has a stoichiometric coefficient that is typically:

A) Positive
B) Negative
C) Zero
D) Depends on temperature

Q4 For the reaction 2A + B → C, if the extent of reaction ξ = 3 mol, how much A is consumed?

A) 2 mol
B) 3 mol
C) 6 mol
D) 1.5 mol

Q5: The fractional conversion of a reactant A is given by:

A) (A0 - A)/A0
B) (A0 + A)/A0
C) (A - A0)/A0
D) (A0 - A0)/A

Q7: If 5 mol of A are fed and 3 mol are consumed, the conversion of A is:

A) 30%
B) 40%
C) 50%
D) 60%

Q8: For the reaction 2A → B, if the initial moles of A are 8 and ξ = 2, the moles of B formed are:

A) 2
B) 4
C) 6
D) 8

Q9: If in a reaction Δn (change in moles) is positive, this indicates:

A) Volume contraction in gas phase
B) Volume expansion in gas phase
C) No volume change
D) Increase in temperature

Q11: A species material balance for a reacting system accounts for:

A) Only inflow
B) Only outflow
C) Generation and consumption
D) Volume changes

Q12: For the combustion of methane ($CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$), the stoichiometric ratio of O_2 to

Q13: If excess air is supplied for combustion, the amount of O_2 supplied is:

A) Less than stoichiometric
B) Equal to stoichiometric
C) Greater than stoichiometric
D) Irrelevant

Q14: For a combustion process with 20% excess air, the oxygen supplied is how much compared to theoretical O_2 required?

A) 120%
B) 100%
C) 80%
D) 140%

Q15: In complete combustion of a hydrocarbon, the carbon forms:

A) CO
B) CO_2
C) C
D) C_2H_2

Q16: For the combustion of propane ($C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$), how many moles of oxygen are required per mole of propane?

A) 3
B) 5
C) 4
D) 2

Q17: In a steady-state reactor with a single reaction, the rate of generation of a species is proportional to:

A) Time
B) Flow rate
C) Stoichiometric coefficient
D) Reaction rate

Q18: When writing a species balance on an inert (non-reacting) species, the generation term is:

A) Zero
B) Positive
C) Negative
D) Depends on reaction rate

Q19: Combustion reactions are generally characterized by:

A) Exothermic heat release
B) Endothermic absorption

C) Constant temperature
D) Pressure increase only

Q20: A feed stream of 100 kg/h containing 40% A and 60% inert splits into two streams. Stream 1 is 60% A. What is the flow rate of Stream 1?

A) 30 kg/h
B) 50 kg/h
C) 60 kg/h
D) 40 kg/h

Q21: In a two-unit system, the first reactor achieves 40% conversion of A. If 100 mol/h enters, how many mol/h of A leave the first reactor?

A) 60
B) 40
C) 50
D) 70

Q22: Stream 1: 200 kg/h (90% A, 10% inert). Stream 2: 300 kg/h (30% A, 70% inert). The combined stream has what % A?

A) 60%
B) 45%
C) 50%
D) 70%

Q23: A distillation column separates 200 kg/h of a binary mixture (50% A, 50% B) into a top and bottom stream. If the top stream is 90% A and 50 kg/h, what is the bottom flow rate?

A) 100 kg/h
B) 150 kg/h
C) 200 kg/h
D) 250 kg/h

Q24: In a two-stage reactor, 80 mol/h of A enters. After the first reactor, 50% is converted. After the second, 50% of the remaining A is converted. Final mol/h of A?

A) 20
B) 30
C) 10
D) 40

Q25: A process involves mixing two streams: 100 kg/h of 40% A and 200 kg/h of 20% A. What is the overall concentration of A?

A) 25%
B) 26.7%
C) 30%
D) 23.3%

Q26: A gas mixture containing 80% N_2 and 20% H_2 enters a unit. If 10% of H_2 reacts, what is the % H_2 in the exit stream?

A) 18% B) 16%

C) 19% D) 17%

Q27: An evaporator removes 50% of water from 2000 kg/h feed (10% solids). What is the mass flow rate of the concentrated stream?

A) 1000 kg/h B) 500 kg/h

C) 1500 kg/h D) 200 kg/h

Q29: A liquid mixture of 70% A and 30% B enters a separator. 90% of A goes to the top. If 100 kg/h feed, how much A is in the top product?

A) 63 kg/h B) 70 kg/h

C) 30 kg/h D) 90 kg/h

Q30: A system consists of a reactor and a separator. 100 mol/h of A reacts to produce B with 80% conversion. The separator recovers 90% of B. What is the flow rate of B recovered?

A) 72 mol/h B) 80 mol/h

C) 90 mol/h D) 70 mol/h

Ministry of Higher Education & Scientific Research Tikrit University College of Engineering Chemical Eng. Dept.	**2026-2025**	**وزارة التعليم العالي والبحث العلمي جامعةتكريت كلية الهندسة قسم الهندسة الكيمياوية**

Process Control

Q1: A 4th order system: G(s) = $\frac{5(2-6s)e^{-s}}{(25s+5)(6s+2)(s+1)(0.5s+1)}$, the approximated First Order Plus Time Delay (FPTD) of this system using Taylor's method is:

A. G(s) = $\frac{5e^{-7s}}{(12s+1)}$

B. G(s) = $\frac{10e^{-7s}}{(5s+1)}$

C. G(s) = $\frac{15e^{-7s}}{(25s+1)}$

D. G(s) = $\frac{e^{-8.5s}}{(5s+1)}$

Q2: A process has the following transfer function: G(s) =$\frac{6e^{-s}}{20s+2}$ =$\frac{\acute{Y}(s)}{\acute{U}(s)}$, The values of initial and final responses {$\acute{y}$(0) and {$\acute{y}(\infty)$} of this system for a unit step change in input [$\acute{u}$=1] are:

A. $\acute{y}(0) = 0$ and $\acute{y}(\infty) = 3$

B. $\acute{y}(0) = 1$ and $\acute{y}(\infty) = 6$

C. $\acute{y}(0) = 0$ and $\acute{y}(\infty) = 5$

D. $\acute{y}(0) = 1$ and $\acute{y}(\infty) = 1$

Q3: A liquid-level control system is configured with a control valve (Fail-Open) manipulating flow of liquid into the holding tank. The signs of gains will be:

A. K_m, K_v, K_p and k_c are negative, K_c is direct action

B. K_m, K_v, K_p and k_c are positive, K_c is reverse action

C. K_m and K_p are positive, K_v and k_c are negative, K_c is direct action

A. K_m and K_v are negative, K_p and k_c are positive, K_c is reverse action

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Q4: Level measurement (sensor/transmitter) has a span (0.5m – 10.5m) and output pneumatic signal, its gain (K_m) will be:

A. k_m = (0.5/15) m/psi

B. k_m = (12/10) psig/m

C. k_m = (0.5/15) m/pa

D. k_m = (3/10.5) atm/m

Q5: A process has the following transfer function: G(s) =$\frac{4}{9s+2}$ =$\frac{\acute{Y}(s)}{\acute{U}(s)}$, For a step change in the input $\acute{u}$(t) = 2, the step response at time=4 {$\acute{y}$(4)} of this system is:

A. $\acute{y}$= 12.5
B. $\acute{y}$= 2.4
C. $\acute{y}$= 0.7
D. $\acute{y}$= 15.3

Q6/ A process has the following transfer function: G(s) =$\frac{4}{6s+2}$ =$\frac{\acute{Y}(s)}{\acute{U}(s)}$, The steady state gain (K) and time constant (τ) of this system are:

A. K=4 and τ=6
B. K=3 and τ=2
C. K=2 and τ=3
D. K=6 and τ=4

Q7/ A process has the following transfer function: G(s) =$\frac{4}{2s^2+s+2}$ =$\frac{\acute{Y}(s)}{\acute{U}(s)}$, For a step change in the input $\acute{u}$(t) = 2, The overshoot (OS) of this system is:

A. OS= 0.44
B. OS= 0.61
C. OS= 0.53
D. OS= 0.32

Q8/ A 4th order system: G(s) = $\frac{5(2-6s)e^{-s}}{(25s+5)(6s+2)(s+1)(0.5s+1)}$, the approximated First Order Plus Time Delay (FPTD) of this system using Skogestad's method is:

- **A.** G(s) = $\frac{e^{-7s}}{(6.5s+1)}$
- **B.** G(s) = $\frac{5e^{-s}}{(5s+1)}$
- **C.** G(s) = $\frac{15e^{-2s}}{(25s+5)}$
- **D.** G(s) = $\frac{3e^{-5s}}{(3s+1)}$

Q9/ Temperature measurement (sensor/transmitter) has a span (50 C^o-150 C^o) and output current signal, its gain (K_m) will be:

- **A.** k_m = (100/15) C^o/A
- **B.** k_m = (3/50) mA/C^o
- **C.** k_m = (16/100) mA/C^o
- **D.** k_m = (50/15) C^o/A

Q10/ For the following closed-loop feedback control system: G_p=G_d=0.2/(-s+1), G_c=K_c, G_v=G_m=1, the range of K_c values that result in a stable closed-loop system are:

- **A.** k_c <0
- **B.** k_c >-1
- **C.** k_c <1
- **D.** k_c <-5

Q11/ For Lag-Dominant Models, reset time (τ_I) using Skogestad IMC (SIMC) method is:

- **A.** $\tau_I = \min\{\tau, (2\theta + \tau_c)\}$
- **B.** $\tau_I = \min\{2\tau, (2\theta + 3\tau_c)\}$
- **C.** $\tau_I = \min\{\tau, (4\theta + 4\tau_c)\}$
- **D.** $\tau_I = \min\{\tau, (2\theta + 2\tau_c)\}$

Q12/ According to the Bode Stability Criterion, the closed loop system is stable if

- **A.** The open-loop amplitude ratio at critical frequency [$AR_{OL}(\omega c)$] >0.
- **B.** The open-loop amplitude ratio at critical frequency [$AR_{OL}(\omega c)$] >1.
- **C.** The open-loop amplitude ratio at critical frequency [$AR_{OL}(\omega c)$] =0.
- **D.** The open-loop amplitude ratio at critical frequency [$AR_{OL}(\omega c)$] <1

Q13/ A process has the following transfer function: G(s) =$\frac{4}{9s+2}$ =$\frac{\acute{Y}(s)}{\acute{U}(s)}$, For a ramp change in the input $\acute{u}$(t) = 2t, the ramp response at time=20 {$\acute{y}(20)$} of this system (assume long-time approximation) is:

- **A.** $\acute{y}$= 90
- **B.** $\acute{y}$= 12
- **C.** $\acute{y}$= 62
- **D.** $\acute{y}$= 35

Q14/ For the following closed-loop feedback control system: G_p=G_d=1/(5s+1), G_c=K_c, G_v=G_m=1, the range of K_c values that that result in a stable closed-loop system are:

- **E.** k_c <0
- **F.** k_c >-1
- **G.** k_c <1
- **H.** k_c >-2

Q15/For the process modeled by 9dy/dt= −3y + 6u, the transfer function G(s)=Y(s)/U(s) is:

- **A.** G(s) =$\frac{3}{9s+6}$
- **B.** G(s) =$\frac{2}{3s+1}$
- **C.** G(s) =$\frac{4}{9s+2}$
- **D.** G(s) =$\frac{6}{9s+1}$

Q16: A counter-current heat exchanger (cooler) is configured with a temperature control system to control the exit hot stream temperature by manipulating the cold stream flowrate using a control valve (Fail-Close). The signs of gains will be:

A. K_m, K_v, K_p and k_c are negative, K_c is direct action

B. K_m, K_v, K_p and k_c are positive, K_c is reverse action

C. K_m and K_v are positive, K_p and k_c are negative, K_c is direct action

D. K_m and K_v are negative, K_p and k_c are positive, K_c is reverse action

Q17/ A process has the following transfer function: G(s) $=\frac{6}{6s^2+s+3}=\frac{\acute{Y}(s)}{\acute{U}(s)}$, For a step change in the input $\acute{u}$(t) = 2, The damping coefficient (δ) of this system is:

A. δ = 0.75
B. δ = 1.25
C. δ = 0.43
D. δ = 0.12

Q18/ A process has the following transfer function: G(s) $=\frac{6}{6s^2+s+3}=\frac{\acute{Y}(s)}{\acute{U}(s)}$, For a step change in the input $\acute{u}$(t) = 2, The decay ratio (DR) of this system is:

A. DR= 0.76
B. DR= 0.14
C. DR= 0.47
D. DR= 0.23

Q19/ A process has the following transfer function: G(s) =$\frac{4}{2s^2+s+2}$ =$\frac{\acute{Y}(s)}{\acute{U}(s)}$, For a step change in the input $\acute{u}$(t) = 2, The damping coefficient (δ) of this system is:

- **A.** δ = 0.75
- **B.** δ = 1.25
- **C.** δ = 0.15
- **D.** δ = 0.25

Q20/ Flowrate measurement (sensor/transmitter) has a span (0 gpm – 400 gpm) and output voltage signal, its gain (K_m) will be:

- **A.** k_m = (400/4) gpm/VDC
- **B.** k_m = (16/400) mA/gpm
- **C.** k_m = (1/100) VDC/gpm
- **D.** k_m = (400/12) gpm/psig

Q21/ A process has the following transfer function: G(s) =$\frac{6}{6s^2+s+3}$ =$\frac{\acute{Y}(s)}{\acute{U}(s)}$, For a step change in the input $\acute{u}$(t) = 2, The rise time (t_r) of this system is:

- **A.** t_r= 1.2
- **B.** t_r= 4.8
- **C.** t_r= 3.6
- **D.** t_r= 2.4

Q22/ A process has the following transfer function: G(s) =$\frac{4}{2s^2+s+2}$ =$\frac{\acute{Y}(s)}{\acute{U}(s)}$, For a step change in the input $\acute{u}$(t) = 2, The rise time (t_r) of this system is:

- **A.** t_r= 1.9
- **B.** t_r= 4.8
- **C.** t_r= 3.6
- **D.** t_r= 2.7

Q23/ A process has the following transfer function: G(s) =$\frac{6}{6s^2+s+3}$ =$\frac{\acute{Y}(s)}{\acute{U}(s)}$, For a step change in the input $\acute{u}$(t) = 2, The time to 1st peak (t_p) of this system is:

- **A.** t_p= 3.25
- **B.** t_p= 4.47
- **C.** t_p= 1.62
- **D.** t_p= 0.26

Q24/ A process has the following transfer function: G(s) =$\frac{4}{2s^2+s+2}$ =$\frac{\acute{Y}(s)}{\acute{U}(s)}$, For a step change in the input $\acute{u}$(t) = 2, The period of oscillation (P) of this system is:

- **A.** P= 0.25
- **B.** P= 1.5
- **C.** P= 6.5
- **D.** P= 4.26

Q25/ A 4th order system: G(s) = $\frac{5(2-6s)e^{-s}}{(25s+5)(6s+2)(s+1)(0.5s+1)}$, the approximated overdamped-Second Order Plus Time Delay (SPTD) of this system using Skogestad's method is:

- **A.** G(s) = $\frac{5e^{-7s}}{(6.5s+1)(2S+1)}$
- **B.** G(s) = $\frac{e^{-5s}}{(5s+1)(3.5S+1)}$
- **C.** G(s) = $\frac{15e^{-2s}}{(25s+5)(6S+2)}$
- **D.** G(s) = $\frac{3e^{-5s}}{(3s+1)(S+1)}$

Q26/ A 4th order system: G(s) = $\frac{5(2-6s)e^{-s}}{(25s+5)(6s+2)(s+1)(0.5s+1)}$, the approximated overdamped-Second Order Plus Time Delay (SPTD) of this system using Taylor's method is:

- **A.** G(s) = $\frac{5e^{-7s}}{(6.5s+1)(2S+1)}$
- **B.** G(s) = $\frac{e^{-5s}}{(5s+1)(3.5S+1)}$
- **C.** G(s) = $\frac{15e^{-2s}}{(25s+5)(6S+2)}$
- **D.** G(s) = $\frac{e^{-5.5s}}{(5s+1)(3S+1)}$

Q27/ If the measured input to a PI controller is a step change ($Y_m(s) = 2/s$) and the controller output changes initially as (P'=6+1.2t), the values of the controller gain (K_c) and integral time (τ_I) are:

- **A.** $K_c = 5$ and $\tau_I = 10$
- **B.** $K_c = -3$ and $\tau_I = 5$
- **C.** $K_c = 1$ and $\tau_I = 15$
- **D.** $K_c = -1$ and $\tau_I = 1$

Q28/ A control valve has the following information: specific gravity of liquid (g_s) =1, pressure drop across the valve (ΔP_v) = 40 - 0.00075q^2 (psi) and valve size coefficient (cv) = 100. If the valve characteristic (trim) is linear trim, the liquid flowrate (q) at {fractional stem position = 0.75 (l=0.75)} is:

- **A.** q = 208 gpm
- **B.** q = 173 gpm
- **C.** q = 291 gpm
- **D.** q = 161 gpm

Q29/A control valve has the following information: specific gravity of non-flashing liquid (g_s) =1.15, pressure drop across the valve (ΔP_v) = 500 - $0.3q^2$ (kPa), volumetric liquid flowrate at design condition (q_d) = 24 m^3/h and the valve is sized to be completely closed at 5% of the design flow rate. The valve size coefficient (cv) will be:

- **A.** cv = 21.2
- **B.** cv = 147.8
- **C.** cv = 276.3
- **D.** cv = 6.7

Q30/ Lag-Dominant Model has the following: time constant (τ)=5 min, time delay (θ)=0.1 min and desired closed-loop time constant (τ_c)=0.5 θ. The reset time (τ_I) using Skogestad IMC (SIMC) method will be:

- **A.** τ_I = 0.5 min
- **B.** τ_I = 5 min
- **C.** τ_I = 0.6 min
- **D.** τ_I = 4 min

Q31/ The controller output (P´) of PI controller changes initially as shown in the following equation {$P'(t) = (t^2/4) + 3t$, where t in minutes} if the error signal is increased at the rate of 0.3 mA/min. The PI controller settings (tuning parameters) will be:

- **A.** K_c = 10 and τ_I = 6 min
- **B.** K_c = -3 and τ_I = 5 min
- **C.** K_c = 1 and τ_I = 15 min
- **D.** K_c = -1 and τ_I = 1 min

Q32/ Using Bode Stability Criterion, the ultimate controller gain (K_{cu}) of the following closed-loop system {$G_p(s) = \frac{4e^{-s}}{5s+1}$, $G_v = 2$, $G_m = 0.25$, $G_c = K_c = 1$ and critical frequency (w_c) =1.69 rad/min} will be:

- **A.** $K_{cu} = 1.35$
- **B.** $K_{cu} = 4.25$
- **C.** $K_{cu} = 6.33$
- **D.** $K_{cu} = 2.54$

Q33/ Using Bode Stability Criterion, the ultimate controller gain (K_{cu}) of the following closed-loop system {$G_p(s) = \frac{2}{(0.5s+1)^3}$, $G_v = 0.1$, $G_m = 10$, $G_c = K_c = 1$ and critical frequency (w_c) =3.46 rad/min} will be:

- **A.** $K_{cu} = 3$
- **B.** $K_{cu} = 6$
- **C.** $K_{cu} = 4$
- **D.** $K_{cu} = 2$

Good Luck

Examination Committee

1. The SI unit of dynamic viscosity is:

A) Pa·s

B) N/m^2

C) kg/m^3

D) m^2/s

2. Viscosity is defined as:

A) Resistance to compression

B) Resistance to flow

C) Rate of shear strain

D) None of the above

3. For Newtonian fluids, the relationship between shear stress (τ) and shear rate is:

A) Linear

B) Exponential

C) Parabolic

D) No relation

4. Kinematic viscosity is defined as:

A) $\mu \times \rho$

B) μ/ρ

C) ρ/μ

D) $1/\mu$

5. Which of the following fluids is Newtonian?

A) Toothpaste

B) Honey

C) Water

D) Blood

6. The Navier-Stokes equations are based on:

A) Conservation of mass and energy

B) Conservation of momentum

C) Conservation of angular momentum

D) Conservation of pressure

7. Navier-Stokes equations are:

A) Linear differential equations

B) Nonlinear partial differential equations

C) Algebraic equations

D) Second-order linear

8. The incompressible Navier-Stokes equation assumes:

A) Density is constant

B) Pressure is constant

C) Viscosity is zero

D) Temperature is variable

9. Which term represents viscous forces in Navier-Stokes equations?

A) ∇P

B) $\mu \nabla^2 u$

C) ρg

D) $\rho(\partial u/\partial t)$

10. The pressure term in the Navier-Stokes equation is:

A) Scalar

B) Vector

C) Tensor

D) Constant

11. The Darcy-Weisbach equation relates head loss due to friction to:

A) Pressure

B) Flow velocity

C) Fluid density

D) Pipe diameter

12. The friction factor in laminar flow is given by:

A) 0.316/Re

B) 64/Re

C) $1/Re^2$

D) Re/64

13. Major losses in pipe flow are due to:

A) Sudden expansions

B) Pipe length and friction

C) Valves

D) Elbows

14. Minor losses occur due to:

A) Pipe roughness

B) Fittings and bends

C) Fluid velocity

D) Elevation change

15. Macroscopic momentum balance is used to determine:

A) Pressure losses

B) Velocity distribution

C) Molecular diffusion

D) Eddy viscosity

16. Which principle is applied in Bernoulli's equation?

A) Energy conservation

B) Mass transfer

C) Friction losses

D) Heat conduction

17. Macroscopic mass balance assumes:

A) Control volume approach

B) Pointwise calculation

C) Molecular diffusion

D) Incompressible fluid only

18. Steady-state implies:

A) $\partial/\partial t = 0$

B) No convection

C) No turbulence

D) Constant density

19. Total pressure drop in a pipe includes:

A) Elevation loss

B) Friction loss

C) Momentum change

D) All of the above

20. Bernoulli's equation neglects:

A) Kinetic energy

B) Friction losses

C) Potential energy

D) Pressure energy

21. Control volume analysis simplifies the:

A) Entire system into a boundary

B) Laminar equation

C) Energy equation

D) Mass transfer coefficient

22. The body force in momentum balances typically represents:

A) Viscous effects

B) Gravity

C) Friction

D) Shear

23. A macroscopic energy balance considers:

A) Work done

B) Heat transfer

C) Flow energy

D) All of the above

24. Which of the following is a defining feature of turbulent flow compared to laminar flow?

A) Streamlines are parallel

B) Velocity profile is linear

C) Random fluctuations and mixing

D) Flow occurs only at low Reynolds numbers

25. Which of the following is the correct SI unit for dynamic viscosity?

A) Pa·s

B) N/m^2

C) m^2/s

D) $kg/m^2 \cdot s$

26. In boundary layer theory, the thickness of the boundary layer is defined as:

A) Distance from the wall to where velocity = 0

B) Distance where velocity reaches 99% of free stream

C) Constant for all fluids

D) Always equal to the pipe radius

27. Which term is NOT present in the Navier-Stokes equations for incompressible, Newtonian flow?

A) Inertial term

B) Pressure gradient term

C) Viscous term

D) Compressibility term

28. The z-momentum equation for a Newtonian fluid under steady, isothermal flow in Cartesian coordinates (neglecting body forces) is:

A) $\rho\, dv_z/dt = -\partial P/\partial z + \mu \nabla^2 v_z$
B) $dv_z/dt = \mu \nabla^2 v_z$
C) $\nabla \cdot v = 0$
D) $\rho \nabla^2 v_z = \partial P/\partial z$

29. In turbulent pipe flow, the velocity profile near the wall follows the law:

A) Linear
B) Quadratic
C) Logarithmic
D) Parabolic

30. The region in turbulent flow near the wall where viscous effects dominate is called:

A) Core region
B) Buffer layer
C) Viscous sublayer
D) Logarithmic layer