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UNIVERSITY OF GHANA

BSc. (Engineering) SECOND SEMESTER EXAMINATIONS: 2015/2016

DEPARTMENT OF AGRICULTURAL ENGINEERING

FAEN 204: FLUID MECHANICS (3 Credits)

INSTRUCTIONS: ANSWER ALL QUESTIONS

TIME ALLOWED: 3 HOURS

- *An incorrect answer attracts* $-1/4$
- *Answer all questions on the question paper*
- *For some questions you are required to show work in the space provided.*
- *Circle the correct response for each question. Make sure that your answer is clearly marked.*
- *This examination is a closed book one. You may use a calculator if you wish.*
- *Any discussion or communication between students, as well as the appearance of any unnecessary material will be dealt with severely*

1. A fluid in direct contact with a solid surface sticks to the surface and there is no slip. This is the no-slip condition and accounts for:

   a. the development of boundary layer
   b. the development of surface tension
   c. the development of viscosity in fluids
   d. all of the above
   e. none of the above

2. Which of the following distinguishes a closed system from an open system?

   a. the mass or region outside it
   b. the real or imaginary surface that separates it from its surroundings
   c. the quantity of matter within it
   d. the fixed mass or volume in space chosen for study
   e. the mass or region surface that separates it from its surroundings

3. Which of the following is true about viscosity?

   I. It is a constant of proportionality relating shear stress with change in velocity
   II. It accounts for the internal resistance to fluid flow
   III. It is a fluid property which varies with temperature

   a. I and III
   b. III and II
   c. All of the above
   d. None of the above
   e. I and II

4. How high is the capillary rise if the radius is halved considering the relation involving capillary rise in tubes?

   a. Capillary rise is halved
   b. Capillary rise is tripled
   c. Capillary rise is quadruples
   d. Capillary rise is doubled
   e. No rise

5. Nutrients dissolved in water are carried to upper parts of plant by tiny tubes partly because of the capillary effect. Determine how high the water solution will rise in a tree in a 0.0025-mm-diameter tube as a result of the capillary effect if

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the solution is taken to be water with surface tension σ_s of 0.073 at 20°C with a contact angle of 15°

a. 5.75 m
b. 0.575 m
c. 14.4 m
d. 23 m
e. 2.3 m

6. Low density air in low atmospheric pressure areas accounts for the following **except**

a. lower amount of oxygen per unit volume
b. development of lungs to be able withstand shortness of breath
c. car engine generating less power
d. food taking a shorter time to cook
e. tiredness of a person

7. In a pool of water, the pressure at 2 depths is shown in Figure 1. Determine the pressure at P_2 if the pressure at $P_1 = 28\ kPa$ and the depths at h_1 and h_2 are respectively 3 m and 12 m.

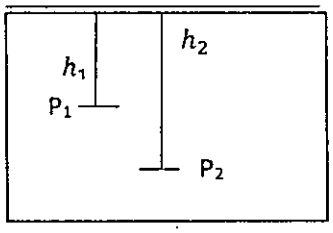

Figure 1

a. 101.3 kPa
b. 112 kPa
c. 2.8 kPa
d. 9.33 kPa
e. 37 kPa

8. The magnitude of a buoyant force acting on a body submerged in a fluid whose volume is v can be derived as:

a. $F = \rho_f g V$
b. $F = mgV$
c. $F = \rho_f \gamma V$
d. $P = \gamma g V$
e. $F = \gamma g V$

9. A helium balloon tied to the ground carries two people 70 kg each upward. If the diameter of the balloon is 10 m and the density of air is $\rho = 1.16\ kg/m^3$ determine the buoyant force.

a. 596 KN
b. 596 N
c. 5.96 KN
d. 0.596 KN

10. The stability of heavy bodies like ships floating on water is determined in the following ways **except**

a. the metacentric height is greater than 1.
b. the centre of gravity is above the centre of buoyancy
c. the metacenter is higher than the centre of gravity
d. the metacentre is between the centre of gravity and the centre of buoyancy
e. the centre of of gravity above the metacentre

11. Air enters a nozzle steadily at 2.21 kg/m^3 and 30 m/s and leaves at 0.762 kg/m^3 and 180 m/s. If the inlet area of the nozzle is 80 cm^2, determine the mass flow rate through the nozzle

a. 1.06 kg/s
b. 5.300 kg/s
c. 0.596 kg/s
d. 0.530 kg/s
e. 1.596 kg/s

12. Based on the preamble in the previous question, determine the exit area of the nozzle

a. 56 cm^2
b. 5.96 cm^2
c. 0.596 cm^2
d. 77.4 cm^2
e. 38.7 cm^2

13. Will the buoyant forces acting on a 3-kg copper cube and a 3-kg copper ball submerged in a liquid be the same or different?

a. same since buoyant forces depend on shape of body
b. different since buoyant forces depend on shape of body
c. same since buoyant forces does not depend on shape of body
d. different since buoyant forces does not depend on shape of body
e. same since buoyant forces are similar to weight of body

14. What is the direction and the line of action of the buoyant force

a. upwards through the centroid
b. downwards through the centre of pressure
c. downwards through the centroid

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d. upwards through the centre of pressure
e. upwards through centre of action

15. It is said that Archimedes discovered his principle during a bath while thinking about how he could determine if King Hiero's crown was actually made of pure gold. While in the bathtub, he conceived the idea that he could determine the average density of an irregularly shaped object by weighing it in air and also in water. If the crown weighed 31.4 N in air and 28.9 N in water, determine if the crown is made of pure gold. The density of gold is 19,300 kg/m^3. (use the space provided below)

16. Determine the magnitude of the velocity at $Q(x = 3, y = -1 z = 2, t = 3)$ in a flow field expressed as (use the space provided below):

$$\vec{V} = (7t + 2xy)\hat{\imath} + (-2yz - 4t)\hat{\jmath} + \left(-yz - \frac{z^2}{8}\right)\hat{k}$$

17. Which of the following describes fluid kinematics?

I. The study of how fluids flow and the description of fluid motion.
II. Description of the motion of fluids without considering the forces and moments that cause the motion.
III. Description of how a fluid particle translates, distorts, and rotates, and how to visualize flow fields.

a. II only
b. III and II
c. I and II
d. All of the above
e. None of the above

18. Both a gage and a manometer are attached to a gas tank to measure its pressure. If the reading on the pressure gage is 80 kPa, determine the distance between the two fluid levels of the manometer if the fluid is mercury (ρ = 13,600 kg/m^3)

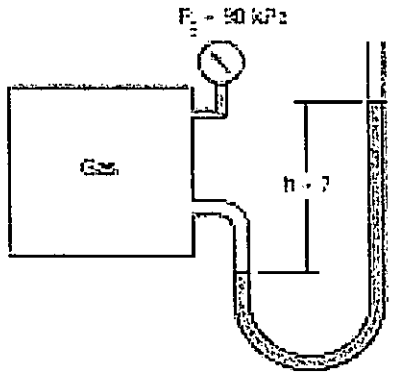

Figure 3

a. 1.2 m
b. 16.32 m
c. 8.16 m
d. 0.6 m
e. 10 m

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19. Using the same preamble in question 18, determine the distance between the two fluid levels of the manometer given that density of water ($\rho = 1000\ kg/m^3$).

    a. $1.2\ m$
    b. $16.32\ m$
    c. $8.16\ m$
    d. $0.6\ m$
    e. $10\ m$

20. Which of the following is not true about the material derivative?

    a. it can be referred to as total or particle derivative
    b. does not include both local and convective parts
    c. to transform from Lagrangian to Eulerian reference frames
    d. similar to the Reynolds transport theorem

21. A steady, incompressible, two-dimensional velocity field is given by where the x- and y-coordinates are in m and the magnitude of velocity is in m/s. Determine if there are any stagnation points in this flow field (use the space provided below).

$$\vec{V} = (u, v) = (1 + 2.5x + y)\hat{\imath} + (-0.5 - 1.5x - 2.5y)\hat{\jmath}$$

    a. $x = -0.0526$ m, $y = -0.421$ m
    b. $x = -0.421$ m, $y = 0.0526$ m
    c. $x = 0.421$ m, $y = -0.0526$ m
    d. $x = -0.421$ m, $y = -0.0526$ m
    e. $x = 0.0526$ m, $y = -0.421$ m

22. The difference between pathlines and streamlines is that:

    a. pathlines are instantaneous while streamlines have a finite period of time
    b. streamlines are instantaneous while pathlines a finite period of time
    c. streamline is the locus of fluid particles while pathline sequentially passes through a prescribed point in the flow.
    d. pathline is the locus of fluid particles while streamline sequentially passes through a prescribed point in the flow.
    e. streamline is the locus of fluid particles while pathline sequentially passes through a prescribed point in the flow.

23. How are vorticity and rotationality of a fluid particle related?

    a. If a particle rotates, its vorticity is non-zero.
    b. the angular velocity vector is half the vorticity
    c. the angular velocity vector is twice the vorticity
    d. If the vorticity is zero, the flow is called irrotational.
    e. If a particle rotates, its vorticity is zero

24. Consider fully developed Couette flow—flow between two infinite parallel plates separated by distance h, with the top plate moving and the bottom plate stationary as illustrated in Figure 4 The flow is steady, incompressible, and two dimensional in the xy-plane. The velocity field is given by

$$\vec{V} = (u, v) = V\frac{y}{h}\hat{\imath} + 0\hat{\jmath}$$

Is this flow rotational or irrotational?

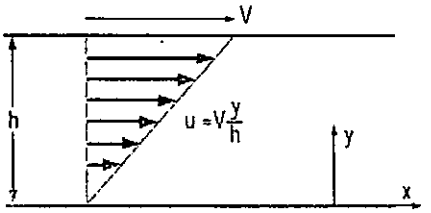

Figure 4

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25. Determine the magnitude of the component of vorticity in the vertical direction given that a cylindrical tank of radius $r_{rim} = 0.35\ m$ rotates on its vertical axis. Take speed of rim to be $2.6\ m/s$.

    a. $0.15\ rad/s$
    b. $15\ rad/s$
    c. $7.5\ rad/s\ kPa$
    d. $30\ rad/s\ kPa$
    e. $60\ rad/s\ kPa$

26. The direction of the vorticity vector is determined in one of the following ways.

    a. Right-hand rule for cross product
    b. Right-hand rule for dot product
    c. The direction of rotation of the fluid particle
    d. The direction of fluid flow
    e. The direction of particle flow

27. What is unique about schlieren images as compared to shadowgraphs?

    a. Shadowgraphs use refractive property of light wave while Schlieren images do not
    b. Translation vector
    c. Shadowgraphs have no optical distortion
    d. Schlieren images have no optical distortion
    e. Schlieren images use refractive property of light wave while shadowgraphs do not

28. For each statement, choose whether the statement is True (T) or False (F).

    a. The Reynolds transport theorem is useful for transforming conservation equations from their naturally occurring control volume forms to their system forms. True or False?
    b. The Reynolds transport theorem is applicable only to non-deforming control volumes. True or False?
    c. The Reynolds transport theorem can be applied to both steady and unsteady flow fields. True or False?
    d. The Reynolds transport theorem can be applied to both scalar and vector quantities True or False?

a. The Reynolds transport theorem cannot be applied to both steady and unsteady flow fields. **True or False?**

Water is pumped from a lower reservoir to a higher reservoir by a pump that provides 20 kW of useful mechanical power to the water as shown in Figure 5 below. The free surface of the upper reservoir is 45 m higher than the surface of the lower reservoir. If the flow rate of water is measured to be 0.03 m^3/s, determine and the lost mechanical power during this process. Use this preamble to answer questions 29 and 30

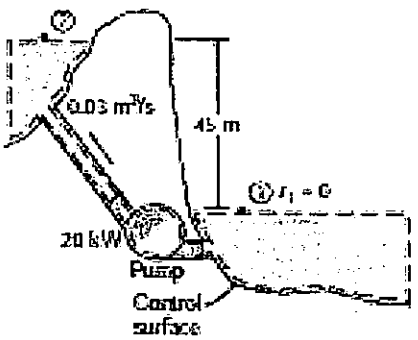

Figure 5

29. What is the mechanical power lost during the process?

    a. $10\ kW$
    b. $14.14\ kW$
    c. $13.24\ kW$
    d. $6.76\ kW$
    e. $16.76\ kW$

30. Determine the irreversible head loss of the system.

    a. $23\ m$
    b. $69\ m$
    c. $10\ m$
    d. $225\ m$
    e. $100\ m$

A reducing elbow is used to deflect water flow at a rate of $30\ kg/s$ in a horizontal pipe upward by an angle $\theta = 45°$ from the flow direction while accelerating it. The elbow discharges water into the atmosphere. The cross-sectional area of the elbow is $150\ cm^2$ at the inlet and $25\ cm^2$ at the exit. The elevation difference between the centers of the exit and the inlet is $40\ cm$. The mass of the elbow and the water in it is $50\ kg$. Answer questions 31 to 34 with this preamble.

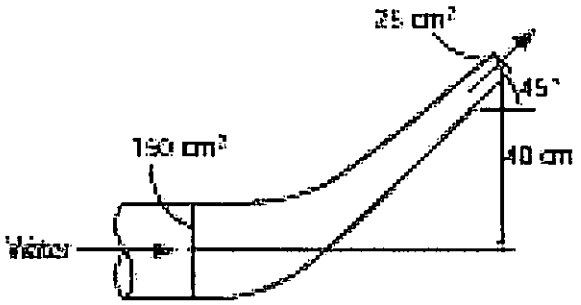

Figure 6

31. What is the inlet velocity?

    a. $2\,m/s$
    b. $12\,m/s$
    c. $24\,m/s$
    d. $20\,m/s$
    e. $0.24\,m/s$

32. Determine the pressure at the centre of the inlet (use the space provided below).

    a. $70\ kPa$
    b. $15\ kPa$
    c. $73.9\ kPa$
    d. $8.9\ kPa$
    e. $173.9\ kPa$

33. Write down the expression for the horizontal and vertical components of the force that is required to keep the elbow in place (use the space provided below).

34. Determine the anchoring force needed to hold the elbow in place. Take the momentum-flux correction factor to be 1.03.

    a. $118\ KN$
    b. $7.53\ KN$
    c. $0.753\ kN$
    d. $1.18\ kN$
    e. $18\ kN$

35. The conservation of mass relation for a control volume is expressed as:

    i. $\frac{d}{dt}\int_{CV}\rho dV + \int_{CS}\rho(\vec{V}\cdot\vec{n})dA = 0$

    ii. $\frac{dm_{CV}}{dt} = \sum_{in}\dot{m} - \sum_{out}\dot{m}$

    iii. $\sum\vec{F} = \frac{d}{dt}\int_{CV}\rho\vec{V}dV + \int_{CS}\rho\vec{V}(\vec{V}\cdot\vec{n})dA$

    a. II only
    b. I and II
    c. I and III
    d. All of the above
    e. None of the above

36. The line that represents the sum of static pressure and the elevation head is the

    a. Energy grade line
    b. Hydraulic line
    c. Dynamic head line
    d. Hydraulic grade line
    e. Head loss line

37. The Bernoulli equation is expressed along a streamline and in regions where net viscous forces are negligible as:

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38. What accounts for the difference between hydraulic grade line and energy grade line?

    a. Static pressure
    b. Elevation head
    c. Velocity head
    d. Pressure head
    e. Head loss

39. The correction factor which accounts for the kinetic energy measured with average velocity instead of actual velocity is known as

    a. Pressure correction factor
    b. Velocity profile factor
    c. Kinetic energy correction factor α
    d. Momentum flux correction factor β
    e. Kinetic-Momentum flux correction factor β

40. Venturi meter is to flow rate measurement as pitot tube is to

    a. Pressure measurement
    b. Velocity measurement
    c. River flow measurement
    d. Dynamic head measurement
    e. Head loss measurement

41. An air-conditioning system requires a $20-m$-long section of $15-cm$ –diameter ductwork to be laid underwater. Determine the upward force the water will exert on the duct. Take the densities of air and water to be $1.3\ kg/m^3$ and $1000\ kg/m^3$, respectively.

    a. $3.470\ kN$
    b. $7.48\ kN$
    c. $16\ kN$
    d. $78\ kN$
    e. $0.753\ kN$

42. The momentum flux correction factor β is crucial for which types of flow?

    a. Turbulent flow
    b. Transitional flow
    c. Laminar flow
    d. Compressible and inviscid flow
    e. Two dimensional flows

43. How is the linear momentum equation obtained from the Reynold Transport Theorem? By replacing b and B with:

    a. $b = \vec{V},\ B = m\vec{V}$
    b. $b = 1,\ B = mV$
    c. $b = V,\ B = mV$
    d. $b = \vec{V},\ B = mV$
    e. $b = 1,\ B = m\vec{V}$

44. The difference between body forces and surface forces is that

    a. body forces act on a control volume
    b. weight acts both on control surface and control volume.
    c. body force acts throughout the entire control body while surface forces act on a control surface
    d. body force acts throughout the entire control surface while surface forces act on a control body
    e. Pressure force is the difference between body forces and surface forces.

45. Which of the following statements is false?

    a. Flow through a control volume is always steady
    b. Flow into a control volume is equal to flow out of a control volume during steady flow
    c. Flow through a control volume is steady when it involves no changes with time at any specified position.
    d. Flow with the same volume flow rate at the inlet and the exit is not necessarily steady
    e. Flow with the same volume flow rate at steady

46. Consider a river flowing toward a lake at an average velocity of $3\ m/s$ at a rate of $500\ m^3/s$ at a location $90\ m$ above the lake surface. Determine the total mechanical energy of the river water per unit mass and the power generation potential of the entire river at that location (use the space provided below).

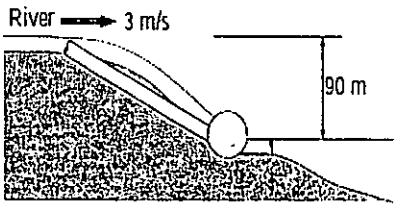

Figure 7

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a. 30.74 kW
b. 144 kW
c. 6 MW
d. 78 kN
e. 444 MW

47. Which correction factor applied to take care of non-uniformity of velocity in a control volume with multiple inlet and outlet?

a. Pressure correction factor
b. Velocity profile factor
c. Kinetic energy correction factor α
d. Momentum flux correction factor β
e. Kinetic-Momentum flux correction factor β

48. An airplane is flying at an altitude of 12,000 m. Determine the gage pressure at the stagnation point on the nose of the plane if the speed of the plane is 200 km/h. How would you solve this problem if the speed were 1050 km/h (use the space provided below).

49. Which of the following about irreversible head loss are true: it is:

i. the loss of mechanical energy due to irreversible processes such as friction.
ii. always positive
iii. related to mechanical energy loss in piping

a. II only
b. I and II
c. I and III
d. All of the above
e. None of the above

50. A pressurized tank of water has a $10-cm$-diameter orifice at the bottom, where water discharges to the atmosphere. The water level is $3\,m$ above the outlet. The tank air pressure above the water level is 300 kPa (absolute) while the atmospheric pressure is 100 kPa. Neglecting frictional effects, determine the initial discharge rate of water from the tank.

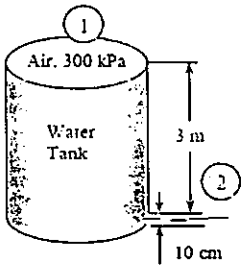

Figure 3

a. 21.40 m^3/s
b. 0.168 m^3/s
c. 1681 m^3/s
d. 78.53 m^3/s
e. 0.753 m^3/s