L-2/T-1/BME

18/05/2024

Date : ~~27/04/2024~~

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-2/T-1 B. Sc. Engineering Examinations 2022-2023

Sub : **BME 201** (Biomechanics)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

Question No. 1 is **MANDATORY**. Answer any **TWO** of the remaining **THREE** questions.

1. (a) A weightlifter is performing a bench press exercise with dumbbells. During the extended state of the forearms, the load on his spinal column can be modeled with a hypothetical beam as shown in the Figure for Q. 1(a). Illustrate the corresponding shear force diagram and the bending moment diagram. The reaction force of the bench and the legs are considered together at the left terminal end. [Convert into S.I.: 1 lb = 0.4536 kg] **(16)**

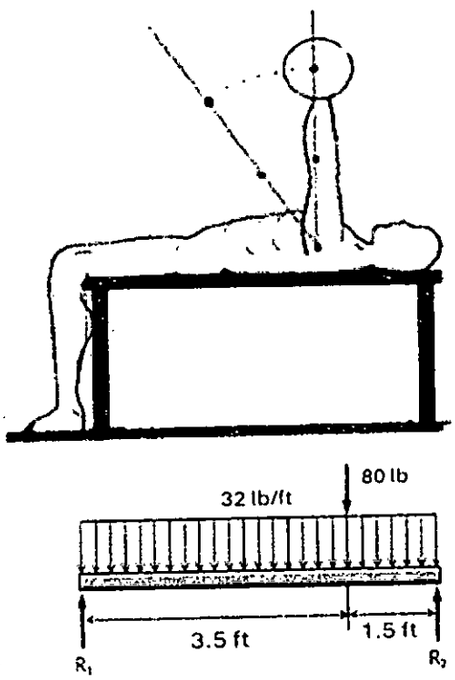

Figure: Question 1 (a)

(b) Prof. Bashir's lab group analyzes the mechanical properties of rabbit cartilage with the goal of creating xenografts with higher compressive resistance to be used in human beings. One day, to perform the confined compression test, they cut four specimens of equal thickness from the rabbit cartilage. After the experiment, they reported the aggregate equilibrium modulus (H_A) as shown in the Figure for Q. 1(b). **(14)**

(i) Based on your knowledge of biomechanics, propose which of the samples is of the most interest to them. Is it possible to infer anything regarding the tensile strength from the given data? If not, explain how that can be done.

(ii) With a neat schematic of the layered architecture of cartilage, anticipate which zone of cartilage your chosen sample may belong to.

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(iii) Briefly express the biphasic theory of the cartilage.

Sample Name	H_A Content
1	0.76
2	1.85
3	1.09
4	0.32

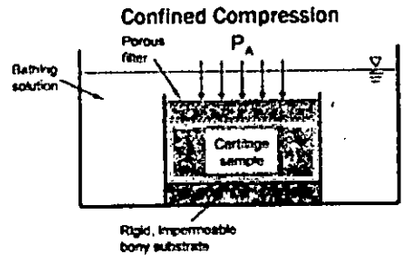

Figure: Question 1 (b)

(c) Lipid-based giant uni-lamellar vesicles (GUVs) closely mimic the mechanical characteristics of the cell membrane. The viscoelastic behavior of a GUV can be simply modeled using a Maxwell model (elastic modulus = 4 GPa, viscosity coefficient = 1 GPa.s). During a stress-relaxation test, a constant strain of 0.5% is applied to the GUV at t = 0, which is sustained till the end of the experiment (t = 50 sec). At t = 30 sec, an additional strain of 3% is applied to the GUV. Determine the net strain in the surface of the GUV at the end of the experiment (t = 50 sec). **(8)**

(d) With a neat schematic, explain how the magnetic bead microrheometry technique can be used to measure the mechanical properties of a WBC. **(7)**

2. (a) Suppose an arthroplasty of the hip with a ceramic head (hard and brittle) is implanted in a patient. During a particular instance of walking, a stress element on the head is in a rotated state (14° clockwise), as shown in the Figure for Q. 2(a). **(30)**

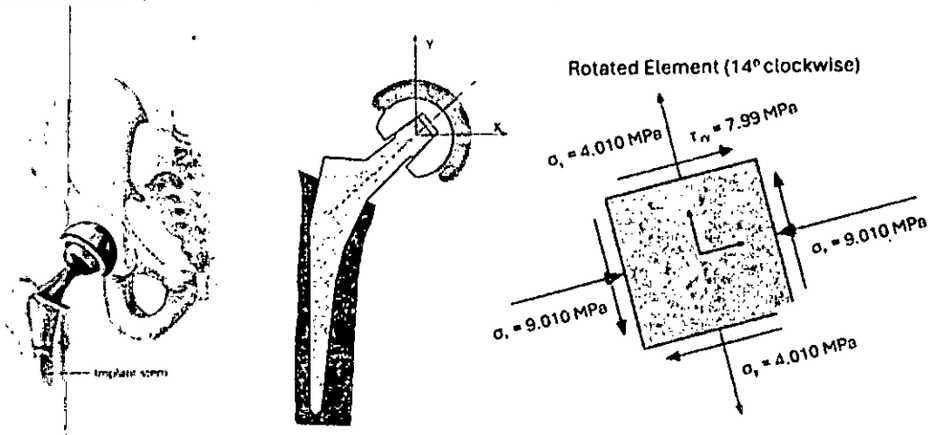

Figure: Question 2 (a)

(i) Determine the stress tensor when the stress element is unrotated.

(ii) Draw a Mohr's circle to find the principal stresses and orientation of the principal plane when the system is unrotated. Also, mark the maximum and minimum shear stress with the orientation of the secondary plane. Verify the values you obtained from the plot using the analytical method (using the formulae).

(iii) The yield stress of the ceramic head of the implant is 23.5 MPa. In the unrotated state, determine whether it will fail according to the von Mises failure criterion.

Comment on whether we are right to use the von Mises criterion to assess the failure of the head. If not, explain why.

3. (a) The typical compressive stress-strain curves for cortical bone and for trabecular bone of two different densities are shown in the Fig. for Q. 3(a). **(13)**

(i) Calculate the approximate strain energy density to failure in each case.

(ii) Determine the cases with the highest resilience, highest toughness and highest stiffness.

(iii) What does your result imply about the function of trabecular versus cortical bone and the consequences of loss of trabecular bone density, as occurs in osteoporosis?

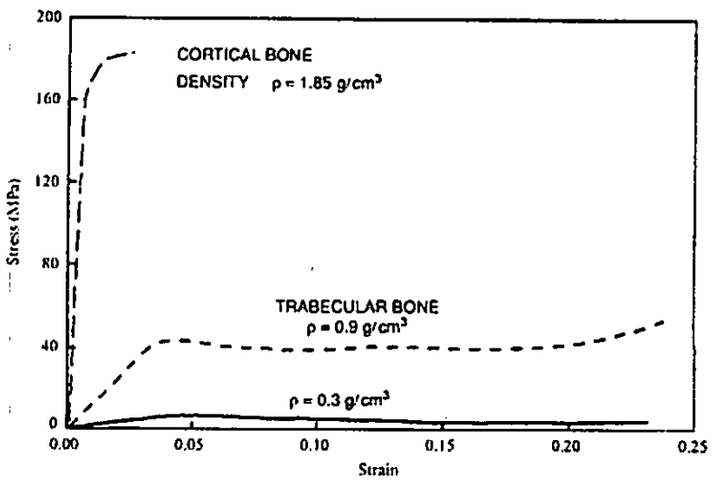

Figure: Question 3(a)

(b) The cytoskeleton of RBCs primarily consists of microtubules. As illustrated in the Fig. for Q. 3(b), the flexural rigidity of microtubules can be determined by applying compressive forces to both ends of the microtubule and considering the critical force (P_{cr}) at which it buckled. The microtubules can be assumed to behave like slender solid rods of average length L= 10.5 μm and average diameter D = 4 μm. If the Young's modulus of the microtubules is 7.41 GPa and the average critical load is 2.9 pN, determine the average flexural rigidity, section modulus and the maximum bending stress of the microtubules. If the shear force acting on the vertical cross-section is 0.9 pN, determine the maximum shear stress at the neutral axis of the microtubules. **(12)**

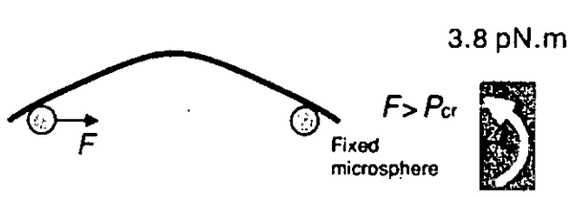

Figure: Question 3(b)

(c) Sachin Tendulkar is one of the most prolific batsman ever in the history of international cricket. He used to bat right-handed, bowl right-handed but off the field, he **(5)**

is a left-hand dominant. According to biomechanics, which of his hands should have more mass? Explain your reasonings.

4. (a) Figure for Q. 4(a) illustrates a three-element model for muscle, consisting of a linear spring (constant k_0 = 180 N/m), a dashpot (constant η_0 = 2.5 Pa.s), and a contractile element that generates a tension T_0 = 7 N for a period C = 6 s after being stimulated. During an isotonic experiment with imposed tension T_1 = 3 N, derive the expression of the muscle length, L for all t > 0 in response to a single stimulus at time t = 0. The muscle length before the stimulus is L_0 = 30 mm and upon relaxation, the muscle cannot stretch past L_0. Sketch your predictions on a graph of muscle length vs time. **(15)**

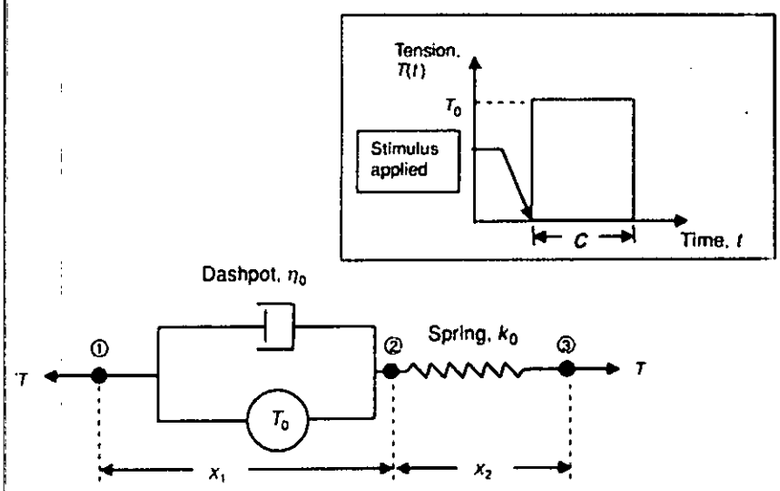

Figure: Question 4(a)

(b) Cristopher is a 25-year-old young man weighing 78 kg. Last month, he fractured his right leg (femur). Since then, for stabilizing fractured bones, he has been using a fixation device as shown in the Figure for Q. 4(b). If the diameter of the screws is 4.5 mm, determine the shear stress exerted on the screws of a four-screw fixation device when Christopher is standing in the anatomical position. **(8)**

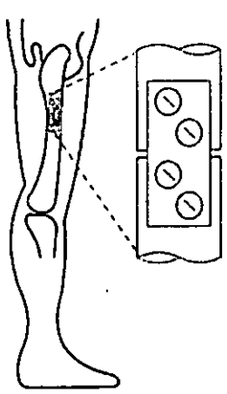

Figure: Question 4(b)

(c) Drawing a typical force-deformation curve (regions properly annotated) of a rabbit ligament, graphically explain how the crimp pattern of collagen structure plays a vital role in determining its mechanical properties. **(7)**

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SECTION – B

Question No. 5 is **MANDATORY**. Answer any **TWO** of the remaining **THREE** questions.

5. (a) Consider the situation of a person bending over to lift a heavy object from the floor, with straight legs, i.e., without bending of the knees, as shown in Figure for Q. no. 5(a). The column, considered as a rigid body, makes an angle Φ of 30° to the horizontal. The weight W_1 of the trunk of this person is of 300 N and is applied at the middle of the column. The weight W_2 of the head + two (arms/forearms/hands) of 150 N added to the weight of an object of 200 N acts on the upper part of the column. The muscle force F exerted by the erector muscles acts at 2/3 of the column length that is 70 cm, forming an angle of 12° with the column. The contact force C compresses the intervertebral disc between the sacrum and the fifth lumbar vertebra. Assuming that the body is in equilibrium, determine the intensities of F, C, and the direction of C. The given data refers to a standard adult of 70 kg. Do you think the person's posture is correct? If not, suggest a correct posture, and back up your suggestion mathematically. **(16)**

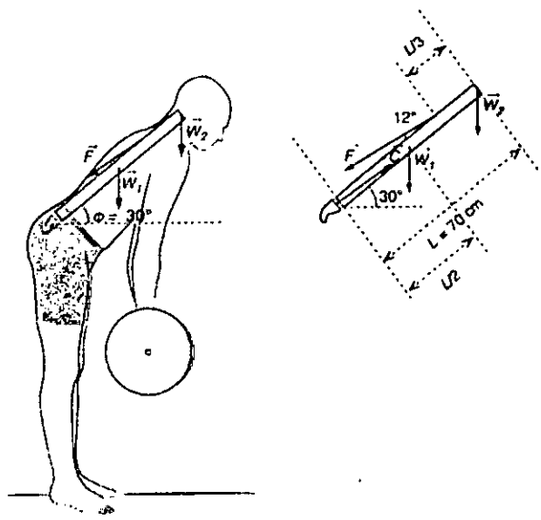


Figure for Q. no. 5(a)

(b) The Figure for Q. no. 5(b) shows a horizontal human arm lifting a dumbbell. The forearm is in equilibrium under the action of the weight w of the dumbbell, the tension T in the tendon connected to the biceps muscle, and the joint reaction force E exerted on the forearm by the upper arm at the elbow joint. The distance between the object and the axis of rotation through O, located at the elbow joint between the ulna and the humerus, is 30 cm. The weight of the forearm is 20 N. Consider the forearm to be analogous to a uniform cylinder with a consistent diameter. For clarity, point A where the tendon is attached is drawn 10 cm. farther from the elbow joint than its actual position. Given the weight of the dumbbell, W=100 N, and the angle between the tension force and the horizontal is 60°. **(14)**

(i) Determine the tension force (T) and joint reaction forces within the system.

(ii) Identify the lever class in the provided system with an appropriate diagram. What is the value of the mechanical advantage (MA) of the lever? Mention one advantage and one disadvantage of this lever class.

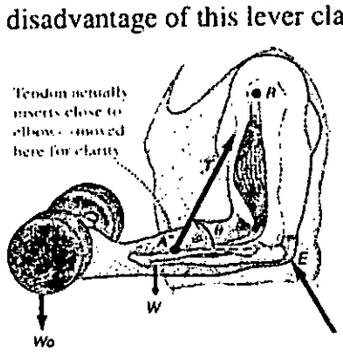


Figure for Q. no. 5(b)

(c) According to The Guinness Book of World Records, 14th edition (1976), the world record was held by Johan Christian Evandt (Norway, 1962); who cleared a bar positioned at 5 feet 9.3 inches (1.76m) above the ground. To attempt breaking his record, let's consider a scenario where a jumper, with a height of 6 feet, executes a standing jump from a platform. The vertical ground reaction force experienced by the jumper is provided in Figure for Q. no. 5(c) during the crouch and push-off phase. Assume that during the jump he oriented his body so that his center of gravity just cleared the bar and his center of gravity is half of his height at the end of the push-off. **(15)**

(i) Derive an expression for the height attained by the center of gravity during a standing jump, relating it to crouch depth and average push-off force. Mention necessary assumptions

(ii) Determine the crouch depth of the jumper. What is the push-off velocity of the jumper? Is he able to break the record by Johan Christian Evandt?

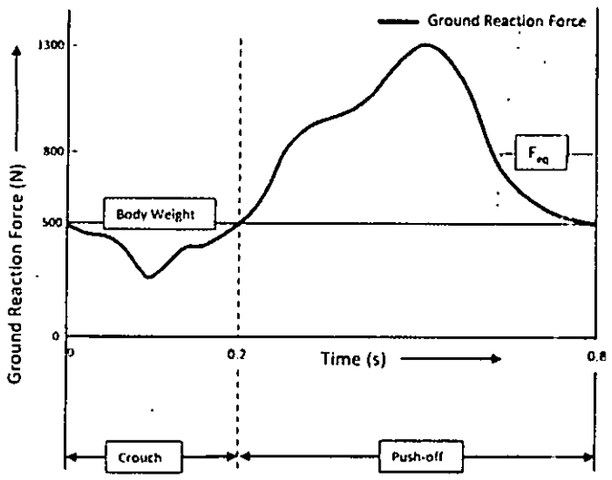
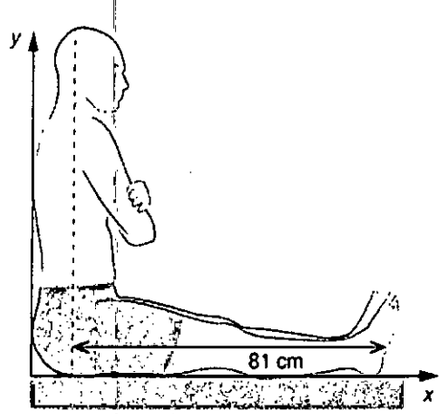


Figure for Q. no. 5(c)

6. (a) Consider an adult with 70 kg mass and 1.70 m height, seated on the floor, with crossed arms and outstretched legs, as shown in Figure for Q. no. 6(a). The figure shows the lateral cut, and the table gives the x and y coordinates of the center of gravity of some segments, as well as the respective masses. The C.G. of the head and neck-trunk-crossed arms are vertically aligned at a distance of 81 cm from the sole of the feet. **(12)**

(i) Calculate the coordinates $x_{C.G.}$ and $y_{C.G.}$ of C.G. of this person's body.

(ii) Mention the factors on which the degree of body stability and equilibrium depend. Do we feel comfortable in the following posture? Provide an explanation.



Parts of body	Coordinates of C.G. x (cm)	y (cm)	Mass
Head	10.0	77.5	4.8
Neck-trunk-crossed arms	10.0	36.0	41.1
Thigh (both)	19.0	10.0	15.0
Leg (both)	60.0	10.0	6.7
Feet (both)	88.0	10.0	2.4

Figure for Q. no. 6(a)

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(b) Consider the split Russel traction device and a mechanical model of the leg shown in Figure for Q. no. 6(b). The leg is held in the position shown by two weights that are connected to the leg via two cables. The combined weight of the leg and the cast is W = 300N. L is the horizontal distance between points A and B where the cables are attached to the leg. Point C is the center of gravity of the leg including the cast which is located at a distance two-thirds of L as measured from point A. The angle cable 2 makes with the horizontal is measured as β=45°. Determine the tensions T_1 and T_2 in the cables, weights W_1 and W_2, and angle α that cable 1 makes with the horizontal so that the leg remains in equilibrium at the position shown. **(10)**

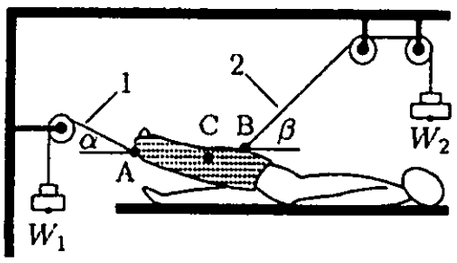

Figure for Q. no. 6(b)

(c) A subject of mass 65 kg has her gait analyzed. Suppose that the x component of the force measured by a force plate takes the shape shown in Figure for Q. no. 6(c). **(8)**

(i) If the forward velocity of the walker is 2m/s at heel strike, what is it 0.4 s after heel strike?

(ii) Estimate the corresponding change in height for the subject's center of gravity (i.e., from heel strike to 0.4s later).

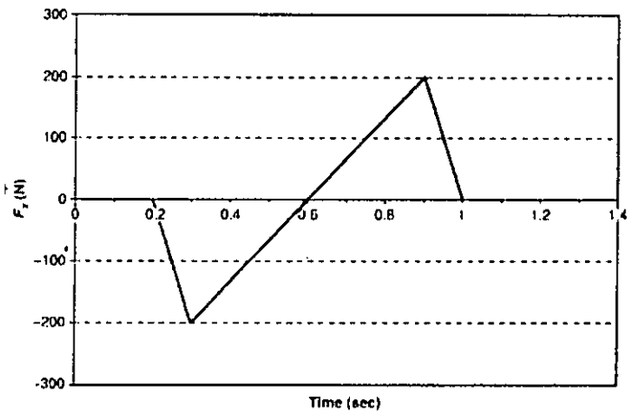

Figure for Q. no. 6(c)

7. (a) Consider a soccer player kicking a stationary ball from point A. If the effect of air resistance is negligible, the ball will undergo a projectile motion. Assuming that the mass of the ball is m =0.5 kg, the horizontal range of motion of the ball is R = 40m, the maximum height the ball reaches in the air is H = 4 m, and the time at which the foot of the soccer player remains in contact with the ball is Δt = 0.1 s. The direction (θ) of the velocity of the rebounding ball at B is 13°. **(10)**

(i) Determine the momentum of the ball at the instant of takeoff and the impulsive force applied by the player on the ball.

(ii) What is the value of the coefficient of restitution between the ball and the field at point B?

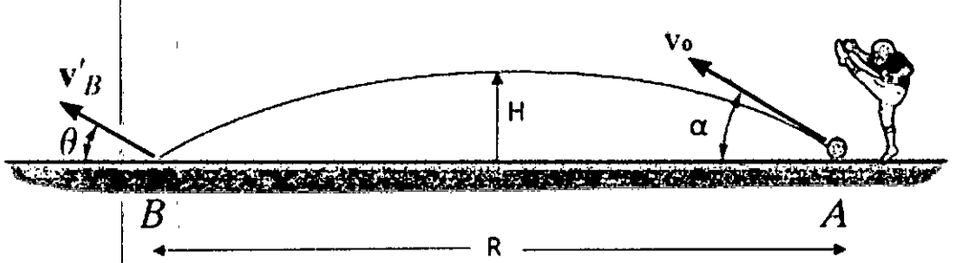

Figure for Q. no. 7(a)

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(b) The 40-kg boy in Figure for Q. no. 7(b) slides down the smooth water slide. If he starts from rest at A, determine the normal reaction exerted by the slide on the boy at position B. **(10)**

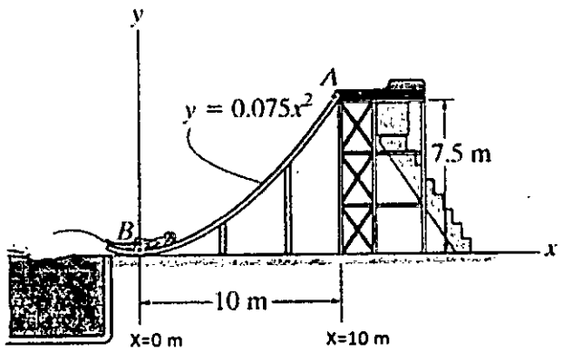
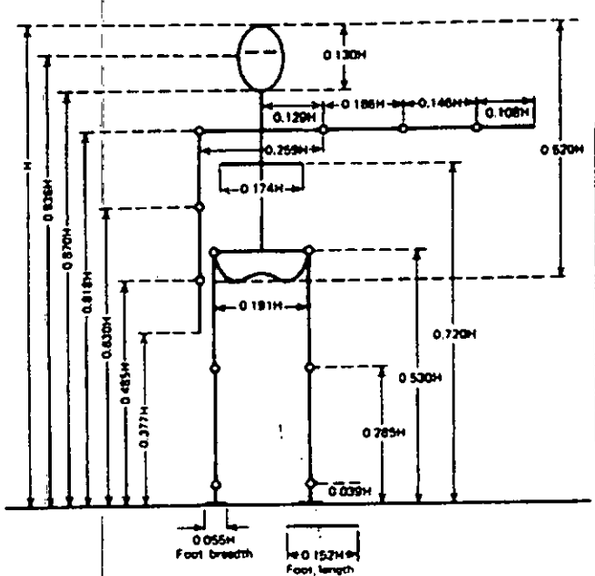


Figure for Q. no. 7(b)

(c) Handball is a game in which a small rubber ball is hit with the palm of the hand. Suppose a 70kg handball player who is 1.8m tall swings his arm in a horizontal plane with his hand outstretched so as to hit the ball. The muscles in his shoulder exert a constant moment of 10 Nm on the arm during this procedure. In uniformly accelerated rotational motion, the angular velocity, ω, is related to the angular position, θ, by: $\omega^2 - \omega_o^2 = 2\alpha(\theta - \theta_o)$. Assuming his arm starts from rest, that his elbow is locked during the swing, and that the arm swings through 80° before contacting the ball, what is the speed of the hand at the instant of contact with the ball? **(10)**



Segment	(Segment weight/ total body weight)*100%	Radius of gyration/ segment length	
		C of G.	Proximal
Upper arm	2.8	0.322	0.542
Forearm	1.60	0.303	0.526
Hand	0.6	0.297	0.587
Total arm	5	0.368	0.645
Thigh	10	0.323	0.540
Shank	4.65	0.302	0.528
Foot	1.45	0.475	0.690
Total Leg	16.1	0.326	0.560

Figure for Q. no. 7(c)

8. (a) A bipedal gait cycle refers to the sequence of movements involved in walking or running on two legs. It is a complex process involving coordination between various muscles and joints to maintain balance and propel the body forward efficiently. Understanding the gait cycle is crucial in fields such as biomechanics, physical therapy, and sports science for analyzing and improving human movement patterns. The gait cycle encompasses numerous phases and sub-phases that offer comprehensive insight into its understanding. **(10)**

   (i) Mention the major phases, sub-phases, and movements of the bipedal gait cycle.

   (ii) What is an antalgic gait? Consider the data obtained in Figure for Q. no. 8(a) from an adult through a standard gait cycle experiment. Evaluate whether his gait cycle is antalgic or normal.

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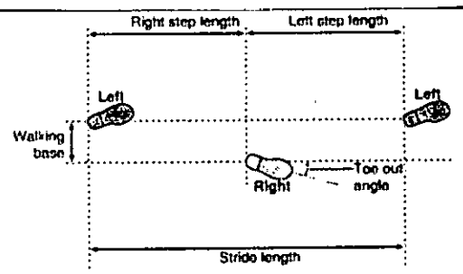

	Gait Cycle Event	Time Stamp (from ImageJ)
Right Leg	First Right Initial Contact (RIC1)	2.44 s
	Right Toe off	2.8 s
	Second Right Initial Contact (RIC2)	3.34 s
Left Leg	First Left Initial Contact (LIC1)	1.94 s
	Left Toe off	2.3 s
	Second Left Initial Contact (LIC2)	2.90 s

Figure for Q. no. 8(a)

(b) In the Figure for Q. no. 8(b), a person is shown performing a seated lower leg flexion/extension exercise to strengthen the quadriceps muscles by wearing a weight boot. The simple mechanical model of the leg is also depicted. W_1 represents the weight of the lower leg, W_0 represents the weight of the boot, F_M represents the magnitude of the pulling force applied to the tibia by the quadriceps muscles through the patellar tendon, and F_J represents the magnitude of the reaction force acting on the tibiofemoral joint. Point O is the center of the tibiofemoral joint, point A is where the patellar tendon attaches to the tibia, point B is the center of gravity of the lower leg, and point C is the center of gravity of the weight boot. The distances between point O and points A, B, and C are measured as a=13 cm, b=27 cm, and c=36 cm, respectively. The angle β between the horizontal and the long axis of the tibia is 34°, and the angle α between the line of action of the quadriceps muscle force and the long axis of the tibia is 18°. Points O, A, B, and C are aligned in a straight line. The weight of the boot, W_0, is 0.3 times the weight of the person's lower leg (W_0=0.3 W_1). Given that the muscle force F_M is given as 434 N. **(15)**

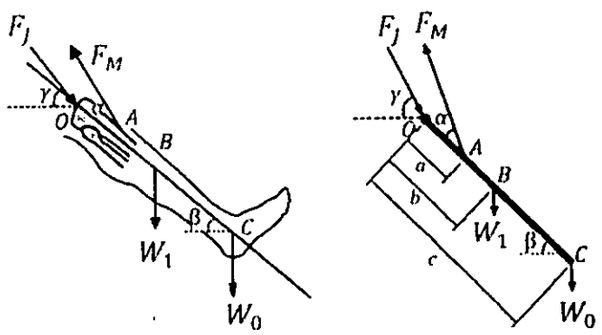

Figure for Q. no. 8(b)

(i) Find the weight W_1 of the lower leg.

(ii) Find the joint reaction force (F_J) and the direction (γ) of joint reaction force with the horizontal direction.

(iii) Assume that the angular displacement of the lower leg during knee extension is determined via a goniometer attached to the leg. After a series of computations, it is determined that the lower leg was extended from θ=30° to 60° in a time period of 0.174s with a mass moment of inertia about the center of rotation of the knee joint is 92 kgm^2 producing an average extensor muscle torque of 90 N m. Calculate the average angular kinetic energy produced, angular work done, and angular power generated by the knee extensor muscles to extend the lower leg from θ=30° to 60°.

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(c) An athlete aspires to complete a 200m race within 40 seconds through a 240 cadence sprint. Will he successfully achieve this goal, and if so, what will be his finishing time and velocity? [The step frequency vs stride length relationship is given in Figure for Q. no. 8(c). Assume that he maintains a constant speed throughout the entire sprint] **(5)**

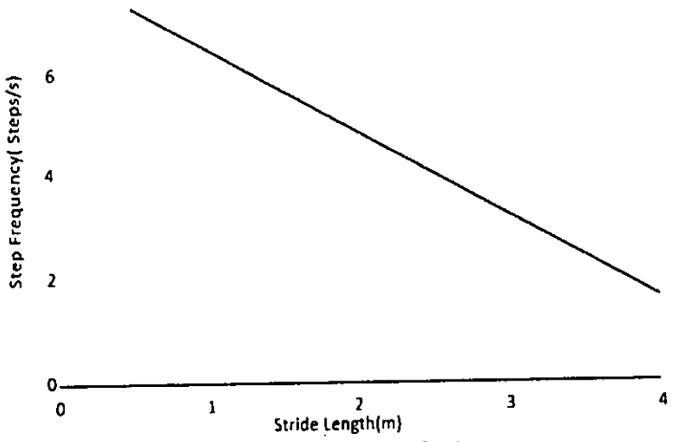


Figure for Q. no. 8(c)

L-2/T-1/BME **Date: 27/03/2024**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-2/T-1 B. Sc. Engineering Examinations 2022-2023

Sub: **BME 203** (Human Physiology)

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. **Question No. 1 is MANDATORY**. Answer any **TWO** of the remaining **THREE** questions.

1. (a) Zenith noticed her skin tone turned a bit bronzed. She was always feeling fatigued, weak and had severe pain in knuckles. Her physician ordered some tests and found that her blood Hb content is 20g% with certain elevated plasma proteins and concluded that Zenith has *hemochromatosis*, a hereditary disease in which the body absorbs iron excessively, resulting in an elevated total body load of iron. **(20)**

   (i) What is the concentration of Hb in her blood? [The molecular weight of Hb is 66,500/g mol]

   (ii) What plasma protein(s) may have elevated in her? How does the elevation in plasma protein affect her oncotic pressure in capillaries? Comment on the change in filtration and absorption.

   (iii) Schematically represent how Hb is synthesized and metabolized through different pathways in the human body. From the schematic, can you think of any simple treatment for Zenith that could keep her body's overload of iron somewhat in check?

   (b) With neat schematics, state the events that happen in the E-C coupling phase and relaxation phase during muscle stimulation. **(15)**

   (c) Briefly discuss the four main themes of physiology. **(10)**

2. (a) In the auditory system, a specific type of ion channels is present in the hair cells. Demonstrate their role in audio signal transduction. When excited or inhibited, how does the signal alter from the resting state? How is the basilar membrane optimized for the sensory coding of pitch ? **(13)**

   (b) How does lateral inhibition make a stimulus easier to perceive? How does this help in visual perception? Explain with properly labeled diagrams. **(11)**

   (c) What are the core differences between reflexive and declarative memory? Recognizing a friend/relative after 10-12 years of staying abroad (no contact through social media) falls under which category? **(6)**

Continued ... Page 2

3. (a) Why do graded potentials lose strength as they move through the cytoplasm? **(14)** Schematically describe the temporal and spatial summation of graded potentials. Discuss how the conditions for "all-or-none phenomenon" can vary for normokalemia and hyperkalemia.

(b) In the context of hyperemia, discuss how paracrine signals influence the vascular smooth muscles. **(10)**

(c) With a schematic, discuss how fluid transfer takes place between blood and brain ECF and CSF. How can we get through the blood-brain barrier? **(6)**

4. (a) What are the three phases of digestion? "Short reflexes integrate in the enteric nervous system while long reflexes are integrated in CNS"- do you agree with the statement? Represent the integration of digestive reflexes in a schematic diagram. **(14)**

(b) Table for Q. 4(b) shows the ionic concentration of a squid axon at 14°C: **(10)**

Table: Question 4(b)

	Nerve (squid axon)	
	Intracellular mM	Extracellular mM
K^+	397	20
Na^+	50	437
Cl^-	40	556

The relative permeability of the K^+, Na^+ and Cl^- channels of the *Aplysia* axon are 0.93, 0.05 and 0.27, respectively. Calculate the ionic contribution to the total resting membrane potential using Goldman- Hodgkin-Katz equation.

(c) Explain why Aspirin is given as an emergency treatment for a suspected heart attack. Which natural mediators behave similarly in an intact blood vessel? **(6)**

Continued... Page 3

SECTION – B

There are **FOUR** questions in this section. **Question No. 5 is MANDATORY.** Answer any **TWO** of the remaining **THREE** questions.

5. (a) Robert is a 52-year-old nonsmoker. He weighs 180 lbs and stands 5'9" tall. His family history is marked by cardiac issues, with his father, grandfather, and uncle experiencing heart attacks in their early 50s, while his mother passed away from a stroke at the age of 71. Aware of his genetic predisposition to hypertension, Robert consulted a doctor to assess his blood pressure. The doctor employed a noninvasive indirect method, observing cuff pressure, to estimate Robert's blood pressure. Consequently, the doctor recommended regular weekly blood pressure checkups for Robert. **(15)**

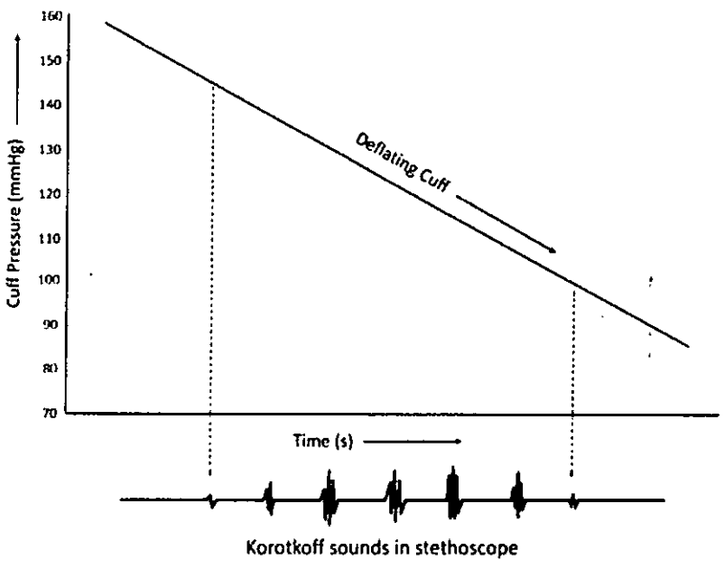


Figure for Q. no. 5(a)

(i) Estimate Robert's pulse pressure and mean arterial pressure (MAP)

(ii) Explain the indirect non-invasive method employed by the doctor to estimate Robert's blood pressure.

(iii) Robert's doctor prescribes a drug called a beta blocker. Explain the mechanism by which beta-receptor-blocking drugs may help control his blood pressure.

(b) Insulin is an essential hormone that is synthesized and secreted by beta cells in the Langerhans islets of the pancreas. It has a number of important functions in the human body, particularly in the control of blood glucose. It is secreted when blood glucose concentrations increase following a meal and finally broken down into inactive metabolites (by the liver and kidney). The metabolites are then excreted in either the bile or the urine and disappear from the blood. The following graph represents the disappearance of insulin hormone from the blood. **(14)**

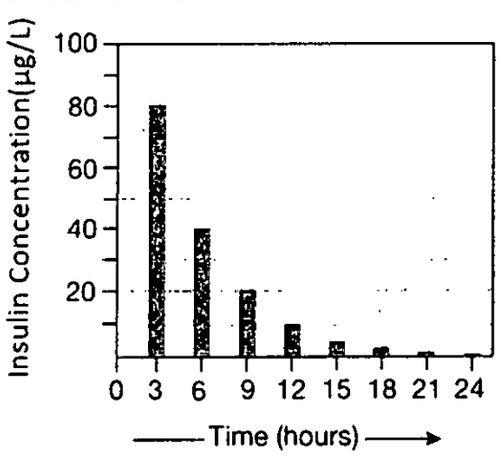


Figure for Q. no. 5(b)

Continued ... Page 4

(i) Based on the graph, what is the half-life of insulin? Mention the type of this hormone according to the chemical composition and site of the receptor.

(ii) Glucose uptake in response to insulin in skeletal muscle and adipose tissue is mediated by the glucose transporter (GLUT4). Draw the flow diagram of the mechanism of glucose uptake by insulin. What will happen if there is a lack of this hormone in the blood? Explain briefly.

(c) Police Captain Jeffers experienced a myocardial infarction and sought medical attention. During his visit, the doctor likely conducted several diagnostic tests to evaluate the severity of the cardiac damage and select the best treatment plan. Among these tests, an electrocardiogram (ECG) was performed, revealing specific cardiac parameters. Additionally, the doctor determined that Captain Jeffers' heart has an ejection fraction of only 25%, with a stroke volume of 40 mL/beat. Assume that his arterial oxygen content of 105 mL O_2/L blood, and a vena cava oxygen content of 50 mL O_2/L blood. Calculate his heart rate, cardiac output (CO), and oxygen consumption (Q_{O2}). **(6)**

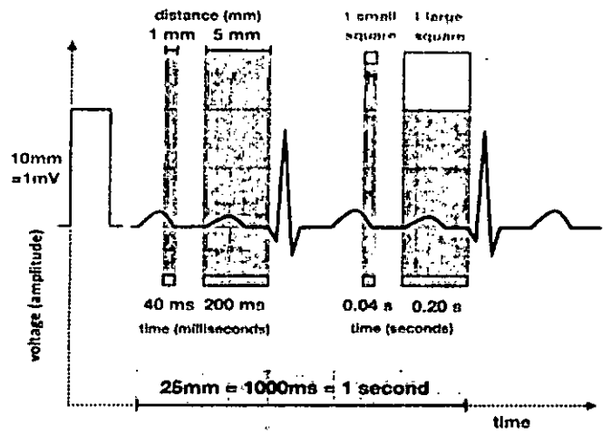


Figure for Q. no. 5(c)

(d) Hannah, a 31-year-old woman, decided to have colonic irrigation, a procedure during which large volumes of distilled water were infused into her rectum. During the treatment, she absorbed 3000 mL of water. About 12 hours later, her roommate found her in convulsions and took her to the emergency room. Her blood pressure was 140/90, her plasma Na^+ concentration was 106 mEq/L (normal: 135 mEq/L), and her plasma osmolarity was 270 mOsM. In a concept map or flowchart, diagram all the homeostatic responses her body was using to attempt compensation for the changes in blood pressure and osmolarity. **(10)**

6. (a) Respiratory distress syndrome (RDS) occurs in babies born early (premature) whose lungs are not fully developed. The earlier the infant is born, the more likely it is for them to have RDS and need extra oxygen and help breathing. RDS is caused by the baby not having enough surfactant in the lungs and unable to produce adequate surfactant. **(13)**

(i) To inhale an adequate amount of air, what do you think the intra-pleural pressure needs to be compared to a full-term baby? Does the significant deficiency in surfactant production contribute to the development of pulmonary edema?

(ii) What are the factors involved in the collapsing tendency of the lungs? Why lung does not collapse?

(iii) Will pulmonary surfactant increase, decrease, or not change the following?

a) Work required for breathing
b) Lung compliance
c) Surface tension in the alveoli

Continued... Page 5

(b) Autoregulation of the glomerular filtration rate is a local control process in which the kidney maintains a relatively constant GFR in the face of normal fluctuations in blood pressure. Explain the processes of the regulation of GFR by tubuloglomerular feedback. What is the effect on GFR if efferent arteriole constricts? **(10)**

(c) Use the data below to answer the questions on capillary filtration and reabsorption. **(7)**

	Interstitial Fluid Hydrostatic Pressure (mmHg)	*Capillary Hydrostatic Pressure* (mmHg)	*Capillary Colloid Osmotic Pressure* (mmHg)	*Interstitial Fluid Colloid Osmotic Pressure* (mmHg)
Arterial end of capillary	-1	30	25	4
Venous end of capillary	-1	8	25	4

Assume that the Average Filtration Pressure for the Entire Capillary is just the average of the net filtration pressures at the arterial end and venous end of the capillary. Now calculate the Average Filtration Pressure and decide whether you expect to see any lymphatic fluid flowing away from this capillary bed.

7. (a) Pulmonary edema is when fluid collects in the air sacs of the lungs, making it difficult to breathe. Assume that a patient has been enduring an extended period of pulmonary edema. During this period, the patient's respiratory rate is noted as 3 breaths/15 seconds. Additionally, the dead space volume is measured at 200 mL, and the alveolar ventilation rate is calculated to be 2.25 L/min. **(12)**

   (i) What is the minute volume of the patient?

   (ii) How would each of the following factors be affected by the patient?

   a) arterial PO_2

   b) arterial hemoglobin saturation

   c) alveolar ventilation

   (iii) Explain the effect on the oxy-hemoglobin saturation curve of the patient during heavy exercise.

(b) The Department of BME organized the "Football Tournament 2024" on February 7, 2024, at the playground of Bangladesh University of Engineering and Technology. Adil was selected as the player of the match of the tournament. Throughout the final match, he engaged in significant physical activity, resulting in a substantial loss of fluid from his body's extracellular fluid. There are several hormones that play key roles in regulating fluid and electrolyte balance. Mention two hormones that are responsible for recovering Adil's lost fluids and maintaining fluid homeostasis. Explain briefly how these hormones maintain fluid homeostasis. What will happen if he takes an excessive amount of water over a threshold after running? **(15)**

(c) The graph shows one lung under two different conditions, A and B. This graph shows the effect of pressure on lung volume. In which condition does the lung have higher compliance, higher elastance, and more amount of work needed for breathing? **(3)**

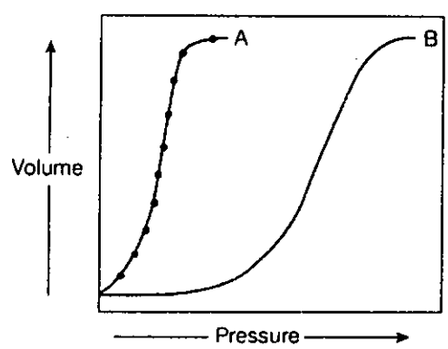


Figure for Q. no. 7(c)

Continued...Page 6

8. (a) Diabetes is a chronic condition characterized by insufficient insulin production or ineffective utilization of insulin by the body, resulting in elevated blood glucose levels. Hyperglycemia in diabetic patients leads to osmotic diuresis, causing excessive loss of water through urine and subsequent dehydration. Suppose a diabetic patient's plasma contains 1 mg/mL of inulin concentration, and over a 24-hour period, urine collected from the patient measures 2450 mL with an inulin concentration of 100 mg/mL. Assume that the plasma glucose concentration of the patient is 500 mg/dL and the transport maximum (Tm) of glucose is 400 mg/min. **(13)**

   (i) What are the values of glomerular filtration rate (GFR), renal threshold, filtration, reabsorption, and excretion rates of glucose? Illustrate the composite graph showing the relationship between filtration, reabsorption, and excretion rate of glucose with respect to plasma glucose concentration.

   (ii) The doctor prescribes a drug to reduce the patient's blood glucose level, which subsequently drops to 200 mg/dL. What will be the effect on filtration, reabsorption, and excretion rates of glucose if GFR remains unchanged?

(b) Cretinism manifests as a condition marked by inadequate production of specific hormones during fetal development or infancy. Insufficient levels of these hormones can result in impaired growth and development, intellectual disability, a distended abdomen, cognitive deficits, an enlarged protruding tongue, and various other developmental abnormalities. Identify the hormones responsible for this condition. With the necessary flow diagrams, write down the steps of the synthesis and mechanism or mode of action of these hormones. **(13)**

(c) What would be the consequences if the refractory period of cardiac muscle is similar to that of skeletal muscle? **(4)**

L-2/T-1/BME **Date: 02/05/2024**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-2/T-1 B. Sc. Engineering Examinations 2022-2023

Sub: **MATH 213** (Differential Equations)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks.

Symbols used have their usual meaning.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) Find the differential equation of all circles in the plane. **(11)**

   (b) Solve the differential equation $(2x - 5y + 3)dx - (2x + 4y - 6)dy = 0$. **(12)**

   (c) What do you mean by oblique trajectories? Find a family of oblique trajectories that intersect the family of circles $x^2 + y^2 = c^2$ at angle 45°. **(12)**

2. (a) Solve the IVP: $(2x+3)\frac{dy}{dx} = y + \sqrt{2x+3},\ y(-1) = 0$. **(11)**

   (b) Assume that the rate at which radioactive nuclei decay is proportional to the number of nuclei in the sample. In a certain sample 10% of the original number of radioactive nuclei have undergone disintegration in a period of 200 years. (i) What percentage of the original radioactive nuclei will remain after 1000 years (ii) In how many years will only one-fourth of the original number remain. **(12)**

   (c) What is integrating factor? Find the integrating factor of the differential equation $(2xy^4e^y + 2xy^3 + y)dx + (x^2y^4e^y - x^2y^2 - 3x)dy = 0$ and solve it. **(12)**

3. Solve the following differential equations:

   (a) $(D^2 - 6D + 9)y = \frac{e^{3x}}{x^2}$. **(11)**

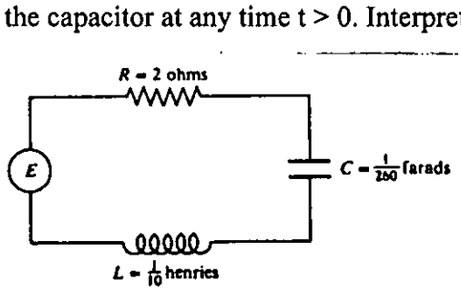
   (b) $(x^2D^2 - xD + 4)y = \cos \ln x + x \sin \ln x$. **(12)**

   (c) $y = 2\frac{dy}{dx}x + \left(\frac{dy}{dx}\right)^4 x^2$. **(12)**

4. (a) Factorize the operator and solve the following differential equation: **(15)**

   $$\left(xD^2 - 3D + \frac{3}{x}\right)y = 2x^2 - x.$$

   (b) A circuit has in series an electromotive force given by E = 100 sin 60t volts, a resistor of 2 ohms, an inductor of 0.1 henries, and a capacitor of $\frac{1}{260}$ farads showing in the following figure. If the initial current and the initial charge on the capacitor are both zero, find the charge on the capacitor at any time t > 0. Interpret your result. **(20)**



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MATH 213/BME

SECTION – B

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

5. (a) Classify $x = 0$ is a regular or irregular singular point. Find the series solution of the following differential equation by using the method of Fröbenius: **(25)**

$$x^2\frac{d^2y}{dx^2} + x\frac{dy}{dx} + \left(x^2 - \frac{1}{4}\right)y = 0$$

(b) Form a partial differential equation by eliminating arbitrary constants from **(10)**

$$x^2 + y^2 = (z - c)^2 \tan^2\alpha$$

6. (a) Apply Lagrange's auxiliary equation technique to solve: **(17)**

$$(y^3x - 2x^4)p + (2y^4 - x^3y)q = 9z(x^3 - y^3)$$

(b) Using Charpit's method find the complete integral of the following partial differential equation: **(18)**

$$(p^2 + q^2)x = pz$$

Does singular integral exist for this equation? If exists, find it.

7. Solve the following higher order partial differential equations:

(a) $\left(D_x^2 - 6D_xD_y + 9D_y^2\right)z = 12x^2 + 36xy$ **(11)**

(b) $\left(D_x^2 - D_xD_y - 2D_y^2 + 2D_x + 2D_y\right)z = e^{2x+3y} + \sin(2x + y)$ **(12)**

(c) $\left(D_x^2 - D_y\right)z = (4x + y)e^{3x+9y}$ **(12)**

8. (a) Solve the following higher order partial differential equation: **(15)**

$$\left(x^2D_x^2 - 2xyD_xD_y - 3y^2D_y^2 + xD_x - 3yD_y\right)z = x^2y\sin\left(\log x^2\right)$$

(b) Solve the following boundary value problem by the method of separation of variables and interpret the solution physically: **(20)**

$$\frac{\partial u}{\partial t} = c^2\frac{\partial^2 u}{\partial x^2}$$

$$u(0, t) = u(l, t) = 0 \qquad t > 0$$

$$u(x, 0) = 100\frac{x}{l}, \qquad 0 < x < l$$

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-2/T-1 B. Sc. Engineering Examinations 2022-2023

Sub: **EEE 273** (Basic Electronic Devices and Circuits)

Full Marks: 210 Time: 3 Hours

The figures in the margin indicate full marks.

The corresponding Course Outcomes (COs) of each part of Question 1 and 5 are mentioned on the right most column. The COs of the Course are mentioned at the end of the question paper.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this section. Answer to **Question No. 1 is compulsory.**

Answer any TWO questions from Questions 2-4.

1. (a) Design a ±20dB/decade wideband bandpass active filter to meet the following specifications: **(18)** (CO3)

$f_R = 3\text{kHz}$

$Q = 0.4$

(b) The circuit in Fig. for Q 1(b) has parameters $V^+ = 5$ V, $V^- = -5$ V, $R_E = 4\text{K}\Omega$, $R_C = 4\text{K}\Omega$, $R_B = 100$ KΩ, and $R_S = 0.5$ KΩ. The transistor parameters are $\beta = 120$, $V_{BE}(\text{on}) = 0.7$ V, and $V_A = 80$ V. Analyze the circuit and (i) determine the input resistance seen by the signal source, (ii) find the small-signal voltage gain. **(17)** (CO2)

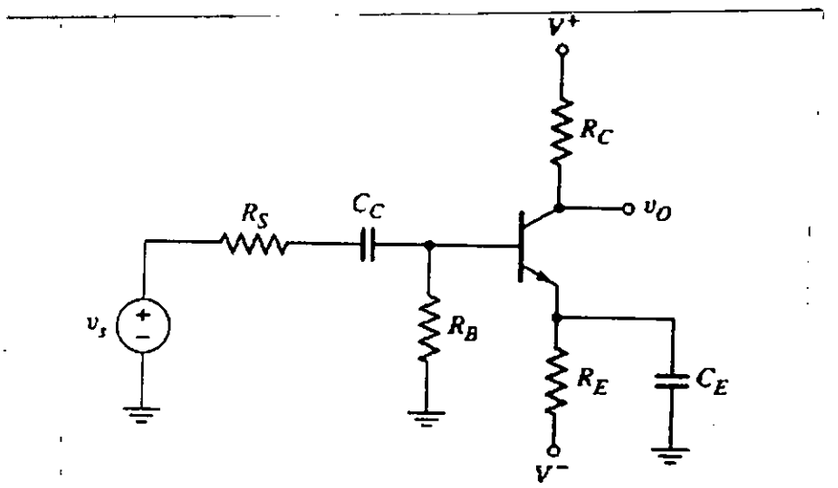

Fig. for Q 1(b)

2. (a) Suppose you have two supply voltage sources $v_1 = \sin(100t)\text{V}$ and $v_2 = 1$ V. Design a circuit using op-amps that will produce an output voltage of $v_0 = (\sin(50t))^2$ V. Show the circuit diagram. **(20)**

Contd P/2

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Contd... Q. No. 2

(b) Suppose you have two inputs v_1 and v_2. Design a subtractor circuit using op amps, so the output voltage is $v_0 = v_1 - v_2$. **(15)**

3. (a) The parameters for each transistor in the circuit in Fig. for Q 3(a) are β = 80 and V_{BE} (on) = 0.7 V. Determine the quiescent values of base, collector, and emitter currents in Q_1 and Q_2. **(17)**

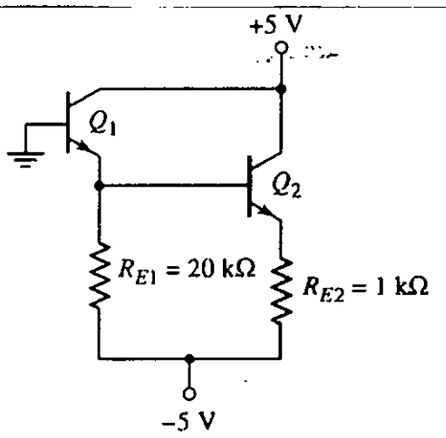

Fig. for Q 3(a)

(b) Derive the expressions of R_i, R_o, A_v and G_v for a common emitter amplifier with emitter resistance (R_E) using small signal analysis. **(18)**

4. (a) For the circuit is Fig. for 4(a), let β = 100 and R_E = 3kΩ. Design the circuit such that $V_E = 0$. **(15)**

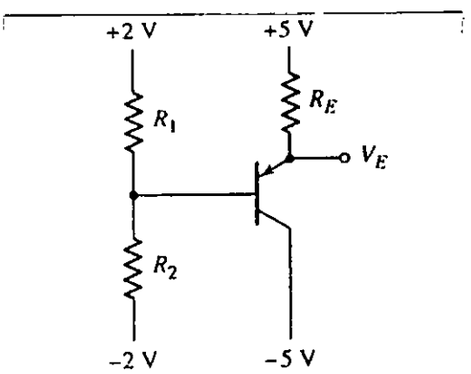

Fig. for Q 4(a)

(b) Draw a +40dB/decade high pass Butterworth filter. Derive the expression for its cutoff frequency. Using your analysis, design a filter with 50 MHz cutoff frequency. **(20)**

Contd P/3

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SECTION – B

There are **FOUR** questions in this section. Answer to **Question No. 5 is compulsory.**
Answer any TWO questions from Questions 6-8.

5. (a) For the following circuit, V_s is a sine wave of 40V peak to peak and has a time period of 1 ms. Explain the operation of the circuit. Plot the voltage across the 100KΩ resistor and determine the maximum current through it. Assume that the diodes have a forward voltage drop of 0.7V. **(15)** (CO1, CO2)

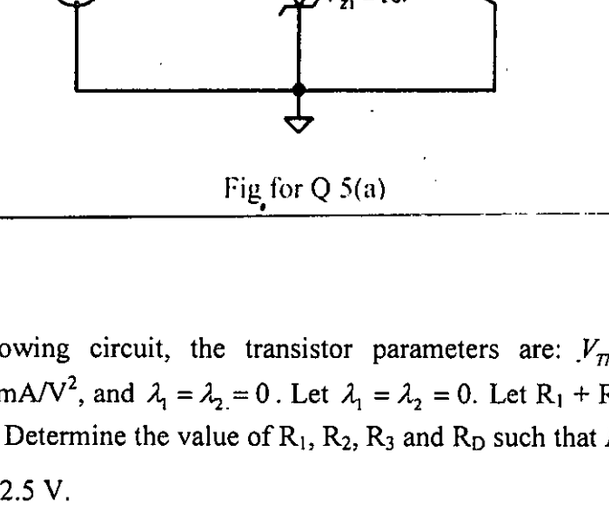

Fig for Q 5(a)

(b) For the following circuit, the transistor parameters are: $V_{TN1} = V_{TN2} = 1.2$ V, $K_{n1} = K_{n2} = 0.8$ mA/V^2, and $\lambda_1 = \lambda_2 = 0$. Let $\lambda_1 = \lambda_2 = 0$. Let $R_1 + R_2 + R_3 = 300$ KΩ and $R_S = 10$ KΩ. Determine the value of R_1, R_2, R_3 and R_D such that $I_{DQ} = 0.4$ mA and $V_{DSQ1} = V_{DSQ2} = 2.5$ V. **(20)** (CO3)

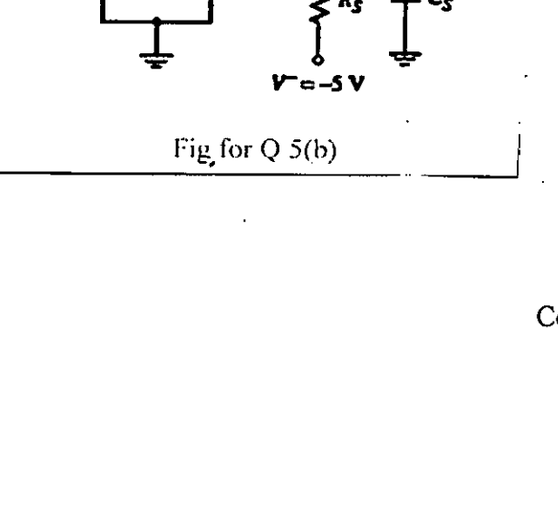

Fig for Q 5(b)

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6. (a) For the following circuit, determine the current in each diode and the voltages V_A and V_B. Assume that each diode has a forward voltage drop of 0.7 V. **(15)**

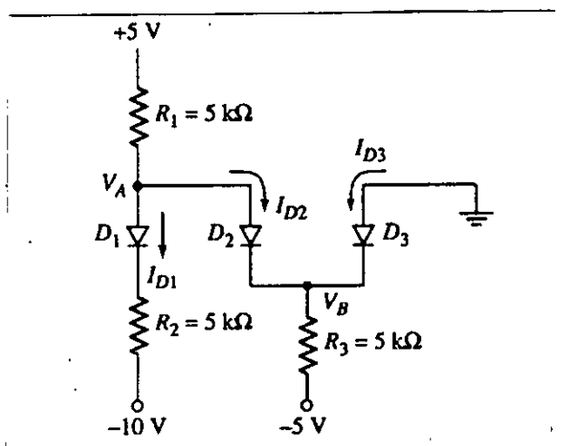

Fig for Q 6(a)

(b) For the following circuit, assume the diodes have zero voltage drop under forward bias. The secondary voltage is given by $v_s = V_s \sin\omega t$, where V_s = 24 V. The Zener diode has parameters V_Z = 16 V at I_Z = 40 mA and $r_z = 2\Omega$. **(20)**

(i) Determine R_i such that the load current can vary over the range $40 \le I_L \le 400$ mA with I_Z (min) = 40 mA.

(ii) Find C such that the ripple voltage is no larger than 1 V.

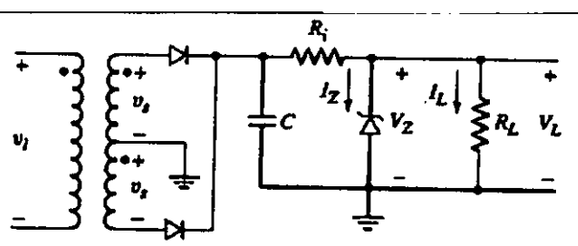

Fig for Q 6(b)

7. (a) For the following circuit, the transistors are identical with the following parameters: K_n = 1 mA/V^2, V_{TN} = 2V *and* $\lambda = 0$. Determine i_0 and v_0. **(15)**

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Contd... Q. No. 7(a)

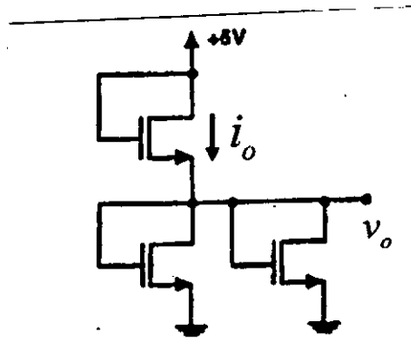

Fig. for Q 7(a)

(b) In the following source-follower circuit, the most negative output signal voltage occurs when the transistor just cuts off. **(20)**

(i) Show that this output voltage v_0 (min) is given by:

$$v_0(\text{min}) = \frac{-I_{DQ}R_S}{1 + R_S / R_L}$$

(ii) Show that the corresponding input voltage is given by:

$$v_i(\text{min}) = -\frac{I_{DQ}}{g_m}\left(1 + g_m\left(R_S \parallel R_L\right)\right)$$

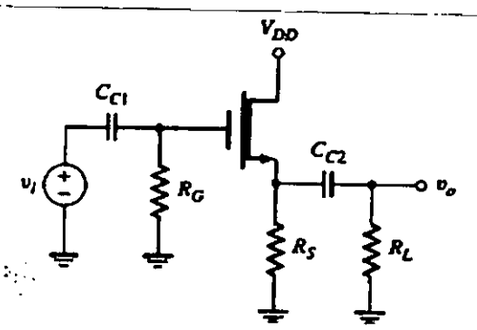

Fig. for Q 7(b)

8. For the following common-gate circuit, the transistor parameters are as follows: **(35)**

$$V_{TP} = -1\text{ V},\ K_p = 0.5\text{ mA/V}^2, \text{ and } \lambda = 0.$$

(i) Determine R_S and R_D such that $I_{DQ} = 0.75$ mA and $V_{SDQ} = 6$ V.

(ii) Draw the small signal equivalent circuit.

(iii) Determine the input impedance R_i and the output impedance R_o.

(iv) Determine the load current i_o and the output voltage v_0, if $i_i = 5 \sin \omega t\ \mu$A.

Contd P/6

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Contd... Q. No. 8

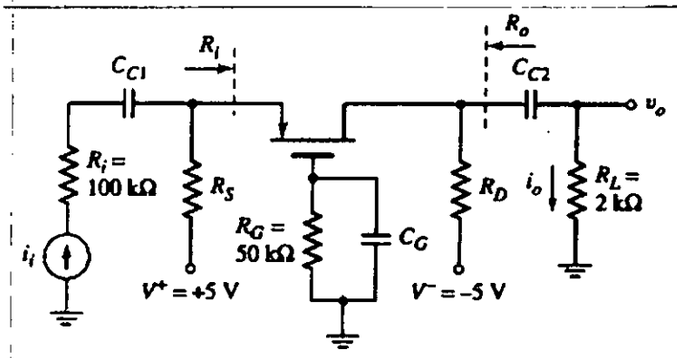

Fig for Q 8
