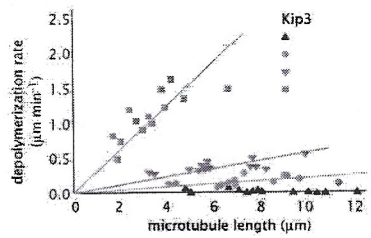
Indian Association for the Cultivation of Science
(Deemed to be University under *de novo* Category)
Integrated Bachelor's-Master's Program
End-Semester (Sem-I) Examination-Autumn 2023

Subject: Molecules of life and cells ***Subject Code(s): BIS 1101***
Full Marks: 50 ***Time Allotted: 3 h***

Instructions: Use separate pages for Part A and Part B
(Keep all subparts of a question together)

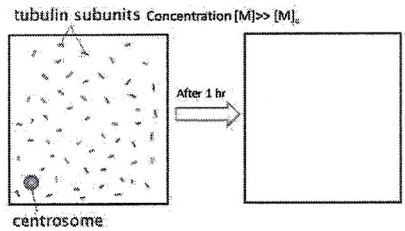
Part A: Answer all questions (25 marks)

1. i. In the adjacent figure, the correct concentrations of Kip3 (a plus end-directed depolymerizing motor) would be **1**



(a) ▲> ● >▼> ■ (b) ▲< ● <▼< ■
(c) ▲≤ ● <▼< ■ (d) ▲≥ ● >▼> ■

ii. Draw the appropriate configuration for the vacant space on the right suitable for polymerization. **1**



iii. Name three focal adhesion (FA) proteins. **1**

iv. An essential protein required to create a branched actin network is **1**
(a) Formin (b) Filamin (c) Spectrin (d) Arp 2/3

v. True or False: Although lipid molecules are free to diffuse in the plane of the bilayer, they cannot flip-flop across the bilayer unless enzyme catalysts called phospholipid translocators are present in the membrane. **1**

2. i. Consider a microtubule filament polymerizing against the cell membrane offering a resistive force F. The average growth speed at temperature T can be expressed as **1 + 2**

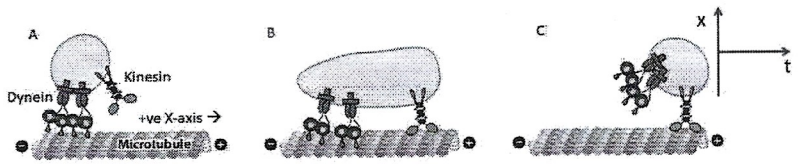
$$v = \frac{D}{\delta}\frac{(F\delta/k_BT)^2}{(e^{F\delta/k_BT} - 1 - F\delta/k_BT)}$$

Plot v as a function of F. Obtain the limiting values of v when $F\delta \ll k_BT$ and $F\delta \gg k_BT$

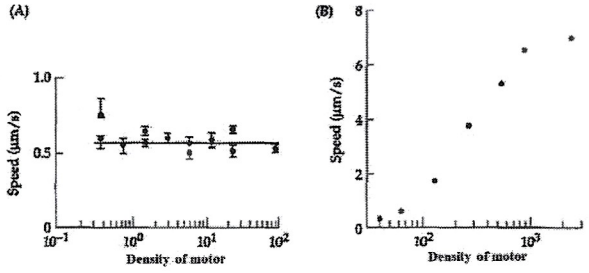
ii. Schematically describe an experimental setup using an optical trap and a barrier by which the polymerization force due to a single microtubule nucleated from a bead can be measured. What would be the expected behavior of the force as a function of time? **2**

iii. Calculate the equilibrium force (maximum) for a microtubule at room temperature (25^oC) when the free tubulin concentration is 100 times the critical concentration. The size of a microtubule heterodimer is ~ 8 nm. 2

3. i. Draw probable trajectories (x vs. t) of the cargo vesicles in each case. 2



ii. Figures show the results from gliding assays where cytoskeletal filaments are moved by molecular motors. Based on these observations, discuss the specific feature of motors responsible for different outcomes in (A) and (B). Give examples of the motors that are likely to represent the figures. 2



iii. What is the duty ratio of a motor protein? Consider the duty ratio of 0.01 for a single-headed motor. How many motors would be required to generate continuous motion? 2

iv. Consider flagellar motors propelling an *E. coli* through the water at a speed of 25 $\mu m/s$. Calculate the drag force applied on the bacterium. Approximately, how far the bacterium will move if the motors stop suddenly. Consider *E.coli* as a sphere of diameter $2\mu m$ in water with viscosity $10^{-3}\ Pa.s$ and density $1000\ kg/m^3$ 1 + 2

4. Receptors on a spherical cell of radius a may not be fast enough to adsorb all the ligand molecules diffusing into them. The effective current or the number of ligand molecules adsorbed per unit time is given by $dn/dt = N\ k_{on}\ c(a)$, where N is the number of surface-bound receptors, k_{on} is the finite rate of adsorption, $c(a)$ is the concentration of ligand at the surface of the cell (i.e. $r = a$) and $c(\infty) = c_0$ at $r = \infty$.

i. Using Fick's 1st law define overall flux for a sphere of radius r and then integrate to find an expression for $c(a)$. 2

ii. Show that for large k_{on} you can recover the limit of perfect adsorbers and for small k_{on} no adsorption occurs. 2

Part B: Answer all questions (25 marks)

5. Name the molecule/structure that describes the following (1/2 marks each) 3

A) Artificial phospholipid bilayer vesicle formed from an aqueous suspension of phospholipid molecules.

B) Small region of the plasma membrane enriched in sphingolipids and cholesterol.

C) Any glycolipid having one or more sialic acid residues in its structure; especially abundant in the plasma membranes of nerve cells.

D) Having both hydrophobic and hydrophilic regions, as in a phospholipid or a detergent molecule.

E) The main type of phospholipid in animal cell membranes, with two fatty acids and a polar head group attached to a three-carbon glycerol backbone.

F) Lipid molecule with a characteristic four-ring steroid structure that is an important component of the plasma membranes of animal cells.

6. State true or false, and then explain why. (1 marks each, 1/2+1/2) **6**

A) Although lipid molecules are free to diffuse in the plane of the bilayer, they cannot flip-flop across the bilayer unless enzyme catalysts called phospholipid translocators are present in the membrane.

B) All of the common phospholipids—phosphatidylcholine, phosphatidylethanolamine, phosphatidylserine, and sphingomyelin—carry a positively charged moiety on their head group, but none carry a net positive charge.

C) Glycolipids are never found on the cytoplasmic face of membranes in cells.

D) Since introns are largely genetic "junk," they do not have to be removed precisely from the primary transcript during RNA splicing

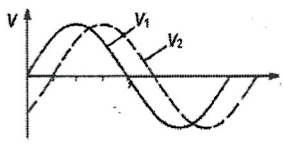
E) No two cells in your body have the identical nucleotide sequence.

F) Most of the interactions between macromolecules could be mediated just as well by covalent bonds as by noncovalent bonds.

7. Choose all of the correct options (1/2 marks each only if all the correct options are indicated) **3**

A) Which of the following optical microscopy techniques have best z-resolution (smallest resolution)
1) Confocal 2) Fluorescence microscopy 3) TIRF 4) Two photon imaging

B) What is the phase difference between wave V1 and V2, in the following figure?
1) 45Deg 2) 90Deg 3) 135Deg 4) 180Deg



C) Which of the following does not alter the wave front
1) Prism 2) Concave lens 3) Convex lens 4) Rectangular Glass slab

D) Which of the following improves the resolution (r) in optical imaging (small value of r)?
1) Increasing the wavelength of light 2) Increasing the diameter of the lens 3) Increasing the size of the object 4) increasing the refractive index of the object

E) Which of the following improves the Z-resolution (r) in confocal imaging
1) decreasing the pin hole 2) increasing the pin hole 3) increasing the gain of the detector 4) increasing the laser paper

F) Information-containing element that controls a discrete hereditary characteristic.
1) Genome 2) Double helix 3) Gene 4)Base pair

8. When egg white is heated, it hardens. This cooking process cannot be reversed, but hard-boiled egg white can be dissolved by heating it in a solution containing a strong detergent (such as sodium dodecyl sulfate) together with a reducing agent, like 2-mercaptoethanol. Neither reagent alone has any effect. **1 + 1**

A) Why does boiling an egg white cause it to harden?

B) Why does it require both a detergent and a reducing agent to dissolve the hard-boiled egg white?

9. Typical proteins have a stability ranging from 30 to 60 kJ/mole at 37°C. Stability is a measure of the equilibrium between the folded and unfolded forms of the protein: folded [F] ↔ unfolded [U], K = [U]/[F] For a protein with a stability of 41.5 kJ/mole, calculate the fraction of unfolded protein that would exist at equilibrium at 37°C. At equilibrium, $\Delta G° = -RT\ln K = -2.3RT\log K$, where $R = 8.3 \times 10^{-3}$ kJ/(mole K) and T is temperature in K (37°C = 310 K). **2**

10. **A)** Draw schematic of a fluorescence microscope **7**

B) Define and explain lateral and axial optical resolution and indicate it(in the diagram-a) **(1 +**

C) For an objective lense of diameter 2mm, focal length of 100 micro meter , find the lateral resolution at 500 nm wavelength **2 +**

D) explain the principle that is used to improve the lateral and axial resolution in PALM **2 + 2)**

11. An RNA polymerase is transcribing a segment of DNA that contains the sequence 5′-GTAACGGATG-3′ 3′-CATTGCCTAC-5′ **2**

5′-GTAACGGATG-3′
3′-CATTGCCTAC-5′

If the polymerase transcribes this sequence from left to right, what will the sequence of the RNA be? What will the RNA sequence be if the polymerase moves right to left?
