GATE 2021 ES

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1 General Aptitude (GA)

Q.1 - Q.5 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: -1/3)

1) The current population of a city is 11,02,500. If it has been increasing at the rate of 5% per annum, what was its population 2 years ago? (*GATE ES* 2021)

a) 9,92,500
b) 9,95,006
c) 10,00,000
d) 12,51,506

2) p and q are positive integers and $\frac{p}{q} + \frac{q}{p} = 3$, then, $\frac{p^2}{q^2} + \frac{q^2}{p^2}$ (*GATE ES* 2021)

a) 3 b) 7 c) 9 d) 11

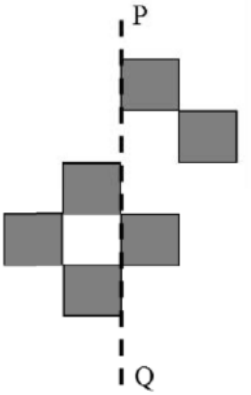

Fig. 1: Figure for Q.3

3) The least number of squares that must be added so that the line P-Q becomes the line of symmetry is _ _ _ _ _ _ (*GATE ES* 2021)

a) 4 b) 3 c) 6 d) 7

4) *Nostalgia* is to *anticipation* as _____ is to _____
Which one of the following options maintains a similar logical relation in the above sentence? (*GATE ES* 2021)

a) Present, past
b) Future, past
c) Past, future
d) Future, present

5) Consider the following sentences:
(i) I woke up from sleep.
(ii) I woked up from sleep.
(iii) I was woken up from sleep.
(iv) I was wokened up from sleep.
Which of the above sentences are grammatically CORRECT? (*GATE ES* 2021)

a) (i) and (ii)
b) (i) and (iii)
c) (ii) and (iii)
d) (i) and (iv)

Q.6 - Q.10 Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: -2/3).

6) Given below are two statements and two conclusions.
Statement 1: All purple are green.
Statement 2: All black are green.
Conclusion I: Some black are purple.
Conclusion II: No black is purple.
Based on the above statements and conclusions, which one of the following options is logically CORRECT? (*GATE ES* 2021)
a) Only conclusion I is correct.
b) Only conclusion II is correct.
c) Either conclusion I or II is correct.
d) Both conclusion I and II are correct.

7) Computers are ubiquitous. They are used to improve efficiency in almost all fields from agriculture to space exploration. Artificial intelligence (AI) is currently a hot topic. AI enables computers to learn, given enough training data. For humans, sitting in front of a computer for long hours can lead to health issues.
Which of the following can be deduced from the above passage?
(i) Nowadays, computers are present in almost all places.
(ii) Computers cannot be used for solving problems in engineering.
(iii) For humans, there are both positive and negative effects of using computers.
(iv) Artificial intelligence can be done without data. (*GATE ES* 2021)

a) (ii) and (iii)
b) (ii) and (iv)
c) (i), (iii) and (iv)
d) (i) and (iii)

8) Consider a square sheet of side 1 unit. In the first step, it is cut along the main diagonal to get two triangles. In the next step, one of the cut triangles is revolved about its short edge to form a solid cone. The volume of the resulting cone, in cubic units, is _____ (*GATE ES* 2021)

a) $\frac{\pi}{3}$ b) $\frac{2\pi}{3}$ c) $\frac{3\pi}{2}$ d) 3π

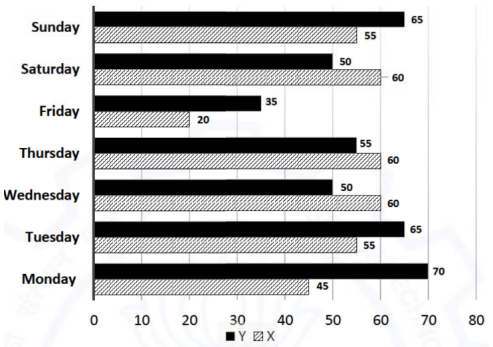

Fig. 2: Bar Chart for Q.9

9) The number of minutes spent by two students, X and Y, exercising every day in a given week are shown in the Fig. **??** above.
The number of days in the given week in which one of the students spent a minimum of 10% more than the other student, on a given day, is (*GATE ES* 2021)

a) 4 b) 5 c) 6 d) 7

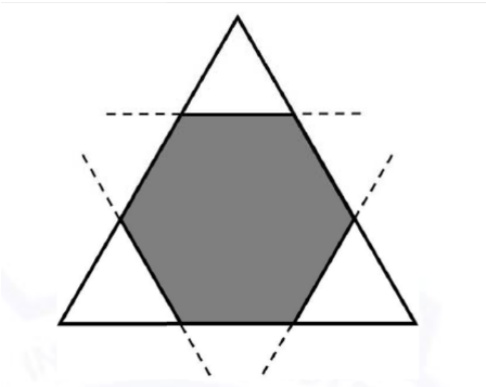

Fig. 3: Figure for Q.10

10) Corners are cut from an equilateral triangle to produce a regular conved hexagon as shown in Fig. **??**.
The ratio of the area of the regular convex hexagon to the area of the original equilateral triangle is (*GATE ES* 2021)

a) 2 : 3
b) 3 : 4
c) 4 : 5
d) 5 : 6

2 Environmental Science and Engineering(ES)

Q.1 - Q.18 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: -1/3).

1) A tangent is drawn on the curve of the funtion $y = x^2$ at the point $(x, y) = (3, 9)$. The slope of the tangent is _____. (*GATE ES* 2021)

a) 3
b) 6
c) 9
d) 12

2) $\lim_{x \to 0} \frac{x^2}{\sin x}$ (*GATE ES* 2021)

a) 0
b) 1
c) 2
d) -1

3) The table below shows the carbon content of four samples of powdered coal. If these four samples are mixed completely, what would be the resultant carbon percentage of the mixture by weight?

Sample number	Mass of sample (kg)	Carbon % by weight
1	2	88
2	1	90
3	2	80
4	1	90

(*GATE ES* 2021)

a) 58 %
b) 86 %
c) 87 %
d) 90 %

4) A sample of air is collected in the morning at an ambient temperature of 25°C. The concentration of carbon monoxide (CO) in this sample is 30 ppmv (ppm by volume). The same sample is analysed later in the afternoon when the sample temperature is 35°C. The analysis results will show the CO concentration as _____. (*GATE ES* 2021)

a) < 29 ppmv b) > 30 ppmv c) $= 30$ ppmv d) $= 29$ ppmv

5) In fluid statics, the line of action of the buoyant force *always* acts through the _____. (*GATE ES* 2021)
   a) centre of gravuty of any submerged body
   b) centroid of the volume of any floating body
   c) centroid of the displaced volume of fluid by the body
   d) centroid of the volume of fluid vertically above the body

6) What is the order of preference of the various elements in integrated waste management hierarchy (highest preference to lowest preference)? (*GATE ES* 2021)
   a) Reduce > Reuse & recycle > Energy recovery > Landfilling
   b) Reuse & recycle > Reduce > Energy recovery > Landfilling
   c) Reduce > Energy recovery > Reuse & recycle > Landfilling
   d) Reduce > Reuse & recycle > Landfilling > Energy recovery

7) If d is the depth of an quifier through which water is flowing, then the relationship between permeability K and transmissibility (also known as transmissivity)T is given by _____. (*GATE ES* 2021)

   a) $T = Kd$ b) $T = K/d$ c) $T = \sqrt{Kd}$ d) $K = \sqrt{Td}$

8) Which of the following is the terminal electron acceptor in the electron transport chain of aerobic respiration? (*GATE ES* 2021)
   a) Water
   b) NADH
   c) O_2
   d) Cytochrome-c

9) Which of the following causes 'Type-I' settling in a sedimentation tank? (*GATE ES* 2021)
   a) Agglomeration
   b) Compression
   c) Force of gravity
   d) Charge neutralization

10) In the context of noise pollution, SPL is the sound pressure level in decibels (dB). The relationship between SPL, the root mean square (rms) sound pressure p, and the reference (hearing threshold) pressure p_o is expressed as _____. (*GATE ES* 2021)
    a) $\text{SPL} = 20 \times \log_{10} \frac{p}{p_o}$
    b) $\text{SPL} = 20 \times \log_{10} \frac{p_o}{p}$
    c) $\text{SPL} = 20 - \log_{10} \frac{p}{p_o}$
    d) $\text{SPL} = 20 + \log_{10} \frac{p}{p_o}$

11) The following Fig. **??** highlights the typical phases of the life cycle of a product. In the figure, 'P', 'Q', and 'R' represent various possible scopes of analyses in life cycle assesment. Which of the following statements is true? (*GATE ES* 2021)

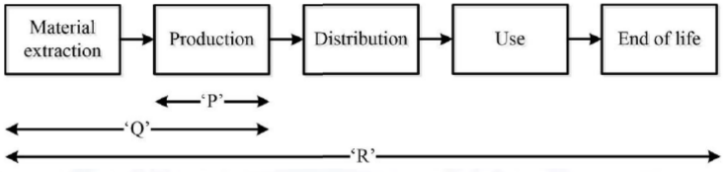

Fig. 4: Typical Phases of the life cycle of a product

a) 'R' represents cradle-to-grave analysis.
b) 'P' represents cradle-to-gate analysis.
c) 'Q' represents gate-to-grave analysis.
d) 'R' represents gate-to-gate analysis.

12) The United Nations Conference on Environment and Development was held in 1992 in Rio de Janeiro, Brazil. During this conference, several environmental management principles were adopted by many countries.

Which one of the following principles allows the governments to take mitigation measures on the environmental issues having serious threats or irreversible damage, even if there is scientific uncertainty about such issues? (*GATE ES* 2021)

a) Polluters pay principle
b) Precautionary priniciple
c) Extended producer responsibility
d) Common but differentiated responsibilities

13) Choose the correct order of biodegradability (highest to lowest) of the following municipal solid waste components. (*GATE ES* 2021)

a) Food > Newspaper > Polyvinyl Chloride (PVC)
b) Newspaper > Food waste > Polyvinyl Chloride (PVC)
c) Food waste > Polyvinyl Chloride (PVC) > Newspaper
d) Polyvinyl Chloride(PVC) > Food waste > Newspaper

14) In proximate analysis, when a $10kg$ moisture-free solid sample is heated in a furnace at 950°C in the *absence* of air, its mass is reduced by $6kg$. If the same $10kg$ moisture-free solid sample is heated in the furnace at the same temperature in the *presence* of air, its mass is reduced by $7kg$. The percentage of fixed carbon in the sample is _____. (*GATE ES* 2021)

a) 20 %
b) 60 %
c) 10 %
d) 30 %

15) Chlorine is most effective as a water disinfectant at a pH of _____. (*GATE ES* 2021)

a) 6
b) 8
c) 10

d) 12

16) The oxidation states of $'N'$ in NH_4^+, NO_2^- and NO are _____, respectively. (*GATE ES* 2021)

a) +2, -3, and +3
b) -3, +3, and +2
c) -3, +3, and -4
d) +4, -2, and +2

17) What is the pH of a water sample having H^+ concentration of $10 mg/L$? The atomic weight of H is $1 g/mol$. (*GATE ES* 2021)

a) 2
b) 4
c) 6
d) 8

18) Which of the following pairing of nucleotide bases is present in double helix DNA? (*GATE ES* 2021)

a) Thymine - Cystosine
b) Adenine - Thymine
c) Cytosine - Adenine
d) Uracil - Thymine

19) Which of the following is/are both greenhouse gas(es) and ozone depleting substance(s)? (*GATE ES* 2021)

a) $CFC - 11$
b) CO_2
c) $HCFC - 22$
d) N_2O

20) The ordinary differential equation
$\frac{dy}{dx} = x^2 y$
has y as the dependent variable and x as the independent variable. Which of the following classification(s) is/are applicable to the equation? (*GATE ES* 2021)

a) Linear
b) Non-linear
c) First order
d) Second order

21) Consider the following equation:

$$x^3 - 10x^2 + 31x - 30 = 0$$

Which of the following is/are the root(s) of the above equation? (*GATE ES* 2021)

a) 1
b) 2
c) 3
d) 4

22) A wind rose is a representation of meteorological conditions. Which of the follwing

is.are included in this representation? (*GATE ES* 2021)

a) Mixing height
b) Wind Speed
c) Wind direction
d) Percentage of time

Q.23-Q.25 Numerical Answer Type(NAT), carry ONE mark each (no negative marks).

23) A flocculation tank used for water treatment has a velocity gradient (G) of $800s^{-1}$. The volume of the tank is $40m^3$. The dynamic viscosity of water is $9 \times 10^{-4} Ns/m^2$. The theoretical power required to maintain the given velocity gradient is _____ kW *(rounded off to the nearest integer)*. (*GATE ES* 2021)

24) In a sample, the growth of microbial cells started with an initial concentration of 5×10^4 cells per millilitre (mL) of the sample. After a certain time period, the cell concentration was found to be 1280×10^4 cells per mL of the sample. Assuming binary fission of cells and no cell death, the number of generations of cell growth occurred in this time period is _____ *(answer in integer)*. (*GATE ES* 2021)

25) A water jet discharging from a $4cm$ diameter orifice has a diameter of $3.5cm$ at its vena contracta. The coefficient of velocity is defined as the ratio of the actual velocity of the jet at vena contracta to the theoretical velocity of the jet. If the coefficient of velocity is 0.98, the coefficient of discharge for the orifice will be _____ *(rounded off to two decimal places)*. (*GATE ES* 2021)

Q.26-Q.34 Multiple Choice Question (MCQ), carry TWO mark each (for each wrong answer: -2/3).

26) The 2×2 matrices P and Q satisfy the following relations:
$P + Q = \begin{pmatrix} 3 & 1 \\ 2 & 12 \end{pmatrix}$ and
$P - Q = \begin{pmatrix} -1 & -7 \\ 8 & 2 \end{pmatrix}$
The matrix Q is equal to _____. (*GATE ES* 2021)

a) $\begin{pmatrix} 2 & 4 \\ -3 & 5 \end{pmatrix}$
b) $\begin{pmatrix} 1 & -3 \\ 5 & 7 \end{pmatrix}$
c) $\begin{pmatrix} 2 & -3 \\ 4 & 5 \end{pmatrix}$
d) $\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$

27) A biased die has six faces numbered as $k = 1, 2, 3, 4, 5,$ and 6. On rolling the die, the probability of the number k appearing is proportional to k^2. What is the probability that an even number will appear on rolling the die? (*GATE ES* 2021)

a) $\frac{35}{91}$

b) $\frac{56}{91}$
c) $\frac{12}{21}$
d) $\frac{9}{21}$

28) Match the entries in Column I with the correct entries in column II. (*GATE ES* 2021)

Column I	**Column II**
P. Diffusion	(i) Pasquill
Q. Drag force	(ii) Fick
R. Atmospheric stability	(iii) Stokes

a) P-(iii), Q-(ii), R-(ii), S-(i)
b) P-(iv), Q-(ii), R-(iii), S-(i)
c) P-(iii), Q-(i), R-(ii), S-(iv)
d) P-(i), Q-(iii), R-(iv), S-(ii)

29) Which of the following international multilateral agreements (conventions, protocols) from column I match with the entries in Column II? (*GATE ES* 2021)

Column I	Column II
P. Ramsar Convention	(i) Ozone depletion
Q. Kyoto Protocol	(ii) Trans-boundary movement of hazardous wastes
R. Basel Convention	(iii) Climate change
S. Montreal Protocol	(iv) Conservation of wetlands

a) P-(iv), Q-(iii), R-(ii)
b) P-(ii), Q-(i), R-(iii)
c) P-(i), Q-(iii), R-(ii)
d) P-(oo), Q-(iii), R-(i)

30) An ideal PFR or an ideal CFSTR may be used to degrade a pollutant with first order reaction kinetics. Both the reactors are fed with the same inlet concentration and the same volumetric flow rate, and are designed to achieve the same outlet concentration. Which of the following statements is true when comparing PFR with CFSTR?

PFR is Plug Flow Reactor.

CFSTR is Continuous Flow Stirred Tank Reactor (also referred to as CSTR). (*GATE ES* 2021)

a) PFR will always require less reactor volume than CFSTR.
b) PFR will require the same reactor volume as CFSTR.
c) CFSTR will always require less reactor volume than PFR.
d) CFSTR can sometimes require less reactor volume than PFR.

31) A $200mL$ sample of water has an initial $pH = 9$. In order to determine alkalinity,

the sample was titrated using $0.02N$ H_2SO_4 acid to an end point of $pH = 4.5$. In the titration, $25mL$ of $0.02N$ H_2SO_4 acid was required. What is the total alkalinity of the sample in mg/L as $NaHCO_3$?
[Atomic weight (g/mol): $Ca = 40, Na = 23, H = 1, C = 12, S = 32,$ and $O = 16$] ($GATE\ ES$ 2021)

a) 20
b) 125
c) 210
d) 305

32) A sewage treatment plant (STP) receives sewage at a flow rate of $20000m^3$ per day. The sewage has $200mg/L$ of suspended solids. Assume 60% suspended solids are removed in the primary clarifier. The underflow (i.e. sludge) removed from the clarifier contains 5% solids (by weight).
The daily volume of the sludge generated will be _____ m^3 per day.
Assume sludge density = $1000kg/m^3$. ($GATE\ ES$ 2021)

a) 48
b) 80
c) 480
d) 800

33) In context of municipal solid waste treatment, match the equipment in List I with their function in List II. ($GATE\ ES$ 2021)

List I	List II
P. Trommel	(i) Size reduction
Q. Magnetic separator	(ii) Aluminium separation
R. Hammer mill	(iii) Screening
S. Eddy current separator	(iv) Ferrous metal recovery

a) P-(iii), Q-(iv), R-(i), S-(ii)
b) P-(iii), Q-(ii), R-(iv), S-(i)
c) P-(i), Q-(iv), R-(iii), S-(ii)
d) P-(iv), Q-(ii), R-(i), S-(iii)

34) The characteristics of a water sample are as follows: $Na^+ = 92\ mg/L$, $K^+ = 19.5\ mg/L$, $Ca^{2+} = 40\ mg/L$, and $Mg^{2+} = 24\ mg/L$. What is the sodium adsorption ratio (SAR) of the water sample which may be considered for irrigation purposes?
Atomic weight (g/mol): $Na = 23$, $K = 39$, $Ca = 40$, and $Mg = 24$. ($GATE\ ES$ 2021)

a) 2.83
b) 1.94
c) 2.00
d) 4.00

Q.35-Q.40 Multiple Select Question (MSQ), carry TWO mark each (no negative

marks).

35) Which of the following is true for the nitrifying bacteria belonging to genus *Nitrobacter*? (*GATE ES* 2021)
   a) They are autotrophs.
   b) They are eukaryotes.
   c) They convert chemical energy to cellular energy using mitochondria.
   d) They convert NO_3^- to NO_2^-.

36) Which of the following is/are the dominant mechanism(s) for the renoval of spherical particles with diameter less than $10\mu m$ from a gas stream using a fabric filter? (*GATE ES* 2021)
   a) Impaction
   b) Gravitation
   c) Interception
   d) Diffusion

37) In air pollutio, which of the following is/are classified as *primary* pollutants? (*GATE ES* 2021)
   a) Carbon Monoxide (CO)
   b) Sulphur dioxide (SO_2)
   c) Ozone (O_3)
   d) Nitrogen dioxide (NO_2)

38) Which of the following is/are correct for the process of glycolysis? (*GATE ES* 2021)
   a) There is net decrease in standard Gibbs free energy
   b) The end product is glyceraldehyde 3-phosphate.
   c) First phase includes the phosphorylation of the glucose molecule.
   d) It results in the net gain of NADH.

39) In the context of water quality, which of the following is/are correct for the most probable number (MPN) of a water sample? (*GATE ES* 2021)
   a) The estimated organisms are gram negative,
   b) It is based on the assumption of Poisson distribution.
   c) It measures the exact number of microorganisms present in the sample.
   d) It includes the quantification of pathogenic virus.

40) For any particular location, which of the following would influence the solar radiation incident on a rooftop solar water heater? (*GATE ES* 2021)
   a) Heater surface temperature
   b) Day of the year
   c) Hot water temperature
   d) Sky clearness

Q.41-Q.55 Numerical Answer Type (NAT), carry TWO mark each (no negative marks).

41) If $f(x) + 3f(g(x)) = x - 2$,

where $g(x) = \frac{3x+1}{x-3}$,
then the value of the ratio $\frac{f(5)}{f(8)}$ is _____ *(answer in integer).* (*GATE ES* 2021)

42) Consider a funtion $y = f(x)$ which satisfies the following equation:
$\frac{d^2y}{dx^2} - \frac{dy}{dx} = 0$
As $x \to -\infty, y = 1$, and at $x = 0, y = 2$.
The value of $\frac{dy}{dx}$ at $x = 0$ is _____ *(answer in integer).* (*GATE ES* 2021)

43) The concentration of NO_2 in the air at NTP is reported as 0.30 ppmv (ppm by volume). The concentration of NO_2 in $\mu g/m^3$ is _____ *(rounded off to the nearest integer).*

[At NTP, temperature = $298K$, pressure = $1atm$, and one mole of ideal gas occupies $24.45L$]
[Molecular weight of $NO_2 = 46g/mol$] (*GATE ES* 2021)

44) In open channel flow, the specific energy is the total energy per unit weight of a liquid, where the component potential energy is measured from the bed of the channel as the datum.
A rectangular channel of $10m$ width carries $20m^3/s$ of water. The depth of flowing water is $1m$. The specific energy for this flow condition is _____ *m (rounded off to one decimal place).*

Consider acceleration due to gravity $(g) = 10m/s^2$. (*GATE ES* 2021)

45) Two reservoirs are connected by a pipeline consisting of two pipes $'A'$ and $'B'$ in series. The two pipes are of same length and have the same Darcy friction factor. If the internal diameter of pipe $'B'$ is twice as large as the internal diameter of pipe $'A'$, the ratio of the head loss in pipe $'A'$ to that in pipe $'B'$ is _____ *(answer in integer).* Neglect all minor losses. (*GATE ES* 2021)

46) In a field test of a geological formation of permeable soil (porosity = 20%), the hydraulic gradient was found to be 2%. The actual seepage velocity of the flow was found to be $0.0025m/s$. Assume that the flow is in the laminar regime. The permeability(K) of the aquifer is _____ m/s *(rounded off to three decimal places).* (*GATE ES* 2021)

47) An underground hazardous waste storage tank is leaking. The contaminant concentration directly beneath the site is $0.5mg/L$. The contaminant is travelling at an effective rate of 0.4 m per day towards a water well which is $2km$ away.
Assume that the degradation of the contaminant follows a first order reaction, and the initial concentration of the contaminant becomes half in 10 years.
In this case, the contaminant concentration expected at the well under steady state conditions is _____ mg/L *(rounded off to two decimal places).* (*GATE ES* 2021)

48) The net profit expected from a manufacturing unit is ₹6000 per year. The operational life of the unit is 15 years. Assuming a fixed discount rate of 8% per annum, the net present worth of the profit earned over the operational life is ₹_____ *(answer in integer).* (*GATE ES* 2021)

49) A $900mm$ internal diameter sewer is laid at a slope of 0.004 and has an actual flow

of $0.15 m^3/s$. Assuming Manning's roughness coefficient to be 0.013, the ratio of the actual flow to the flow when the sewer is running full is _____ *(rounded off to two decimal places).*

Take $\pi = 3.14$. (*GATE ES* 2021)

50) A 10 million litres per day (MLD) sewage treatment plant (STP) is based on the Activated Sludge Process (ASP). First, the sewage undergoes primary treatment and the resulting treated sewage has BOD_5 of $140 mg/L$ concentration. This is further passed through a $1500 m^3$ capacity aeration tank (in ASP), where the mixed liquor volatile suspended solids (MLVSS) concentration is maintained at $3000 mg/L$. The concentration of BOD_5 of the treated sewage is $5 mg/L$.

The Food to Microorganisms ratio (F/M) of the ASP is _____ day^{-1} *(rounded off to two decimal places).* (*GATE ES* 2021)

51) The municipal solid waste (MSW) generated in a community (population = 100000) is disposed on a $12 \times 10^4 m^2$ landfill site, which can be filled to a total depth of $25m$ (including soil cover). Assume that MSW is generated at a rate of $2.5 kg$ per person per day and its compacted density is $800 kg/m^3$. If the volumetric ratio of MSW and soil cover is 5:1, the useful life of the landfill site is _____ years *(rounded off to the nearest integer).* (*GATE ES* 2021)

52) A mechanized stationary container system is proposed for waste collection from a commercial area. The container unloading time is 0.1 hours per container. There are two containers at each location and the drive time between the two locations is 0.2 hours. The maximum waste 'pick-up time' is 2.4 hours per trip.

The 'pick-up time' starts at the instant the truck arrives at the first pick-up location and ends when the last container on the route is emptied. The maximum number of locations which can be covered in a trip by the collection vehicle are _____ *(answer in integer).* (*GATE ES* 2021)

53) The molar concentrations ($M, i.e. mol/L$) of some ionic species in a water sample were estimated as follows:

$Na^+ = 0.25M$; $Ca^{2+} = 0.12M$; $Cl^- = 0.32M$; $HCO_3^- = 0.05M$.

The ionic strength of this water sample is _____ *M (up to two decimal places).* (*GATE ES* 2021)

54) Excess amount of solid calcium sulphate ($CaSO_4$) was added to a pure water sample ($pH = 7$) so that some solids remain undissolved at the equilibrium. The solubility product of $CaSO_4$ is $2 \times 10^{-5} mol^2/L^2$. The molar concentration of SO_4^{2-} in this water sample at equilibrium will be _____ *mol/L (rounded off to three decimal places).* (*GATE ES* 2021)

55) A facultative pond system for sewage treatment consists of two ponds in series. The hydraulic retention time (HRT) of each pond is 6 days. The total BOD_5 reduction through the entire pond system is 90%. If the ponds are considered to be completely mixed, then the rate constant describing the BOD_5 removal is _____ day^{-1} *(rounded off to two decimal points).* Assume that the rate constant is same for both the ponds. (*GATE ES* 2021)

END OF THE QUESTION PAPER