

## GATE 2014: General Instructions during Examination

1. Total duration of the GATE examination is **180** minutes.
2. The clock will be set at the server. The countdown timer at the top right corner of screen will display the remaining time available for you to complete the examination. When the timer reaches zero, the examination will end by itself. You need not terminate the examination or submit your paper.
3. Any useful data required for your paper can be viewed by clicking on the **Useful Common Data** button that appears on the screen.
4. Use the scribble pad provided to you for any rough work. Submit the scribble pad at the end of the examination.
5. You are allowed to use a non-programmable type calculator, however, sharing of calculators is not allowed.
6. The Question Palette displayed on the right side of screen will show the status of each question using one of the following symbols:

 You have not visited the question yet.

 You have not answered the question.

 You have answered the question.

 You have NOT answered the question, but have marked the question for review.

 You have answered the question, but marked it for review.

The **Marked for Review** status for a question simply indicates that you would like to look at that question again. *If a question is answered, but marked for review, then the answer will be considered for evaluation unless the status is modified by the candidate.*

### Navigating to a Question :

7. To answer a question, do the following:
  - a. Click on the question number in the Question Palette to go to that question directly.
  - b. Select an answer for a multiple choice type question by clicking on the bubble placed before the 4 choices, namely A, B, C and D. Use the virtual numeric keypad to enter a number as answer for a numerical type question.
  - c. Click on **Save & Next** to save your answer for the current question and then go to the next question.
  - d. Click on **Mark for Review & Next** to save your answer for the current question and also mark it for review, and then go to the next question.

**Caution:** Note that your answer for the current question will not be saved, if you navigate to another question directly by clicking on a question number without saving the answer to the previous question.

You can view all the questions by clicking on the **Question Paper** button. This feature is provided, so that if you want you can just see the entire question paper at a glance.

### Answering a Question :

8. Procedure for answering a multiple choice (MCQ) type question:
  - a. Choose one answer from the 4 options (A,B,C,D) given below the question, click on the bubble placed before the chosen option.
  - b. To deselect your chosen answer, click on the bubble of the chosen option again or click on the **Clear Response** button.
  - c. To change your chosen answer, click on the bubble of another option.
  - d. To save your answer, you **MUST** click on the **Save & Next** button.
9. Procedure for answering a numerical answer type question:
  - a. To enter a number as your answer, use the virtual numerical keypad.
  - b. A fraction (e.g. -0.3 or -.3) can be entered as an answer with or without '0' before the decimal point. As many as four decimal points, e.g. 12.5435 or 0.003 or -932.6711 or 12.82 can be entered.
  - c. To clear your answer, click on the **Clear Response** button.
  - d. To save your answer, you **MUST** click on the **Save & Next** button
10. To mark a question for review, click on the **Mark for Review & Next** button. *If an answer is selected (for MCQ) or entered (for numerical answer type) for a question that is **Marked for Review**, that answer will be considered in the evaluation unless the status is modified by the candidate.*
11. To change your answer to a question that has already been answered, first select that question for answering and then follow the procedure for answering that type of question.
12. Note that **ONLY** Questions for which answers are *saved* or *marked for review after answering* will be considered for evaluation.

### Choosing a Section :

13. Sections in this question paper are displayed on the top bar of the screen. Questions in a Section can be viewed by clicking on the name of that Section. The Section you are currently viewing will be highlighted.
14. A checkbox is displayed for every optional Section, if any, in the Question Paper. To select the optional Section for answering, click on the checkbox for that Section.
15. If the checkbox for an optional Section is not selected, the **Save & Next** button and the **Mark for Review & Next** button will **NOT** be enabled for that Section. You will

only be able to see questions in this Section, but you will not be able to answer questions in the Section.

16. After clicking the **Save & Next** button for the last question in a Section, you will automatically be taken to the first question of the next Section in sequence.
17. You can move the mouse cursor over the name of a Section to view the answering status for that Section.

### **Changing the Optional Section :**

18. After answering the chosen optional Section, partially or completely, you can change the optional Section by selecting the checkbox for a new Section that you want to attempt. A warning message will appear along with a table showing the number of questions answered in each of the previously chosen optional Sections and a checkbox against each of these Sections. Click on a checkbox against a Section that you want to reset and then click on the **RESET** button. Note that RESETTING a Section will DELETE all the answers for questions in that Section. Hence, if you think that you may want to select this Section again later, you will have to note down your answers for questions in that Section. If you do not want to reset the Section and want to continue answering the previously chosen optional Section, then click on the **BACK** button.
19. If you deselect the checkbox for an optional Section in the top bar, the following warning message will appear: "Deselecting the checkbox will DELETE all the answers for questions in this Section. Do you want to deselect this Section?" If you want to deselect, click on the **RESET** button. If you do not want to deselect, click on the **BACK** button.
20. You can shuffle between different Sections or change the optional Sections any number of times.

# GATE 2014 Examination

## AE: Aerospace Engineering

Duration: 180 minutes

Maximum Marks: 100

### Read the following instructions carefully.

1. To login, enter your Registration Number and password provided to you. Kindly go through the various symbols used in the test and understand their meaning before you start the examination.
2. Once you login and after the start of the examination, you can view all the questions in the question paper, by clicking on the **View All Questions** button in the screen.
3. This question paper consists of **2 sections**, General Aptitude (GA) for **15 marks** and the subject specific GATE paper for **85 marks**. Both these sections are compulsory.  
The GA section consists of **10** questions. Question numbers 1 to 5 are of 1-mark each, while question numbers 6 to 10 are of 2-mark each.  
The subject specific GATE paper section consists of **55** questions, out of which question numbers 1 to 25 are of 1-mark each, while question numbers 26 to 55 are of 2-mark each.
4. Depending upon the GATE paper, there may be useful common data that may be required for answering the questions. If the paper has such useful data, the same can be viewed by clicking on the **Useful Common Data** button that appears at the top, right hand side of the screen.
5. The computer allotted to you at the examination center runs specialized software that permits only one answer to be selected for multiple-choice questions using a mouse and to enter a suitable number for the numerical answer type questions using the virtual keyboard and mouse.
6. Your answers shall be updated and saved on a server periodically and also at the end of the examination. The examination will **stop automatically** at the end of **180 minutes**.
7. In each paper a candidate can answer a total of 65 questions carrying 100 marks.
8. The question paper may consist of questions of **multiple choice type (MCQ)** and **numerical answer type**.
9. Multiple choice type questions will have four choices against A, B, C, D, out of which only **ONE** is the correct answer. The candidate has to choose the correct answer by clicking on the bubble (○) placed before the choice.
10. For numerical answer type questions, each question will have a numerical answer and there will not be any choices. **For these questions, the answer should be entered** by using the virtual keyboard that appears on the monitor and the mouse.
11. All questions that are not attempted will result in zero marks. However, wrong answers for multiple choice type questions (MCQ) will result in **NEGATIVE** marks. For all MCQ questions a wrong answer will result in deduction of  $\frac{1}{3}$  marks for a 1-mark question and  $\frac{2}{3}$  marks for a 2-mark question.
12. There is **NO NEGATIVE MARKING** for questions of **NUMERICAL ANSWER TYPE**.
13. Non-programmable type Calculator is allowed. Charts, graph sheets, and mathematical tables are **NOT** allowed in the Examination Hall. You must use the Scribble pad provided to you at the examination centre for all your rough work. The Scribble Pad has to be returned at the end of the examination.

### Declaration by the candidate:

“I have read and understood all the above instructions. I have also read and understood clearly the instructions given on the admit card and shall follow the same. I also understand that in case I am found to violate any of these instructions, my candidature is liable to be cancelled. I also confirm that at the start of the examination all the computer hardware allotted to me are in proper working condition”.

**Q. 1 – Q. 5 carry one mark each.**

- Q.1 A student is required to demonstrate a high level of comprehension of the subject, especially in the social sciences.

The word closest in meaning to comprehension is

- (A) understanding (B) meaning (C) concentration (D) stability

- Q.2 Choose the most appropriate word from the options given below to complete the following sentence.

One of his biggest \_\_\_\_\_ was his ability to forgive.

- (A) vice (B) virtues (C) choices (D) strength

- Q.3 Rajan was not happy that Sajan decided to do the project on his own. On observing his unhappiness, Sajan explained to Rajan that he preferred to work independently.

Which one of the statements below is logically valid and can be inferred from the above sentences?

- (A) Rajan has decided to work only in a group.  
 (B) Rajan and Sajan were formed into a group against their wishes.  
 (C) Sajan had decided to give in to Rajan's request to work with him.  
 (D) Rajan had believed that Sajan and he would be working together.

- Q.4 If  $y = 5x^2 + 3$ , then the tangent at  $x = 0, y = 3$

- (A) passes through  $x = 0, y = 0$  (B) has a slope of +1  
 (C) is parallel to the  $x$ -axis (D) has a slope of -1

- Q.5 A foundry has a fixed daily cost of Rs 50,000 whenever it operates and a variable cost of Rs 800Q, where Q is the daily production in tonnes. What is the cost of production in Rs per tonne for a daily production of 100 tonnes?

**Q. 6 – Q. 10 carry two marks each.**

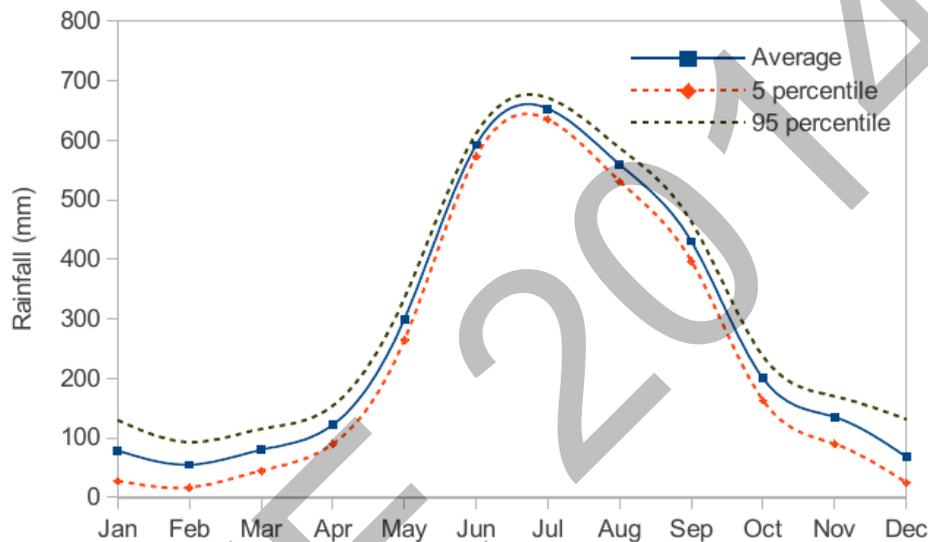
- Q.6 Find the odd one in the following group: ALRVX, EPVZB, ITZDF, OYEIK

- (A) ALRVX (B) EPVZB (C) ITZDF (D) OYEIK

- Q.7 Anuj, Bhola, Chandan, Dilip, Eswar and Faisal live on different floors in a six-storeyed building (the ground floor is numbered 1, the floor above it 2, and so on). Anuj lives on an even-numbered floor. Bhola does not live on an odd numbered floor. Chandan does not live on any of the floors below Faisal's floor. Dilip does not live on floor number 2. Eswar does not live on a floor immediately above or immediately below Bhola. Faisal lives three floors above Dilip. Which of the following floor-person combinations is correct?

	Anuj	Bhola	Chandan	Dilip	Eswar	Faisal
(A)	6	2	5	1	3	4
(B)	2	6	5	1	3	4
(C)	4	2	6	3	1	5
(D)	2	4	6	1	3	5

- Q.8 The smallest angle of a triangle is equal to two thirds of the smallest angle of a quadrilateral. The ratio between the angles of the quadrilateral is 3:4:5:6. The largest angle of the triangle is twice its smallest angle. What is the sum, in degrees, of the second largest angle of the triangle and the largest angle of the quadrilateral?
- Q.9 One percent of the people of country X are taller than 6 ft. Two percent of the people of country Y are taller than 6 ft. There are thrice as many people in country X as in country Y. Taking both countries together, what is the percentage of people taller than 6 ft?
- (A) 3.0 (B) 2.5 (C) 1.5 (D) 1.25
- Q.10 The monthly rainfall chart based on 50 years of rainfall in Agra is shown in the following figure. Which of the following are true? ( $k$  percentile is the value such that  $k$  percent of the data fall below that value)



- (i) On average, it rains more in July than in December  
(ii) Every year, the amount of rainfall in August is more than that in January  
(iii) July rainfall can be estimated with better confidence than February rainfall  
(iv) In August, there is at least 500 mm of rainfall
- (A) (i) and (ii) (B) (i) and (iii)  
(C) (ii) and (iii) (D) (iii) and (iv)

**END OF THE QUESTION PAPER**

**Q. 1 – Q. 25 carry one mark each.**

Q.1 For a real symmetric matrix  $[A]$ , which of the following statements is true:

- (A) The matrix is always diagonalizable and invertible.  
 (B) The matrix is always invertible but not necessarily diagonalizable.  
 (C) The matrix is always diagonalizable but not necessarily invertible.  
 (D) The matrix is always neither diagonalizable nor invertible.

Q.2 The series  $s = \sum_{m=1}^{\infty} \frac{m^2}{3^m} (x-2)^m$  converges for all  $x$  with  $|x-2| \leq R$  given by

- (A)  $R = 0$                       (B)  $R = 3$                       (C)  $R = \infty$                       (D)  $R = 1/3$

Q.3 The function given by  $f(x) = \begin{cases} \sin(1/x), & x \neq 0 \\ 0, & x = 0 \end{cases}$  is

- (A) Unbounded everywhere                      (B) Bounded and continuous everywhere  
 (C) Bounded but not continuous at  $x = 0$                       (D) Continuous and differentiable everywhere

Q.4 Given the boundary-value problem  $\frac{d}{dx} \left( x \frac{dy}{dx} \right) + ky = 0$ ,  $0 < x < 1$ , with  $y(0) = y(1) = 0$ . Then the solutions of the boundary-value problem for  $k = 1$  (given by  $y_1$ ) and  $k = 5$  (given by  $y_5$ ) satisfy:

- (A)  $\int_0^1 y_1 y_5 dx = 0$                       (B)  $\int_0^1 \frac{dy_1}{dx} \frac{dy_5}{dx} dx = 0$   
 (C)  $\int_0^1 y_1 y_5 dx \neq 0$                       (D)  $\int_0^1 \left( y_1 y_5 + \frac{dy_1}{dx} \frac{dy_5}{dx} \right) dx = 0$

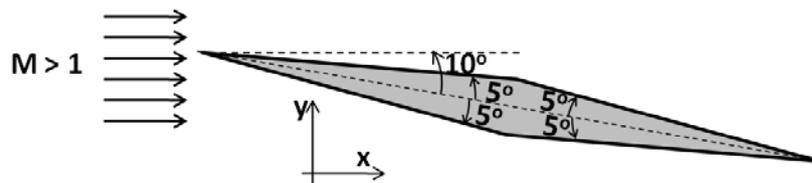
Q.5 The value of  $I = \int_0^1 1000x^4 dx$ , obtained by using Simpson's rule with 2 equally spaced intervals is,

- (A) 200                      (B) 400                      (C) 180                      (D) 208

Q.6 For a *NACA 5-digit* airfoil of chord  $c$ , the designed lift coefficient and location of maximum camber along the chord from the leading edge are denoted by  $C_L$  and  $X_m$  respectively. For *NACA12018* airfoil, which combination of  $C_L$  and  $X_m$  given below are correct?

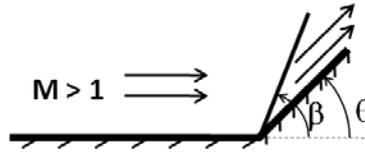
- (A)  $C_L = 0.15$  and  $X_m = 0.1c$                       (B)  $C_L = 0.12$  and  $X_m = 0.2c$   
 (C)  $C_L = 0.12$  and  $X_m = 0.18c$                       (D)  $C_L = 0.15$  and  $X_m = 0.2c$

Q.7 For inviscid, supersonic flow over a diamond shaped airfoil, shown in the figure, which statement is correct among the following?



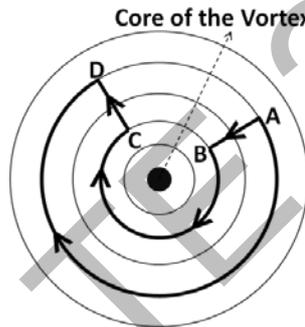
- (A) The airfoil will experience zero lift and positive drag force  
 (B) The airfoil will experience positive lift and zero drag force  
 (C) The airfoil will experience negative lift and zero drag force  
 (D) The airfoil will experience positive lift and positive drag force

Q.8 Consider supersonic flow near a corner (at an angle  $\theta$  from the horizontal) with an attached oblique shock (at an angle  $\beta$  with horizontal) as shown in figure. If Mach number  $M$  decreases gradually from a high supersonic value, which of the following statements is correct?



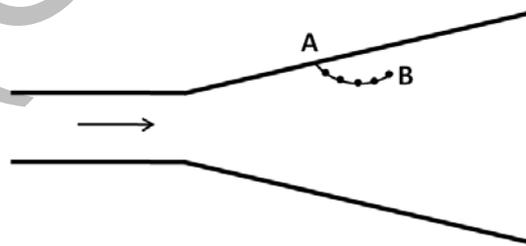
- (A)  $\beta$  will decrease if the shock is a weak shock
- (B)  $\beta$  will decrease if the shock is a strong shock
- (C)  $\beta$  will increase for both weak and strong shocks
- (D)  $\beta$  remains unchanged for both weak and strong shocks

Q.9 The streamlines of a potential line vortex is concentric circles with respect to the vortex center as shown in figure. Velocity along these streamlines, outside the core of the vortex can be written as,  $v_\theta = \frac{\Gamma}{2\pi r}$ , where strength of the vortex is  $\frac{\Gamma}{2\pi}$  and  $r$  is radial direction. The value of circulation along the curve shown in the figure is:



- (A)  $\Gamma$
- (B)  $-2\Gamma$
- (C)  $2\Gamma$
- (D) 0

Q.10 To observe unsteady separated flow in a diverging channel, bubbles are injected at each 10ms interval at point A as shown in figure. These bubbles act as tracer particles and follow the flow faithfully. The curved line AB shown at any instant represents:



- (A) Streamline, streakline and pathline
- (B) Streamline and pathline
- (C) Only a pathline
- (D) Only a streakline

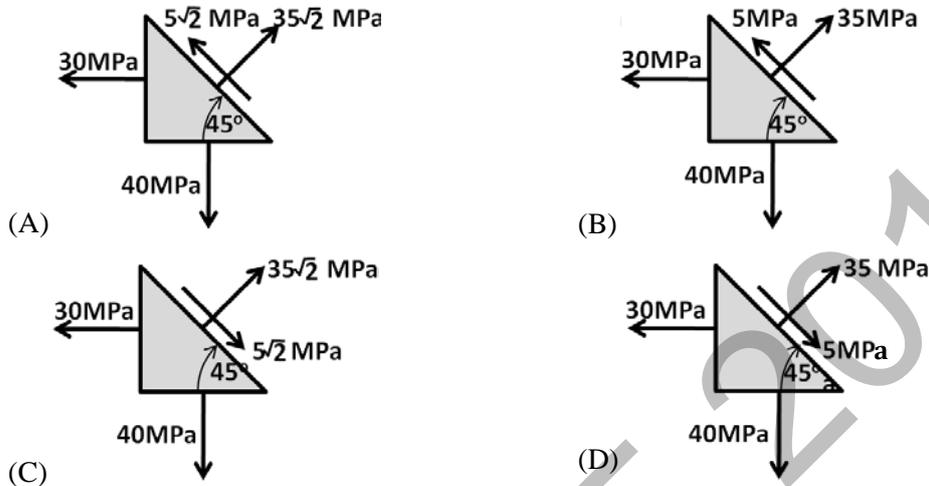
Q.11 It is desired to measure the Young's modulus and the Poisson's ratio of a given homogeneous, isotropic material. A bar of length 20cm and square cross-section (10mm x 10mm) of this material is subjected to a tensile load of 40kN. Under this load, length increases to 20.1cm while the cross-section reduces to 9.98mm x 9.98mm. Young's modulus and Poisson's ratio of the material are:

- (A) 80GPa & 0.4 respectively
- (B) 40GPa & -0.4 respectively
- (C) 80GPa & -0.2 respectively
- (D) 40GPa & 0.2 respectively

Q.12 In general, for any given solid subjected to arbitrary loading, which of the following statements is *always* true:

- (A) Volume does not vary with loading                      (B) Mass does not vary with loading  
 (C) Density does not vary with loading                    (D) Volume, mass and density vary with loading

Q.13 Which one of the following objects with inclined face at  $45^\circ$ , subjected to the given stresses, are in static equilibrium:



Q.14 A damped single degree of freedom system whose undamped natural frequency,  $\omega_n = 10 \text{ Hz}$ , is subjected to sinusoidal external force. Power is half of the maximum for the two frequencies of  $60.9469 \text{ rad/s}$  and  $64.7168 \text{ rad/s}$ . The damping factor associated with the vibrating system (in %) is \_\_\_\_\_.

Q.15 The boundary conditions for a rod with circular cross-section, under torsional vibration, are changed from fixed-free to fixed-fixed. The fundamental natural frequency of the fixed-fixed rod is  $k$  times that of fixed-free rod. The value of  $k$  is

- (A) 1.5                      (B)  $\pi$                       (C) 2.0                      (D) 0.5

Q.16 Match the appropriate engine (in right column) with the corresponding aircraft (in left column) for most efficient performance of the engine.

- |                                    |               |
|------------------------------------|---------------|
| a. Low speed transport aircraft    | i. Ramjet     |
| b. High subsonic civilian aircraft | ii. Turboprop |
| c. Supersonic fighter aircraft     | iii. Turbojet |
| d. Hypersonic aircraft             | iv. Turbofan  |
- (A) a – iv, b – iii, c – i, d – ii                      (B) a – ii, b – i, c – iii, d – iv  
 (C) a – i, b – ii, c – iv, d – iii                      (D) a – ii, b – iv, c – iii, d – i

Q.17 For a given fuel flow rate and thermal efficiency, the take-off thrust for a gas turbine engine burning aviation turbine fuel (considering fuel-air ratio  $\ll 1$ ) is

- (A) Directly proportional to exhaust velocity  
 (B) Inversely proportional to exhaust velocity  
 (C) Independent of exhaust velocity  
 (D) Directly proportional to the square of the exhaust velocity

- Q.18 For a fifty percent reaction axial compressor stage, following statements are given:  
 I. Velocity triangles at the entry and exit of the rotor are symmetrical  
 II. The whirl or swirl component of absolute velocity at the entry of rotor and entry of stator are same.  
 Which of the following options are correct?
- (A) Both I and II are correct statements                      (B) I is correct but II is incorrect  
 (C) I is incorrect but II is correct                              (D) Both I and II are incorrect
- Q.19 A small rocket having a specific impulse of  $200s$  produces a total thrust of  $98kN$ , out of which  $10kN$  is the pressure thrust. Considering the acceleration due to gravity to be  $9.8m/s^2$ , the propellant mass flow rate in  $kg/s$  is
- (A) 55.1                      (B) 44.9                      (C) 50                      (D) 60.2
- Q.20 The thrust produced by a turbojet engine
- (A) Increases with increasing compressor pressure ratio  
 (B) Decreases with increasing compressor pressure ratio  
 (C) Remains constant with increasing compressor pressure ratio  
 (D) First increases and then decreases with increasing compressor pressure ratio
- Q.21 The moment coefficient measured about the centre of gravity and about aerodynamic centre of a given wing-body combination are  $0.0065$  and  $-0.0235$  respectively. The aerodynamic centre lies  $0.06$  chord lengths ahead of the centre of gravity. The lift coefficient for this wing-body is \_\_\_\_\_.
- Q.22 The vertical ground load factor on a stationary aircraft parked in its hangar is:
- (A) 0                      (B) -1                      (C) Not defined                      (D) 1
- Q.23 Under what conditions should a glider be operated to ensure minimum sink rate?
- (A) Maximum  $C_L/C_D$                       (B) Minimum  $C_L/C_D$   
 (C) Maximum  $C_D/C_L^{3/2}$                       (D) Minimum  $C_D/C_L^{3/2}$
- Q.24 In most airplanes, the Dutch roll mode can be excited by applying
- (A) a step input to the elevators                      (B) a step input to the rudder  
 (C) a sinusoidal input to the aileron                      (D) an impulse input to the elevators
- Q.25 Considering  $R$  as the radius of the moon, the ratio of the velocities of two spacecraft orbiting moon in circular orbit at altitudes  $R$  and  $2R$  above the surface of the moon is \_\_\_\_\_.
- Q. 26 – Q. 55 carry two marks each.**
- Q.26 If  $[A] = \begin{bmatrix} 3 & -3 \\ -3 & 4 \end{bmatrix}$ . Then  $\det(-[A]^2 + 7[A] - 3[I])$  is
- (A) 0                      (B) -324                      (C) 324                      (D) 6

Q.27

For the periodic function given by  $f(x) = \begin{cases} -2, & -\pi < x < 0 \\ 2, & 0 < x < \pi \end{cases}$  with  $f(x+2\pi) = f(x)$ , using

Fourier series, the sum  $s = 1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \dots$  converges to

- (A) 1                      (B)  $\frac{\pi}{3}$                       (C)  $\frac{\pi}{4}$                       (D)  $\frac{\pi}{5}$

Q.28 Let  $\Gamma$  be the boundary of the closed circular region  $A$  given by  $x^2 + y^2 \leq 1$ . Then

$I = \int_{\Gamma} (3x^3 - 9xy^2) ds$  (where  $ds$  means integration along the bounding curve) is

- (A)  $\pi$                       (B)  $-\pi$                       (C) 1                      (D) 0

Q.29 Solution to the boundary-value problem

$-9 \frac{d^2 u}{dx^2} + u = 5x$ ,  $0 < x < 3$  with  $u(0) = 0$ ,  $\left. \frac{du}{dx} \right|_{x=3} = 0$  is

- (A)  $u(x) = \frac{15e}{1+e^2} (e^{-x/3} - e^{x/3}) + 5x$                       (B)  $u(x) = \frac{15e}{1+e^2} (e^{-x/3} + e^{x/3}) + 5x$   
 (C)  $u(x) = -\frac{15 \sin(x/3)}{\cos(1)} + 5x$                       (D)  $u(x) = -\frac{15 \sin(x/3)}{\cos(1)} - \frac{5}{54} x^3$

Q.30

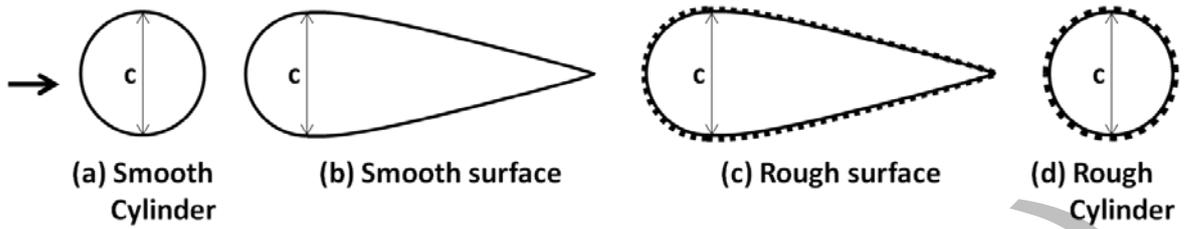
The Laplace transform  $L(u(t)) = U(s)$ , for the solution  $u(t)$  of the problem  $\frac{d^2 u}{dt^2} + 2 \frac{du}{dt} + u = 1$ ,  $t > 0$

with initial conditions  $u(0) = 0$ ,  $\left. \frac{du}{dt} \right|_{t=0} = 5$  is given by:

- (A)  $\frac{6}{(s+1)^2}$                       (B)  $\frac{5s+1}{s(s+1)^2}$                       (C)  $\frac{1-5s}{s(s+1)^2}$                       (D)  $\frac{5s^2+1}{s(s+1)^2}$

Q.31 For a steady, incompressible two-dimensional flow, represented in Cartesian co-ordinates  $(x, y)$ , a student correctly writes the equation of pathline of any arbitrary particle as,  $\frac{dx}{dt} = ax$  and  $\frac{dy}{dt} = by$ , where  $a$  and  $b$  are constants having unit of  $(\text{second})^{-1}$ . If value of  $a$  is 5, the value of  $b$  is \_\_\_\_\_.

Q.32 Figures (a) - (d) below show four objects. Dimensions and surface conditions of the objects are shown in the respective figures. All four objects are placed independently in a steady, uniform flow of same velocity and the direction of flow is from left to right as shown in (a). The flow field can be considered as 2-D, viscous and incompressible. Following statements are made regarding the drag that these objects experience.

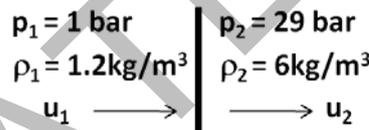


- (i) Drag of object (a) is more than the drag of object (d)
- (ii) Drag of object (a) is less than the drag of object (d)
- (iii) Drag of object (b) is more than the drag of object (c)
- (iv) Drag of object (c) is more than the drag of object (b)
- (v) Drag of object (a) is more than the drag of object (b)

Choose the correct combination of statements from the options given above:

- (A) (i), (iii), (v)
- (B) (ii), (iv), (v)
- (C) (i), (iv), (v)
- (D) (i), (iii)

Q.33 A student needs to find velocity across a stationary normal shock. He measures density and pressure across the shock as shown in the figure below.  $1\text{bar} = 10^5\text{Pa}$ . (No shock table is needed for the calculations). The value of  $u_1$  in  $\text{m/s}$  is \_\_\_\_\_.



Q.34 For inviscid, compressible flow past a thin airfoil, shown in the figure, free-stream Mach number and pressure are denoted by  $M_\infty$  and  $p_\infty$  respectively. Ratio of pressure at point A and  $p_\infty$  is 0.8 and specific heat ratio is 1.4. If the Mach number at point A is 1.0 and rest of the flow field is subsonic, the value of  $M_\infty$  is



- (A) 2.95
- (B) 0.79
- (C) 1.18
- (D) 0.64

- Q.35 A student can measure free-stream velocity of a low-speed wind tunnel using a
- Pitot tube alone aligned with the flow direction.
  - Pitot tube aligned with the flow direction with static pressure measurement at an appropriate position on the tunnel wall.
  - Pitot tube aligned with the flow direction along with barometer pressure reading of the outside ambient.
  - Pitot static tube alone aligned with the flow direction.

Considering the above statements, which of the following options is correct?

- (A) (i) only                      (B) (i) & (ii)                      (C) (ii) & (iv)                      (D) (i), (iii) & (iv)

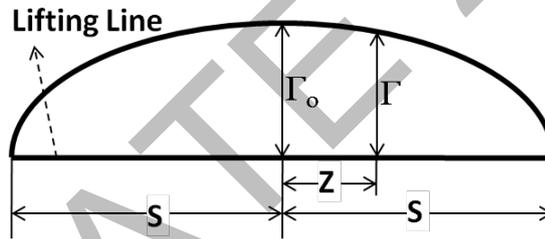
- Q.36 Induced velocity  $w$  at a point  $z = z_1$  along the lifting line can be calculated using the formula

$$w(z_1) = -\frac{1}{4\pi} \int_{-s}^s \frac{d\Gamma}{dz} \frac{1}{z-z_1} dz.$$

Given  $\frac{\Gamma^2}{\Gamma_0^2} + \frac{z^2}{s^2} = 1$ , where  $z, \Gamma_0$  and  $s$  are given in figure below.

For the above semi-elliptic distribution of circulation,  $\Gamma$ , the downwash velocity at any point  $z_1$ , for symmetric flight can be obtained as,  $w(z_1) = \frac{\Gamma_0}{4\pi s} [\pi + z_1 I]$ , where  $I = z_1 \int_{-s}^s \frac{dz}{\sqrt{s^2-z^2}(z-z_1)}$ .

Which of the following options is correct if the induced drag is  $D_i$  (given  $\int_{-s}^s \sqrt{1 - \frac{z^2}{s^2}} dz = \frac{\pi s}{2}$ )



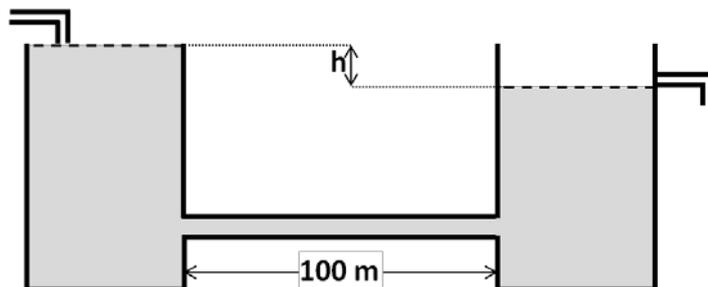
- (A)  $I=0$  and  $D_i = \frac{8\rho\Gamma_0^2}{\pi}$                       (B)  $I= 1$  and  $D_i = \frac{8\rho\Gamma_0^2}{\pi}$   
 (C)  $I=0$  and  $D_i = \frac{\pi\rho\Gamma_0^2}{8}$                       (D)  $I= 1$  and  $D_i = \frac{\pi\rho\Gamma_0^2}{8}$

- Q.37 Two overflowing water reservoirs are connected with a 100m long pipe of circular cross-section (of radius,  $R = 0.02m$ ), such that height difference  $h$  remains constant as shown in the figure below. The centerline velocity in the pipe is 10m/s. The velocity profile inside the pipe over the entire

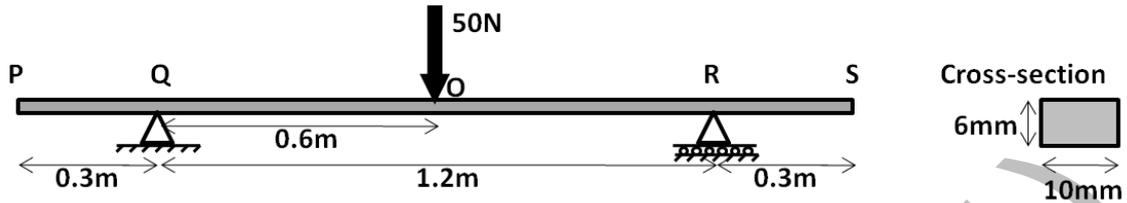
length is  $u = -\frac{R^2}{4\mu} \frac{dp}{dx} \left[ 1 - \frac{r^2}{R^2} \right]$ , where,  $\frac{dp}{dx}$  is a constant pressure gradient along the pipe length,

$x$  is measured from the left end of the pipe along its central axis and  $r$  is radial location inside the pipe with respect to its axis. (Given data: Density and kinematic viscosity of water are  $1000kg/m^3$  and  $1 \times 10^{-6} m^2/s$  respectively; acceleration due to gravity is  $10m/s^2$ ).

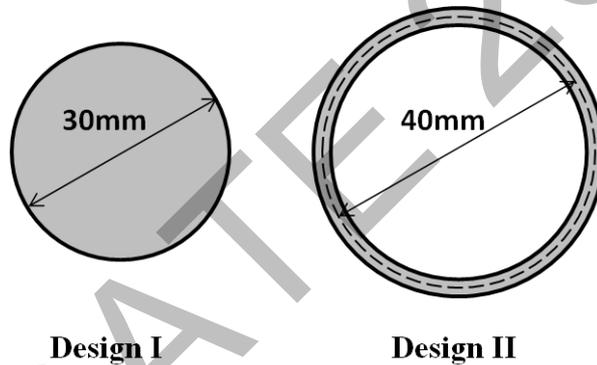
If all other losses except the frictional losses at the pipe wall are neglected, the value of  $h$  in meter is \_\_\_\_.



- Q.38 A 1.8m long steel beam of rectangular cross section ( $10\text{mm} \times 6\text{mm}$ ) is simply supported with a length of 1.2m between the supports and an overhang of 0.3m on either side. Young's modulus for the material of the beam is  $200\text{GPa}$ . For a 50N load applied at the center of the beam, magnitude of the slope of the beam at tip  $S$  is \_\_\_\_\_.

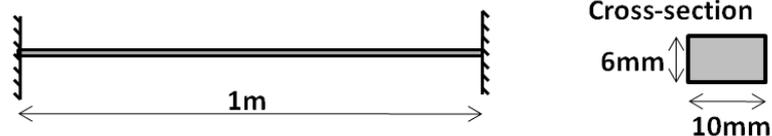


- Q.39 There are 2 designs proposed for a shaft of length  $l$ , with a torque carrying capacity of  $T$ . *Design I* is a solid circular cross-section shaft of diameter  $30\text{mm}$ . *Design II* is a thin-walled circular shaft of average diameter  $40\text{mm}$ . Thickness of the wall in *Design II* has to be determined such that maximum shear stress is the same in both the designs for the given torque  $T$  (so that same material can be used for manufacturing both the shafts). Ratio of mass of shaft using *Design I* to the mass of shaft using *Design II* is



- (A) 2.68      (B) 5.36      (C) 1.79      (D) 3.58

- Q.40 A structural member of rectangular cross-section  $10\text{mm} \times 6\text{mm}$  and length  $1\text{m}$  is made of steel (Young's modulus is  $200\text{GPa}$  and coefficient of thermal expansion is  $12 \times 10^{-6} / ^\circ\text{C}$ ). It is rigidly fixed at both the ends and then subjected to a gradual increase in temperature. Ignoring the three dimensional effects, the structural member will buckle if the temperature is increased by  $\Delta T$   $^\circ\text{C}$  which is

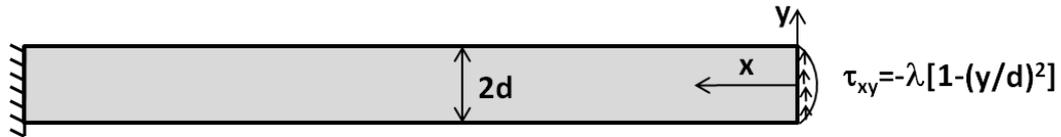


- (A) 19.74      (B) 9.87      (C) 78.96      (D) 39.48

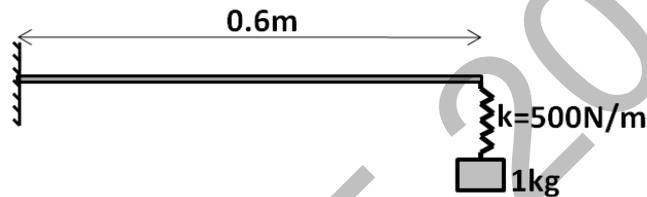
- Q.41 A gas cylinder (closed thin-walled cylindrical pressure vessel) of diameter  $30\text{cm}$  and wall thickness  $1\text{mm}$  is subjected to a design maximum internal pressure of  $5\text{bar}$  ( $0.5\text{MPa}$ ). The material used for manufacturing this cylinder has a failure stress of  $260\text{MPa}$ . Assuming von Mises failure criterion, the factor of safety (with respect to maximum allowable stress) for this cylinder is

- (A) 2.8      (B) 2.0      (C) 6.9      (D) 4.0

- Q.42 A cantilevered beam is subjected to a parabolic distribution of shear traction at the right edge while the top and bottom surfaces are traction free. To solve this problem, following Airy's stress function is proposed:  $\phi = C_1xy + C_2xy^3 + C_3x^2y^2 + C_4x^3y$ . This is an admissible Airy's function that would satisfy the bi-harmonic equation as well as the boundary conditions if and only if



- (A)  $C_1 = 0, C_2 = \lambda, C_3 = 0, C_4 = \frac{\lambda}{3d^2}$       (B)  $C_1 = \lambda, C_2 = \frac{\lambda}{3d^2}, C_3 = 0, C_4 = 0$   
 (C)  $C_1 = 0, C_2 = 0, C_3 = \lambda, C_4 = -\frac{\lambda}{3d^2}$       (D)  $C_1 = \lambda, C_2 = -\frac{\lambda}{3d^2}, C_3 = 0, C_4 = 0$
- Q.43 1kg mass is hanging from a spring of stiffness 500N/m attached to a massless, symmetric beam of length 0.6m, moment of inertia about the bending axis  $I = 8.33 \times 10^{-10} m^4$  and Young's modulus  $E = 210 GPa$  as shown in the figure. The fundamental natural frequency (in rad/s) of the system is



- (A) 3.24      (B) 20.36      (C) 22.36      (D) 3.56
- Q.44 A single degree of freedom system is vibrating with initial (first cycle) amplitude of 5cm. The viscous damping factor associated with the vibrating system is 2%. Vibration amplitude of the fifth cycle (in cm) is
- (A) 1.65      (B) 4.41      (C) 2.67      (D) 3.02
- Q.45 A cruise missile with an *ideal* ramjet engine is flying at Mach 4.0 at an altitude where the ambient temperature is 100K. Consider ratio of specific heats  $\gamma = 1.4$  and specific gas constant  $R = 287 J/kgK$ . If the stagnation temperature in the combustion chamber is equal to 2310K, the speed of the exhaust gases (in m/s) is \_\_\_\_\_.
- Q.46 A gas turbine engine is operating under the following conditions:

Stagnation temperature at turbine inlet	1350 K
Stagnation pressure at the turbine inlet	10 bar
Static temperature at turbine exit	800 K
Velocity at turbine exit	200 m/s
Total-to-total efficiency of turbine	0.96
$\gamma$ (ratio of specific heats)	1.33
$C_p$ (specific heat at constant pressure)	1.147 kJ/kgK

The stagnation pressure (in bar) in the nozzle (considering isentropic nozzle) is equal to \_\_\_\_\_.

- Q.47 Air at a stagnation temperature of  $300K$  (ratio of specific heats,  $\gamma = 1.4$  and specific gas constant  $R = 287 J/kgK$ ) enters the impeller of a centrifugal compressor in axial direction. The stagnation pressure ratio between the diffuser outlet and impeller inlet is 4.0. The impeller blade radius is 0.3 m and it is rotating at  $15000 rev/min$ . If the slip factor  $\sigma_s$  (Ratio of tangential component of air velocity at the blade tip to the blade tip speed) is 0.88, the overall efficiency (total-to-total) of the compressor (in %) is \_\_\_\_\_.
- Q.48 A stationary two stage rocket with initial mass of  $16000kg$ , carrying a payload of  $1000kg$ , is fired in a vertical trajectory from the surface of the earth. Both the stages of the rocket have same specific impulse,  $I_{sp}$ , of  $300s$  and same structural coefficient of 0.14. The acceleration due to gravity is  $9.8m/s^2$ . Neglecting drag and gravity effects and considering both the stages with same payload ratio, the terminal velocity attained by the payload in  $m/s$  is \_\_\_\_\_.
- Q.49 An aircraft is flying at Mach 3.0 at an altitude where the ambient pressure and temperature are  $50 kPa$  and  $200 K$  respectively. If the converging-diverging diffuser of the engine (considered isentropic with ratio of specific heats,  $\gamma = 1.4$  and specific gas constant  $R = 287 J/kgK$ ) has a throat area of  $0.05 m^2$ , the mass flow rate through the engine in  $kg/s$  is  
 (A) 197 (B) 232 (C) 790 (D) 157
- Q.50 A cryogenic rocket has a specific impulse of  $455s$  and characteristic velocity of  $2386 m/s$ . The value of thrust coefficient for this rocket is  
 (A) 1.78 (B) 1.73 (C) 1.87 (D) 1.95
- Q.51 For a given airplane with a given wing loading executing a turn in the vertical plane, under what conditions will the turn radius be minimum and the turn rate be maximum?  
 (A) Highest possible  $C_L$  and lowest possible load factor  
 (B) Lowest possible  $C_L$  and lowest possible load factor  
 (C) Lowest possible  $C_L$  and highest possible load factor  
 (D) Highest possible  $C_L$  and highest possible load factor
- Q.52 Lift-off distance for a given aircraft of weight  $W$  is  $S_{LO}$ . If the take-off weight is reduced by 10%, then the magnitude of percentage change in the lift-off distance (assume all other parameters to remain constant) is \_\_\_\_\_.
- Q.53 Which of the following design parameters influence the maximum rate-of-climb for a jet-propelled airplane?  
 P. Wing loading  
 Q. Maximum thrust-to-weight ratio  
 R. Zero-lift drag coefficient  
 S. Maximum lift-to-drag ratio  
 (A) P and Q alone (B) P, Q, R and S (C) P, Q and S alone (D) Q, R, and S alone

Q.54 Consider the following four statements regarding aircraft longitudinal stability:

- P.  $C_{M, cg}$  at zero lift must be positive
- Q.  $\partial C_{M, cg} / \partial \alpha_a$  must be negative ( $\alpha_a$  is absolute angle of attack)
- R.  $C_{M, cg}$  at zero lift must be negative
- S. Slope of  $C_L$  versus  $\alpha_a$  must be negative

Which of the following combination is the necessary criterion for stick fixed longitudinal balance and static stability?

- (A) Q and R only      (B) Q, R, and S only      (C) P and Q only      (D) Q and S only

Q.55 Data for a light, single-engine, propeller driven aircraft in steady level flight at sea-level is as follows: velocity  $V_\infty = 40 \text{ m/s}$ , weight  $W = 13000 \text{ N}$ , lift coefficient  $C_L = 0.65$ , drag coefficient  $C_D = 0.025 + 0.04 C_L^2$  and power available  $P_{av} = 100,000 \text{ J/s}$ . The rate of climb possible for this aircraft under the given conditions (in  $\text{m/s}$ ) is

- (A) 7.20      (B) 5.11      (C) 6.32      (D) 4.23

**END OF THE QUESTION PAPER**