Sikkim Public Service Commission

Written (Main) Examination for the post of
Sub-Jailer

INSTRUCTIONS TO CANDIDATES

Read the instructions carefully before answering the questions: -

1. This Test Booklet consists of 12 (twelve) pages and has 63 (sixty-three) printed questions.
2. IMMEDIATELY AFTER THE COMMENCEMENT OF THE EXAMINATION, YOU SHOULD CHECK THAT THIS BOOKLET DOES NOT HAVE ANY UNPRINTED, TORN OR MISSING PAGES OR ITEMS. IF SO, GET IT REPLACED BY A COMPLETE TEST BOOKLET.
3. **Use only Black Ball Point Pen to fill the OMR Sheet.**
4. Please note that it is the candidate's responsibility to fill in the Roll Number carefully without any omission or discrepancy at the appropriate places in the **OMR ANSWER SHEET** as well as on **SEPARATE ANSWER BOOKLET** for Conventional Type Questions. Any omission/discrepancy will render the Answer Sheet liable for rejection.
5. Do not write anything else on the OMR Answer Sheet except the required information. Before you proceed to mark in the OMR Answer Sheet, please ensure that you have filled in the required particulars as per given instructions.
6. This Test Booklet is divided into 3 (three) parts – **Part-I, Part-II** and **Part-III**.
7. All three parts are **Compulsory**.
8. **Part-I consists of Multiple-Choice Questions.** The answers for these questions have to be marked in the **OMR Answer Sheet** provided to you.
9. **Parts II and III consist of Conventional Type Questions.** The answers for these questions have to be written in the **Separate Answer Booklet** provided to you.
10. After you have completed filling in all your responses on the OMR Answer Sheet and the Answer Booklet(s) and the examination has concluded, you should hand over the OMR Answer Sheet and the Answer Booklet(s) to the Invigilator only. You are permitted to take the Test Booklet with you.
11. **Marking Scheme**
    THERE WIL BE **NEGATIVE MARKING** FOR WRONG ANSWERS MARKED BY A CANDIDATE IN THE OBECTVE TYPE QUESTIONS
    (i) There are four alternatives for the answer to every question. **For each question for which a wrong answer has been given by the candidate, one-third of the marks assigned to the question will be deducted as penalty.**
    (ii) If a candidate gives more than one answer, it will be treated as a wrong answer even if one of the given answers happens to be correct and there will be same penalty as above to the question.
    (iii) If a question is left blank. i.e., no answer is given by the candidate, there will be no penalty for that question.
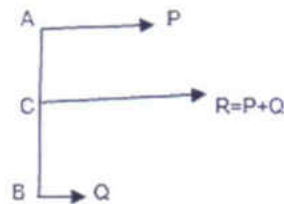

DO NOT OPEN THIS TEST BOOKLET UNTIL YOU ARE ASKED TO DO SO

PART – I
(Multiple Choice Questions)

Choose the correct answer for Questions 1 to 50 from the given options. Each question carries 3 marks. No Data Books / Tables are allowed; assume the data if required anywhere.
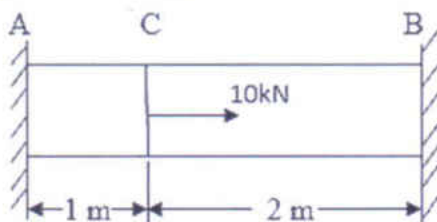
$$[50 \times 3 = 150]$$

1. Two unlike parallel forces are shown in following figure


   The resultant 'R' will be located by the relation:
   - (a) $P \times AC = Q \times BC$
   - (b) $P \times AB = Q \times AC$
   - (c) $P \times BC = Q \times AC$
   - (d) $P \times AB = Q \times AC$

2. Condition of static equilibrium of a planar force system is written as:
   - (a) $\Sigma M = 0$
   - (b) $\Sigma F = 0, and \, \Sigma M = 0$
   - (c) $\Sigma F = 0$
   - (d) None of the above

3. A prismatic bar is supported between two rigid supports as shown in figure. The support reaction will be:


   - (a) $R_A = 10/3 \, kN, R_B = 20/3 \, kN$
   - (b) $R_A = 20/3 \, kN, R_B = 10/3 \, kN$
   - (c) $R_A = 10 \, kN, R_B = 10 \, kN$
   - (d) $R_A = 5 \, kN, R_B = 5 \, kN$

4. The degree of freedom of the mechanism shown in figure is:
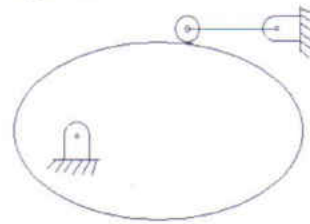
   - (a) Two
   - (b) Zero
   - (c) One
   - (d) Negative one

5. A link OB is rotating with a constant angular velocity of 2 rad/s in counter clockwise direction and a block is sliding radially outward on it with a uniform velocity of 0.75 m/s with respect to the rod. If OA = 1m, the magnitude of the absolute acceleration of the block at location A in m/s^2 is:
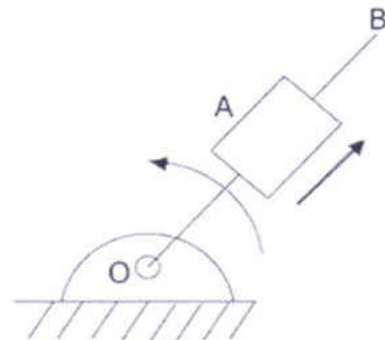
   - (a) 4
   - (b) 5
   - (c) 6
   - (d) 3

6. The maximum fluctuation of energy 'e' in a fly wheel is equal to:
   - (a) $I\omega(\omega_1 - \omega_2)$
   - (b) $I\omega^2 K$
   - (c) $2KE$
   - (d) All are correct

7. Which of the following tooth profiles can take very heavy load?
   (a) $14\frac{1}{2}°$ composite system
   (b) $14\frac{1}{2}°$ full depth involute system
   (c) 20° full depth involute
   (d) $14\frac{1}{2}°$ sub involute

8. A governor is said to be isochronous when:
   (a) For each speed within the working range the ball weights occupy a definite specific position
   (b) The equilibrium ball radii are constant for a given speed
   (c) There is only one equilibrium speed which is constant for all radii of rotation of the balls within the working range.
   (d) There is only one equilibrium radius of the governor weights for each equilibrium speed

9. The natural frequency of the spring mass system shown in figure is closest to:

   m = 1.4 kg

   $k_1 = 4000\,N\,m$ $k_2 = 1600\,N\,m$
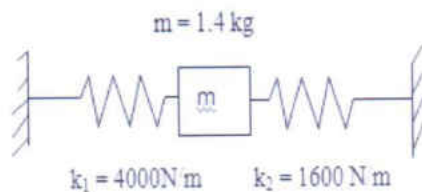
   (a) 10 Hz
   (b) 12 Hz
   (c) 16 Hz
   (d) 8 Hz

10. The damping ratio of a single degree of freedom spring-mass-damper system with mass of 1kg, stiffness 100 N/m and viscous damping coefficient of 25 Ns/m is:
    (a) 1.21
    (b) 1.22
    (c) 1.23
    (d) 1.25

11. The block of volume V mm³ is subjected to hydrostatic pressure p MPa, modulus of Elasticity is E GPa and Poisson's Ratio v = 0.5. Which of the following statements is true about the block?
    (a) Bulk modulus $K = \infty$, perfectly incompressible and change in volume is zero
    (b) Bulk modulus $K = 1$, perfectly incompressible and change in volume is zero
    (c) Bulk modulus $K = 0$, perfectly incompressible and change in volume is ∞
    (d) Bulk modulus $K = \infty$, perfectly compressible and change in volume is zero

12. A cantilever is subjected to a uniformly distributed load over its entire length. The variation of bending stress along the length of the cantilever is:
    (a) Constant
    (b) Linear
    (c) Parabolic
    (d) Not defined

13. A cantilever beam of diameter D, length L, cross-section A, subjected to a uniformly distributed load W and a concentrated load W_1 at a distance L_1 from free end will have maximum bending moment of:
    (a) $\frac{WL}{2} + W_1(L - L_1)$
    (b) $\frac{WL^2}{2} + W_1 L_1$
    (c) $\frac{W(L-L_1)}{2} + W_1(L - L_1)$
    (d) $\frac{W(L-L_1)}{2} + \frac{W(L+L_1)}{2}$

14. For a helical spring having diameter of cylindrical surface passing through the centre of coils as D, pitch of helix P, number of coils n and wire diameter d, the angle of inclination θ of the helix is given by:

   (a) $\theta = \cos^{-1} \dfrac{\pi n d}{\sqrt{\pi^2 D^2 + P^2}}$

   (b) $\theta = \sin^{-1} \dfrac{P d}{\sqrt{\pi^2 D^2 + P^2}}$

   (c) $\theta = \sin^{-1} \dfrac{D}{\sqrt{\pi^2 D^2 + P^2}}$

   (d) $\theta = \cos^{-1} \dfrac{D}{\sqrt{\pi^2 D^2 + P^2}}$

15. For applied load P kg, diameter of ball D mm, and diameter of Indentation d mm, the Brinell Hardness number B_{HN} is given by:

   (a) $B_{HN} = \dfrac{P}{\frac{\pi}{2}(D - \sqrt{D^2 - d^2})}$

   (b) $B_{HN} = \dfrac{D}{\frac{\pi}{2}(D - \sqrt{D^2 - d^2})}$

   (c) $B_{HN} = \dfrac{P.D}{\frac{1}{2}(D - \sqrt{D^2 - d^2})}$

   (d) $B_{HN} = \dfrac{P}{\{\frac{\pi D}{2}\}(D - \sqrt{D^2 - d^2})}$

16. The behaviour of metals in which strength of a metal is increased and the ductility is decreased on heating at a relatively low temperature after cold working is known as:

   (a) Clustering
   (b) Strain aging
   (c) Twinning
   (d) Screw dislocation

17. According to Lee and Shaffer theory, the shear angle $\emptyset$ is given by the relation (α = rake angle, β = friction angle):

   (a) $\emptyset = \frac{\pi}{2} + \frac{\beta}{2} + \frac{\alpha}{2}$

   (b) $\emptyset = \frac{\pi}{4} + (\alpha - \beta)$

   (c) $\emptyset = \frac{\pi}{4} - \frac{\beta}{2} + \frac{\alpha}{2}$

   (d) $\frac{\emptyset}{2} = \frac{\pi}{4} + (\alpha + \beta)$

18. What is the effect of rake angle of cutting tool on machinability?

   (a) No effect
   (b) Increases machinability up to a certain limit
   (c) Decreases machinability
   (d) Very little effect on machinability

19. The relation for cutting tool life is given as $VT^n = C$ where V is cutting speed, T is corresponding life and n and c are constants depending on cutting conditions. The numerical value of value of n for roughing cut as compared to that for light cuts in mild steel would be:

   (a) More
   (b) Less
   (c) Same
   (d) Does not depend on type of cut

20. In a continuous casting process:

   (a) Ingot is produced from melt
   (b) Die cast products are produced in bulk
   (c) Blooms or billets may be produced from melts.
   (d) All of the above

21. The camber is a term related to:

   (a) Forging
   (b) Rolling
   (c) Extrusion
   (d) Drawing

22. Which of the following materials may be having best machinability?

   (a) Titanium
   (b) Magnesium
   (c) Aluminium
   (d) Stainless Steel

23. Cold or hot rolling does not produce:
    (a) A hollow circular section
    (b) A T- Section
    (c) An I - section
    (d) A channel section

24. In arc welding the temperature of heat produced by the electric arc is of the order of:
    (a) 3000°C to 4000°C
    (b) 4000°C to 5000°C
    (c) 5000°C to 6000°C
    (d) 6000°C to 7000°C

25. SIMO charts are used in:
    (a) Method study
    (b) Micro motion study
    (c) Process analysis
    (d) Layout analysis

26. ABC analysis is based on:
    (a) The unit price of the item
    (b) The quantity of the item used in a year
    (c) The annual usage value of the item
    (d) The life of the item

27. In PERT the activity duration follows:
    (a) Normal distribution
    (b) Beta distribution
    (c) Binomial distribution
    (d) Poisson distribution

28. The use of CPM lies in:
    (a) Taking corrective measures
    (b) Scheduling and controlling the project
    (c) Planning and controlling the most logical sequence of operations
    (d) None of the above

29. Jobs going behind the schedule are conveniently shown in:
    (a) Milestone chart
    (b) Pie chart
    (c) Bar chart
    (d) Gantt chart

30. A competitive firm will maximize profit at the output where:
    (a) The difference between price and marginal cost is highest
    (b) The difference between marginal revenue and price is highest
    (c) Price is higher than the average total cost by the largest possible amount
    (d) The excess of total revenue over the total cost is greatest

31. Consider a heat engine that operates at 80% maximum possible efficiency. If the temperatures of the heat source and heat sink conform to the ratio 5:3, what fraction of heat supplied is converted to work?
    (a) 0.24
    (b) 0.28
    (c) 0.32
    (d) 0.40

32. A heat engine is supplied with 280 kJ/s of heat at a constant fixed temperature of 520 K and heat rejection takes place at 260 K temperature. If the engine is reversible, the heat rejected in kJ/s would be approximately equal to:
    (a) 85
    (b) 110
    (c) 140
    (d) 155

33. The specific weight of water in S.I units is taken as:
    (a) 9.81 kN/m^3
    (b) $9.81 \times 10^3 \text{ N/m}^3$
    (c) $9.81 \times 10^{-6} \text{ N/mm}^3$
    (d) All of the above

34. According to Bernoulli's equation:

    (a) $Z + \frac{p}{w} + \frac{v^2}{g} = constant$

    (b) $Z + \frac{p}{w} - \frac{v^2}{2g} = constant$

    (c) $Z - \frac{p}{w} + \frac{v^2}{g} = constant$

    (d) $Z - \frac{p}{w} - \frac{v^2}{2g} = constant$

35. The Reynolds number of a fluid flowing over a flat plate at a distance of 16 cm from the leading edge is 25600. The thickness of the boundary layer in mm at this point will be:

    (a) 5.0
    (b) 7.5
    (c) 10.0
    (d) 10.5

36. For maximum power transmission through a pipe line, the frictional head loss is equal to:

    (a) H/4
    (b) H/2
    (c) H/3
    (d) H/5

37. The discharge over a rectangular notch is:

    (a) Inversely proportional to $H^{3/2}$
    (b) Directly proportional to $H^{3/2}$
    (c) Inversely proportional to $H^{5/2}$
    (d) Directly proportional to $H^{5/2}$

38. Inspite of large heat transfer coefficients in boiling liquids, fins are used advantageously when the entire surface is exposed to:

    (a) Film boiling
    (b) Transition boiling
    (c) Nucleate boiling
    (d) All modes of boiling

39. Heat is conducted through 10 cm thick wall at the rate of $30 \, W/m^2$ when the temperature difference across the wall is 100°C. What is the thermal conductivity of the wall material?

    (a) 0.03 W/mK
    (b) 0.30 W/mK
    (c) 3.0 W/mK
    (d) 3.0 W/mK

40. If R_1 and R_2 are the inner and outer radii of a cylinder, the heat conduction through a cylinder is proportional to:

    (a) $(R_1 - R_2)$

    (b) $(R_1 \times R_2)$

    (c) $\frac{1}{(R_1 - R_2)}$

    (d) $\frac{1}{\log_e\left\{\frac{R_1}{R_2}\right\}}$

41. If one of the two fluids flowing through a heat exchanger of NTU = 2 remains at constant temperature throughout the exchanger length, the effectiveness of the heat exchanger will be:

    (a) $1 - e^{-4}$

    (b) $1 - e^{-2}$

    (c) $\frac{1 - e^{-2}}{2}$

    (d) $\frac{1 - e^2}{2}$

42. Which one of the following type of swirls is generated by a pre-combustion chamber in the diesel engine?

    (a) Squish
    (b) Compression swirl
    (c) Induction swirl
    (d) Combustion induced swirl

43. The commercially available petrol in India has an octane rating of:

    (a) 20 - 30
    (b) 40 - 50
    (c) 60 - 75
    (d) 85 - 90

44. Adjustment in the fuel injection timing in the fuel injection pumping of diesel engine is made by adjusting the:
    (a) Plunger rotation
    (b) Needle valve
    (c) Control rack
    (d) Pump camshaft

45. In person's reaction turbine when α is the angle with the direction of motion of the blade at which steams enters the blade, then the maximum efficiency of the turbine is given by:
    (a) $\dfrac{2 \cos \alpha}{1 + \cos \alpha}$

    (b) $\dfrac{2 \cos^2 \alpha}{1 + \cos^2 \alpha}$

    (c) $\dfrac{2 \cos^2 \alpha}{1 - \cos \alpha}$

    (d) $\dfrac{2 \cos^2 \alpha}{1 + 2 \cos^2 \alpha}$

46. The critical pressure ratio (r) for a steam nozzle, where n is the polytropic index of the fluid, is given by:
    (a) $r = \{\dfrac{2}{n+1}\}^{\frac{n}{n-1}}$
    (b) $r = \{\dfrac{1}{n+1}\}^{\frac{2n}{n-1}}$
    (c) $r = \{\dfrac{1}{n+1}\}^{\frac{1}{n-1}}$
    (d) $r = \{\dfrac{2}{n+1}\}^{\frac{1}{n-1}}$

47. The refrigerating efficiency, i.e., the ratio of actual COP to the reversible COP of a refrigeration cycle is 0.8, the condenser and evaporator temperatures are 51°C and −30°C respectively. If cooling capacity of the plant is 2.4 kW, then what is the work requirement in kW?
    (a) 1.00
    (b) 1.33
    (c) 1.25
    (d) 2.01

48. Aqua ammonia solution used in vapour absorption refrigeration system is a solution of ammonia in:
    (a) Carbon tetrachloride
    (b) Lithium bromide
    (c) Water
    (d) Hydrogen

49. Two reversible refrigerators are arranged in series and their coefficients of performance are 4 and 5 respectively. The COP of the composite refrigeration system would be:
    (a) 1.5
    (b) 2.0
    (c) 3.0
    (d) 4.5

50. On a psychrometric chart, the constant wet bulb temperature lines coincide with:
    (a) Constant relative humidity lines
    (b) Constant enthalpy lines
    (c) Constant dew point temperature lines
    (d) Constant volume lines

PART – II
(Conventional Type Questions)

Answer any 2 (two) from Questions 51 to 55. Each question carries 25 marks.
Candidates are required to give their answers in their own words as far as practicable.
*No Data Books/Tables are allowed, assume the data if required anywhere.*

$[2 \times 25 = 50]$

51. In a spring-loaded Hartnell type of governor, the mass of each ball is 4 kg and the lift of the sleeve is 40 mm. The governor begins to float at 200 rpm when the radius of the ball path is 90 mm. The mean working speed of the governor is 16 times the range of speed when friction is neglected. The lengths of the ball and roller arms of the bell crank lever are 100 mm and 80 mm respectively. The pivot centre and the axis of governor are 115 mm apart. Determine the initial compression of the spring, considering the obliquity of arms.

Assuming the friction at the sleeve to be equivalent to a force of 15 N. determine the total alteration in speed before the sleeve begins to move from the mid-position.

52. A steel specimen shown in **Figure-1**, is used by SAE laboratory to perform standard tension test on UTM to evaluate several mechanical properties.
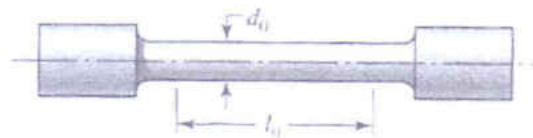
Figure-1

The dimensions of the specimen and observations made during the test are described below

Diameter of the specimen d_0	= 12.5 mm
Gauge length l_0	= 62.5 mm
Load at upper yield point	= 42.5 kN
Load at lower yield point	= 41.0 kN
Maximum load	= 72.5 kN
Fracture load	= 51.25 kN
Gauge length at fracture	= 80.5 mm
Diameter of fracture section	= 9.5 mm
Strain at a load of 20 kN	= 7.764×10^{-6} mm/mm.

Determine:

(i)   The yield strength
(ii)   The Ultimate Strength
(iii) The % elongation
(iv)   The % Reduction in Area
(v)   Modulus of toughness
(vi)   Modulus of resilience
(vii) Modulus of elasticity
(viii) Fracture Stress

53.   A 600 mm long job of 150 mm diameter of AISI 4140 steel is to be turned with a depth of cut of 1.5 mm and a feed rate 0.25 mm/rev. The following data is applicable for the problem:

Labour cost per hour	= Rs 12.00
Machine overhead per hour	= Rs 40.00
Grinding cost per hour	= Rs 15.00
Grinding machine overhead per hour	= Rs 50.00
Idle time	= 5 minutes

The Taylor's tool-life equation is given by $VT^{0.22} = 475$

The operation can be carried out using tungsten carbide tools either as brazed tools or throwaway tools.

For brazed tools tip:

Initial cost	= Rs 60.00
Grinding time	= 5 minutes/edge
Tool change time	= 2 minutes

9 grinds per tool before salvage

For throwaway tool tip:

Initial cost	= Rs 40.00
Tool change time	= 1.5 minutes
Total cutting edges	= 8

For both tools brazed tip and the throwaway, using the criteria of minimum production cost, and maximum production rate, find:

(i) The optimum cutting speed.

(ii) The Tool life.

(iii) The cost of operation.

54.   A one-shell, two-tube pass heat exchanger having 3000 thin wall brass tubes of 20 mm diameter has been installed in a steam power plant with a heat load of 2.3×10^8 W. The steam condenses at 50°C and the cooling water enters the tubes at 20°C at the rate of 3000 kg/s.

Calculate:

(i) The overall heat transfer coefficient

(ii) The tube length per pass

(iii) The rate of condensation of steam.

Take the heat transfer coefficient for condensation on the outer surfaces of the tubes as 15500 W/m²K and the latent heat of steam as 2380 kJ/kg. Further presume the following fluid properties:

Specific Heat C	= 4180 J/kg K
Dynamic Viscosity μ	= 855 x 10^{-6}Ns/m²
Thermal Conductivity K	= 0.613 W/m K
Prandtl Number Pr	= 5.83

55.   A six-cylinder, four-stroke CI engine is tested against a water brake dynamometer for which $B.P. = WN/17 \times 10^3$ in kW, where W is the brake load in newton and N is the speed of the engine in r.p.m. The air consumption was measured by means of a sharp edge orifice. During the test following observations were taken:

Bore	= 10 cm
Stroke	= 14 cm
Speed	= 2500 r.p.m.
Brake load	= 480 N
Barometer reading	= 76 cm of Hg
Orifice diameter	= 3.3 cm
Co-efficient of discharge of orifice	= 0.62
Pressure-drop across orifice	= 14 cm of Hg
Room temperature	= 25°C
Fuel consumption	= 0.32 kg/m

Calculate the following:
   (i)   The volumetric efficiency
   (ii) The brake mean effective pressure (b.m.e.p.)
   (iii) The engine torque
   (iv) The brake specific fuel consumption (b.s.f.c.)

PART – III
(Conventional Type Questions)

Write the answers in short for any 5 (five) from Questions 56 to 63. Each question carries 10 marks.
Candidates are required to give their answers in their own words as far as practicable.
No Data Books/Tables are allowed, assume the data if required anywhere.

[5 x 10 = 50]

56.   Discuss the different cases for the resultant of two parallel forces.

57.   State & explain the Law of Gearing with its significance.

58.   Explain the TIG system of arc welding with example.

59.   Describe the systemic procedure for work study explaining all steps.

60.   What is the First Law of Thermodynamics for closed system? Explain the Perpetual Motion Machine of first kind - PMM 1.

61.   State the Euler's equation of motion and explain how it led to the development of Bernoulli's equation.

62.   Explain the term "Steam Nozzle" and its types along with their applications.

63.   Describe the elements of a refrigeration system. What is Open & Closed Air Refrigeration Systems.

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