ME-2024

EE24Btech11022 - Eshan Sharma

1) Consider the system of linear equations

$$\begin{aligned} x + 2y + z &= 5 \\ 2x + ay + 4z &= 12 \\ 2x + 4y + 6z &= b \end{aligned}$$

The values of a and b such that there exists a non-trivial null space and the system admits infinite solutions are

a) $a = 8$, $b = 14$
b) $a = 4$, $b = 12$
c) $a = 8$, $b = 12$
d) $a = 4$, $b = 14$

2) Let $f(\cdot)$ be a twice differentiable function from $\mathbb{R}^2 \to \mathbb{R}$. If $p, x_0 \in \mathbb{R}^2$ where $\|p\|$ is sufficiently small (here $\|\cdot\|$ is the Euclidean norm or distance function), then

$$f(x_0 + p) = f(x_0) + \nabla f(x_0)^T p + \frac{1}{2} p^T \nabla^2 f(\psi) p$$

where $\psi \in \mathbb{R}^2$ is a point on the line segment joining x_0 and $x_0 + p$. If x_0 is a strict local minimum of $f(x)$, then which one of the following statements is TRUE?

a) $\nabla f(x_0)^T p > 0$ and $p^T \nabla^2 f(\psi) p = 0$
b) $\nabla f(x_0)^T p = 0$ and $p^T \nabla^2 f(\psi) p > 0$
c) $\nabla f(x_0)^T p = 0$ and $p^T \nabla^2 f(\psi) p < 0$
d) $\nabla f(x_0)^T p = 0$ and $p^T \nabla^2 f(\psi) p = 0$

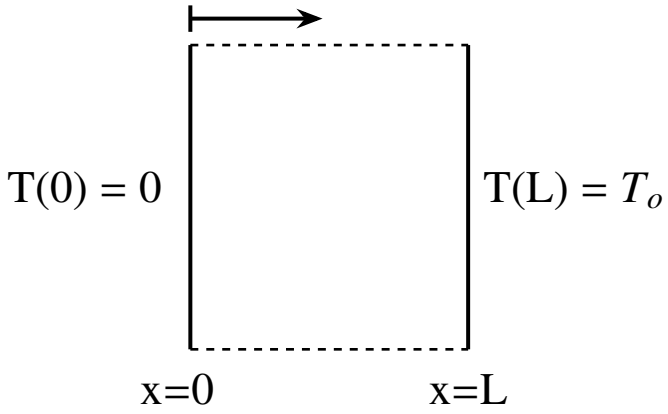
3) The velocity field of a two-dimensional, incompressible flow is given by

$$\mathbf{V} = 2 \sin hx \, \hat{i} + v(x, y) \, \hat{j}$$

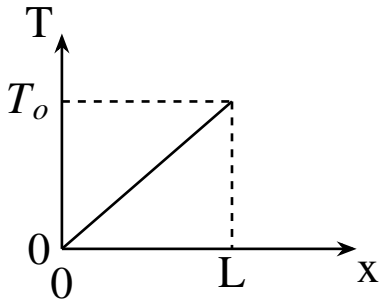
where $\hat{i}$ and $\hat{j}$ denote the unit vectors in x and y directions, respectively. If $v(x, 0) = \cos hx$, then $v(0, -1)$ is

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

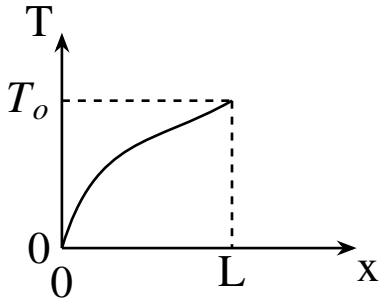
4) A plane, solid slab of thickness L, shown in the figure, has thermal conductivity k that varies with the spatial coordinate x as $k = A + Bx$, where A and B are positive constants ($A > 0$, $B > 0$). The slab walls are maintained at fixed temperatures of $T(x = 0) = 0$ and $T(x = L) = T_0 > 0$. The slab has no internal heat sources. Considering one-dimensional heat transfer, which one of the following plots qualitatively depicts the steady-state temperature distribution within the slab?



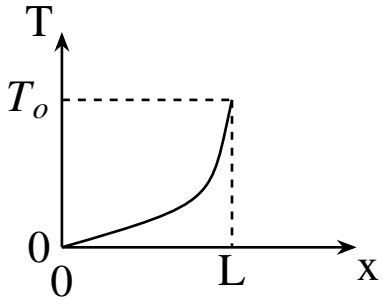
a)



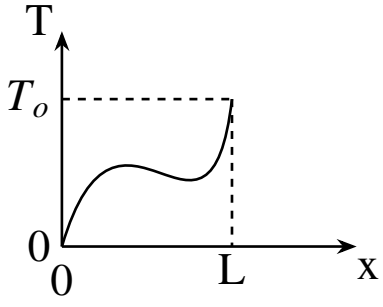
b)



c)



d)



5) Consider incompressible laminar flow over a flat plate with freestream velocity of u_∞. The Nusselt number corresponding to this flow velocity is Nu_1. If the freestream velocity is doubled, the Nusselt number changes to Nu_2. Choose the correct option for Nu_2/Nu_1.

a) $\sqrt{2}$

b) 2
c) 1.26
d) 1

6) Consider a hydrodynamically fully developed laminar flow through a circular pipe with the flow along the axis (i.e., z direction). In the following statements, T is the temperature of the fluid, T_w is the wall temperature, and T_m is the bulk mean temperature of the fluid. Which one of the following statements is TRUE?
   a) For a thermally fully developed flow, $\frac{\partial T}{\partial z} = 0$, always.
   b) For constant wall temperature of the duct, $\frac{dT_m}{dz}$ = constant.
   c) Nusselt number varies linearly along the z direction for a thermally fully developed flow.
   d) For constant wall temperature ($T_w > T_m$) of the duct, $\frac{dT_m}{dz}$ increases exponentially with distance along z direction.

7) A furnace can supply heat steadily at 1200 K at a rate of 24000 kJ/min. The maximum amount of power (in kW) that can be produced by using the heat supplied by this furnace in an environment at 300 K is
   a) 300
   b) 150
   c) 18000
   d) 0

8) Which one of the following statements regarding a Rankine cycle is FALSE?
   a) Superheating the steam in the boiler increases the cycle efficiency.
   b) The pressure at the turbine outlet depends on the condenser temperature.
   c) Cycle efficiency increases as condenser pressure decreases.
   d) Cycle efficiency increases as boiler pressure decreases.

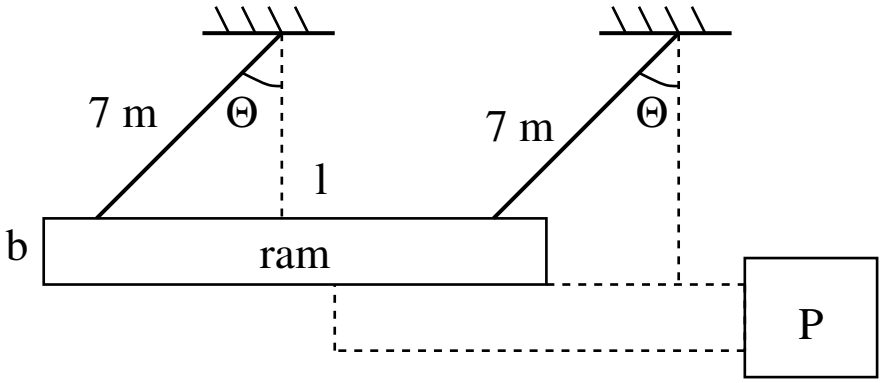
9) For a ball bearing, the fatigue life in millions of revolutions is given by

$$L = \left(\frac{C}{P}\right)^n,$$

   where P is the constant applied load and C is the basic dynamic load rating. Which one of the following statements is TRUE?
   a) $n = 3$, assuming that the inner race is fixed and the outer race is revolving
   b) $n = \frac{1}{3}$, assuming that the inner race is fixed and the outer race is revolving
   c) $n = 3$, assuming that the outer race is fixed and the inner race is revolving
   d) $n = \frac{1}{3}$, assuming that the outer race is fixed and the inner race is revolving

10) The change in kinetic energy ΔE of an engine is 300 J, and minimum and maximum shaft speeds are $\omega_{\min} = 220$ rad/s and $\omega_{\max} = 280$ rad/s, respectively. Assume that the torque-time function is purely harmonic. To achieve a coefficient of fluctuation of 0.05, the moment of inertia (in kg.m^2) of the flywheel to be mounted on the engine shaft is
   a) 0.113
   b) 0.096
   c) 0.071
   d) 0.053

11) A ram in the form of a rectangular body of size $l = 9$ m and $b = 2$ m is suspended by two parallel ropes of lengths 7 m. Assume the center-of-mass of the body is at its geometric center and $g = 9.81$ m/s^2. For striking the object P with a horizontal velocity of 5 m/s, what is the angle θ with the vertical from which the ram should be released from rest?



a) 67.1°
b) 40.2°
c) 35.1°
d) 79.5°

12) A linear spring-mass-dashpot system with a mass of 2 kg is set in motion with viscous damping. If the natural frequency is 15 Hz, and the amplitudes of two successive cycles measured are 7.75 mm and 7.20 mm, the coefficient of viscous damping (in N.s/m) is
a) 4.41
b) 7.51
c) 2.52
d) 6.11

13) Which one of the following failure theories is the most conservative design approach against fatigue failure?
a) Soderberg line
b) Modified Goodman line
c) Gerber line
d) Yield line