

FINAL JEE–MAIN EXAMINATION – JANUARY, 2024

(Held On Thursday 01st February, 2024)

TIME : 3 : 00 PM to 06 : 00 PM

SECTION-A

31. In an ammeter, 5% of the main current passes through the galvanometer. If resistance of the galvanometer is G , the resistance of ammeter will be :

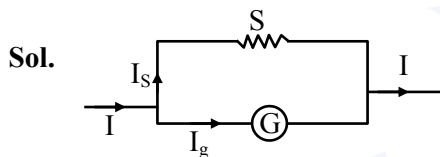
(1) $\frac{G}{200}$

(2) $\frac{G}{199}$

(3) $199 G$

(4) $200 G$

Ans. (Bonus)



$$I_s S = I_g G$$

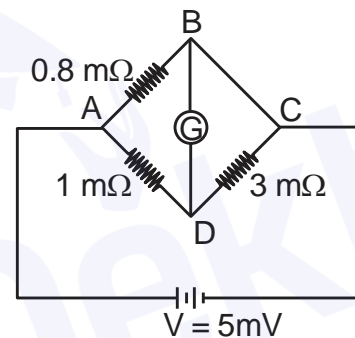
$$\frac{95}{100} I S = \frac{5I}{100} G$$

$$S = \frac{G}{19}$$

$$R_A = \frac{SG}{S+G} = \frac{\frac{G^2}{19}}{\frac{20G}{19}}$$

$$R_A = \frac{G}{20}$$

32. To measure the temperature coefficient of resistivity α of a semiconductor, an electrical arrangement shown in the figure is prepared. The arm BC is made up of the semiconductor. The experiment is being conducted at 25°C and resistance of the semiconductor arm is $3\text{ m}\Omega$. Arm BC is cooled at a constant rate of 2°C/s . If the galvanometer G shows no deflection after 10s, then α is :



(1) $-2 \times 10^{-2} \text{ }^\circ\text{C}^{-1}$

(2) $-1.5 \times 10^{-2} \text{ }^\circ\text{C}^{-1}$

(3) $-1 \times 10^{-2} \text{ }^\circ\text{C}^{-1}$

(4) $-2.5 \times 10^{-2} \text{ }^\circ\text{C}^{-1}$

Ans. (3)

Sol. For no deflection $\frac{0.8}{1} = \frac{R}{3}$

$$\Rightarrow R = 2.4\text{m}\Omega$$

Temperature fall in 10s = 20°C

$$\Delta R = R \alpha \Delta t$$

$$\alpha = \frac{\Delta R}{R \Delta t} = \frac{-0.6}{3 \times 20}$$

$$= -10^{-2} \text{ }^\circ\text{C}^{-1}$$

33. From the statements given below :
- (A) The angular momentum of an electron in n^{th} orbit is an integral multiple of h .
- (B) Nuclear forces do not obey inverse square law.
- (C) Nuclear forces are spin dependent.
- (D) Nuclear forces are central and charge independent.
- (E) Stability of nucleus is inversely proportional to the value of packing fraction.

Choose the correct answer from the options given below :

- (1) (A), (B), (C), (D) only
 (2) (A), (C), (D), (E) only
 (3) (A), (B), (C), (E) only
 (4) (B), (C), (D), (E) only

Ans. (3)

Sol. Part of theory

34. A diatomic gas ($\gamma = 1.4$) does 200 J of work when it is expanded isobarically. The heat given to the gas in the process is :

- (1) 850 J (2) 800 J
 (3) 600 J (4) 700 J

Ans. (4)

Sol. $\gamma = 1 + \frac{2}{f} = 1.4 \Rightarrow \frac{2}{f} = 0.4$

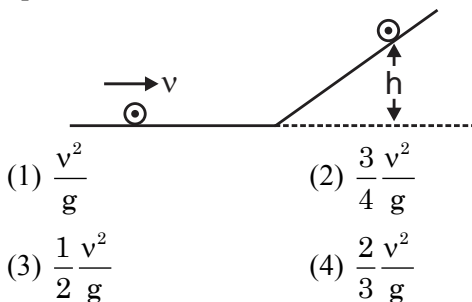
$\Rightarrow f = 5$

$W = n R \Delta T = 200 \text{ J}$

$Q = \left(\frac{f+2}{2} \right) n R \Delta T$

$200 = 700 \text{ J}$

35. A disc of radius R and mass M is rolling horizontally without slipping with speed v . It then moves up an inclined smooth surface as shown in figure. The maximum height that the disc can go up the incline is :



Ans. (3)

- Sol. Only the translational kinetic energy of disc changes into gravitational potential energy. And rotational KE remains unchanged as there is no friction.

$$\frac{1}{2} m v^2 = m g h$$

$$h = \frac{v^2}{2g}$$

36. Conductivity of a photodiode starts changing only if the wavelength of incident light is less than 660 nm. The band gap of photodiode is found to be

$\left(\frac{X}{8} \right) \text{ eV}$. The value of X is :

(Given, $h = 6.6 \times 10^{-34} \text{ Js}$, $e = 1.6 \times 10^{-19} \text{ C}$)

- (1) 15 (2) 11
 (3) 13 (4) 21

Ans. (1)

Sol. $E_g = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{660 \times 10^{-9}} \text{ J}$

$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{660 \times 10^{-9} \times 1.6 \times 10^{-19}} \text{ eV}$

$= \frac{15}{8} \text{ eV}$

So $x = 15$

37. A big drop is formed by coalescing 1000 small droplets of water. The surface energy will become :

- (1) 100 times (2) 10 times
 (3) $\frac{1}{100}$ th (4) $\frac{1}{10}$ th

Ans. (4)

- Sol. Lets say radius of small droplets is r and that of big drop is R

$$\frac{4}{3} \pi R^3 = 1000 \frac{4}{3} \pi r^3$$

$R = 10r$

$U_i = 1000 (4\pi r^2 S)$

$U_f = 4\pi R^2 S$

$= 100 (4\pi r^2 S)$

$U_f = \frac{1}{10} U_i$

38. If frequency of electromagnetic wave is 60 MHz and it travels in air along z direction then the corresponding electric and magnetic field vectors will be mutually perpendicular to each other and the wavelength of the wave (in m) is :

- (1) 2.5 (2) 10
(3) 5 (4) 2

Ans. (3)

Sol. $\lambda = \frac{c}{f} = \frac{3 \times 10^8}{60 \times 10^6} = 5\text{m}$

39. A cricket player catches a ball of mass 120 g moving with 25 m/s speed. If the catching process is completed in 0.1 s then the magnitude of force exerted by the ball on the hand of player will be (in SI unit):

- (1) 24 (2) 12
(3) 25 (4) 30

Ans. (4)

Sol. $F_{av} = \frac{\Delta p}{\Delta t}$
 $= \frac{0.12 \times 25}{0.1} = 30\text{N}$

40. Monochromatic light of frequency 6×10^{14} Hz is produced by a laser. The power emitted is 2×10^{-3} W. How many photons per second on an average, are emitted by the source ?

- (Given $h = 6.63 \times 10^{-34}$ Js)
(1) 9×10^{18} (2) 6×10^{15}
(3) 5×10^{15} (4) 7×10^{16}

Ans. (3)

Sol. $P = nh\nu$
 $n = \frac{P}{h\nu} = \frac{2 \times 10^{-3}}{6.63 \times 10^{-34} \times 6 \times 10^{14}}$
 $= 5 \times 10^{15}$

41. A microwave of wavelength 2.0 cm falls normally on a slit of width 4.0 cm. The angular spread of the central maxima of the diffraction pattern obtained on a screen 1.5 m away from the slit, will be:

- (1) 30° (2) 15°
(3) 60° (4) 45°

Ans. (3)

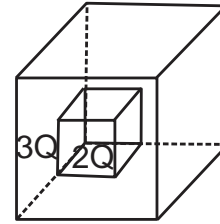
Sol. For first minima a $\sin\theta = \lambda$

$$\sin\theta = \frac{\lambda}{a} = \frac{1}{2}$$

$$\theta = 30^\circ$$

$$\text{Angular spread} = 60^\circ$$

42. C_1 and C_2 are two hollow concentric cubes enclosing charges $2Q$ and $3Q$ respectively as shown in figure. The ratio of electric flux passing through C_1 and C_2 is :



- (1) 2 : 5 (2) 5 : 2
(3) 2 : 3 (4) 3 : 2

Ans. (1)

Sol. $\phi_{\text{smaller cube}} = \frac{2Q}{\epsilon_0}$

$$\phi_{\text{bigger cube}} = \frac{5Q}{\epsilon_0}$$

$$\frac{\phi_{\text{smaller cube}}}{\phi_{\text{bigger cube}}} = \frac{2}{5}$$

43. If the root mean square velocity of hydrogen molecule at a given temperature and pressure is 2 km/s, the root mean square velocity of oxygen at the same condition in km/s is :

- (1) 2.0 (2) 0.5
(3) 1.5 (4) 1.0

Ans. (2)

Sol. $V_{rms} = \sqrt{\frac{3RT}{M}}$

$$\frac{V_1}{V_2} = \sqrt{\frac{M_2}{M_1}} \Rightarrow \frac{2}{V_2} = \sqrt{\frac{32}{2}}$$

$$V_2 = 0.5 \text{ km/s}$$

44. Train A is moving along two parallel rail tracks towards north with speed 72 km/h and train B is moving towards south with speed 108 km/h. Velocity of train B with respect to A and velocity of ground with respect to B are (in ms^{-1}):

- (1) -30 and 50
- (2) -50 and -30
- (3) -50 and 30
- (4) 50 and -30

Ans. (3)

Sol. $B \downarrow 30 \text{ m/s}$
 $A \uparrow 20 \text{ m/s}$

$$V_A = 20 \text{ m/s}$$

$$V_B = -30 \text{ m/s}$$

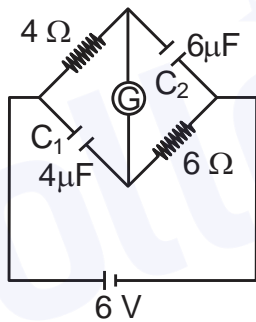
Velocity of B w.r.t. A

$$V_{B/A} = -50 \text{ m/s}$$

Velocity of ground w.r.t. B

$$V_{G/B} = 30 \text{ m/s}$$

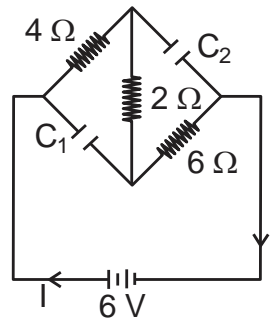
45. A galvanometer (G) of 2Ω resistance is connected in the given circuit. The ratio of charge stored in C_1 and C_2 is :



- (1) $\frac{2}{3}$
- (2) $\frac{3}{2}$
- (3) 1
- (4) $\frac{1}{2}$

Ans. (4)

Sol.



In steady state

$$R_{eq} = 12\Omega$$

$$I = \frac{6}{12} = 0.5 \text{ A}$$

$$\text{P.D across } C_1 = 3 \text{ V}$$

$$\text{P.D across } C_2 = 4 \text{ V}$$

$$q_1 = C_1 V_1 = 12 \mu\text{C}$$

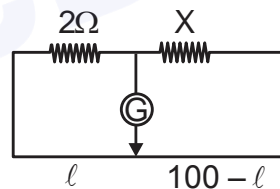
$$q_2 = C_2 V_2 = 24 \mu\text{C}$$

$$\frac{q_1}{q_2} = \frac{1}{2}$$

46. In a metre-bridge when a resistance in the left gap is 2Ω and unknown resistance in the right gap, the balance length is found to be 40 cm. On shunting the unknown resistance with 2Ω , the balance length changes by :

- (1) 22.5 cm
- (2) 20 cm
- (3) 62.5 cm
- (4) 65 cm

Ans. (1)



Sol.

$$\text{First case } \frac{2}{40} = \frac{X}{60} \Rightarrow X = 3\Omega$$

$$\text{In second case } X' = \frac{2 \times 3}{2 + 3} = 1.2\Omega$$

$$\frac{2}{l} = \frac{1.2}{100 - l}$$

$$200 - 2l = 1.2l$$

$$l = \frac{200}{3.2} = 62.5 \text{ cm}$$

Balance length changes by 22.5 cm

47. Match List - I with List - II.

List - I (Number)	List - II (Significant figure)
(A) 1001	(I) 3
(B) 010.1	(II) 4
(C) 100.100	(III) 5
(D) 0.0010010	(IV) 6

Choose the correct answer from the options given below :

- (1) (A)-(III), (B)-(IV), (C)-(II), (D)-(I)
 (2) (A)-(IV), (B)-(III), (C)-(I), (D)-(II)
 (3) (A)-(II), (B)-(I), (C)-(IV), (D)-(III)
 (4) (A)-(I), (B)-(II), (C)-(III), (D)-(IV)

Ans. (3)

Sol. Theoretical

48. A transformer has an efficiency of 80% and works at 10 V and 4 kW. If the secondary voltage is 240 V, then the current in the secondary coil is :

- (1) 1.59 A (2) 13.33 A
 (3) 1.33 A (4) 15.1 A

Ans. (2)

Sol. Efficiency = $\frac{E_S I_S}{E_P I_P}$

$$0.8 = \frac{240 I_S}{4000}$$

$$I_S = \frac{3200}{240} = 13.33 \text{ A}$$

49. A light planet is revolving around a massive star in a circular orbit of radius R with a period of revolution T. If the force of attraction between planet and star is proportional to $R^{-3/2}$ then choose the correct option :

- (1) $T^2 \propto R^{5/2}$ (2) $T^2 \propto R^{7/2}$
 (3) $T^2 \propto R^{3/2}$ (4) $T^2 \propto R^3$

Ans. (1)

Sol. $F = \frac{GMm}{R^{3/2}} = m\omega^2 R$

$$\omega^2 \propto \frac{1}{R^{5/2}} \quad \therefore T = \frac{2\pi}{\omega} \quad \text{so}$$

$$T^2 \propto R^{5/2}$$

50. A body of mass 4 kg experiences two forces $\vec{F}_1 = 5\hat{i} + 8\hat{j} + 7\hat{k}$ and $\vec{F}_2 = 3\hat{i} - 4\hat{j} - 3\hat{k}$. The acceleration acting on the body is :

- (1) $-2\hat{i} - \hat{j} - \hat{k}$
 (2) $4\hat{i} + 2\hat{j} + 2\hat{k}$
 (3) $2\hat{i} + \hat{j} + \hat{k}$
 (4) $2\hat{i} + 3\hat{j} + 3\hat{k}$

Ans. (3)

Sol. Net force = $8\hat{i} + 4\hat{j} + 4\hat{k}$

$$\vec{a} = \frac{\vec{F}}{m} = 2\hat{i} + \hat{j} + \hat{k}$$

SECTION-B

51. A mass m is suspended from a spring of negligible mass and the system oscillates with a frequency f_1 . The frequency of oscillations if a mass 9 m is suspended from the same spring is f_2 . The value of $\frac{f_1}{f_2}$ is ____.

Ans. (3)

Sol. $f_1 = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$

$$f_2 = \frac{1}{2\pi} \sqrt{\frac{k}{9m}}$$

$$\frac{f_1}{f_2} = \sqrt{\frac{9}{1}} = \frac{3}{1}$$

52. A particle initially at rest starts moving from reference point. $x = 0$ along x-axis, with velocity v that varies as $v = 4\sqrt{x}$ m/s. The acceleration of the particle is ____ ms^{-2} .

Ans. (8)

Sol. $V = 4\sqrt{x}$

$$a = V \frac{dv}{dx}$$

$$= 4\sqrt{x} \times 4 \times \frac{1}{2} x^{-1/2} = 8 \text{ m/s}^2$$

53. A moving coil galvanometer has 100 turns and each turn has an area of 2.0 cm^2 . The magnetic field produced by the magnet is 0.01 T and the deflection in the coil is 0.05 radian when a current of 10 mA is passed through it. The torsional constant of the suspension wire is $x \times 10^{-5} \text{ N-m/rad}$. The value of x is ____.

Ans. (4)

Sol. $\tau = BINAsin\phi$

$$C\theta = BINAsin90^\circ$$

$$C = \frac{BINA}{\theta} = \frac{0.01 \times 100 \times 10^{-3} \times 100 \times 2 \times 10^{-4}}{0.05}$$

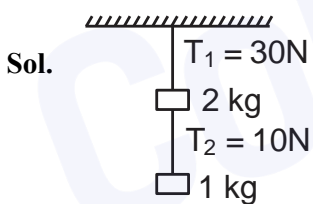
$$= 4 \times 10^{-5} \text{ N-m/rad.}$$

$$x = 4$$

54. One end of a metal wire is fixed to a ceiling and a load of 2 kg hangs from the other end. A similar wire is attached to the bottom of the load and another load of 1 kg hangs from this lower wire. Then the ratio of longitudinal strain of upper wire to that of the lower wire will be ____.

[Area of cross section of wire = 0.005 cm^2 , $Y = 2 \times 10^{11} \text{ Nm}^{-2}$ and $g = 10 \text{ ms}^{-2}$]

Ans. (3)



$$\Delta L = \frac{FL}{AY}$$

$$\frac{\Delta L}{L} = \frac{F}{AY}$$

$$\frac{\frac{\Delta L_1}{L_1}}{\frac{\Delta L_2}{L_2}} = \frac{F_1}{F_2} = \frac{30}{10} = 3$$

55. A particular hydrogen - like ion emits the radiation of frequency $3 \times 10^{15} \text{ Hz}$ when it makes transition from $n = 2$ to $n = 1$. The frequency of radiation emitted in transition from $n = 3$ to $n = 1$ is $\frac{x}{9} \times 10^{15} \text{ Hz}$, when $x =$ ____.

Ans. (32)

Sol. $E = -13.6z^2 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$

$$E = C \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$h\nu = C \left[\frac{1}{n_f^2} - \frac{1}{n_i^2} \right]$$

$$\frac{\nu_1}{\nu_2} = \frac{\left[\frac{1}{n_f^2} - \frac{1}{n_i^2} \right]_{2-1}}{\left[\frac{1}{n_f^2} - \frac{1}{n_i^2} \right]_{3-1}}$$

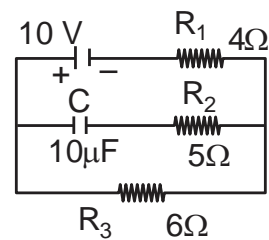
$$= \frac{\left[\frac{1}{1} - \frac{1}{4} \right]}{\left[\frac{1}{1} - \frac{1}{9} \right]} = \frac{3/4}{8/9}$$

$$= \frac{3}{4} \times \frac{9}{8}$$

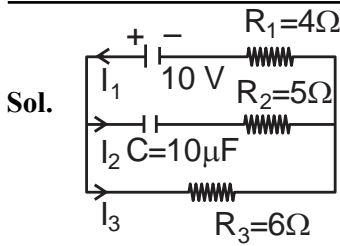
$$\frac{\nu_1}{\nu_2} = \frac{27}{32}$$

$$\nu_2 = \frac{32}{27} \nu_1 = \frac{32}{27} \times 3 \times 10^{15} \text{ Hz} = \frac{32}{9} \times 10^{15} \text{ Hz}$$

56. In an electrical circuit drawn below the amount of charge stored in the capacitor is ____ μC .



Ans. (60)



In steady state there will be no current in branch of capacitor, so no voltage drop across $R_2 = 5\Omega$
 $I_2 = 0$

$$I_1 = I_3 = \frac{10}{4 + 6} = 1A$$

$$V_{R_3} = V_c + V_{R_2} \quad V_{R_2} = 0$$

$$I_3 R_3 = V_c$$

$$V_c = 1 \times 6 = 6 \text{ volt}$$

$$q_c = CV_c = 10 \times 6 = 60 \mu C$$

57. A coil of 200 turns and area 0.20 m^2 is rotated at half a revolution per second and is placed in uniform magnetic field of 0.01 T perpendicular to axis of rotation of the coil. The maximum voltage generated in the coil is $\frac{2\pi}{\beta}$ volt. The value of β is ___.

Ans. (5)

Sol. $\phi = NAB \cos(\omega t)$

$$\frac{d\phi}{dt} = NAB\omega \sin(\omega t)$$

$$\epsilon_{\text{max}} = NAB\omega$$

$$= 200 \times 0.2 \times 0.01 \times \pi$$

$$= \frac{4\pi}{10} = \frac{2\pi}{5} \text{ volt}$$

58. In Young's double slit experiment, monochromatic light of wavelength 5000 \AA is used. The slits are 1.0 mm apart and screen is placed at 1.0 m away from slits. The distance from the centre of the screen where intensity becomes half of the maximum intensity for the first time is $___ \times 10^{-6} \text{ m}$.

Ans. (125)

- Sol. Let intensity of light on screen due to each slit is I_0
 So intensity at centre of screen is $4I_0$

Intensity at distance y from centre-

$$I = I_0 + I_0 + 2\sqrt{I_0 I_0} \cos \phi$$

$$I_{\text{max}} = 4I_0$$

$$\frac{I_{\text{max}}}{2} = 2I_0 = 2I_0 + 2I_0 \cos \phi$$

$$\cos \phi = 0$$

$$\phi = \frac{\pi}{2}$$

$$K\Delta x = \frac{\pi}{2}$$

$$\frac{2\pi}{\lambda} d \sin \theta = \frac{\pi}{2}$$

$$\frac{2}{\lambda} d \times \frac{y}{D} = \frac{1}{2}$$

$$y = \frac{\lambda D}{4d} = \frac{5 \times 10^{-7} \times 1}{4 \times 10^{-3}}$$

$$= 125 \times 10^{-6}$$

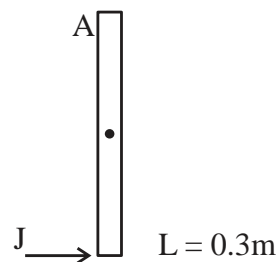
$$= 125$$

59. A uniform rod AB of mass 2 kg and Length 30 cm at rest on a smooth horizontal surface. An impulse of force 0.2 N s is applied to end B. The time taken by the rod to turn through at right angles will be

$$\frac{\pi}{x} \text{ s, where } x = ______.$$

Ans. (4)

Sol.



Impulse $J = 0.2 \text{ N-s}$

$$J = \int F dt = 0.2 \text{ N-s}$$

Angular impuls (\vec{M})

$$\vec{M}_c = \int \tau dt$$

$$= \int F \frac{L}{2} dt$$

$$= \frac{L}{2} \int F dt = \frac{L}{2} \times J$$

$$= \frac{0.3}{2} \times 0.2$$

$$= 0.03$$

$$I_{cm} = \frac{ML^2}{12} = \frac{2 \times (0.3)^2}{12} = \frac{0.09}{6}$$

$$M = I_{cm} (\omega_f - \omega_i)$$

$$0.03 = \frac{0.09}{6} (\omega_f)$$

$$\omega_f = 2 \text{ rad/s}$$

$$\theta = \omega t$$

$$t = \frac{\theta}{\omega} = \frac{\pi}{2 \times 2} = \frac{\pi}{4} \text{ sec.}$$

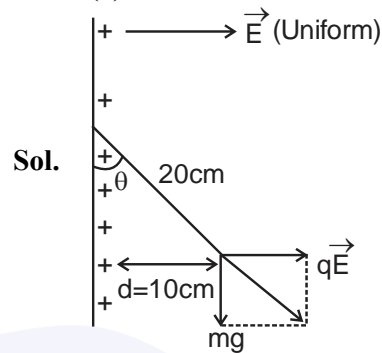
$$X = 4$$

60. Suppose a uniformly charged wall provides a uniform electric field of $2 \times 10^4 \text{ N/C}$ normally. A charged particle of mass 2 g being suspended through a silk thread of length 20 cm and remain stayed at a distance of 10 cm from the wall. Then

the charge on the particle will be $\frac{1}{\sqrt{x}} \mu\text{C}$ where

$x = \underline{\hspace{2cm}}$. [use $g = 10 \text{ m/s}^2$]

Ans. (3)



Sol.

$$\sin \theta = \frac{10}{20} = \frac{1}{2}$$

$$\theta = 30^\circ$$

$$\tan \theta = \frac{qE}{mg}$$

$$\tan 30^\circ = \frac{q \times 2 \times 10^4}{1 \times 10^{-3} \times 10}$$

$$\frac{1}{\sqrt{3}} = q \times 10^6$$

$$q = \frac{1}{\sqrt{3}} \times 10^{-6} \text{ C}$$

$$x = 3$$