1. The solar heat pipe works on the principle of

(A) heating and condensation cycle

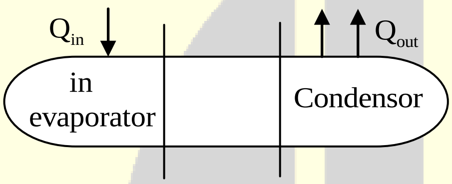
(B) evaporation and condensation cycle

(C) cooling and condensation cycle

(D) heating and evaporation cycle

Key: (D)

Exp: When the solar radiation energy falls on the fin tube heat pipe, heat is absorbed and transmitted to the working fluid in the heat pipe. This heat is absorbed by the working fluid by which it evaporates and again it is moved in a close cycle for condensation.



2. A good approximation of the measured solar spectrum is made by

(A) black-body energy distribution

(B) Planck's energy distribution

(C) inverse square law

(D) solar constant

Key: (A)

Exp: The spectrum of the sun's solar radiation close to that of black body with a temperature about 5800K.

3. Which one of the following types of tracker uses liquid contained in canisters that can turn easily into vapour?

(A) Active tracker

(B) Passive tracker

(C) Single-axis tracker

(D) Altitude-azimuth tracker

Key: (B)

Exp: Passive trackers use the heat from sunlight to vaporize liquid Freon contained in cannsiters mounted on the tracker.

4. Which type of flat-plate collector is used to heat the swimming pools with plastic panel, utilizing solar energy?

(A) Pipe and fin type

(B) Full water sandwich type

(C) Thermal traps type

(D) Corrugated plate with selective surface

Key: (B)

Exp: Full water sandwich type are used where both the wetted area and the water capacity are high e.g. swimming pool.

5. The edge loss U_e in a solar collector with respect to edge area A_e, collector area A_C and back loss coefficient U_b is

(A) $U_b\left(\frac{A_e}{A_c}\right)$

(B) $U_b\left(\frac{A_c}{A_e}\right)$

(C) $A_c\left(\frac{A_e}{U_b}\right)$

(D) $U_b\left(\frac{A_e}{2A_c}\right)$

Key: (A)

Exp: $U_b\left(\frac{A_e}{A_c} = U_e\right)$

6. In solar porous type air heater, the pressure drop is usually

(A) higher than non-porous type

(B) same as in non-porous type

(C) lower than non-porous type

(D) zero

Key: (B)

The non porous systems are generally irreversible and used where higher pressure drops are required. Porous type air heaters $\rightarrow$ lesser pressure drop is achieved due to lower power consumption.

7. In a drainback solar water heating system

(A) the water in the heat exchanger is recycled

(B) the water is heated in collectors only during times when there is available heat

(C) at the collector, the mixture of water and propylene-glycol is heated and returned to a solar storage tank

(D) there is an expansion tank with enclosed air chamber to assist water draining

Key: (C)

Exp: Drain back solar systems do not have expansion tank or propylene glycol system. The water is recycled in heat exchange by separation method is used further is a closed cycle.

8. A PV cell is illuminated with irradiance (E) of $1000\,W/m^2$. If the cell is 100 mm × 100 mm in size and produces 3 A at 0.5V at the maximum power point, the conversion efficiency will be

(A) 15%

(B) 19%

(C) 23%

(D) 27%

Key: (A)

Exp: $\text{Conversion efficiency} = \dfrac{V_m.I_m}{\text{Irradiation} \times \text{area}}$

$$= \frac{3\times0.5}{1000\times100\times100\times10^{-6}} = \frac{1.5}{10}\times100 = 15\%$$

9. In a barrage of 300000 m^2 area with a tide height of 3m, barrage drain time of 10hr, density of seawater as 1025 kg/m^3 acceleration as 9.8 m/s^2, the average power will be

(A) 377 kW

(B) 381 kW

(C) 388 kW

(D) 396 kW

Key: (A)

Average power, = mgh/2

$$P_{avg} = \frac{W}{t} = \frac{1}{2}\frac{\rho g A R^2}{t}$$

$$= \frac{1}{2}\times\frac{1025\times9.8\times300000\times3^2}{10\times3600} = 377\text{ kW}$$

10. The platinum nano-coating is made on the anode of the fuel cell to

(A) Create lighter and more efficient fuel cell membranes

(B) Make the fuel effective

(C) Create high thermal conductivity in the cell

(D) Make the fuel cell non-corrosive

Key: (B)

Platinum nano-coating make the fuel effective.

11. In a fuel cell, electric current is produced when

(A) Hydrogen and oxygen react with each other and electrons are freed

(B) Hydrogen reacts with water and electrons are freed

(C) Oxygen reacts with water and electrons are freed

(D) Electrons react with molecules of hydrogen and oxygen is freed

Key: (A)

They generate electricity from the reaction of hydrogen with oxygen to from water in a process which is the reverse of electrolysis.

12. Which one of the following is suitable for fuel cell electric vehicle (FCEV)?

(A) Direct methanol fuel cell (DMFC)

(B) Alkaline fuel cell (AFC)

(C) Proton exchange membrane fuel cell (PEMFC)

(D) Solid oxide fuel cell (SOFC)

Key: (C)

Direct methanol fuel cell DMFC is being used in electric vehicles.

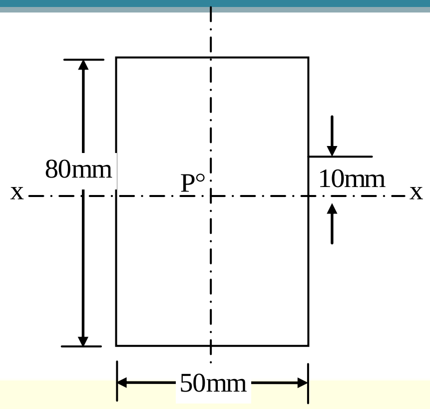
Ex: Tesla car works on this.

Alkali cell $\rightarrow$ Rockets

PEMFC $\rightarrow$ Power generation

DMFC $\rightarrow$ Transport Applications

13. A pull of 100 kN acts on a bar as shown in the figure in such a way that it is parallel to the bar axis and is 10 mm away from xx:



The maximum bending stress produced in the bar at xx is nearly

(A) 20.5 N/mm^2

(B) 18.8 N/mm^2

(C) 16.3 N/mm^2

(D) 14.5 N/mm^2

Key: (B)

Exp: P = 100kN

e = 10 mm

b = 50 mm

d = 80 mm

$$\sigma = \frac{M}{I}y = \frac{6Pe}{bd^2}$$

$$= \frac{6\times100\times10^3\times10}{50\times80^2} = 18.75\text{ MPa}$$

14. The frequency of oscillation is the number of cycles per unit time described by the particle, given by the relation

(A) $f = \frac{\omega}{2\pi}$

(B) $\frac{1}{f} = \frac{\omega}{2\pi}$

(C) $f' = \frac{2\pi r}{T}$

(D) $f' = \frac{2\pi NT}{\omega}$

Key: (A)

15. A particle of mass 1 kg moves in a straight line under the influence of a force which increases linearly with time at the rate of 60N/s, it being 40 N initially. The position of the particle after a lapse of 5 s, if it started from rest at the origin, will be

(A) 1250 m
(B) 1500 m
(C) 1750 m
(D) 2000 m

Key: (A)

m = 1 kg

$$\frac{F}{t}=60,\ F=m\frac{dv}{dt}$$

$$\frac{m}{t}.\frac{dv}{dt}=60 \quad (m=1)$$

$$dv=60t\,dt$$

$$v=\frac{60t^2}{2}+c\Rightarrow v=\frac{60t^2}{2}$$

$$s=\frac{60t^3}{6}=\frac{60\times(5)^3}{6}=1250\text{ m}$$

16. Rails are laid such that there will be no stress in them at 24°C. If the rails are 32 m long with an expansion allowance of 8 mm per rail, coefficient of linear expansion the stress in the rails at 80°c will be nearly

(A) 68 MPa
(B) 75 MPa
(C) 83 MPa
(D) 90 MPa

Key: (B)

L = 32 m

$$\Delta=8\text{mm};\ \alpha=11\times10^{-6}/°C;\ E=205\text{ GPa}$$

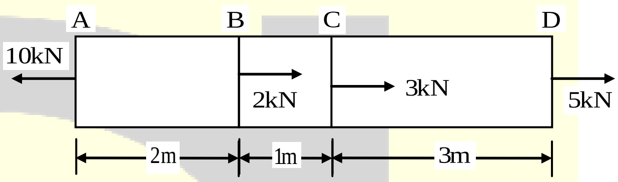
$$\Delta T=80-24=56°$$

$$\sigma=E\left(\frac{\alpha\Delta TL-\Delta}{L}\right)$$

$$=205\times10^3\left(\frac{11\times10^{-6}\times56\times32000-8}{32000}\right)$$

$$=75.03\text{ MPa}$$

17. The loads acting on a 3mm diameter bar at different points are as shown in the figure:



If $E=205$Gpa, the total elongation of the bar will be nearly

(A) 29.7mm
(B) 25.6 mm
(C) 21.5 mm
(D) 17.4 mm

Key: (A)

$$\delta\ell_{total}=\frac{(P_1L_1+P_2L_2+P_3L_3)}{AE}$$

P_1 = 10kN
P_2 = 10 – 2 = 8kN
P_3 = 5kN
L_1 = 2000 mm
L_2 = 1000 mm
L_3 = 3000 mm

$$A=\frac{\pi}{4}(3)^2,\ E=205\times10^3\text{MPa}$$

$$\delta\ell_{total}=\frac{(10\times10^3\times2000)+(8\times10^3\times1000)+(5000\times3000)}{\frac{\pi}{4}\times(3)^2\times205\times10^3}$$

$$=29.68\text{ mm}$$

18. A hollow circular bar used as a beam has its outer diameter thrice the inside diameter. It is subjected to a maximum bending moment of 60 MN m. If the permissible bending stress is limited to 120 MPa, the inside diameter of the beam will be.

(A) 49.2 mm
(B) 53.4 mm
(C) 57.6 mm
(D) 61.8 mm

Key: (C)

$d_o = 3d_i$

$M = 60MN - m$

$= 60\times10^6 N - m = 60\times10^9 N - m$

$\sigma = 120\text{ MPa} \Rightarrow \sigma = \dfrac{32M}{\pi d_0^3\left(1-k^4\right)}$

$d_0^3 = \dfrac{32\times60\times10^9}{\pi\times120\times\left(1-0.33^4\right)}$

$d_o = 172.76mm;\ d_i = 57.6mm$

19. In a beam of I-section, which of the following parts will take the maximum shear stress when subjected to traverse loading?

1. Flange
2. Web

Select the **CORRECT** answer using code given below.

(A) 1 only
(B) 2 only
(C) Both 1 and 2
(D) Neither 1 nor 2

Key: (B)

20. Which of the following statements is/are **CORRECT**?

1. In uniformly distributed load, the nature of shear force is linear and bending moment is parabolic.
2. In uniformly varying load, the nature of shear force is linear and bending moment is parabolic.
3. Under no loading condition, the nature of shear force is linear and bending moment is constant.

Select the **CORRECT** answer using the code given below.

(A) 1 and 2
(B) 1 and 3
(C) 2 only
(D) 1 only

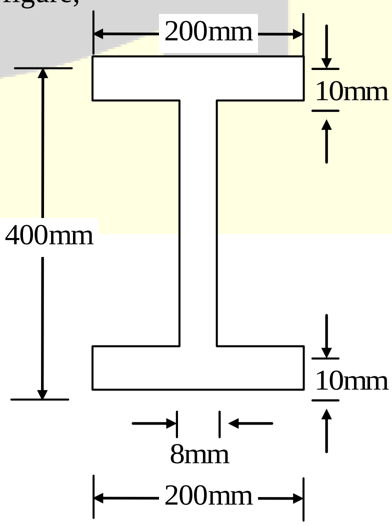
Key: (D)

$\omega(x) = \omega x^o$

$S.F = \int \omega(x)dx = \omega x'(\text{linear})$

$B.M = \int S.Fdx = \dfrac{\omega x^2}{2}(\text{parabolic})$

21. The cross-section of the beam is as shown in the figure;



If the permissible stress is $150 N/mm^2$, the bending moment M will be nearly

(A) 1.21×10^8 N mm

(B) 1.42×10^8 N mm

(C) 1.64×10^8 N mm

(D) 1.88×10^8 N mm

Key: (B)

$$I = \frac{200 \times 400^3}{12} - \frac{2 \times 96 \times 380^3}{12}$$

$$= 1.8871 \times 10^8 \, mm^4$$

$\sigma = 150$ MPa; $y = 200$ mm

$$M = \frac{\sigma I}{y} = \frac{150 \times 1.8871 \times 10^8}{200}$$

$$= 1.42 \times 10^8 \, N - mm.$$

22. In a propeller shaft, sometimes apart from bending and twisting, end thrust will also develop stresses which would be

(A) Tensile in nature and uniform over the cross-section

(B) Compressive in nature and uniform over the cross-section

(C) Tensile in nature and non-uniform over the cross-section

(D) Compressive in nature and non-uniform over the cross-section

Key: (B)

23. A spherical shell of 1.2 m internal diameter and 6 mm thickness is filled with water under pressure until volume is increased by $400 \times 10^3 mm^3$. If E = 204 GPa, Poisson's ratio $\nu = 0.3$, neglecting radial stresses, the hoop stress developed in the shell will be nearly

(A) 43 MPa

(B) 38 MPa

(C) 33 Mpa

(D) 28 Mpa

Key: (A)

D = 1200 mm; t = 6mm

$\Delta V = 400 \times 10^3$

$E = 204$ GPa

$\nu = 0.3$

$\sigma_t = ?$

$$V = \frac{4}{3} \times \pi \times \left(600^3\right) = 904,778,684.2 \, mm^3$$

$$\epsilon_V = \frac{\delta V}{V} = \frac{3\sigma_t}{E}(1 - \nu)$$

$$\Rightarrow \frac{400 \times 10^3}{904,778,684.2} = \frac{3 \times \sigma_t}{204 \times 10^3}(1 - 0.3)$$

$\sigma_t = 43$ MPa

24. The inner diameter of a cylindrical tank for liquefied gas is 250 mm. The gas pressure is limited to 15 MPa. The tank is made of plain carbon steel with ultimate tensile strength of $340 N/mm^2$, Poisson's ratio of 0.27 and the factor of safety of 5. The thickness of the cylinder wall will be.

(A) 60 mm

(B) 50 mm

(C) 40 mm

(D) 30 mm

Key: (D)

D = 250 mm

P = 15MPa

$\sigma_{ut} = 340$ MPa

$\nu = 0.27$

$FOS = 5$

$t = ?$

$$\frac{PD}{2t} \le \frac{\sigma_{ut}}{FOS}$$
$$\frac{15\times 250}{2\times t} = \frac{340}{5}$$
$$t = 27.5\ \text{mm} \simeq 30\ \text{mm}$$

25. The structure of sodium chloride is considered as

(A) a body-centered crystal

(B) a simple cubic crystal

(C) two interpenetrating FCC sub-lattices of Cl^- ions and Na^+ ions

(D) a cubic crystal with Na^+ and Cl^- alternatively at the cubic corners

Key: (C)

The structure of NaCl is considered as two interpenetrating FCC subtitute of Cl ions and Na+ ions.

26. Hardenability of steel is assessed by

(A) Charpy impact test

(B) Rockwell hardness test

(C) Jominy end-quench test

(D) Open- hole test

Key: (C)

27. A metal has lattice parameter of 2.9 A, density of of 7.87 g/cc, atomic weight of 55.85, and Avogadro's number is 6.0238 × 10^{23}. The number of atoms per unit cell will be nearly

(A) 1

(B) 2

(C) 8

(D) 16

Key: (B)

Density, $\rho = \frac{n.A}{V_c.N_A}$

n = number of atoms (is to be determined)

A = Atomic weight = 55.85

V_c = volume of unit cell

$V_c = a^3 = (2.9 \times 10^{-10})^3\ m^3$

N_A = Avogado's Number

$= 6.023 \times 10^{23}$ atom/mol

$\rho = 7.87\ \text{gm/cc} = 7.87\times 10^6\ \text{gm/m}^3$

$$\Rightarrow 7.87\times 10^6 = \frac{n\times 55.85}{\left(2.9\times 10^{-10}\right)^3 \times 6.023\times 10^{23}}$$

$\Rightarrow n = 2.06 \approx 2$

28. An atomic packing factor (APF) for the BCC unit cell of hard spheres atoms will be

(A) 0.63

(B) 0.68

(C) 0.73

(D) 0.78

Key: (B)

29. The distinct characteristic of Invar is

(A) It is magnetic

(B) It has low coefficient of thermal expansion

(C) It has high tensile strength

(D) It is non corrosive

Key: (B)

30. An alloy produced by adding 1% of tin to Muntz metal is called as

(A) A brass

(B) Admiralty brass

(C) Naval brass

(D) Leaded brass

Key: (C)

Naval Brass = 60% Cu + 39% Zn + 1%Sn

31. A sample of glass has a crack of half-length 2μm. The Young's modulus of glass is 70 GN/m^2 and specific surface energy is 1 J/m^2. The fractures strength will be

(A) 885 MPa
(B) 895 MPa
(C) 915 MPa
(D) 935 MPa

Key: (D)

Fracture strength

$$=\frac{1}{2}\left[\gamma_f\frac{E}{C}\right]^{1/2}=\frac{1}{2}\left[1\times\frac{70\times10^9}{2\times10^{-6}}\right]^{1/2}=935.4\text{ MPa}$$

32. In the Pb-Sn system, the fraction of total α phase is 3 times the fraction of β phase at eutectic temperature of 182°C, Pb with 19% Sn dissolved in it, Sn with 2.5% Pb dissolved in it, and liquid is in equilibrium. The alloy composition of tin (Sn) and lead (Pb) are nearly

(A) 28.6% and 71.4%
(B) 38.6% and 61.4%
(C) 48.6% and 51.4%
(D) 58.6% and 41.4%

Key: (B)

$$m_\alpha=\frac{QR}{PR}$$

$$m_\beta=\frac{PQ}{PR}$$

$$Bm_\alpha=3m_\beta$$

$$\frac{QR}{PR}=3\times\frac{PQ}{PR}$$

$$97.5-C_0=3\times(C_0-19)$$

$$97.5-C_0=3C_0-57$$

$$4C_0=97.5+57$$

$$C_0=38.6\%\text{ Sn}$$

$$\therefore\%\text{ Pb}=100-38.6=61.4$$

33. A cylindrical specimen of steel having an original diameter of 12.8 mm is tensile tested to fracture and found to have engineering fracture strength σ_f of 460 MPa. If its cross-sectional diameter at fracture is 10.7 mm, the true stress at fracture will be

(A) 660 MPa
(B) 645 MPa
(C) 630 MPa
(D) 615 MPa

Key: (A)

True stress at fracture

True stress = engineering stress×(1+ true strain)

$$\sigma_t=\sigma_f\frac{A_0}{A}=460\left(\frac{12.8}{10.7}\right)^2=658.3\text{ MPa}$$

34. An iron container 10cm × 10cm at its base is filled to a height of 20 cm with a corrosive liquid. A current is produced as a result of an electrolytic cell, and after four weeks, the container has decreased in weight by 70 g. If n = 2, F = 96500 C and M = 55.84 g/mole, the current will be

(A) 0.05 A
(B) 0.10 A
(C) 0.20 A
(D) 0.40 A

Key: (B)

Total exposure time = 4 × 7 × 24 = 3600

= 2.42×10^6S

As per Faraday's law,

$$m = \frac{QM}{nF} = \frac{ItM}{nF}$$

Where Q=charge, F=current,

F= Faraday's constant = 96500 C

n = number of equivalents (moles of electrons)transferred per mol of metal

m = mass of metal oxidised (g)

M = molecular wt. of metal (g/mole)

From Faraday law,

$$\Rightarrow I = \frac{mnF}{tM} = \frac{70 \times 2 \times 96500}{(2.42 \times 10^6 \times 55.84)} = 0.1A$$

35. A copper piece originally 305 mm long is pulled in tension with a stress of 276 MPa. If the deformation is entirely elastic and the modulus of elasticity is 110 GPa, the resultant elongation will be nearly

(A) 0.43 mm

(B) 0.54 mm

(C) 0.65 mm

(D) 0.77 mm

Key: (D)

$$\text{Elongation, } \delta\ell = \frac{\sigma\ell}{E} = \frac{276 \times 305}{110 \times 10^3} = 0.77\text{mm}$$

36. The indentation on a steel sample has been taken using 10 mm tungsten carbide ball at 500 kgf load. If the average diameter of the indentation is 2.5 mm, the BHN will be nearly

(A) 90

(B) 100

(C) 110

(D) 120

Key: (B)

Brinell hardness number,

$$BHN = \frac{F}{\frac{\pi D}{2}\left(D - \sqrt{D^2 - d^2}\right)}$$

$$= \frac{2 \times 500}{\pi \times 10\left[10 - \sqrt{10^2 - 2.5^2}\right]} = 100$$

37. Which of the following statements are **CORRECT** with respect to inversion of mechanisms?

1. It is a method of obtaining different mechanisms by fixing different links of the same kinematic chain.
2. It is a method of obtaining different mechanisms by fixing the same links of different kinematic chains.
3. In the process of inversion, the relative motions of the links of the mechanisms produced remain unchanged.
4. In the process of inversion, the relative motions of the links of the mechanisms produced will change accordingly.

Select the **CORRECT** answer using the code given below:

(A) 1 and 3

(B) 1 and 4

(C) 2 and 3

(D) 2 and 4

Key: (A)

38. For the follower with stroke S, following the cycloidal motion, the radius of the rolling circle will be

(A) $S \times 2\pi$

(B) $\frac{S}{2\pi}$

(C) $\frac{2\pi}{S}$

(D) $S + 2\pi$

Key: (B)

39. A vertical shaft of 100 mm diameter and 1 m length has its upper end fixed at the top. The other end carries a disc of 5000 N and the modulus of elasticity of the shaft material is $2 \times 10^5 \, N/mm^2$. Neglecting the weight of the shaft, the frequency of the longitudinal vibrations will be nearly

(A) 279.5 Hz

(B) 266.5 Hz

(C) 253.5 Hz

(D) 241.5 Hz

Key: (A)

$d = 100mm; \; \ell = 1000mm; \; W = 5000N$

$E = 2 \times 10^5 \, N/mm^2$

$$\delta = \frac{WL}{AE} = \frac{5000 \times 1000}{\frac{\pi}{4} \times 100^2 \times 2 \times 10^5} = 3.18 \times 10^{-3} mm$$

$$\omega_n = \sqrt{\frac{g}{\delta}} = \sqrt{\frac{9.81 \times 10^3}{3.18 \times 10^{-9}}} = 1755.019 \text{ rad/sec}$$

$$= 280 \text{ Hz}$$

40. The accurate method of finding the natural frequency of transverse vibrations of a system of several loads attached to some shaft is

(A) Dunkerley method

(B) energy method

(C) Stodola method

(D) Dunkerley and energy method

Key: (B)

41. The speed at which the shaft runs, so that the deflection of the shaft from the axis of rotation becomes infinite, is known as

(A) whipping speed

(B) damping speed

(C) resonant speed

(D) gravitational speed

Key: (A)

42. Which one of the following is **not** the **CORRECT** statement with respect to the involute profile toothed gears in mesh?

(A) Pressure angle remains constant from the start till the end of the engagement.

(B) The base circle diameter and the pitch circle diameter of the two mating involutes are proportional.

(C) When two involutes are in mesh, the angular velocity ratio is proportional to the size of the base circles.

(D) The shape of the involute profile depends only on the dimensions of the base circle.

Key: (C)

43. The centre distance C between two gears, in terms of base circle radii R_1, R_2 and the pressure angle ϕ, is

(A) $\frac{\cos\phi}{R_1 + R_2}$

(B) $\frac{R_1 + R_2}{\cos\phi}$

(C) $\left(\frac{R_1}{R_2}\right).\cos\phi$

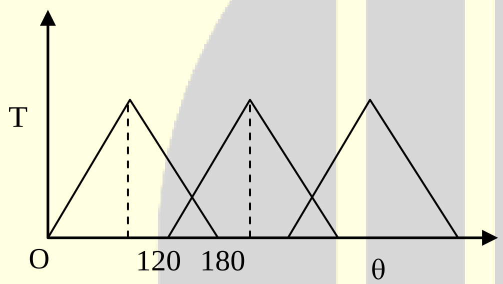
(D) $\left(\frac{R_2}{R_1}\right).\cos\phi$

Key: (B)

44. A three-cylinder single-acting engine has its cranks at 120°. The turning moment diagram for each cycle is a triangle for the power stroke with a maximum torque of 60 Nm at 60° after the dead centre of the corresponding crank. There is no torque on the return stroke. The engine runs at 400 r.p.m. the power developed will be

(A) 1745 W
(B) 1885 W
(C) 1935 W
(D) 1995 W

Key: (B)



Work done $=\frac{1}{2}\times\pi\times60\times3=90\pi$ N-m

Mean Torque $=\frac{W.D}{2\pi}=\frac{90\pi}{2\pi}=45$ N-m

$P=\frac{2\pi NT}{60}=\frac{2\pi\times400\times45}{60}$
$=1884.9W=1885W$

45. A vertical single-cylinder opposed piston type engine has reciprocating parts of mass 2000 kg for the lower piston and 2750 kg for the upper piston. The lower piston has a stroke of 60 cm and the engine is in primary balance. If the ratio of the length of connecting rod to crank is 4 for the lower piston and 8 for the upper piston, and when the crankshaft speed is of 135 r.p.m., the maximum secondary unbalanced force will be

(A) 48935.5 N
(B) 46946.5 N
(C) 44968.5 N
(D) 42989.5 N

Key: (C)

$m_1=2000\text{ kg};\ m_2=2750\text{kg}$

$r_1=\frac{60}{2}=30\text{cm};\quad r_2=?$

$n_1=\frac{\ell_1}{r_1}=4;\quad n_2=\frac{\ell_2}{r_2}=8$

$N=135\text{ rpm}$

$\omega=\frac{2\pi\times135}{60}=14.137\text{ rad/sec}$

$m_1r_1=m_2r_2$

$r_2=\frac{2000\times30}{2750}=21.81\text{m}$

Unbalanced force $=\frac{m_1r_1\omega_1^2}{n_1}+\frac{m_2r_2\omega_2^2}{n_1}$

$=\left(\frac{2000\times0.3\times14.137^2}{4}\right)+\left(\frac{2750\times0.2181\times14.137^2}{8}\right)$

$=29978.2+14983.48=44,961.6N$

46. The reciprocating mass is balanced when primary force is

1. balanced by the mass $=\ cmr\omega^2\cos\theta$

2. unbalanced by the mass $=cmr\omega^2\cos\theta$

3. balanced by the mass =
$(1-c)cmr\omega^2\cos\theta$

4. unbalanced by the mass =
$(1-c)cmr\omega^2\cos\theta$

Select the **CORRECT** answer using the code given below:

(A) 1 and 3
(B) 2 and 3
(C) 1 and 4
(D) 2 and 4

Key: (B)

47. The active gyroscopic torque in gyroscope about a horizontal axis represents

(A) the torque required to cause the axis of spin to precess in the vertical plane

(B) the torque required to cause the axis of spin to precess in the horizontal plane

(C) the force required to cause the axis of spin to process in the horizontal plane

(D) the force required to cause the axis of spin to process in the vertical plane

Key: (B)

48. The change in governor height for a Watt governor when speed varies from 100 r.p.m. to 101 r.p.m. will be nearly

(A) 1.8 mm

(B) 2.6 mm

(C) 3.4 mm

(D) 4.2 mm

Key: (A)

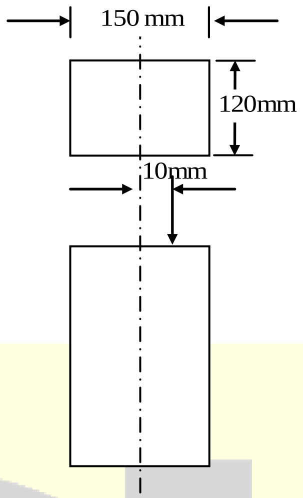
$$\omega_1 = \frac{2\pi \times 100}{60} = 10.47 \text{ rad/sec}$$

$$\omega_2 = \frac{2\pi \times 101}{60} = 10.57 \text{ rad/sec}$$

$$h = \frac{g}{\omega_1^2} - \frac{g}{\omega_2^2}$$

$$= 9.81\left[\frac{1}{10.47^2} - \frac{1}{10.57^2}\right] = 1.68 \text{ mm.}$$

49. A rectangular strut is 150 mm wide and 120 mm thick. It carries a load of 180 kN at an eccentricity of 10 mm in a plane bisecting the thickness as shown in the figure:



The maximum intensity of stress in the section will be

(A) 14 MPa

(B) 12MPa

(C) 10Mpa

(D) 8 MPa

Key: (A)

$$b = 150\text{mm},\ t = 120\text{mm},\ P = 180 \text{ kN}$$
$$e = 10\text{mm}$$

$$\sigma = \frac{M}{I}y \pm \frac{P}{A}$$

$$\sigma_{max} = \frac{M}{I}y + \frac{P}{A} = \frac{Pe}{I}y + \frac{P}{A}$$

$$= \left(\frac{180\times10^3\times10}{\frac{120\times150^3}{12}}\times75\right) + \left(\frac{180\times10^3}{120\times150}\right)$$

$$= 4 + 10 = 14 \text{ MPa}$$

50. The theory of failure used in designing the ductile materials in a most accurate way is by

(1) maximum principal stress theory

(2) distortion energy theory

(3) maximum strain theory

Select the **CORRECT** answer using the code given below:

(A) 1, 2 and 3
(B) 1 only
(C) 2 only
(D) 3 only

Key: (C)

51. When a load of 20 kN is gradually applied at a particular point in a beam, it produces a maximum bending stress of 20 MPa and deflection of 10mm. What will be the height from which a load of 5kN should fall onto the beam at the same point if the maximum bending stress is 40 MPa?

(A) 80 mm
(B) 70 mm
(C) 60 mm
(D) 50 mm

Key: (C)

$\delta = 10\text{mm}$

Static loading

$\sigma_1 = 20\text{MPa} \qquad P_1 = 20\text{ kN}$

$\sigma_2 = ? \qquad P_2 = 50\text{kN}$

$\sigma \propto P$

$$\frac{\sigma_1}{\sigma_2} = \frac{P_1}{P_2} \Rightarrow \frac{20}{\sigma_2} = \frac{20\times10^3}{5000} \Rightarrow \sigma_2 = 5\text{MPa}$$

$\delta \propto P$

$$\frac{\delta_1}{\delta_2} = \frac{P_1}{P_2} \Rightarrow \frac{10}{\delta_2} = \frac{20\times10^3}{5\times10^3} \Rightarrow \delta_2 = 2.5\text{mm}$$

$$\sigma_{max} = \frac{W}{A}\left[1+\sqrt{1+\frac{2hAE}{WL}}\right] = \sigma\left[1+\sqrt{\frac{2h}{\delta}}\right]$$

$$40 = 5\left[1+\sqrt{\frac{2h}{2.5}}\right]$$

$$8 = 1+\sqrt{\frac{2h}{2.5}} 7^2 = \frac{2h}{2.5}$$

$$h = 49\times1.25 = 60\text{mm}$$

52. The areas of fatigue failure in a part may be in the

1. Region having slow growth of crack with a fine fibrous appearance.
2. Region having faster growth of crack with a fine fibrous appearance.
3. Region of sudden fracture with a coarse granular appearance.
4. Region of gradual fracture with a coarse granular appearance.

Select the correct answer using the code given below.

(A) 2 and 3
(B) 2 and 4
(C) 1 and 4
(D) 1 and 3

Key: (D)

53. The shock-absorbing capacity (resilience) of bolts can be increased by

(A) increasing the shank diameter above the core diameter of threads
(B) reducing the shank diameter to the core diameter of threads
(C) decreasing the length of shank portion of the bolt
(D) pre-heating of the shank portion of the bolt

Key: (B)

54. The torque required to tighten the bolt comprises of the

(A) torque required in overcoming thread friction only
(B) torque required in inducing the overcoming circumference hoop stress

(C) torque required in overcoming circumferential hoop stress

(D) torque required in overcoming thread friction and inducing the pre-load and also the torque required to overcome collar friction between the nut and the washer

Key: (D)

55. A steel spindle transmits 4 kW at 800 r.p.m. The angular deflection should not exceed 0.25°/m length of the spindle. If the modulus of rigidity for the material of the spindle is 84 GPa, the diameter of the spindle will be

(A) 46 mm

(B) 42 mm

(C) 38 mm

(D) 34 mm

Key: (D)

$P = 4\text{kW},\ N = 800\text{ rpm},\ \theta = 0.25°/\text{mt}$

$G = 84\text{ GPa},\ d = ?$

$$\frac{\theta}{\ell} = \frac{T}{GJ}$$

$$T = \frac{4\times 60,000}{2\pi\times 800} = 47.74\text{ N-m}$$

$$\frac{0.25\times\pi}{180\times 1000} = \frac{47.74\times 10^3}{84\times 10^3\times\frac{\pi}{32}d^4} \Rightarrow d = 34\text{ mm}$$

56. A taper roller bearing has a dynamic load capacity of 26 kN. The desired life for 90% of the bearings is 8000 hr and the speed is 300 p.m. The equivalent radial load that the bearing can carry will be nearly

(A) 5854 N

(B) 5645 N

(C) 5436 N

(D) 5227 N

Key: (A)

$C = 26\text{kN},\ L_h = 8000\text{ hrs},\ N = 300\text{ rpm}$

$$L_{10} = \frac{L_h\times N\times 60}{10^6} = \frac{8000\times 300\times 60}{10^6}$$

$= 144\text{ mill rev}$

$$P_e = \frac{C}{(L_{10})^{3/10}} = \frac{26000}{144^{0.3}} = 5854\text{N}$$

57. Hollow shafts are stronger than solid shafts having same weight because

(A) the stiffness of hollow shaft is less than that of solid shaft

(B) the strength of hollow shaft is more than that of solid shaft

(C) the natural frequency of hollow shaft is less than that of solid shaft

(D) in hollow shafts, material is not spread at large radius

Key: (B)

58. A propeller shaft is required to transmit 45 kW power at 500 r.p.m. It is a hollow shaft having inside diameter 0.6 times the outside diameter. It is made of plain carbon steel and the permissible shear stress is 84 N/mm^2. The inner and outer diameters of the shaft are nearly.

(A) 21.7 mm and 39.1 mm

(B) 23.5 mm and 39.1 mm

(C) 21.7 mm and 32.2 mm

(D) 23.5 mm and 32.2 mm

Key: (B)

$P = 45\text{ kW}$

$N = 500\text{ rpm}$

$$T = \frac{P\times 60000}{2\pi N} = \frac{45\times 60000}{2\pi\times 500} = 859.436\text{ N}-\text{m}$$

$d_i = 0.6d_o,\quad \tau = 84\text{ N/mm}^2$

$$\tau = \frac{16\times T}{\pi d_0^3\left(1-k^4\right)}$$

$$84 = \frac{16\times 859.436\times 10^3}{\pi\times d_o^3\left(1-0.6^4\right)}$$

$$d_o = 39.11\text{mm},\quad d_i = 23.47\text{mm}$$

59. A bicycle and rider travelling at 12 km/hr on a level road have a mass of 105 kg. A brake is applied to a rear wheel having 800 mm diameter. The pressure on the brake is 80 N and the coefficient of friction is 0.06. The number of turns of the wheel before coming to rest will be

(A) 48.3 revolutions

(B) 42.6 revolutions

(C) 38.3 revolutions

(D) 32.6 revolutions

Key: (A)

$V = 12\text{ kmph},\quad m = 105\text{kg},\quad D = 800\text{mm}$

$P = 80\text{N},\ \mu = 0.06$

KE = Work done

$$\frac{1}{2}\times mv^2 = F\times \text{distance}$$

$$\frac{1}{2}\times 105\times\left(12\times\frac{5}{18}\right)^2 = (0.06\times 80)\times\text{distance}$$

Distance = 121.52 m

Number of revolution

$$= \frac{\text{Distance}}{\text{Circumference}} = \frac{121.52}{2\pi\times 0.8} = 48.3\text{ rev}$$

60. To avoid self-engagement in cone clutch, its semi-cone angle is always kept

(A) smaller than the angle of static friction

(B) equal to the angle of static friction

(C) greater than the angle of static friction

(D) half of the angle of static friction

Key: (C)

61. Water is discharged from a tank maintained at a constant head of 5 m above the exit of a straight pipe 100 m long and 15 cm in diameter. If the friction coefficient for the pipe is 0.01 the rate of flow will be nearly

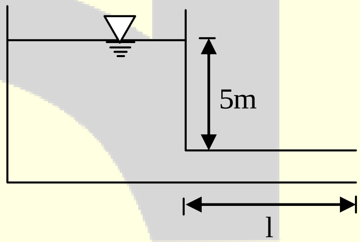
(A) 0.04 m^3/s

(B) 0.05 m^3/s

(C) 0.06 m^3/s

(D) 0.07 m^3/s

Key: (D)



Two losses are present in this case

a) Friction loss

b) Sudden energy losses

$$H = \frac{0.5V^2}{2g} + \frac{flV^2}{2dg} \because V = \frac{Q}{A} = \frac{4Q}{\pi d^2}$$

$$\Rightarrow 5 = \frac{0.5\times 16Q^2}{\pi^2.d^4.2g} + \frac{fl.16Q^2}{2\pi^2.d^5.g}$$

$$= Q^2\left[\frac{0.5\times 16}{\pi^2.(0.15)^4.2\times 9.81} + \frac{0.01\times 100\times 16}{2\pi^2(0.15)^s.9.81}\right]$$

$$5 = Q^2\times 1169.697$$

$$Q^2 = 0.0042746 \Rightarrow Q = 0.06538\ m^3/s$$

62. A plate weighing 150 N and measuring 0.8m ×0.8m just slides down an inclined plane over an oil film of 1.2 mm thickness for an inclination of 30° and velocity of 0.2 m/s. Then the viscosity of the oil used is

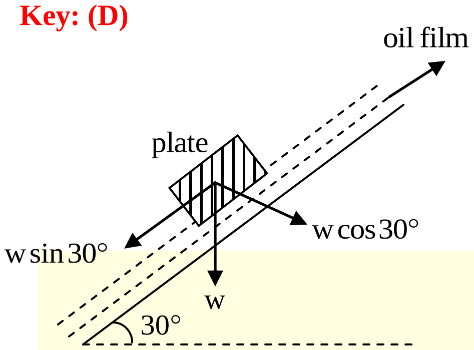
(A) 0.3 Ns/m^2

(B) 0.4 Ns/m^2

(C) 0.5 Ns/m^2

(D) 0.7 Ns/m^2

Key: (D)



For Newtonian fluid,

$$\tau = \mu \frac{du}{dy}$$

Where, $\tau = \text{shear stress}$

$$= \frac{F}{A} = \frac{w \sin 30°}{A}$$

$$= \frac{150 \times 1}{2 \times 0.8 \times 0.8} = \frac{1500}{128} \frac{N}{m^2}$$

$\mu = \text{Dynamic viscosity}$

$\frac{du}{dy} = \text{Rate of shear strain}$

$$\frac{0.2}{1.2 \times 10^{-3}} = \frac{1000}{6} \sec^{-1}$$

$$\text{So, } \frac{15000}{128} = \mu \times \frac{1000}{6}$$

$$\Rightarrow \mu = \frac{15 \times 6}{128} = \frac{90}{128} \Rightarrow \mu = 0.70 \frac{N-S}{m^2}$$

63. A spherical balloon of 1.5 m diameter is completely immersed in water and chained to the bottom. If the chain has a tension of 10 kN, the weight of the balloon will be nearly

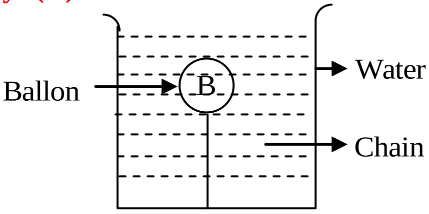
(A) 9.11 kN

(B) 8.22 kN

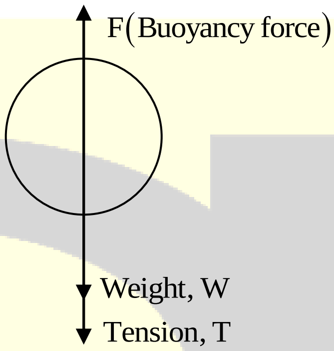
(C) 6.44 kN

(D) 7.33 kN

Key: (D)



Free body diagram for balloon,



So, $F = W + T \Rightarrow W = F - T$

Weight, $W = \rho.g.V - T$

$[\because \rho = \text{Density of water}]$

$$= 1000 \times 9.81 \times \frac{\pi(1.5)^3}{6} - 10 = 17.33 - 10$$

W = 7.33 kN

64. A nozzle at the end of an 80 mm hosepipe produces a jet 40 mm in diameter. When it is discharging the water 1200 rpm, the force on the joint at the base of the nozzle will be

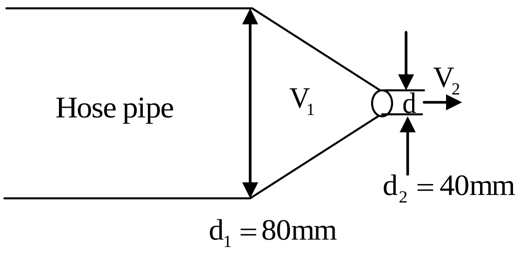
(A) 180 N

(B) 200 N

(C) 220 N

(D) 240 N

Key: (D)



Force at joint

$$F = \rho Q(V_2 - V_1) \qquad \ldots(i)$$

$$\therefore \; V_1 = \frac{Q_1}{A_1} = \frac{1.2\times 4}{60\times\pi\times(0.08)} = 3.98\ \text{m/sec}$$

$$V_2 = 4V_1 = 15.9155\ \text{m/s}$$

$$\therefore \quad F = \rho Q(V_2.V_2)$$

$$= \frac{100\times 1.2}{60}(15.9155 - 398) = 238.71\text{N}$$

65. A vertical water pipe 1.5 m long, tapers from 75 mm diameter at the bottom to 150 mm diameter at the top and the rate of flow is 50 L/s upwards. If the pressure at the bottom end is 150 kN/m^2, the pressure at the top will be nearly

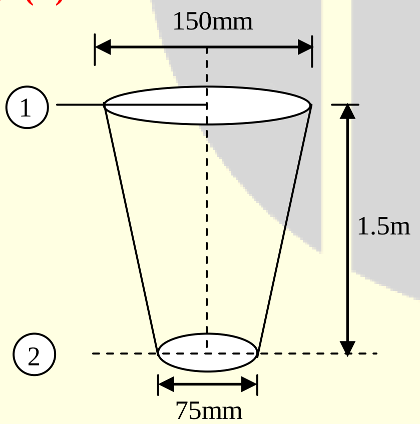
(A) 195.2 kN/m^2

(B) 191.4 kN/m^2

(C) 187.6 kN/m^2

(D) 183.8 kN/m^2

Key: (A)



Applying Bernoulli's equation between (1) and (2)

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$

$$\because \; Q = v_1 A_1 = V_2 A_2$$

$$\Rightarrow \frac{P_1}{\rho g} + \frac{Q^2\times 16}{2\times g.\pi^2.d_1^4} + z_1 = \frac{P_2}{\rho g} + \frac{Q^2\times 16}{2.g.\pi^2.d_2^4}$$

$$\Rightarrow \frac{P_1}{\rho g} = \frac{150\times 10^3}{10^3\times 9.81} + \frac{(0.05)^2\times 16}{2\times\pi^2\times 9.81\times(0.075)^4}$$

$$- \frac{(0.05)^2\times 16}{2\times\pi^2\times 9.81\times(0.15)^4} - 1.5$$

$$\frac{P_1}{\rho g} = 19.91 \Rightarrow P_1 = 1000\times 9.81\times 19.91$$

Pressure at the top of the pipe.

$$P_1 = 195.327\ \text{kN/m}^2$$

66. The stream function for a flow field is $\psi = 3x^2y + (2+t)y^2$. The velocity at a point P for position vector r = 1 + 2j-3k time t = 2 will be

(A) 19i = 12j

(B) 21 i – 12 j

(C) 19i + 22j

(D) 21 i + 22j

Key: (A)

$$\psi = 3xzy + (2+t)/y^2$$

$$u = \frac{\partial\psi}{\partial y} = 3x^2 + 2(2+t)y = 3 + 8\times 2 = 19$$

$$v = -\frac{\partial\psi}{\partial x} = 6xy + 0 = -6\times 1\times 2 = -12$$

$$\bar{v} = u\hat{i} + v\hat{j} = 19\hat{i} = 12\hat{j}$$

67. In a laminar flow through pipe, the point of maximum instability exists at a distance of y from the wall which is

(A) $\frac{3}{2}$ of pipe radius R

(B) $\frac{2}{3}$ of pipe radius R

(C) $\frac{1}{2}$ of pipe radius R

(D) $\frac{1}{3}$ of pipe radius R

Key: (B)

The parameter for instability,

Since, the velocity distribute in pipe

$$u = V_{max}\left(1-\frac{r^2}{R^2}\right)$$

$$\therefore \frac{du}{dr} = \frac{-du}{dy}$$

$$\therefore \frac{du}{dy} = \frac{+2V_{max}r}{R^2} = \frac{2V_{max}.r}{R^2} = \frac{2V_{max}(R-y)}{R^2}$$

$$\therefore X = 2y^2\frac{\rho V_{max}r}{R^2} = (R-y) \qquad \ldots(2)$$

Differentially and equal to zero

$$\frac{dx}{dy} = \frac{2fV_{max}}{\mu R^2}\frac{d}{dy}\left(Ry^2 - y^3\right) = 0$$

$$\therefore 2Ry - 3y^2 = 0 \quad \therefore y(2R-3y) = 0$$

$$\therefore y = 0 \Rightarrow y = \frac{2R}{3}$$

68. $Q = \frac{\partial u'}{\partial x} = \frac{-\partial v'}{\partial y}$ for a turbulent flow signifies

(A) Conservation of bulk momentum transport

(B) Increase in u' in x-direction followed by increase in v' in negative y-direction

(C) turbulence is anisotropic

(D) turbulence is isotropic

Key: (B)

69. A flow field satisfying $\nabla.\vec{V} = 0$ as the continuity equation represents always

(A) A steady compressible flow

(B) An incompressible flow

(C) an unsteady and incompressible flow

(D) an unsteady and compressible flow

Key: (B)

Equation of continuity,

$$\rho(\nabla,\bar{v}) + \frac{\Delta\rho}{\Delta t} = 0$$

For incompressible flow, $\frac{\Delta\rho}{\Delta t} = 0$

$$\nabla.\bar{v} = 0$$

70. An oil of viscosity 8 poise flows between two parallel fixed plates, which are kept at a distance of 30 mm apart. If the drop of pressure for a length of 1m is 0.3 × 10^4 N/m^2 and width of the plates is 500 mm, the rate of oil flow between the plates will be

(A) 4.2 × 10^{-3} m^3/s

(B) 5.4 × 10^{-3} m^3/s

(C) 6.6 × 10^{-3} m^3/s

(D) 7.8 × 10^{-3} m^3/s

Key: (A)

Pressure head loss,

$$h_f = \frac{p_1 - p_2}{\omega} = \frac{12\mu VL}{\omega B^2} \Rightarrow \frac{p_1 - p_2}{L} = \frac{12\mu V}{B^2}$$

$$0.3\times10^4 = \frac{12\times8\times10^{-1}\times V}{\left(30\times10^{-3}\right)^2}$$

$$V = 0.281\,ms^{-1}$$

$\therefore$ Discharge,

$$Q = VBW$$
$$= 0.281\times30\times10^{-3}\times500\times10^{-3}$$
$$= 4.2\times10^{-3}\,m^3/sec$$

71. In case of transmission of hydraulic power by a pipeline to a turbine in a hydroelectric power station the maximum power transmission efficiency through the pipeline is

(A) 76%

(B) 67%

(C) 54%

(D) 42%

Key: (B)

Transmission of power through pipes:

Power (energy/sec) available at the outlet of pipe is

P = weight of water per sec × head available at exit of pipe

$$=\omega Q(H-h_f)=\omega\left(\frac{\pi D^2}{4}V\right)\left(H-\frac{flv^2}{2gD}\right)$$

$$=\omega\frac{\pi}{4}D^2\left(HV-\frac{flv^3}{2gD}\right)$$

For maximum power,

$$\frac{dP}{dV}=\omega\left(\frac{\pi}{4}D^2\right)\left(H-\frac{3flv^2}{2gD}\right)=0$$

$$\Rightarrow H=3h_f$$

i.e., power transmitted through a pipe is maximum if head loss due to friction is $\frac{1}{3}$ of total head loss.

$\therefore$ Efficiency,

$$\eta_{max}=\frac{H-h_f}{H}=\frac{3h_f-h_f}{3h_f}=\frac{2}{3}=66.7\%$$

72. A pipe having a length 200 m and 200 mm diameter with friction factor 0.015, is to be replaced by a 400 mm diameter pipe of friction factor 0.012 to convey the same quantity of flow. The equivalent length of the new pipe for the same head loss will be

(A) 8300 m

(B) 8240 m

(C) 8110 m

(D) 8000 m

Key: (D)

$$h_f=\frac{f\ell Q^2}{12.1d^5}$$

For same discharge and head loss,

$$\frac{f_1\ell_1}{d_1^5}=\frac{f_2\ell_2}{d_2^5}$$

$$\frac{0.015\times 200}{200^5}=\frac{0.012\times\ell_2}{400^5}\Rightarrow\ell_2=8000\text{ m}$$

73. Certain quantities cannot be located on the graph by a point but are given by a point but are given by the area under the curve corresponding to the process. These quantities in concepts of thermodynamics are called as

(A) cyclic functions

(B) point functions

(C) path functions

(D) real function

Key: (C)

Path functions like heat transfer and work transfer can't be represented by points in the graph, but can be given by the area under the curve.

Ex: heat transfer will be area under curve in T-s diagram work transfer will be area under curve in P-V diagram.

74. When 25 kg of water at 95°C is mixed with 35 kg of water at 35°C, the pressure being taken as constant at surrounding temperature of 15°C and C_p of water is 4.2 kJ/kg K, the decrease in available energy due to mixing will be nearly

(A) 270.5 kJ

(B) 277.6 kJ

(C) 281.8 kJ

(D) 288.7 kJ

Key: (C)

After mixing, if t°C in the final temperature, then

$$25\times4.2\times(45-t)=35\times4.2\times(t-35)$$

$$\Rightarrow t=\frac{25\times95+35\times35}{25+35}=60°C$$

Available energy

$$=mCp\left[(T-T_o)-T_o\ell n\frac{T}{T_o}\right]$$

∴ Available energy of 25 kg water at 95°C

$$A_{25}=25\times4.2\times\left[(368-288)288\ell n\frac{368}{288}\right]$$
$$=987.49\text{ kJ}$$

Available energy of 35 kg water at 35°C

$$A_{35}=35\times4.2\times\left[(308-288)-288\ell n\frac{308}{288}\right]$$
$$=97.59\text{ kJ}$$

Final available of 60 kg water at 60°C,

$$A_{60}=60\times4.2\times\left[(333-288)-288\ell n\frac{333}{288}\right]$$
$$=803.27\text{ kJ}$$

∴ Decrease in available energy due to mixing

$$A_{25}+A_{35}-A_{60}=(987.49+97.59-803.27)$$
$$=281.8\text{ kJ}$$

75. A frictionless piston cylinder device contains 5 kg of steam at 400 kPa and 200°C. The heat is now transferred to the steam until the temperature reaches 250°C. If the piston is not attached to a shaft, its mass is constant and by taking the values of specific volume v_1 as 0.53434 m^3/kg and v_2 as 0.529520 m^3/kg the work done by the steam during this process is

(A) 121.7 kJ

(B) 137.5 kJ

(C) 153.3 kJ

(D) 189.1 kJ

Key: (A)

Since the weight of the piston and the atmosphere pressure are constant, so assuming it as a constant pressure process, Work done,

$$W=P(V_2-V_1)$$
$$=P\times m(v_2-v_1)$$
$$=400\times10^3\times5\times(0.59520-0.53434)$$
$$=121.72\text{ kJ}$$

76. A diesel engine has a compression ratio of 14 and cutoff takes place at 6% of the stroke. The air standard efficiency will be

(A) 74.5%

(B) 60.5%

(C) 52.5%

(D) 44.5 %

Key: (B)

$$(V_3-V_2=0.06)(V_1-V_2)$$

$$\left(\frac{V_3}{V_2}-1\right)=0.06\left(\frac{V_1}{V_2}-1\right)$$

$$\Rightarrow(r_c-1)=0.06(r-1)$$
$$\Rightarrow(r_c-1)=0.06(14-1)$$
$$\Rightarrow r_c=1.78$$

$$\eta=1-\frac{1}{(r)^{\gamma-1}}\left[\frac{r_c^{\gamma}-1}{\gamma(r_c-1)}\right]=60.43\%$$

77. A gas mixture consists of 3 kg of O_2, 5kg of N_2 and 12 kg of CH_4. The mass fraction and mole fraction and mole fraction of O_2 are

(A) 0.25 and 0.125

(B) 0.15 and 0.092

(C) 0.25 and 0.092

(D) 0.15 and 0.125

Key: (B)

Mass fraction of

$$O_2 = \frac{m_{o_2}}{m_{o_2} + m_{N_2} + m_{CH_4}} = \frac{3}{3+5+12} = \frac{3}{20} = 0.15$$

Mole fraction of

$$O_2 = \frac{n_{o_2}}{n_{o_2} + n_{N_2} + n_{CH_4}} = \frac{\frac{3}{32}}{\frac{3}{32} + \frac{5}{28} + \frac{12}{6}} = 0.092$$

78. An insulated pipe of 50 mm outside diameter with $\varepsilon = 0.8$ is laid in a room at 30°C. If the surface temperature is 250°C and the convective heat transfer coefficient is $10 W/m^2K$, the total heat loss per unit length of the pipe will be

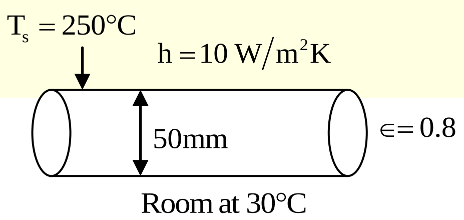
(A) 896.6 W/m

(B) 818.8 w/m

(C) 786.4W/m

(D) 742.2 W/m

Key: (B)



Total heal loss per unit length of the pipe

$$= Q_{conv} + Q_{rad}$$

$$= h_{conv}.A_s\left(T_s - T_{room}\right) + \in \sigma A_s\left(T_s^4 - T_{room}^4\right)$$

$$= A_s\left[h_{conv} + \in\sigma\left(T_s + T_{room}\right)\left(T_s^2 + T_{room}^2\right)\right]\left(T_s - T_{room}\right)$$

$$= 2\pi \times 0.025\left[10 + 0.8 \times 5.67 \times 10^{-8}\left(523+303\right) + \left(523^2 + 303^2\right)\right]\left(523-303\right) = 818.6$$

79. A wire of 8 mm diameter at a temperature of 60°C is to be insulated by a material having k=0.174 W/mK. The heat transfer coefficient on the outside $h_a = 8 W/m^2K$ and ambient temperature $T_a = 25°C$. The maximum thickness of insulation for maximum heat loss will be

(A) 15.25 mm

(B) 16.50 mm

(C) 17.75 mm

(D) 18.25 mm

Key: (C)

Given maximum heat loss, critical radius of insulation,

$$r_c = \frac{k}{h} = \frac{0.174}{8} = 0.02175m = 21.75mm$$

$\therefore$ Maximum thickness of insulation of maximum heat loss

$$= r_c - r = 21.75 - 4 = 17.75mm$$

80. In liquid metals, thermal boundary layer develops much faster than velocity boundary layer due to

(A) lower value of Nusselt number

(B) higher value of Prandtl number

(C) lower value of Prandtl number

(D) higher value of Nusselt number

Key: (C)

Prandtl number $(P_r) = \frac{\delta}{\delta_{th}}$

For liquid metals, Prandtl number $(P_r) < 1$

81. The temperature of a body of area 0.1 m^2 is 900 K. The wavelength for maximum monochromatic emissive power will be nearly

(A) 2.3 m

(B) 3.2 m

(C) 4.1 m

(D) 5.0 m

Key: (B)

From Wien's displacement law

$\lambda_{max} T = 2898$

$\lambda_{max} \times 900 = 2898$

$\lambda_{max} = 3.2 \mu m$

82. Consider the following statements:

For the laminar condensation on a vertical plate, the Nusselt theory says that

1. Inertia force in the film is negligible compared to viscosity and weight

2. Heat flow is mainly by conduction through the liquid film, convection in liquid film as well as in vapour is neglected

3. Velocity of vapour is very high

Which of the above statements are correct?

(A) 1, 2 and 3

(B) 1 and 2 only

(C) 1 and 3 only

(D) 2 and 3 only

Key: (B)

The velocity of the vapor is low (or zero) so that it exerts no drag on the condensate (no viscous shear on the liquid -vapor interface).

83. In transition boiling heat flux decreases due to which of the following?

1. Low value of film heat transfer coefficient at the surface during 100°C to 120°C surface temperature.

2. Major portion of heater surface is covered by vapour film which has smaller thermal conductivity as compared to liquid

3. Nucleate boiling occurs very fast

Select the correct answer using the code given below.

(A) 1 only

(B) 2 only

(C) 3 only

(D) 1, 2 and 3

Key: (B)

In transition boiling heat flux decreases because a large fraction of the heater surface is covered by a vapor film, which acts as an insulation due to the low thermal conductivity of the vapor relative to that of the liquid.

84. A hemispherical furnace of radius 1.0 m has a roof temperature of T_1 = 800 K and emissivity $\varepsilon_1 = 0.8$. The flat floor of the furnace has a temperature T_2 = 600K and emissivity $\varepsilon_2 = 0.5$. The view factor F_{12} from surface 1 to 2 will be

(A) 0.3

(B) 0.4

(C) 0.5

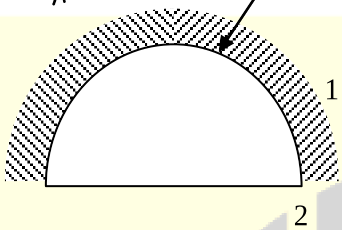
(D) 0.6

Key: (C)

$F_{11} + F_{12} = 1$

$F_{21} + F_{22}^{0} = 1$

Hemispherical furnace $(r_1 = r_2 = 1\text{m})$



From reciprocity theorem

$A_1F_{12} = A_2F_{21}$

$2\pi r_1 F_{12} = \pi r_2^2 \times 1$

$F_{12} = \dfrac{\pi r_1^2}{2\pi r_1} = \dfrac{r_1}{2} = \dfrac{1}{2} = 0.5$

85. Consider the following statements:

Combustion chamber is

1. the volume between TDC and BDC during the combustion process.

2. the space enclosed between the upper part of the cylinder and the top of the piston during the combustion process.

3. the space enclosed between TDC and the top of the piston during the combustion process.

Which of the above statements is/are correct?

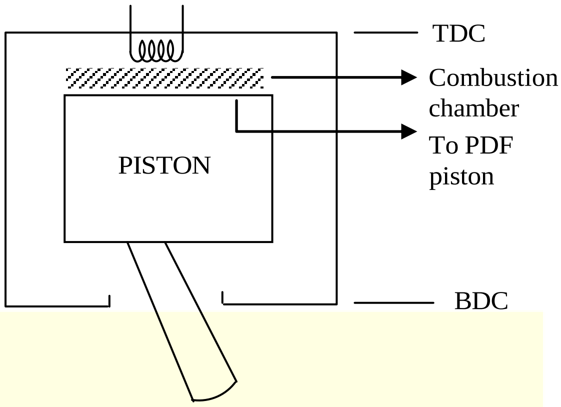
(A) 1 only

(B) 2 only

(C) 3 only

(D) 1, 2 and 3

Key: (B)



86. A 4-stroke diesel engine has length of 20 cm and diameter of 16 cm. The engine is producing power of 25 kW when it is running at 2500 r.p.m. The mean effective pressure of the engine will be nearly

(A) 5.32 bar

(B) 4.54 bar

(C) 3.76 bar

(D) 2.98 bar

Key: (D)

$$\text{I.P.} = P_m \times LA \times \frac{N}{2 \times 60} \times K$$

$$P_m = \frac{25 \times 10^3 \times (2 \times 60)}{0.20 \times 0.020 \times 2500} \times 10^{-5}\,\text{bar} \approx 3\,\text{bar}$$

87. A 4-stroke, 6-cylinder gas engine with a stroke volume of 1.75 litres develops 26.25 kW at 506 r.p.m. and the MEP is 600 kN/m^2. The number of misfires per minute per cylinder will be

(A) 3

(B) 4

(C) 5

(D) 6

Key: (A)

Number of cylinders n = 6

Stroke volume V_s = 1.75 litres

$= 1.75 \times 10^{-3} m^3$

Indicated power ip = 26.25 kW

Engine speed N = 506 rpm,

Mean effective pressure $p_m = 600 \times 10^3\ N/m^2$

For frour stroke engine, k = 1/2

$$ip = p_m \frac{AL \times N'}{2 \times 60} \times n$$

$$\Rightarrow 26.25 \times 10^3 = 600 \times 10^3 \times \frac{1.75 \times 10^{-3} \times N'}{2 \times 60} \times 6$$

$$\Rightarrow N' = \frac{26.25 \times 10^3 \times 2}{10 \times 1.75 \times 6} = 500\ rpm$$

∴ Actual number of fires in one minute

$$= \frac{500}{2} \times 6 = 1500$$

Expected number of fires in one minute

$$= \frac{506}{2} \times 6 = 1518$$

∴ Number of misfires/min

= 1518 – 1500 = 18

∴ Average number of misfires per min per cylinder, $= \frac{18}{6} = 3$

88. Which one of the following compressors will be used in vapour compression refrigerator for plants up to 100 tonnes capacity?

(A) Reciprocating compressor

(B) Rotary compressor

(C) Centrifugal compressor

(D) Double-acting compressor

Key: (A)

Reciprocating compressors are used in plants upto 100 tonnes capacity. For plants of higher capacities, centrifugal compressors are employed.

89. A cold storage is to be maintained at –5°C while the surroundings are at 35°C. The heat leakage from the surroundings into the cold storage is estimated to be 29 kW. The actual COP of the refrigeration plant used is 1/3rd that of an ideal plant working between the same temperatures. The power required to drive the plant will be

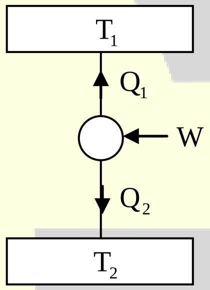
(A) 13 kW

(B) 14 kW

(C) 15 kW

(D) 16 kW

Key: (A)



$Q_2 = 29\ kW$

$T_1 = 35 + 273 = 308K$

$T_2 = 273 - 5 = 268K$

$$\text{Carnot COP} = \frac{T_2}{T_1 - T_2}$$

$$= \frac{268}{308 - 268} = \frac{268}{40} = 6.7$$

$$\therefore \text{Actual COP} = \frac{1}{3} \times \text{carnot COP} = \frac{6.7}{4}$$

$$\therefore \text{Actual COP} = \frac{Q_2}{W}$$

$$\Rightarrow W = \frac{Q_2}{\text{Actual COP}} = \frac{29 \times 3}{6.7} = 12.985\ kW$$

$\simeq 13\ kw$

90. Consider the following statements:

An expansion device in a refrigeration system

1. reduces the pressure from the condenser to the evaporator

2. regulates the flow of the refrigerant to the evaporator depending on the load

3. is essentially a restriction offering resistance to flow

Which of the above statements are correct?

(A) 1 and 2 only

(B) 1 and 3 only

(C) 2 and 3 only

(D) 1, 2 and 3

Key: (D)

An expansion device in a refrigeration system expands the liquid refrigerant from the condenser pressure to the evaporator pressure. The expansion device also controls the supply of the liquid to the evaporator at the rate at which it is evaporated. The expansion device is essentially a restriction.

91. In case of arc welding of steel with a potential of 20 V and current of 200 A, the travel speed is 5 mm/s and the cross-sectional area of the joint is 20 mm^2. The heat required for melting steel may be taken as 10 J/mm^3 and heat transfer efficiency as 0.85. The melting efficiency will be nearly

(A) 18%

(B) 29%

(C) 36%

(D) 42%

Key: (B)

Voltage, V = 20V

Current, I = 200A

Welding speed, v = 5 mm/s

Cross-sectional area, A = 20 mm^2

Heat required to melt steel = 10 J/mm^3 = H_m

Heat transfer efficiency, $\eta_{th} = 0.85$)

(some heat is being transferred to base plate)

Melting efficiency, $\eta_m = ?$

$$\eta_m = \frac{H_m}{H_2} = \frac{10}{\frac{VI}{A \times v}\eta_{HT}} = \frac{10}{\frac{20\times 200}{20\times 5}\times 0.85} = 0.294$$

$$\eta_m = 29.4\%$$

92. What is the force required for 90° bending of St50 steel of 2 mm thickness in a V-die, if the die opening is taken as 8 times the thickness and the length of the bent part is 1 m, ultimate tensile strength is 500 MPa and K = 1.33?

(A) 166.25 kN

(B) 155.45 kN

(C) 154.65 kN

(D) 143.85 kN

Key: (A)

Ultimate tensile strength, UTS = 500 MPa

Thickness, t = 2mm

Length of bent part, L = 1m

Width of die opening,

W = 8 × thickness = 8 × 2 = 16mm

K= 1.33 for V-die

Bending force, $F = k \times UTS \times \frac{L}{W} \times t^2$

$$F = \frac{1.33\times 500\times\left(1\times 10^3\right)\times 2^2}{16}$$
$$= 16{,}6250N = 166.25KN$$

93. A graph is drawn to a vertical magnification of 10000 and horizontal magnification of 100, and the areas above and below the datum line are as follows:

Above	150 mm^2	80 mm^2	170 mm^2	40 mm^2
Below	80 mm^2	60 mm^2	150 mm^2	120 mm^2

The average roughness Ra for sampling length of 0.8 mm will be

(A) 1.14 μm

(B) 1.10 μm

(C) 1.06 μm

(D) 1.02 μm

Key: (C)

Vertical magnification, VM = 10,000

Horizontal magnification, HM = 100

Sum of areas above and below datum line,

$$\Sigma A = 150+80+170+40+80+60+150+120 = 850\ mm^2$$

Sampling length, L = 0.8 mm

Average roughness,

$$R_a = \frac{\Sigma A}{L}\times\frac{1}{\text{vertical scale}}\times\frac{1}{\text{horizontal scale}}$$

$$R_a = \frac{\Sigma A}{L}\times\frac{1}{10^4}\times\frac{1}{10^2}\,mm = \frac{850}{0.8}\times\frac{1}{10^6}\,mm$$

$$R_a = 1.06\mu m$$

94. The radius of arc is measured by allowing a 20 mm diameter roller to oscillate to and fro on it and the time for 25 oscillations is noted at 56.25 s. The radius of arc will be

(A) 865 mm

(B) 850 mm

(C) 835 mm

(D) 820 mm

Key: (C)

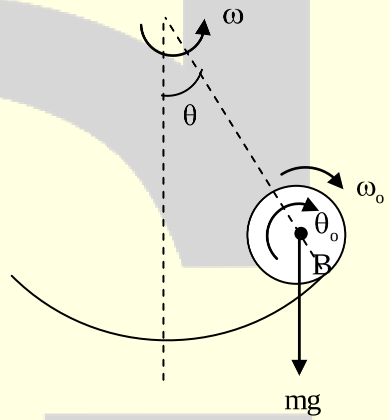
$$d = 20mm$$

$$T = \frac{56.25}{25} = 2.255$$

$$r\times\frac{d\theta_o}{dt} = (R-r)\frac{d\theta}{dt} \quad \ldots(1)$$

$$\frac{r\times d^2\theta_o}{dt^2} = (R-r)\frac{d^2\theta}{dt^2} \quad \ldots(2)$$

$$I_B = \frac{mr^2}{2}+mr^2 = \frac{3}{2}mr^2 \Rightarrow I_B\times\frac{d^2\theta_o}{dt^2} = -mgr\theta$$



On solving,

$$\theta = \frac{r\theta_o}{R-r},\qquad \theta_o = \frac{\theta}{r}(R-r)$$

$$\omega_n = \sqrt{\frac{2g}{3(R-r)}} \Rightarrow T = 2\pi\sqrt{\frac{3(R-r)}{2g}}$$

$$R = 850mm$$

95. Which one of the following systems is consisting of processing stations, material handling and storage, computer control system and human labour?

(A) Portable manufacturing system

(B) Focused integrated system

(C) Flexible manufacturing system

(D) Automated integrated system

Key: (C)

Flexible manufacturing system (FMS) consists of a group of NC machines connected together by an automated material handling system and operating under computer control. The basic components of FMS are machine tools and the related equipment; material handling equipment; computer control system and the human labour.

96. A project initially costs Rs 5,000 and generates year-end cash inflows of Rs 1,800, Rs 1,600, Rs 1,400, Rs 1,200 and Rs 1,000 respectively in five years of its life. If the rate of return is 10%, the net present value (NPV) will be

(A) Rs 500

(B) Rs 450

(C) Rs 400

(D) Rs 350

Key: (B)

$$NPV = \left[\frac{1800}{1.1} + \frac{1600}{1.1^2} + \frac{1400}{1.1^3} + \frac{1200}{1.1^4} + \frac{1000}{1.1^5}\right] - 5000$$

$$= \left[1636.36 + 1322.31 + 1051.84 + 819.62 + 620.92\right] = 451$$

97. What is the mode for the following distribution?

Gross profit as percentage of sales	Number of companies
0–7	19
7–14	25
14–21	36
21–28	72
28–35	51
35–42	43
42–49	28

(A) 19-55

(B) 21-40

(C) 23-25

(D) 25-10

Key: (D)

Mode

$$= L + \left[\frac{(f_m - f_{m-1})}{(f_m - f_{m-1}) + (f_m - f_{m+1})}\right] \times w$$

$$= 21 + \frac{(72-36)}{(72-36)+(72-51)} \times 7$$

$$= 21 + \frac{36}{36+21} \times 7 = 25.42$$

98. Consider the following data for quality acceptance process:

N = 10000, n = 89, c = 2

p = 0.01 (incoming lots of quality)

P_a = 0.9397

The AOQ will be

(A) 0.93%

(B) 0.84%

(C) 0.75%

(D) 0.66%

Key: (A)

$$AOQ = \frac{(N-n)Pa.p}{N}$$

$$= \frac{(10000-89) \times 0.9397 \times 0.01}{10000}$$

$$= 0.0093 \text{ or } 0.93\%$$

99. An engine is to be designed to have a minimum reliability of 0.8 and minimum availability of 0.98 over a period of 2×10^3 hr. The MTTR is nearly

(A) 168 hr

(B) 174 hr

(C) 183 hr

(D) 188 hr

Key: (C)

$R(t) = e^{-\lambda t}$

Given, $R(t) = 0.8 \text{ for } t = 2\times10^{3}\text{hr}$

$\therefore \quad \lambda = -0.5\times10 - 3\text{Ln}(0.8)$

$= 1.12\times10^{-4}/\text{hr}$

Steady state availability, $0.98 = \dfrac{\mu}{\mu+\lambda}$

$\Rightarrow \mu = 0.98\mu + 1.12\times10^{-4}\times0.98$

$\Rightarrow \mu = 5.49\times10^{-3}/\text{hr}$

$\therefore \text{MTTR} = \dfrac{1}{\mu} = \dfrac{10^{3}}{5.49} = 182.2 \text{ hrs}$

100. Which one of the following relations with usual notations will hold good in a dynamic vibration absorber system under tuned conditions?

(A) $k_1k_2 = m_1m_2$

(B) $k_1m_2 = m_1k_2$

(C) $k_1m_1 = k_2m_2$

(D) $k_1 + k_2 = m_1 + m_2$

Key: (B)

For dynamic system of vibration absorbed,

$f_1 = f_2$ (Frequency is equal)

$\sqrt{\dfrac{k_1}{m_1}} = \sqrt{\dfrac{k_2}{m_2}} \quad \therefore k_1m_2 = k_2m_1$

101. In ultrasonic waves, the frequencies for non-destructive testing of materials are in the range of

(A) 0.5 MHz to 10 MHz

(B) 10 MHz to 20 MHz

(C) 20 MHz to 30 MHz

(D) 30 MHz to 40 MHz

Key: (A)

102. The Curie point for most ferrous magnetic materials is about

(A) 390°C

(B) 540°C

(C) 760°C

(D) 880°C

Key: (C)

103. Which of the following is one of the basic units of memory controller in micro-controller?

(A) Microcode engine

(B) Master program counter

(C) Program status word

(D) Slave program counter

Key: (D)

104. Which one of the following ways will be adopted to store the program counter contents?

(A) Last-in-First-out (LIFO)

(B) First-in-First-out (FIFO)

(C) Last-in-Last-out (LILO)

(D) First-in-Last-out (FILO)

Key: (A)

105. In ladder logic programming, an alternative in place of using same internal relay contact for every rung is to use

(A) battery-backed relay

(B) dummy relay

(C) one-shot operation

(D) master control relay

Key: (D)

A whole block of outputs can be simultaneously turned off or on by using the some internal relay contacts in each output rung so that switching it on or off affects every one of the rungs. An alternative way of programming to achieve the some effect is to use a master relay.

106. Consider the following statements:

1. The term 'attenuation' is used to describe the process of removing a certain band of frequencies from a signal and permitting others to be transmitted.

2. The Wheatstone bridge can be used to convert a voltage change to an electrical resistance change.

Which of the above statements is/are correct?

(A) 1 only

(B) 2 only

(C) Both 1 and 2

(D) Neither 1 nor 2

Key: (D)

The wheat stone bridge can be used to convert a resistance change to a voltage change.

The term 'filtering' is used to describe the process of removing a certain band of frequencies from a signal and permitting others to be transmitted.

107. At time t, the excitation voltage to a resolver is 24 V. The shaft angle is 90°. The output signals from the resolver V_{S1} and V_{S2} will be

(A) 12 V and 0 V

(B) 24 V and 0 V

(C) 12 V and 12 V

(D) 24 V and 12 V

Key: (B)

Output signals of resolver are

$V_{s1} = V_1 \sin\alpha; \quad V_{s2} = V_1 \cos\alpha$

For $\alpha = 90°$

$V_{s1} = 24V$ and $V_{s2} = 0V$

108. An actuator having a stem movement at full travel of 30 mm is mounted with a control valve having an equal percentage plug and with minimum flow rate of $2\,m^3/s$ and maximum flow rate of 24 m^3/s. When the stem movement is 10 mm, the flow rate will be

(A) $3.4\,m^3/s$

(B) $3.8\,m^3/s$

(C) $4.2\,m^3/s$

(D) $4.6\,m^3/s$

Key: (D)

$Q_{min} = 2m^3/sec; \quad Q_{max} = 24m^3/sec$

$x_{max} = 30mm; \quad x = 10mm; \quad x_{min} = 0$

$$\frac{Q}{Q_{min}} = \left(\frac{Q_{max}}{Q_{min}}\right)^{\left(\frac{x-x_{min}}{x_{max}-x_{min}}\right)}$$

$$\frac{Q}{2} = \left(\frac{24}{2}\right)^{\left(\frac{10-0}{30-0}\right)} = 4.57\,m^3/sec$$

109. In a rack and pinion system, rack is an element moving in translational direction and pinion is a rotary gear. Which one of the following statements is correct?

(A) Translational acceleration is directly proportional to the moment of inertia of pinion.

(B) Translational acceleration is inversely proportional to the moment of inertia of pinion.

(C) Angular acceleration is inversely proportional to the torque on pinion shaft.

(D) Translational velocity is directly proportional to the moment of inertia of pinion.

Key: (B)

110. For the control signal to change at a rate proportional to the error signal, the robotic controller must employ

(A) Integral control

(B) Proportional-plus-integral control

(C) Proportional-plus-derivative control

(D) Proportional-plus-integral-plus-derivative control

Key: (A)

111. What is the minimum number of degrees of freedom that a robot needs to have in order to locate its end effectors at an arbitrary point with an arbitrary orientation in space?

(A) 3

(B) 4

(C) 5

(D) 6

Key: (B)

The minimum number of degree of freedom required by a robot to reach a deactivation with end collector.

$\Rightarrow$ 3 motions for translation & rotation + 1 motion for end effector

$\Rightarrow$ 4 minimum degrees of freedom.

112. Using a robot with 1 degree of freedom and having 1 sliding joint with a full range of 1 m, if the robot's control memory has a 12-bit storage capacity, the control resolution for the axis of motion will be

(A) 0.236 mm

(B) 0.244 mm

(C) 0.252 mm

(D) 0.260 mm

Key: (B)

$$\text{Control resolution} = \frac{\text{stroke length}}{2^n}$$

Here, stroke length = 1000 mm

$$C.R = \frac{1000}{2^{12}} = 0.244\text{mm}$$

113. Assume that the joint mechanisms at serial link manipulators are frictionless. The joint torque τ required to bear an arbitrary end point force F is

(A) $J^{-1}F$

(B) JF

(C) $J^{T}F$

(D) $J^{-1}F^{T}$

Key: (C)

For an n degree of freedom, serial link robot having no friction at the joints, the joint torques τ, that are required to bear an arbitrary end point force, F is

$$\tau = J^T.F$$

114. Rotate the vector v = 5i + 3j + 8k by an angle of 90° about the x-axis. The rotated vector (Hv) would be

(A) $\begin{bmatrix}1\\3\\-8\\5\end{bmatrix}$ (B) $\begin{bmatrix}-8\\5\\1\\3\end{bmatrix}$

(C) $\begin{bmatrix}3\\-8\\5\\1\end{bmatrix}$ (D) $\begin{bmatrix}5\\-8\\3\\1\end{bmatrix}$

Key: (D)

$$R_{(x,\theta)} = \begin{bmatrix}1 & 0 & 0\\0 & C\theta & -S\theta\\0 & S\theta & C\theta\end{bmatrix}$$

$$\begin{bmatrix}1 & 0 & 0\\0 & C90 & -S90\\0 & S90 & C90\end{bmatrix}\begin{bmatrix}5\\3\\8\end{bmatrix} = \begin{bmatrix}5\\-8\\3\\1\end{bmatrix}$$

Directions:

Each of the ***six (6)*** *items consists of two statements, one labeled as 'Statement (I)' and the other as 'Statement (II)'. You are to examine these two statements carefully and select the answers to these items using the code given below:*

Codes:

(A) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(B) Both Statement (I) and Statement (II) are individually true but Statement (II) is ***not*** *the correct explanation of Statement (I)*

(C) Statement (I) is true but Statement (II) is false

(D) Statement (I) is false but Statement (II) is true

115. Statement (I): The function of arithmetic logic unit (ALU) in microprocessor is to perform data manipulation.

Statement (II): The status register is where data for an input to the arithmetic and logic unit is temporarily stored.

Key: (C)

Assertion is correct

Reason is wrong.

Data for input to the arithmetic & logical unit is temporarily stored in 8 bit register called $\rightarrow$ ACCUMULATOR.

116. Statement (I): To use a sensor, we generally need to add signal conditioning circuitry, such as circuits which amplify and convert from analog to digital, to get the sensor signal in the right form, take account of any non-linearities, and calibrate it.

Statement (II): A smart sensor is integrated with the required buffering and conditioning circuitry in a single element and provides functions beyond that of just a sensor.

Key: (B)

117. Statement (I): The count-up overflow (OV) bit is 1 when the up-counter increments above the maximum positive value.

Statement (II): The count-down underflow (UN) bit is 1 when the counter decrements below the minimum negative value.

Key: (C)

The count-down underflow (UN) bit is 1 when the counter decrements below the maximum negative value.

118. Statement (I): The multiplexer is essentially an electronic switching device which enables each of the inputs to be sampled in turn.

Statement (II): A multiplexer is a circuit that is able to have inputs of data from a number of sources and then, by selecting an input channel, gives an output form just one of them.

Key: (A)

119. Statement (I): The term 'encoder' is used for a device that provides an analog output as a result of angular or linear displacement.

Statement (II): An increment encoder detects changes in angular or linear displacement from some datum position where as an absolute encoder gives the actual angular or linear position.

Key: (D)

An encoder is a device that provides a digital output in response to a linear or angular displacement.

120. Statement (I): Process control valves are used to control the rate of fluid flow and are used where, perhaps, the rate of flow of a liquid into a tank has to be controlled.

Statement (II): A common form of pneumatic actuator used with process control valves is the diaphragm actuator.

Key: (B)

121. A reversed Carnot engine is used for heating a building. It supplies 210×10^3 kJ/hr of heat to the building at 20°C. The outside air is at –5°C. The heat taken from the outside will be nearly

(A) 192×10^3 kJ/hr

(B) 188×10^3 kJ/hr

(C) 184×10^3 kJ/hr

(D) 180×10^3 kJ/hr

Key: (A)

$T_1 = 273 + 20 = 293K$

$T_2 = 273 - 5 = 268K$

$Q_1 = 210\times10^3$ kJ/hr

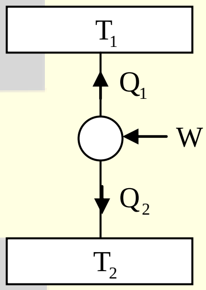
For a reversed Carnot engine, The relations are,

$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$$

$$Q_2 = \frac{Q_1}{T_1}\times T_2$$

$$= 210\times10^3\times\frac{268}{293}$$

$$= 192\times10^3 \text{ kJ/hr}$$



122. In an Electrolux refrigerator, a thermo-siphon bubble pump is used to lift the

(A) weak aqua solution from the generator to the separator

(B) weak aqua solution from the separator to the absorber

(C) strong aqua solution from the generator to the separator

(D) strong aqua solution from the generator to the evaporator

Key: (A)

In electrolux refrigerator, a thermosyphon bubble pump is used to lift the weak aqua solution from the generator to the seperator. The discharge tube from the generator is extended down below the liquid level in the generator. The bubbles rise and carry slugs of weak $NH_3 - H_2O$ solution into the seperator.

123. The enthalpy of moist air with normal notations is given by

(A) $h = (1.005 + 1.88W)t + 2500W$

(B) $h = 1.88Wt + 2500W$

(C) $h = 1.005Wt$

(D) $h = (1.88 + 1.005W)t + 2500W$

Key: (A)

Enthalpy of moist air, $h = h_a + w\,h_v$

$\Rightarrow h = 1.005t + w[2500 + 1.88t]\ kJ/kgda$

$\Rightarrow h = [1.005 + 1.88w]t + 2500W$

124. If the relative humidity of atmospheric air is 100%, then the wet-bulb temperature will be

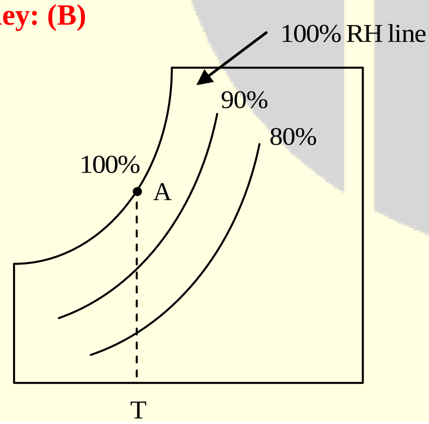
(A) more than dry-bulb temperature

(B) equal to dew-point temperature

(C) equal to dry-bulb temperature

(D) less than dry-bulb temperature

Key: (B)



For point A on 100% RH line

$\therefore$ WBT = DPT

125. During an air-conditioning of a plant, the room sensible heat load is 40 kW and room latent heat load is 10 kW, ventilation air is 25% of supply air. At full load, the room sensible heat factor will be

(A) 0.9

(B) 0.8

(C) 0.7

(D) 0.6

Key: (B)

$$RSHF = \frac{RSH}{RSH + RLH} = \frac{40}{40 + 10} = 0.8$$

126. A 2-stroke oil engine has bore of 20 cm, stroke 30cm, speed 350 r.pm., i.m.e.p. 275 kN/m^2, net brake load 610 N, diameter of brake drum 1m, oil consumption 4.25 kg/hr, calorific value of fuel 44×10^3 kJ/kg. The indicated thermal efficiency will be

(A) 29.1%

(B) 31.3%

(C) 33.5%

(D) 35.7%

Key: (A)

$D = 20cm;\ L = 30cm;\ N = 350rpm$

$i_{mep} = 350\ rpm$

$CV = 44 \times 10^6\ J/kg$

$$\dot{m} = \frac{4.25}{60 \times 60}\ kg/s$$

$$i.p = 275 \times \frac{\pi}{4}\left(20 \times 10^{-2}\right)^2 \times 3 \times 10^{-2} \times \frac{350}{60} \times 10^3$$

$$= 15118.9 \times 10^{-3}\ watt$$

$$\eta_{ip} = \frac{115118.9 \times 10^{-3}}{4.25 \times 44 \times 10^6} \times 60 \times 60 = 0.291 = 29.1\%$$

127. The hydraulic efficiency of a turbine is the ratio of

(A) mechanical energy in the output shaft at coupling and hydrodynamic energy available from the fluid

(B) mechanical energy supplied by the rotor and hydrodynamic energy available from the fluid

(C) useful hydrodynamic energy in the fluid at final discharge and mechanical energy supplied to the rotor

(D) useful hydrodynamic energy in the fluid at final discharge and mechanical energy supplied to the shaft and coupling

Key: (B)

$$\text{Hydraulic efficiency} = \frac{\text{Head extractedby the rotor}}{\text{Net load availableto the rotor}}$$

$$= \frac{\text{work done by the runner}}{\text{K.E. of the jet inlet to bucket}}$$

$$= \frac{\text{Mechanical energy supplied by the rotor}}{\text{Hydrodynamic energy available from fluid}}$$

128. Consider the following statements regarding compounding in steam turbines:

1. In impulse turbine, steam pressure remains constant between ends of the moving blades.

2. In reaction turbine, steam pressure drops from inlet to outlet of the blade.

3. In velocity compounding, partial expansion of steam takes place in the nozzle and further expansion takes place in the rotor blades.

Which of the above statements are correct?

(A) 1 and 2 only

(B) 1 and 3 only

(C) 2 and 3 only

(D) 1, 2 and 3

Key: (D)

- In impulse turbine inlet pressure = outlet pressure and blade is equiangular
  So, change in relative component is zero and hence relative component is same, so no reaction takes place.
- In reaction turbine steam pressure drops from inlet to outlet of the blade
- In velocity compounding whole expansion takes place in nozzle and velocity is reduced subsequent stages.

129. In a lawn sprinkler, water leaves the jet with an absolute velocity of 2m/s and the sprinkler arms are 0.1 m in length. The sprinkler rotates at a speed of 120 r.p.m. The utilization factor of this sprinkler will be nearly

(A) 0.72

(B) 0.64

(C) 0.56

(D) 0.49

Key: (A)

Consider sprinkles as radial blade

$$\eta = \frac{\left(\frac{2\pi N}{60}\times 0.1\right)^2}{\frac{(2)^2}{2}} = \frac{1.578}{2} = 0.788$$

130. Which one of the following statements is correct with respect to axial flow 50% reaction turbine?

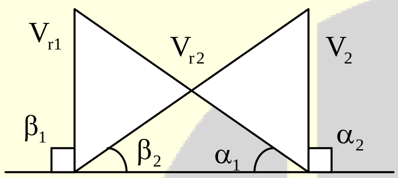
(A) The combined velocity diagram is symmetrical.

(B) The outlet absolute velocity should not be axial for maximum utilization

(C) Angles of both stator and rotor are not identical.

(D) For Maximum utilization, the speed ratio $\frac{U}{V_1} = \sin^2\alpha$.

Key: (A)



for maximum ' η '

In 50% reaction turbine for maximum ' η '

$$\alpha_2 = 90°, \alpha_3 = \alpha_2, \frac{U}{V_1} = \cos\alpha$$

131. In axial flow pumps and compressors, the combined velocity diagram with common base is used to determine change in

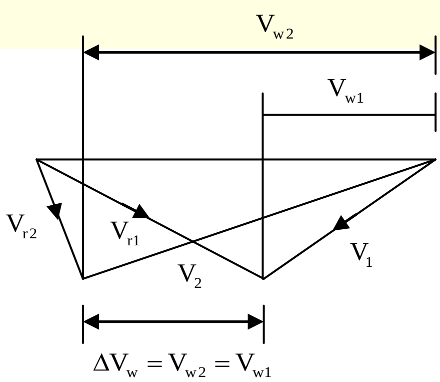
(A) absolute velocity $(V_2 - V_1)$

(B) relative velocity $(V_{r_2} - V_{r_1})$

(C) tangential velocity $(U_2 - U_1)$

(D) whirl velocity $(V_{U_2} - V_{U_1})$

Key: (D)



132. In a steam turbine with steam flow rate of 1 kg/s, inlet velocity of steam of 100 m/s, exit velocity of steam of 150 m/s, enthalpy at inlet of 2900 kJ/kg, enthalpy at outlet of 1600 kJ/kg, the power available from the turbine will be nearly

(A) 1575.5 kW

(B) 1481.6 kW

(C) 1387.7 kW

(D) 1293.8 kW

Key: (D)

$\Delta h_0 =$ stagnation enthalpy

$$= \left(h_1 + \frac{v_1^2}{2}\right) - \left(h_2 + \frac{v_2^2}{2}\right)$$

$$= \left(2900 + \frac{1}{2}(100)^2 - 1600 - \frac{1}{2}(150)^2\right)$$

$$= 1293.8\,\text{kW}.$$

133. In an isentropic flow through a nozzle, air flows at the rate of 600 kg/hr. At inlet to nozzle, the pressure is 2 MPa and the temperature is 127°C. The exit pressure is of 0.5 MPa. If the initial velocity of air is 300 m/s, the exit velocity will be

(A) 867 m/s

(B) 776 m/s

(C) 685 m/s

(D) 594 m/s

Key: (D)

$$T_1 = 127°C = 273 + 127 = 400K$$

$$P_1 = 2MPa,\ P_2 = 0.5\,MPa,\ V_1 = 300\,m/sec$$

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{2}{0.5}\right)^{\frac{1.4-1}{1.4}} = (4)^{0.285} = 1.484$$

$$T_2 = \frac{T_1}{1.484} = 269.54K$$

$$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2}$$

$$V_2 = \sqrt{2(h_1 - h_2) + (300)^2}$$
$$= \sqrt{2 \times 1.005 \times 1000(400 - 269.5) + (300)^2}$$
$$= 594 \text{ m/sec}$$

134. In a steam turbine, the nozzle angle at the inlet is 18°. The relative velocity is reduced to the extent of 6% when steam flows over the moving blades. The output of the turbine is 120 kJ/kg flow of steam. If the blades are equiangular, the speed ratio and the absolute velocity of steam ratio and the absolute velocity of steam at inlet f or maxi mum utilization are nearly

(A) 0.42 and 230.2 m/s

(B) 0.48 and 230.2 m/s

(C) 0.42 and 515.1 m/s

(D) 0.48 and 515.1 m/s

Key: (D)

$$\frac{V_b}{V_1} = \frac{\cos\alpha}{2} = 0.4755 = 0.48$$
$$(V_1 \cos\alpha_1 - V_b)(1+K) \times V_b = 120 \times 10^3$$
$$(V_1 \cos 18 - 0.48V_1)\left(1 + \frac{94}{100}\right) \times 0.48V_1 = 120 \times 10^3$$
$$V_1^2(\cos 18 - 0.48)(1.94) \times 0.48 = 120 \times 10^3$$
$$V_1 \cong 515.1 \text{ m/s}$$

135. An air compressor compresses atmospheric air at 0.1 MPa and 27°C by 10 times of air inlet pressure. During compression, the heat lost to the surrounding is estimated to be 5% of compression work. Air enters the compressor with a velocity of 40 m/s and leaves with 100m/s. The inlet and exit cross-sectional areas are 100 cm^2 and 20cm^2 respectively. The temperature of air at the exit from the compressor will be

(A) 1498 K

(B) 1574 K

(C) 1654 K

(D) 1726 K

Key: (A)

$$\rho_1 = \frac{P_1}{RT_1} = \frac{0.1 \times 10^6}{0.287 \times 10^3 \times 300} = 1.1614 \text{ kg/m}^3$$
$$\dot{m} = \rho_1 A_1 V_1 = 1.1614 \times 100 \times 10^{-4} \times 40 = 0.4646 \text{ kg/s}$$
$$\dot{m} = \rho_2 A_2 V_2 = \frac{P_2}{RT_2} A_2 V_2$$
$$T_2 = \frac{P_2 A_2 V_2}{\dot{m} R} = \frac{1 \times 10^6 \times 20 \times 10^{-4} \times 100}{0.4646 \times 0.287 \times 10^3} = 1499.9\text{K}$$

136. A compressor delivers 4m^3 of air having a mass of 5 kg. The specific weight and specific volume of air being delivered will be nearly

(A) 12.3N/m^3 and $0.8\text{ m}^3/\text{kg}$

(B) 14.6N/m^3 and $0.4\text{ m}^3/\text{kg}$

(C) 12.3N/m^3 and $0.4\text{ m}^3/\text{kg}$

(D) 14.6 N/m^3 and $0.8\text{ m}^3/\text{kg}$

Key: (A)

$$\text{Specific weight} = \frac{\text{weight}}{\text{volume}} = \frac{mg}{V} = \frac{5 \times 9.81}{4} = 12.26 \text{ N/m}^3$$
$$\text{Specific volume} = \frac{\text{volume}}{\text{mass}} = \frac{4}{5} = 0.8 \text{ m}^3/\text{kg}$$

137. In centrifugal compressors, there exists a loss of energy due to the mismatch of direction of relative velocity of fluid at inlet with inlet blade angle. This loss is known as

(A) frictional loss

(B) incidence loss

(C) Clearance loss

(D) leakage loss

Key: (B)

Additional losses that occur in a row of blades in a centrifugal compressor stage on account of incidence (mismatch of direction of relative velocity of fluid of inlet with inlet blade angle) termed as incidence losses. It is conventionally known as shock losses.

138. A centrifugal compressor develops a pressure ratio of 5 and air consumption of 30 kg/s. The inlet temperature and pressure are 15°C and 1 bar respectively. For an isentropic efficiency of 0.85, the power required by the compressor will be nearly

(A) 5964 kW

(B) 5778 kW

(C) 5586 kW

(D) 5397 kW

Key: (A)

$$W = C_p T_0 \left(r_p^{\frac{\gamma-1}{\gamma}} - 1 \right)$$

$$= 1.005 \times 288 \left((5)^{\frac{0.4}{1.4}} - 1 \right)$$

$$= 1.005 \times 288 \times 0.5819 = 168.45 \text{ kW/kg}$$

$$W_{ideal} = 167.615 \times 30 = 5053.62$$

$$\eta_{st} = \frac{W_{ideal}}{W_{actual}}$$

$$W_{actual} = \frac{W_{ideal}}{\eta_{st}} = \frac{5053.62}{0.85} = 5964 \text{ kW}$$

139. The efficiency of superheat Rankine cycle is higher than that of simple Rankine cycle because

(A) the enthalpy of main steam is higher for superheat cycle

(B) the mean temperature of heat addition is higher for superheat cycle

(C) the temperature of steam in the condenser is high

(D) the quality of steam in the condenser is low

Key: (B)

140. In steam power cycle, the process of removing non-condensable gases is called

(A) scavenging process

(B) deaeration process

(C) exhaust process

(D) condensation process

Key: (B)

141. The internal irreversibility of Rankine cycle is caused by

1. fluid friction

2. throttling

3. mixing

Select the correct answer using the code given below.

(A) 1 and 2 only

(B) 1 and 3 only

(C) 2 and 3 only

(D) 1, 2 and 3

Key: (D)

142. A 1 g sample of fuel is burned in a bomb calorimeter containing 1.2 kg of water at an initial temperature of 25°C. After the reaction, the final temperature of the water is 33.2°C. The heat capacity of the calorimeter is 837 J/°C. The specific heat of water is 4.18 J/ °C. The heat released by the fuel will be nearly

(A) 36 kJ/g

(B) 42 kJ/g

(C) 48 kJ/g

(D) 54 kJ/g

Key: (C)

$$Q_{water} = \dot{m}_w \times 4.18 \times (33.2-25)$$
$$= 1.2 \times 4.18 \times 8.2 = 41.3\,kJ$$
$$Q_{calorimeter} = 837 \times \Delta T = 837 \times (33.2-25)$$
$$= 6.8634\,kJ$$
$$Q_{fuel} = Q_{water} + Q_{calorimeter}$$
$$= 41.3 + 6.8634 = 48\,kJ$$

143. A boiler is having a chimney of 35 m height. The draught produced in terms of water column is 20 mm. The temperature of flue gas inside the chimney is 365°C and that of air outside the chimney is 32°C. The mass of air used will be nearly

(A) 10.3 kg/kg of fuel

(B) 12.5 kg/kg of fuel

(C) 14.7 kg/kg of fuel

(D) 16.9 kg/kg of fuel

Key: (D)

$$20 = 3531 + \left[\frac{1}{T_a} - \frac{1}{T_g}\left(\frac{m_a+1}{m_a}\right)\right]$$
$$20 = 353 \times 35\left[\frac{1}{305} - \frac{1}{638}\left(\frac{m_a+1}{m_a}\right)\right]$$
$$1.618 \times 10^{-3} = \left[\frac{1}{305} - \frac{1}{638}\left(\frac{m_a+1}{m_a}\right)\right]$$
$$m_a = 16.9\,kg/kg \text{ of fuel}$$

144. A 2 kg of steam occupying $0.3\,m^3$ at 15 bar is expanded according to the law $pv^{1.3}$ = constant to a pressure of 1.5 bar. The work done during the expansion will be

(A) 602.9 kJ

(B) 606.7 kJ

(C) 612.5 kJ

(D) 618.3 kJ

Key: (D)

$$P_1V_1^{1.3} = P_2V_2^{1.3} \Rightarrow \frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{1.3}$$
$$\Rightarrow V_2 = \left(\frac{P_1}{P_2}\right)^{\frac{1}{1.3}} \times V_1$$
$$\Rightarrow V_2 = \left(\frac{1.5bar}{1.5bar}\right)^{\frac{1}{1.3}} \times 0.3m^3 = 1.7634m^3$$
$$Pv^{1.3} = \text{constant} = C(\text{say})$$
$$P = \frac{C}{V^{1.3}}$$
$$\text{Work done,} \quad W = \int_{V_1}^{V_2} Pdv = \int_{V_1}^{V_2} \frac{C}{V^{1.3}}dV$$
$$= \int_{V_1}^{V_2} CV^{-1.3}dV = C\left|\frac{V^{-0.3}}{-0.3}\right|_{V_1}^{V_2}$$
$$= \frac{C}{-0.3}\left|V_2^{-0.3} - V_1^{-0.3}\right|$$
$$= \frac{-1}{0.3}\left[P_2V_2^{1.3}.V_2^{-0.3} - P_1V_1^{1.3}.V_1^{-0.3}\right]$$
$$= \frac{-1}{0.3}\left[P_2V_2 - P_1V_1\right] = \left[\frac{P_1V_1 - P_2V_2}{0.3}\right]$$
$$= \left[15\times10^5 \times 0.3 - 1.5\times10^5 \times 1.7634\right]/0.3$$
$$= 618.3\,kJ$$

145. Which of the following statements is/are correct regarding superheater in boilers?

1. It is heat exchanger in which heat is transformed to the saturated steam to increase its temperature.

2. It raises the overall efficiency.

3. It reduces turbine internal efficiency.

Select the correct answer using the code given below.

(A) 1 and 2

(B) 1 and 3

(C) 2 and 3

(D) 1 only

Key: (A)

The superheater is a heat exchanger in which heat is transferred to the saturated steam to increase its temperature. It raises the overall efficiency. It reduces the moisture content in last stages of the turbine and thus increases the turbine internal efficiency.

146. Water vapour 90kPa and 150°C enters a subsonic diffuser with a velocity of 150 m/s and leaves the diffuser at 190kPa with a velocity of 55 m/s, and during the process, 1.5 kJ/kg of heat is lost to the surrounding. For water vapour, C_p is $2.1\,kJ/kgK$. The final temperature of water vapour will be

(A) 154°C

(B) 158°C

(C) 162°C

(D) 166°C

Key: (A)

Applying S.F.E.E at inlet and exit of diffuser

$$h_1 + \frac{V_1^2}{20w} + q_{cv} = h_2 + \frac{V_2^2}{2000}$$

$$C_p\left(T_2 - T_1\right) = \frac{V_1^2 - V_2^2}{2000} - 1.5$$

$$\Rightarrow T_2 = 154°C$$

147. A steam turbine is supplied with steam at a pressure of 20 bar gauge. After expansion in the steam turbine, the steam passes to condenser which is maintained at a vacuum of 250 mm of mercury by means of pumps. The inlet and exhaust steam pressures will be nearly

(A) 2101 kPa and 68 kPa

(B) 2430 kPa and 78 kPa

(C) 2101 kPa and 78 kPa

(D) 2430 kPa and 68 kPa

Key: (A)

Inlet pressure = 20 bar guage

Absolute inlet pressure

= Guage Pr. + atmospheric

$$= \left(20\times10^2 + 101\right) kPa = 2101\,kPa$$

Exit pressure= 250 mm of mercury (vaccum)

Absolute exit pressure = Atmospheric pressure – vaccum pressure

$$= \left(101 - 13.6\times9.81\times0.25\right) kPa$$

$$= 67.64\,kPa$$

148. In a power plant, the efficiencies of the electric generator, turbine, boiler, thermodynamic cycle and the overall plant are 0.97, 0.95, 0.92, 0.42 and 0.33 respectively. The total electricity generated for running the auxiliaries will be nearly

(A) 4.9%

(B) 5.7%

(C) 6.5%

(D) 7.3%

Key: (D)

Overall efficiency $= \eta_g \times \eta_t \times \eta_b \times \eta_c \times \eta_a$

$$0.33 = 0.97 \times 0.95 \times 0.92 \times 0.42 \times \eta_a$$

$$\eta_a = 0.926$$

The total electricity generated for running auxilliarities = 1 – 0.926 = 0.073 or 7.3%.

149. A turbine in which steam expands both in nozzle as well as in blades is called as

(A) impulse reaction turbine

(B) reciprocating steam turbine

(C) gas turbine

(D) Curtis turbine

Key: (A)

150. Consider the following statements regarding reaction turbine:

1. Blade shape is s aerofoil type and its manufacturing is difficult.

2. It is suitable for small power.

3. Leakages losses are less compared to friction losses.

Which of the above statements is/are correct?

(A) 1 only

(B) 2 only

(C) 3 only

(D) 1, 2 and 3

Key: (D)