ACE Engineering Academy
Head Office : Sree Sindhi Guru Sangat Sabha Association, # 4-1-1236/1/A, King Koti, Abids, Hyderabad – 500001.
Ph: 040-23234418, 040-23234419, 040-23234420, 040 - 24750437
Hyderabad | Delhi | Bhopal | Pune | Bhubaneswar | Lucknow | Patna | Bengaluru | Chennai | Vijayawada | Vizag | Tirupati | Kukatpally | Kolkata | Ahmedabad

ESE- 2019 (Prelims) - Offline Test Series Test – 13

MECHANICAL ENGINEERING

SUBJECT: Fluid Mechanics + Turbo Machinery + Thermodynamics and Heat Transfer — SOLUTIONS

01. Ans: (a)

Sol: $P_{reading} = P_{fluid} - P_{surrounding}$

Normally $P_{surrounding} = P_{atm} = 0$

$P_{reading} = 305$ kPa

When $P_{surrounding} = 650$ mm Hg Vacuum

$$= \frac{650}{750} \times 100$$

= 86.67 kPa Vacuum

Then,

$P_{reading} = 305 - (-86.67) = 391.67$ kPa

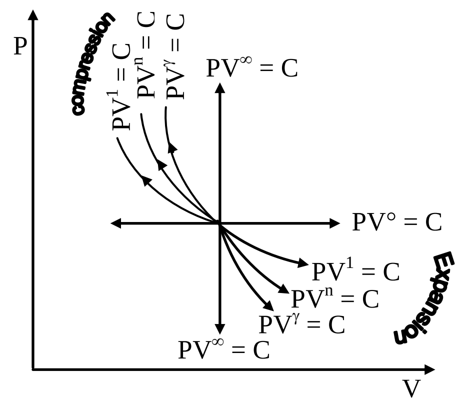
02. Ans: (d)

Sol:

- Thermal diffusivity of material is ability to conduct thermal energy relative to store thermal energy.
- Thermal diffusivity of liquid is less than that of gas.

03. Ans: (b)

Sol:

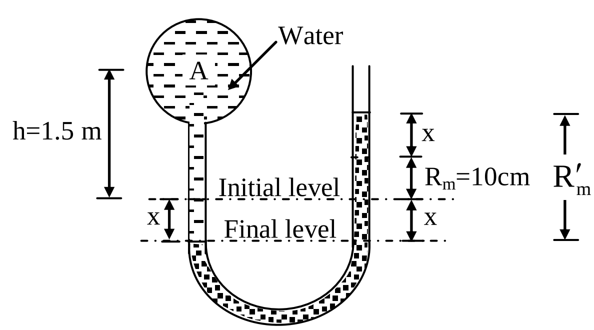


$$W_{closed} = \frac{P_1V_1 - P_2V_2}{n-1} \quad (n \neq 1)$$

As n decreases, W increases.

04. Ans: (c)

Sol:



Initially,

$P_A + \gamma_w \times 1.5 = P_{atm} + \gamma_{Hg} \times 0.1$ ----------(1)

When the pressure in A is doubled,

$2P_A + \gamma_w(1.5 + x) = P_{atm} + \gamma_{Hg}(x + 0.1 + x)$ ------(2)

where x is the displacement of Hg level in the left limb due to pressure change in A.

From (1) ,

$P_A = 100 + 13.6\times10\times0.1 - 10\times1.5$

$= 98.6$ kPa

From (2),

$2\times98.6 + 10\times1.5 + 10\times x = 100 + 13.6 \times 10 \times 2x + 13.6\times10 \times 0.1$

$212.2 - 100 - 13.6 = 272x - 10x$

$98.6 = 262\,x$

$\Rightarrow x = 0.376$ m

So, manometric reading when P_A is doubled is, $R'_m = 2x + 0.1 = 0.852$ m $= 85.2$ cm

05. Ans: (d)

Sol: Efficiency of the engine,

$$\eta_{engine} = \frac{Q - 0.5Q}{Q} = 0.5 = 50\%$$

Efficiency of Carnot Engine,

$$\eta_{Carnot} = \frac{T_1 - T_2}{T_1} = \frac{(377 - 27)}{(377 + 273)}$$

$$= 0.5384 = 53.84\%$$

As $\eta_{engine} < \eta_{Carnot}$, it is a practical engine.

06. Ans: (b)

Sol: Head loss due friction in the first pipe,

$$h_{f1} = \frac{f_1 L_1 Q_1^2}{12.1\, d_1^5} \text{ --------------(1)}$$

Head loss due to friction in the second pipe,

$$h_{f2} = \frac{f_2 L_2 Q_2^2}{12.1\, d_2^5} \text{ ------------(2)}$$

From equations (1) and (2), $h_f \propto \frac{f}{d^5}$

But $L_2 = L_1$; $Q_2 = Q_1$; $d_2 = 2d_1$

For laminar flow :

$$f \propto \frac{1}{Re} \propto \frac{\nu}{Vd}$$

Or, $f \propto \frac{1}{Vd}$

$$\frac{f_2}{f_1} = \frac{V_1}{V_2}\frac{d_1}{d_2} = \frac{d_2^2}{d_1^2}\frac{d_1}{d_2} \quad \left[\text{as } \frac{\pi}{4}d_1^2V_1 = \frac{\pi}{4}d_2^2V_2\right]$$

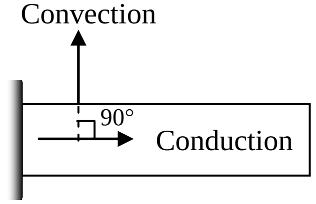
$$= \frac{d_2}{d_1} = 2$$

Hence, $\frac{h_{f1}}{h_{f2}} = \frac{f_1}{f_2} \times \left(\frac{d_2}{d_1}\right)^5 = \frac{1}{2} \times (2)^5 = 16$

Or, $\frac{h_{f1}}{h_{f2}} = 16:1$

07. Ans: (c)

Sol:



There is reduction in the conduction heat transfer with increasing the length of the fin because some part of heat is transferred due to convection as shown in the figure.

According to Fourier's law of heat conduction

$$q = -k\left(\frac{dT}{dx}\right)$$

As $q\downarrow \Rightarrow \frac{dT}{dx}\downarrow$

08. Ans: (c)

Sol: Internal energy of an ideal gas is a function of temperature only.

Specific enthalpy, h = u + pv

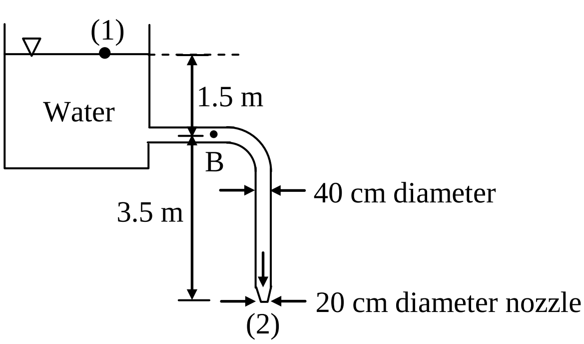
For ideal gas, Pv = RT

h = u(T) + RT

h = h(T) for ideal gas.

09. Ans: (a)

Sol: Since head losses are neglected, Bernoulli's equation can be applied for any two points in the flow.



Thus,

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$$

$P_1 = P_2 = P_{atm} = 0;$

$V_1 = 0,$

$Z_1 = 5$ & $Z_2 = 0$

$$0 + 0 + 5.0 = 0 + \frac{V_2^2}{2g} + 0$$

Or, $V_2 = \sqrt{2g \times 5.0}$ = 10 m/s

(velocity at exit of nozzle)

Thus, velocity in the pipe, V_p = 10/4 = 2.5 m/s as diameter of pipe is twice the diameter of nozzle. Again, applying Bernoulli's equation for pts (1) and (B)

$$\frac{P_B}{\gamma} + \frac{V_B^2}{2g} + Z_B = \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1$$

Here, $Z_1 = 1.5$ m,

$P_1 = P_{atm} = 0,$ $Z_B = 0$

Or, $\frac{P_B}{\gamma} = 1.5 - \frac{2.5^2}{2\times 10} - 0$ = 1.5 – 0.3125

(as $V_B = V_P$)

= 1.1875 m

$\Rightarrow P_B = 1.1875\times 10^4 = 11.875$ kPa

10. Ans: (b)

Sol: If the Biot number tends to zero, the temperature gradient inside the solid body tends to zero.

11. Ans: (a)

Sol: Joule Thomson coefficient, $\mu_{JT} = \left(\frac{\partial T}{\partial P}\right)_h$

In throttling process, ΔP is negative.

Thus, for μ_{JT} to be negative, when dT should be positive.

12. Ans: (c)

Sol: Critical Re for flat plate = 5×10^5

$$\frac{\delta}{x} = \frac{5}{\sqrt{5\times10^5}} = \frac{5}{10^2\sqrt{50}}$$

$$= \frac{5\times10^{-2}}{\sqrt{5}\sqrt{10}} = \left(\sqrt{\frac{5}{10}}\right)\times10^{-2}$$

$$= \frac{1}{\sqrt{2}}\times10^{-2} = \frac{\sqrt{2}}{2}\times10^{-2}$$

$$= \frac{1.414}{2}\times10^{-2} = 0.00707$$

$$\Rightarrow \frac{\delta}{x} = 7.07\times10^{-3}$$

13. Ans: (c)

Sol: Fourier's law of heat conduction :

$$q = -k\frac{dT}{dx}$$

$$200 = -k\frac{d}{dx}(110-60x)$$

$$200 = -k(0-60)$$

$$60k = 200$$

$$k = \frac{200}{60} = 3.33\,W/m-K$$

14. Ans: (a)

Sol: As there is no change in volume of the system, boundary work (PdV) is zero. As work is needed to push fluid into or out of the boundary of the control volume, flow work is non zero.

15. Ans: (c)

Sol: Since at the edge of the boundary layer $\frac{du}{dy} = 0$, the shear stress $\tau_b = 0$

Hence, the required ratio is 0.

16. Ans: (a)

Sol: k = 100 W/m-K, L = 1m,

$T_0 = 90°C$, $T_\infty = 20°C$

$\eta = 0.2$, d = 4 cm = 0.04 m

Efficiency of the long fin :

$$\eta = \frac{1}{mL}$$

$$0.2 = \frac{1}{m\times1}$$

$$m = 5\ m^{-1}$$

Heat loss from the fin = m k A_c θ_0

$$= 5\times100\times\frac{\pi}{4}d^2\times(90-20)$$

$$= 5\times100\times\frac{1}{4}\times\frac{22}{7}\times0.04^2\times70$$

$$= 500\times\frac{22}{7}\times\frac{1}{4}\times0.04\times0.04\times70 = 44\ W$$


ACE
SUMMER
SHORT TERM BATCHES
GATE+PSUs - 2020
Admissions Open From 14th NOV 2018
HYDERABAD
29th April | 06th May | 11th May
18th May | 26th May | 02nd June 2019
DELHI
11th May | 23rd May 2019
Start Early.. Gain Surely...
SHORT TERM BATCHES
EARLY BIRD OFFER :
Register on or Before 31st December 2018 : 5000/- Off | Register on or Before 31st March 2019 : 3000/- Off


ACE
TEST YOUR PREP
IN A REAL TEST ENVIRONMENT
Pre GATE - 2019
Date of Exam : 20th January 2019
Last Date to Apply : 31st December 2018
Highlights :
* Get real-time experience of GATE-2019 test pattern and environment.
* Virtual calculator will be enabled.
* Post exam learning analytics and All India Rank will be provided.
* Post GATE guidance sessions by experts.
* Encouraging awards for GATE-2019 toppers.

17. Ans: (b)

Sol: dW = PdV

If we multiply by $\frac{1}{P}$ then it comes to be dV, which is perfect differential. So $\frac{1}{P}$ is integrating factor for quasi-static displacement work.

18. Ans: (a)

Sol: $\frac{u}{U_\infty} = \frac{y}{\delta} = \eta$

$$\theta = \int_0^\delta \frac{u}{U_\infty}\left(1-\frac{u}{U_\infty}\right)dy = \delta\int_0^1 \eta(1-\eta)d\eta$$

$$= \delta\int_0^1 (\eta-\eta^2)d\eta = \delta\left[\frac{\eta^2}{2}-\frac{\eta^3}{3}\right]_0^1$$

$$\theta = \frac{\delta}{6}$$

Given that, δ = 15 mm at x = 1 m

$$\theta = \frac{15\,\text{mm}}{6}$$

Hence, θ = 2.5 mm

19. Ans: (c)

Sol: Given data:

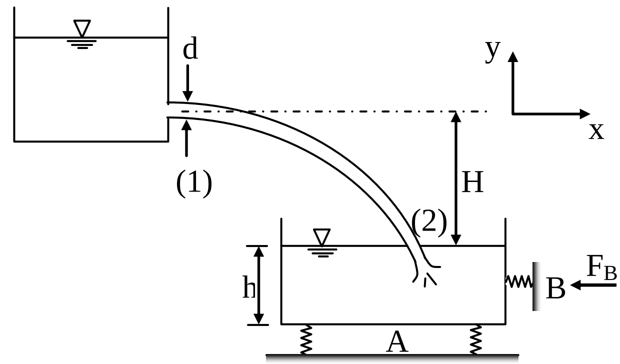
Q = 0.016π m^3/s, d_1 = 0.1 m

h = 0.3 m,

H = 3 m

W_{tank} = 1 kN,

A_2 = 0.5 m^2



Mass flow rate of jet of water = ρQ

$= 10^3 \times 0.016\pi = 16\pi$ kg/s

Jet velocity, $V_1 = \frac{4Q}{\pi d_1^2} = \frac{4\times 0.016\pi}{\pi\times(0.1)^2}$

V_1 = 6.4 m/s

From projectile motion equation:

$V_{2x} = V_1$ = 6.4 m/s

Momentum equation in x - direction:

$-F_B = -\dot{m}(V_{2x}) = -16\pi\times 6.4$

$\Rightarrow$ $F_B = 102.4\,\pi$ N

$\Rightarrow$ k = 102.4

20. Ans: (b)

Sol: Temperature distribution :

$$\frac{T-T_\infty}{T_i - T} = e^{\left(\frac{hA}{\rho v c_p}\times\tau\right)}$$

For the same temperature difference,

$$e^{\left(\frac{h_1 A}{\rho V c_p}\times\tau_1\right)} = e^{\left(\frac{h_2 A}{\rho V c_p}\times\tau_2\right)}$$

$h_1\,\tau_1 = h_2\,\tau_2$

$h_1 \times 30 = 5h_1\times\tau_2$ $\quad[\because h_2 = 5\,h_1]$

$\Rightarrow$ τ_2 = 6 min

21. Ans: (b)

Sol: As long as there is temperature difference between the body and the thermal reservoir, work can be obtained through the engine. Once there is no temperature difference, engine will stop working.

22. Ans: (b)

Sol: Air lift pump has vary low efficiency

- Hydraulic ram can lift small quantity of water to the greater heights by using large quantity of water at small heights using principle of water hammer.
- Centrifugal pump gives continuous supply of water than reciprocating pump. The discharge in reciprocating pump is discontinuous or pulsating. Further, the efficiency of reciprocating pump is 10 to 20% more than that of centrifugal pump.

23. Ans: (c)

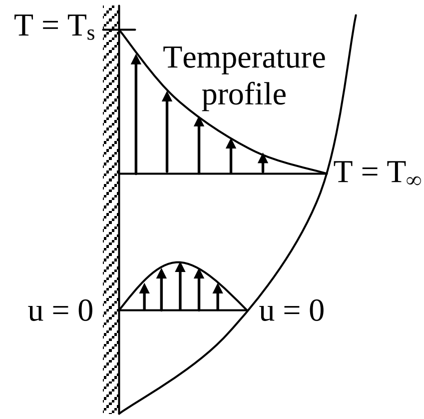
Sol:

- In free convection :

  Characteristic length for a horizontal surface

$$L_c = \frac{A_c}{P} = \frac{\frac{\pi}{4}D^2}{\pi D} = \frac{D}{4}$$

- Velocity and temperature distribution :



24. Ans: (d)

Sol:

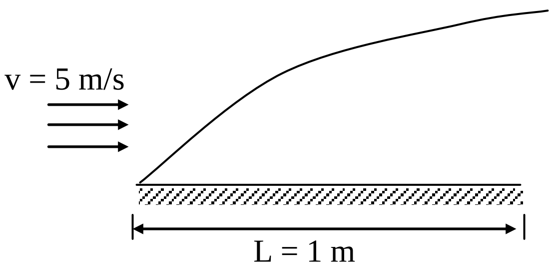
- Leakage loss will take place due to pressure difference across pump which is proportional to manometric head (P - 2).
- Frictional loss is proportional to $\frac{V_r^2}{2g}$ (Q-3)
- Entrance loss means entry with shock which is absent when relative velocity is tangential to blade profile at inlet. This happens at design point. (R-1)

25. Ans: (c)

Sol: Temperature of the object can be increased by supplying heat to it or by doing work on it.

26. Ans: (b)

Sol:



Reynolds number (Re) = $\frac{VL}{\nu} = \frac{5\times1}{2\times10^{-3}}$

$= 2.5 \times 10^3 = 2500$

Flow is laminar.

Average Nusselt number,

$\overline{Nu} = 2\times Nu_x$

$\frac{\bar{h}\times L}{k} = 2\times0.332\times(Re)^{1/2}(Pr)^{1/3}$

$\frac{\bar{h}\times L}{0.5} = 2\times0.332\times(2500)^{1/2}\times(1)^{1/3}$

$\frac{\bar{h}\times1}{0.5} = 2\times0.332\times50\times1$

$\bar{h} = 33.2 \times 0.5$

$\bar{h} = 16.6\ W/m^2\ K$

Heat transfer rate (Q) = $\bar{h}\ A\ (T_s - T_\infty)$

$= 16.6 \times 1 \times 0.5\ (40 - 20)$

$= 16.6 \times 1 \times 0.5 \times 20$

$= 166\ W$

27. Ans: (b)

Sol: Maximum useful work in a closed system

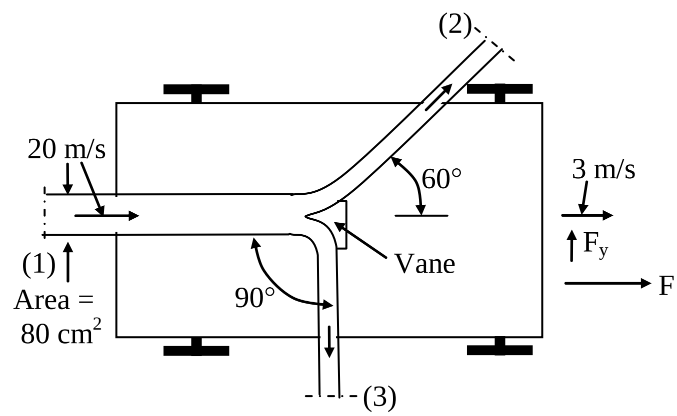
$(WU)_{MAX} = (E_1 - E_2) - T_0(S_1 - S_2) + P_0\ (V_1 - V_2)$

On rearrangement

$(WU)_{MAX} = (E_1 - T_0S_1) - (E_2 - T_0S_2) + P_0(V_1 - V_2)$

28. Ans: (a)

Sol: Make the flow steady by referencing all velocities to the moving vane and let the C.V. move with the vane as shown.



Plan view

Momentum equation in x - direction:

$F_x = \dot{m}_2V_{2x} - \dot{m}_1V_1$

where $\dot{m} = \rho AV = 10^3 \times 8 \times 10^{-3} \times 20$

$= 160\ kg/s$

$F_x = \left(\frac{\dot{m}}{2}V\cos60^o - \dot{m}V\right) = \dot{m}V\left(\frac{1}{4} - 1\right)$

$= -160\times20\times\frac{3}{4} = -2400\ N$

Momentum equation in y - direction.

$F_y = \dot{m}_2V_{2y} - \dot{m}_3V_{3y}$

$= \frac{\dot{m}}{2}V\sin60^o - \frac{\dot{m}}{2}V = \frac{\dot{m}}{2}V(\sin60^o - 1)$

$$= \frac{160 \times 20}{2}(0.866 - 1) = -214.36 \text{ N}$$

From Newton's third law of motion,

$\Rightarrow$ F(water on vane) = $\left(2400\hat{i} + 214.4\hat{j}\right)$ N

Note: Answer can be determined from F_x alone. No need to calculate F_y.

29. Ans: (d)

Sol: Boiling is classified as pool boiling or flow boiling, depending on the presence of bulk fluid motion. Boiling is called pool boiling in the absence of bulk fluid flow and flow boiling (or forced convection boiling) in the presence of it.

30. Ans: (a)

31. Ans: (d)

Sol: Given: $u = 2U\left(1 - \frac{r^2}{R^2}\right)$

$$\frac{du}{dr} = -2U \times \frac{2r}{R^2} = -\frac{4Ur}{R^2}$$

Shear stress, $\tau = -\mu \frac{du}{dr} = 4U\mu \frac{r}{R^2}$

and $\tau_o(r = R) = 4U\mu \frac{R}{R^2} = 4U\mu \times \frac{1}{R}$

Therefore, the required ratio

$$\frac{\tau}{\tau_o} = 4U\mu \frac{r}{R^2} \times \frac{R}{4U\mu} = \frac{r}{R}$$

Thus, for $\frac{r}{R} = 0.5$, $\frac{\tau}{\tau_o} = 0.5$

32. Ans: (b)

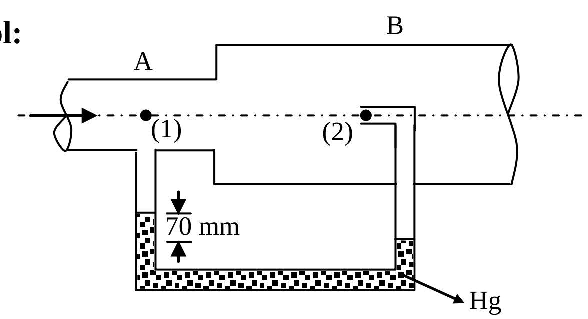
Sol:

- Temperature rise of the cold fluid is equal to temperature fall of hot fluid only when heat capacities of both the fluids are same.
- LMTD is dependent on direction of flow (parallel or counter).
- Temperature difference between hot fluid and cold fluid always decreases only in parallel flow heat exchanger. It may increases or decreases in case of counter flow heat exchanger.

33. Ans: (b)

34. Ans: (b)

Sol:



Applying energy equation for points (1) and (2), considering energy loss due to abrupt change in diameter,

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{P_o}{\gamma} + \frac{(V_1 - V_2)^2}{2g}$$

(as $P_2 = P_{stagnation} = P_o$**)**

Or, $$\frac{P_o}{\gamma} - \frac{P_1}{\gamma} = \frac{V_1^2}{2g} - \frac{(V_1 - V_2)^2}{2g}$$

But $\frac{P_o}{\gamma} - \frac{P_1}{\gamma} = \Delta h_\ell$ from manometer

$$\Delta h_\ell = \frac{V_1^2}{2g}\left[1-\left(1-\frac{V_2}{V_1}\right)^2\right] = \frac{V_1^2}{2g}\left[1-\left(1-\frac{A_1}{A_2}\right)^2\right]$$

$$\Delta h_\ell = \frac{V_1^2}{2g}\left[1-\left(1-\frac{1}{4}\right)^2\right]$$

$$0.07\left(\frac{13.6}{1.2}-1\right) = \frac{V_1^2}{2g}\left[1-\frac{9}{16}\right] = \frac{7}{16}.\frac{V_1^2}{2g}$$

Or, $$\frac{0.07\times12.4}{1.2} = \frac{7}{32}\frac{V_1^2}{10}$$

Or, $$V_1^2 = \frac{32\times10\times0.07\times12.4}{7\times1.2}$$

$$= \frac{32}{12}\times12.4 = 16\times2.07$$

$$V_1 = 4\times\sqrt{2.07} = 5.75 \text{ m/s}$$

$\therefore$ Mass flow rate of the liquid = $\rho_\ell A V_1$

$$= 1200\times2\times10^{-3}\times5.75 = 13.8 \text{ kg/s}$$

Note: Such questions with lengthy calculation are asked in ESE exam to trap the students. Students are, therefore, advised not to spend time on such questions initially.

35. Ans: (a)

Sol: $U = 100$ W/m^{2}K,

$\dot{m} = 60$ kg/min = 1 kg/s

$A_s = 42$ m^2,

$c_p = 4.2$ kJ/kgK

$$NTU = \frac{UA_s}{\dot{m}c_p} = \frac{100\times42}{1\times4.2\times10^3} = \frac{4200}{4200} = 1$$

Effectiveness of the condenser

$$(\varepsilon) = 1 - e^{-NTU}$$

$$= 1 - e^{-1}$$

$$= 1 - \frac{1}{e}$$

$$= 1 - \frac{1}{2.718} = 0.6321 = 63.21\ \%$$

36. Ans: (b)

Sol:

- Critical point $\rightarrow$ Properties of saturated liquid and saturated vapor are same.
- Sublimation $\rightarrow$ On heating solid changes to vapour state.
- Triple point $\rightarrow$ (Solid + liquid + vapour) coexist.
- Melting $\rightarrow$ Phase changes from solid to liquid.

37. Ans: (a)

Sol: The expression of velocity, V_1 is given as :

$$2g\times h = 3.88V_1^2 + 5V_2^2$$

$$= V_1^2\left(3.88 + 5\times\frac{V_2^2}{V_1^2}\right) = V_1^2\left[3.88 + 5\times\left(\frac{d_1}{d_2}\right)^4\right]$$

$$= V_1^2\left(3.88 + 5\times\frac{1}{256}\right)$$

$$= 3.9\,V_1^2$$

Or, $V_1 \propto \sqrt{h}$

When 'h' is changed to 2.42 m, then the velocity V_1 will increase to V_1' when all other data remain constant.

$$\Rightarrow \frac{V_1'}{V_1} = \sqrt{\frac{2.42}{2}} = \sqrt{1.20} = 1.1$$

Thus, the percentage increase in V_1 is 10%

38. Ans: (b)

Sol: For same heat transfer rate :

$$(U\,A_s \times LMTD)_{parallel\ flow} = (U \times A_s \times LMTD)_{counter\ flow}$$

ν = constant

$$(A_s \times LMTD)_{parallel\ flow} = (A_s \times LMTD)_{counter\ flow}$$

As, $(LMTD)_{counter\ flow} > (LMTD)_{parallel\ flow}$

$\therefore (A_s)_{counter\ flow} < (A_s)_{parallel\ flow}$

$$\therefore \frac{(A_s)_{counter\ flow}}{(A_s)_{parallel flow}} < 1$$

39. Ans: (a)

Sol: For an ideal gas :

PV = constant $(\because T = \text{constant})$

Differentiating we get $\frac{PdV}{dP} = -V$

$$\beta = -\left(\frac{1}{V}\right)\left(\frac{dV}{dP}\right) = \left(\frac{1}{P}\right) \Rightarrow \beta \times P = 1$$

$\therefore$ The graph between β and P will be rectangular hyperbola.

40. Ans: (b)

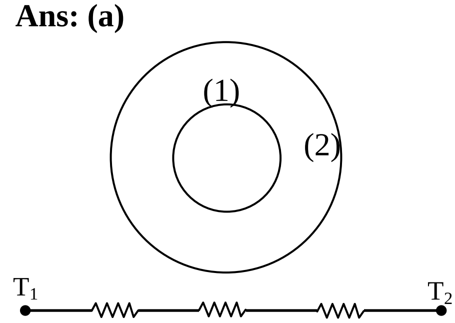
Sol:

- In impulse turbines like Pelton wheel, the pressure remains atmospheric (constant) through out as water passes through runner. The penstocks will have nozzles at the down stream end. As water passes through nozzle pressure energy is completely converted into kinetic energy.
- Water strikes on the wheel tangentially at only one point for single jet Pelton turbine and it strikes at multiple points in case of multi jet Pelton turbine but never at all points along the circumference.

  $\Rightarrow$ Hence, only statements 2 & 3 are correct.
- In case of reaction turbines, at the entry to the runner, only a part of the available pressure energy is converted as kinetic energy. Hence, all along the runner, both pressure and velocity change. The gradual change of pressure is ensured by providing air tight casing.

41. Ans: (a)

Sol:



$$\frac{1-\varepsilon_1}{\varepsilon_1 A_1} \quad \frac{1}{A_1 F_{1-2}} \quad \frac{1-\varepsilon_2}{\varepsilon_2 A_2}$$

$\sigma = 6\times10^{-8}$ W/m^{2}K^4

$T_1 = 300$ K, $T_2 = 500$ K,

$\varepsilon_1 = \varepsilon_2 = 1$

Net radiative heat exchange

$$(Q_{1-2}) = \frac{\sigma(T_1^4 - T_2^4)}{\frac{1-\varepsilon_1}{\varepsilon_1 A_1} + \frac{1}{A_1 F_{1-2}} + \frac{1-\varepsilon_2}{\varepsilon_2 A_2}}$$

$Q_{1-2} = A_1 F_{1-2} \sigma (T_1^4 - T_2^4)$

$$\frac{Q_{1-2}}{A_1} = 1\times 6\times 10^{-8}(300^4 - 500^4)$$

Net radiative heat flux = $6\ (3^4 - 5^4)$

$= -6 \times (5^2 + 3^2)\ (5 + 3)\ (5 - 3)$

$= -6 \times 34 \times 8 \times 2$

$= -6 \times 34 \times 16$

$= -3264$ W/m^2

$= -3.264$ kW/m^2 = 3.264 kW/m^2

(Negative sign indicates that heat is transferring from surface 2 to surface 1).

42. Ans: (b)

Sol: Available energy

$$= 2000\times\left[\frac{500-300}{500}\right] = 800\,\text{kJ}$$

Unavailable energy = 2000 – 800 = 1200 kJ

43. Ans: (a)

Sol: Given, $\frac{D_m}{D_p} = \frac{1}{10}$

where m and p denote for model and prototype turbine :

and $\frac{N_m}{N_p} = \frac{600}{200} = 3$ and $H_p = 30$ m

We know that,

$U \propto \sqrt{H}$

$ND \propto \sqrt{H}$

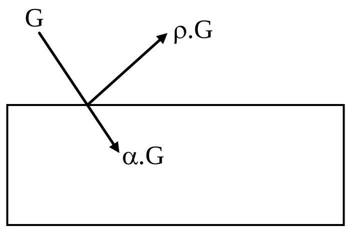
Or, $H \propto N^2D^2$

So, $$\frac{H_m}{H_p} = \left(\frac{N_m}{N_p}\right)^2 \times \left(\frac{D_m}{D_p}\right)^2 = 3^2 \times \left(\frac{1}{10}\right)^2$$

$$\Rightarrow H_m = 30\times 9\times\frac{1}{100} = 2.7\text{ m}$$

44. Ans: (b)

Sol:



$\alpha = 0.4$

For an opaque body, $\tau = 0$

$\alpha + \rho + \tau = 1$

$0.4 + \rho + 0 = 1$

$\rho = 0.6$

$$\frac{\text{Reflected energy}}{\text{Absorbed energy}} = \frac{0.6\,G}{0.4\,G} = \frac{6}{4} = 1.5$$

45. Ans: (b)

Sol: For all variable x, y, z

$$\left(\frac{\partial y}{\partial z}\right)_x \left(\frac{\partial z}{\partial x}\right)_y \left(\frac{\partial x}{\partial y}\right)_z = -1$$

46. Ans: (a)

Sol:

- Isentropic efficiency is, η_{isen} = R.F × η_{stage} where R.F is reheat factor. Reheat factor is always greater than 1.

  Therefore $\eta_{isen} > \eta_{stage}$.

- Reheat factor increases with increase in number of stage because constant pressure lines diverge in T-s diagram.

47. Ans: (d)

Sol: Total heat transfer (average heat transfer)

$= \bar{h}.A.\Delta T$

$\bar{h} = 2h_x$ (For laminar flow)

$Q = 2\ h_x.\ A\ \Delta T$

$Q = 2\times116.89\times1\times60$

$Q = 14027.56\ W/m^2$

48. Ans: (d)

Sol: Enthalpy at final state, $h_2 = h_{f2} + x_2(h_g - h_f)_2$

Initial enthalpy, $h_1 = h_{f2}$

$$ds = \frac{h_2 - h_1}{T_{sat}}$$

$$= \frac{x(h_g - h_f)}{273+120.23} = \frac{0.7\times(2707-505)}{(120+273)}$$

$= 3.922$

49. Ans: (d)

Sol: For n-row Curtis stage

$$\rho_{opt} = \frac{\cos\alpha}{2n} = \frac{\cos 30}{2\times2} = \left(\frac{\sqrt{3}}{2\times2}\right) = 0.22$$

50. Ans: (a)

Sol: **Biot number** - Ratio of internal thermal resistance to boundary layer thermal resistance

Grashof number - Ratio of buoyancy to viscous force

Prandtl number - Ratio of momentum to thermal diffusivities

Reynolds number - Ratio of inertia force to viscous force

51. Ans: (a)

Sol:

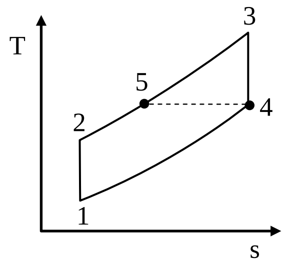
- Maximum temperature that can be allowed in ramjet engine is very high about 2000°C as compared to about 900°C turbojet because in ramjet engines turbine is not used to drive compressor.
- Pulse jet engine has static thrust. Thus, it doesn't need a launching device for initial propulsion.

52. Ans: (d)

Sol: TdS = dU + PdV is applicable to reversible or irreversible process performed by closed system.

53. Ans: (d)

Sol:



For gas turbine plants with ideal regeneration, efficiency is given by

$$\eta = 1-\frac{T_1}{T_3}(r_p)^{\frac{\gamma-1}{\gamma}}.$$

As r_p increases η decreases.

- $\text{Work ratio} = \dfrac{W_T - W_C}{W_T}$

  Work of compression in gas turbine plants is large as compared to pump work in steam power plants due to high specific volume of gas as compared to liquid.

  Thus, work ratio of gas turbine plants is quite smaller than that of steam power plants.

- In gas turbines reheating is more beneficial than intercooling because for the same compression ratio reheating gives more net work than intercooling.

54. Ans: (c)

Sol: First law of thermodynamics is the law of conservation of energy which is not violated.

55. Ans: (c)

Sol: Thrust power (P_T) = F × c_i

= 10 × 600 = 6000 kW

Heat input (Q) = 0.5 × 40000 = 20000 kW

Overall efficiency ,

$$\frac{P_T}{Q} = \frac{6000}{20000} = 0.3 \text{ or } 30\%$$

56. Ans: (c)

Sol: Change in Available Energy

$= (h_1 – h_2) – T_0 (s_1 – s_2)$

= (400 – 100) – 300 (1.1 – 0.7)

= 300 – 120 = 180 kJ/kg

57. Ans: (b)

Sol: NPSH = $H_a – H_S – H_L – h_{fs}$

(if sump is below the pump)

= 10.1 – (–3) – 0.3 – 0.4

= 12.4 m

58. Ans: (a)

Sol: All anti clockwise cycles are work consuming cycles. So, the cycle will heat the environment.

59. Ans: (d)

Sol: $K_u = \dfrac{u}{\sqrt{2gH}} = \dfrac{\pi DN/60}{\sqrt{2gH}}$

$$= \frac{\pi\times 0.7\times 600/60}{\sqrt{2\times 10\times 45}} = \frac{7\pi}{30} = 0.733$$

60. Ans: (b)

Sol: For the cycle 1-2-3-1 thermal efficiency can be written as

$$\eta = \frac{\text{Net work}}{\text{Heat supplied}}$$

$$= \frac{\text{Area under T} - \text{s diagram for cycle } 1-2-3-1}{\text{Area under } 3-1 \text{ process projected on 's' axis}}$$

$$\eta = \frac{\frac{1}{2}(s_b - s_a)(T_3 - T_1)}{\frac{1}{2}(T_3 + T_1)(s_b - s_a)}$$

$$= \frac{T_3 - T_1}{T_3 + T_1}$$

61. Ans: (a)

Sol: Given that:

$u = x - 4y$ and $v = -y - 4x$

$\frac{\partial u}{\partial x} = 1$ and $\frac{\partial v}{\partial y} = -1$

So, $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 1 - 1 = 0$

⇒ Continuity equation is satisfied. Thus, the given flow field does describe a possible 2-D incompressible flow.

Also, $\frac{\partial v}{\partial x} = -4$ and $\frac{\partial u}{\partial y} = -4$

Thus, $\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} = -4 - (-4) = 0$

⇒ This shows that flow is irrotational. Hence, statement 2 is wrong.

62. Ans: (b)

Sol: We know that for an adiabatic process:

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{v_1}{v_2}\right)^{\gamma-1}$$

$$T_2 = T_1 \times \left(\frac{v_1}{v_2}\right)^{\gamma-1} = T_1 \times 2^{\gamma-1} \ldots\ldots\text{(i)}$$

$P_2 = P_1 \times 2^{\gamma}$…………(ii)

$\gamma = 1.67$ for He an Ne

$\gamma = 1.4$ for O_2

From equation (i), $(T_2)_{He,\ Ne} > (T_2)_{O2}$

From equation (ii), $(P_2)_{He,\ Ne} > (P_2)_{O2}$

63. Ans: (c)

Sol: Given data:

$d_1 = 5$ m, $V_1 = 4.5$ m/s,

$d_2 = 4.5$ m, $L = 100$ m

From continuity equation:

$A_1V_1 = A_2V_2$

$$V_2 = \left(\frac{d_1}{d_2}\right)^2 V_1$$

$$= \left(\frac{5}{4.5}\right)^2 \times 4.5 = \frac{2.5}{4.5} = 5.55 \text{ m/s}$$

Given that losses vary as the square of the velocity,

$$\frac{(\text{Losses})_{\text{pipe 2}}}{(\text{Losses})_{\text{pipe 1}}} = \frac{V_2^2}{V_1^2} = \frac{5.55^2}{4.5^2} = 1.52$$

⇒ Thus, losses in 4.5 m diameter pipe are 52% greater than those in 5 m pipe.

64. Ans: (d)

Sol:

- 1-D, steady heat conduction equation with internal thermal energy generation :
  - (1) For solid cylinder with internal heat generation :

    $$T = -\frac{\dot{q}r^2}{4k} + c_2 \quad \text{(Parabolic)}$$

  - (2) For hollow cylinder without internal heat generation :

    $T = c_1\, ln(r) + c_2$ (Logarithmic)

  - (3) For solid sphere :

    $$T = -\frac{\dot{q}\,r^2}{6k} + c_2 \quad \text{(Parabolic)}$$

65. Ans: (a)

66. Ans: (b)

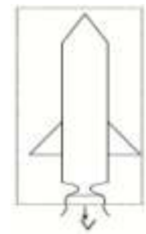
Sol:

- The entropy change of an isolated system is the sum of entropy changes of its components and it always increases or, in limiting case of a reversible process, remains constant.
- A system and its surrounding always form an isolated system.

67. Ans: (a)

Sol: The momentum equation with respect to accelerated control volume is

$$\underbrace{(-mg)}_{\text{external}} + \underbrace{(-ma)}_{\text{inertia}} = \underbrace{\dot{m}\vec{V}_{out} - \dot{m}\vec{V}_{in} + \frac{\partial}{\partial t}\left(m\vec{V}\right)_{c.v}}_{\text{momentum change}}$$



Thus, from the above equation it is evident that external forces acting on rocket do not sum to zero and gravitational force is the only external force acting on the rocket during its propulsion.

68. Ans: (d)

Sol:

- Prandtl number is the property of the fluid.

  $$Pr = \frac{\mu c_p}{k}$$

  All μ, c_p and k are the properties of the fluid.
- For laminar flow,

  $$\frac{\delta}{\delta_t} = (Pr)^{1/3}$$

  when $Pr > 1$

  $\delta > \delta_t$

  Here,

  δ = hydrodynamic boundary layer thickness

  δ_t = thermal boundary layer thickness

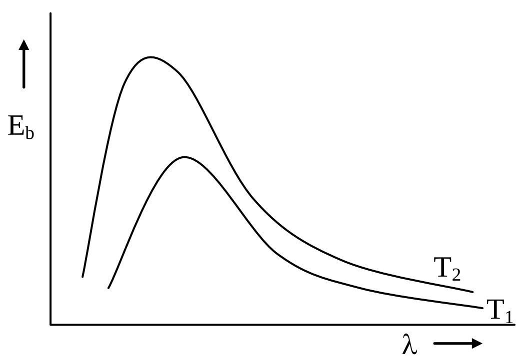
69. Ans: (a)

Sol:

- Integrating total stress (shear stress + normal stress (pressure)) over area gives the net force.
- The net force can be resolved into two components. The component along the direction of flow is called drag force and the normal component is called lift.
- Thus, both statements are correct and statement (II) is the correct explanation of statement (I)

70. Ans: (b)

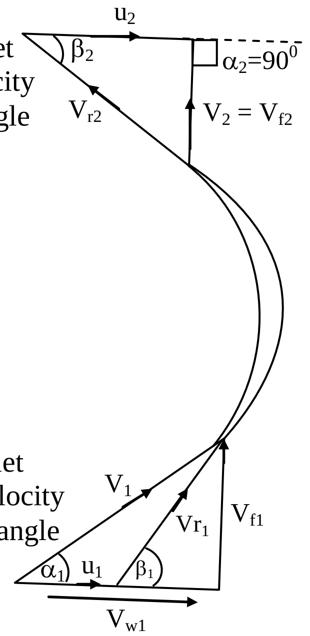
Sol:



According to the above figure, both the statements are correct but statement - II is not a right explanation of statement - (I).

71. Ans: (a)

Sol:



Referring to the exit velocity triangle it is evident that for α_2 other than 90°, V_{w2} is always present and the rejected kinetic energy will be more than that corresponding to α_2 = 90°. This will result in less efficiency.

72. Ans: (c)

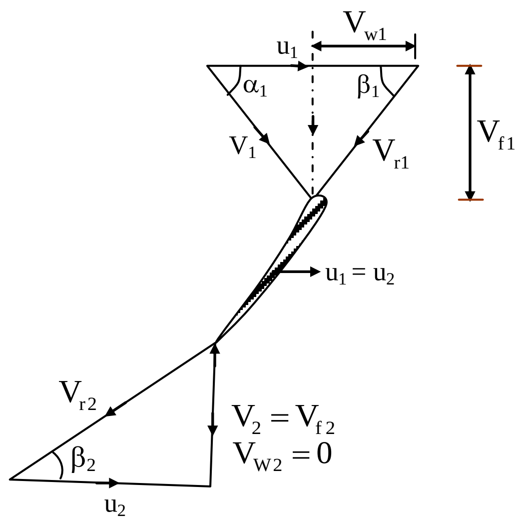
Sol:

- Exergy of heat (Q) supplied = $Q\left(1-\frac{T_0}{T_H}\right)$ =

  Work output of a Carnot heat engine operating between the reservoir (At temperature T_H) and the environment (At temperature T_0).
- Exergy of an isolated system will always decrease.

73. Ans: (a)

Sol:



For Kaplan turbine

$$V_{f1} = V_{f2} = \frac{Q}{\frac{\pi}{4}\left(D_0^2 - D_i^2\right)}$$

$u_1 = u_2 = r\omega$

$V_{w2} = 0, \ V_{w1} > 0$

$$\tan\beta_1 = \frac{V_{f1}}{u_1 - V_{w1}},$$

$$\tan\beta_2 = \frac{V_{f2}}{u_2} = \frac{V_{f1}}{u_1}$$

$$\frac{V_{f1}}{u_1 - V_{w1}} > \frac{V_{f1}}{u_1}$$

$\therefore \beta_1 > \beta_2$

74. Ans: (c)

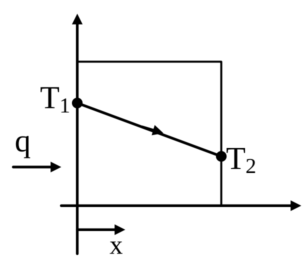
Sol:

- Air vessel on suction pipe eliminates the fluctuations in velocity in suction pipe. This reduces frictional head loss. Hence, pumping power is reduced.
- Air vessel attached to suction pipe has no effect on discharge (quantity of flow rate). Thus, statement (II) is wrong.
- It can be shown that for single acting reciprocating pump frictional head loss reduces by 85% and for double acting pump it reduces by 39% with use of air vessels.

75. Ans: (a)

Sol: Temperature distribution inside the slab :

$$Q = -kA\frac{dT}{dx}$$



As Q = constant,

k = constant and

A = constant

then $\frac{dT}{dx}$ = constant


ACE ENGINEERING ACADEMY
Since 1995
ACE
Engineering Academy
Leading Institute for ESE/GATE/PSUs
23
Years of Excellence
CONGRATULATIONS TO OUR
ESE - 2018 TOP RANKERS
AIR 1 SHASHANK E&T
AIR 1 CHIRAG JHA EE
AIR 1 VINAY PRAKASH CE
AIR 1 AMAN JAIN ME
AIR 2 CHERUKURI SAIDEEP E&T
AIR 2 SHADAB AHAMAD EE
AIR 2 PUNIT SINGH CE
AIR 2 CHIRAG SINGLA ME
AIR 3 RAMESH KAMULLA E&T
AIR 3 SRIJAN VARMA EE
AIR 3 PRAVEEN KUMAR CE
AIR 3 MAYUR PATIL ME
AIR 4 JAPJIT SINGH E&T
AIR 4 ANKIT GARG EE
AIR 4 AMIT KUMAR ME
AIR 5 NARENDRA KUMAR E&T
AIR 5 KARTHIK KOTTURU EE
AIR 5 RISHABH DUTT CE
AIR 5 VITTHAL PANDEY ME
AIR 6 KUMUD JINDAL E&T
AIR 6 RATIPALLI NAGESWAR EE
AIR 7 KARTIKEYA DUTTA E&T
AIR 7 TEKCHAND DESHWAL EE
AIR 7 ROHIT KUMAR CE
AIR 8 SURYASH GAUTAM E&T
AIR 8 RAVI TEJA MANNE EE
AIR 8 VIJAYA NANDAN CE
AIR 8 ROHIT BANSAL ME
AIR 9 SHANAVAS CP E&T
AIR 9 SOUVIK DEB ROY EE
AIR 9 ROOPESH MITTAL CE
AIR 10 PRATHAMESH E&T
AIR 10 MILAN KRISHNA EE
AIR 10 SRICHAND POONIYA CE
TOTAL SELECTIONS in Top 10 34
E&T TOP 10 10
EE TOP 10 10
CE TOP 10 8
ME TOP 10 6
and many more...
www.aceenggacademy.com