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Engineering Academy

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ESE- 2018 (Prelims) - Offline Test Series   Test - 5

MECHANICAL ENGINEERING

SUBJECT: THERMODYNAMICS AND HEAT TRANSFER + RENEWABLE SOURCES OF ENERGY – SOLUTIONS

01. Ans: (c)

Sol: Taking air to be our system and room interior to be system boundary and applying first law of thermodynamics

$Q - W = \Delta U$

As W is negative (external electrical work input), Q is zero (Insulated room)

So, $\Delta U > 0$

$\Rightarrow \Delta T > 0$

So, the room will be gradually warmed up.

02. Ans: (c)

Sol: Since the above equations are the relation among properties which are independent of path, so they are valid for all the processes.

03. Ans: (d)

Sol: Clausius-Clapeyron equaion is applicable to any phase-change process that occurs at constant temperature and pressure and it is derived from Maxwell equation: $\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{\partial s}{\partial V}\right)_T$.

04. Ans: (c)

Sol: $$\left((\Delta S)_{univ}\right)_I = \frac{Q}{T_2} - \frac{Q}{T_1} = -\frac{600}{1200} + \frac{600}{300}$$

$$= 1.5 \text{ kJ/K}$$

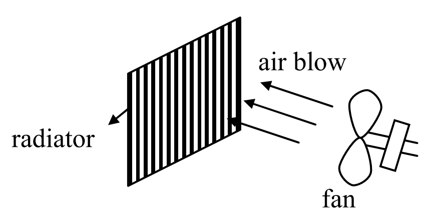
$$\left((\Delta S)_{univ}\right)_{II} = \frac{Q}{T_2} - \frac{Q}{T_1} = -\frac{1000}{2000} + \frac{1000}{500}$$

$$= 1.5 \text{ kJ/K}$$

$$\therefore \left((\Delta S)_{univ}\right)_{II} = \left((\Delta S)_{univ}\right)_I$$

05. Ans: (b)

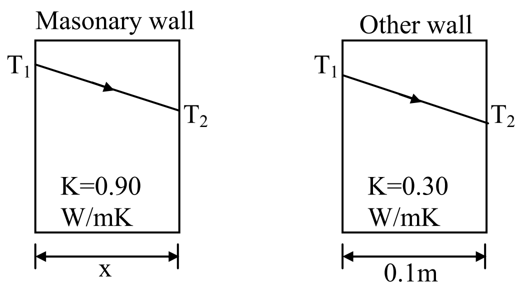
Sol:



Radiator is an example of cross-flow type of heat exchanger, in which most of the heat is transfered due to convection.

06. Ans: (c)

Sol:



Heat transfer through masonary wall = 90% × heat transfer through another wall.

$(q)_{\text{masonary wall}} = 0.9(q)_{\text{other wall}}$

$$\frac{(T_1 - T_2)}{\left(\frac{x}{0.90}\right)} = \frac{0.9(T_1 - T_2)}{\frac{0.1}{0.30}}$$

$$\frac{0.9x}{0.90} = \frac{0.1}{0.30}$$

$$x = \frac{1}{3} = 0.3333 \text{ m}$$

$\Rightarrow x = 333.3$ mm

07. Ans: (b)

Sol: $A_1 = 1 \text{ m}^2$,

$A_2 = 4 \text{ m}^2$,

$F_{1\text{-}2} = 0.4$

Using reciprocity theorem:

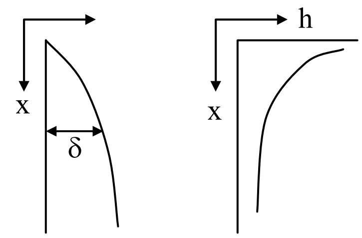
$A_1F_{1\text{-}2} = A_2F_{2\text{-}1}$

$1 \times 0.4 = 4 \times F_{2\text{-}1}$

$$F_{2-1} = \frac{0.4}{4} = 0.1$$

08. Ans: (a)

Sol:



$$\delta \propto (x)^{1/4}$$

$$h \propto \frac{1}{(x)^{1/4}}$$

$$h \propto \frac{1}{\delta}$$

09. Ans: (b)

Sol: Hydrogen cannot be directly heated or transformed to other compounds to liberate energy. It is used as an energy carrier in fuel cells.

10. Ans: (a)

Sol: Turbine in tidal power system is rotated during high tide when the head is large enough to produce energy. During high tide, if water is pumped from ocean to basin then head of the water available for turbine increases which increases the net energy generation. Tidal range depends upon the height of on high and low tide.

11. Ans: (d)

Sol: When solar cells are arranged in series, net effective resistance increases which increases the losses.

12. Ans: (b)

Sol: n–type semiconductors are Phosporous, arsenic and germanium. P-type semi conductors are boron and gallium.

13. Ans: (a)

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

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

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

$$\eta = \frac{\frac{1}{2}(s_b - s_a)(T_3 - T_1)}{(T_2)(s_b - s_a)}$$

$$= \frac{T_3 - T_1}{2T_3} \qquad (\because\ T_2 = T_3)$$

14. Ans: (b)

Sol: $\gamma_d = \left(\frac{1+\cos\beta}{2}\right)$

$\beta = 60^o$

$$\gamma_d = \left(\frac{1+\cos 60^o}{2}\right) = \frac{3}{4} = 0.75$$

15. Ans: (d)

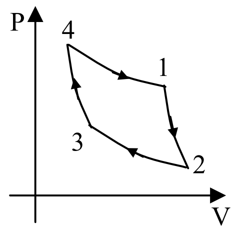
Sol: The desired fraction (f) is

$$f = \frac{\Delta U}{\Delta Q} = \frac{nC_v dT}{nC_p dT} = \frac{C_v}{C_p} = \frac{1}{\gamma}$$

$$f = \frac{5}{7}$$

16. Ans: (b)

Sol:



During adiabatic expansion process (1-2) we can write

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$\frac{T_2}{T_1} = \left(\frac{1}{32}\right)^{\frac{7}{5}-1} = \left(\frac{1}{2^5}\right)^{\frac{2}{5}} \quad \left[\because \gamma = \frac{7}{5} \text{ for diatomic gas}\right]$$

$$T_2 = \frac{1}{4}T_1$$

$$\eta = 1 - \frac{T_2}{T_1} = \frac{3}{4} = 0.75$$

17. Ans: (c)

Sol:

- Temperature at B > Temperature at D [Since, $P_BV_B > P_DV_D$]
  $\Rightarrow U_D < U_B$

Applying first law of thermodynamics to path B → C → D

$Q - W = U_D - U_B$

$Q = (U_D - U_B) + W$

As W is negative $\Rightarrow Q < 0$

So, heat flows out of the gas

- Since, ABCDA is clockwise cycle. So, work done by the gas is positive.

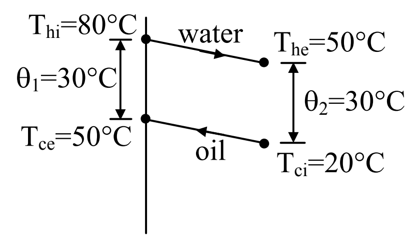
18. Ans: (d)

Sol:

Black body	-	$\rho = \tau = 0$
Gray body	-	Emissivity is constant
Opaque body	-	$\alpha + \rho = 1$
Specular body	-	Reflection is angle dependent

19. Ans: (b)

Sol:



For water, $C_w = \dot{m}_w.C_{p_w}$

$$= \rho A v \times C_{p_w} = 1000 \times \left(\frac{0.02}{60}\right) \times 4$$

$$C_w = \frac{80}{60} \text{ kW/K}$$

For oil, $C_o = \dot{m}_o.C_{p_o}$

$$= \rho A v \times C_{p_w} = 800 \times \left(\frac{0.05}{60}\right) \times 2$$

$$C_o = \frac{80}{60} \text{ kW/K}$$

When, $C_{min} = C_{max} \Rightarrow C = \frac{C_{min}}{C_{max}} = 1$ (every where the temperature difference will be same)

LMTD $= \theta_1 = \theta_2 = 30°C$

$T_{ce} = T_{hi} - \text{LMTD} = 80 - 30$

$T_{ce} = 50°C$

20. Ans: (b)

Sol: $F_{1-2} = 1$ (from the geometry)

Using reciprocity theorem:

$A_1F_{1-2} = A_2F_{2-1}$

$$\pi R^2 \times 1 = \left(\frac{4\pi R^2}{2}\right) \times F_{2-1}$$

$$F_{2-1} = \frac{1}{2} = 0.5$$

Using summation rule:

$F_{2-1} + F_{2-2} = 1$

$F_{2-2} = 1 – 0.5 = 0.5$

21. Ans: (b)

Sol: Heat transfer coefficient for turbulent free convection is independent of x

Average heat transfer coefficient

$$(\bar{h}) = \frac{1}{L}\int_0^L h_x\, dx$$

$$= \frac{h_x}{L} \times L$$

$$\bar{h} = h_x$$

22. Ans: (a)

Sol: At higher altitudes, pressure is less and due to low pressure, wind speed increases.

23. Ans: (d)

Sol: Yawing is the rotation about axis which is perpendicular to wind direction and shaft . It helps to keep rotor in wind direction.

24. Ans: (c)

Sol: Main Ingredient of biogas is methane. It does not produce any kind of smoke or ash.

25. Ans: (c)

Sol: Intrinsic Semiconductors have properties as average of conductor and non conductor. Its Fermi level lies in middle of the energy gap.

26. Ans: (d)

Sol: $\left(\frac{V_1}{V_2}\right)^{\gamma-1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$ is valid for reversible adiabatic (Isentropic process) performed by an ideal gas and assuming constant specific heat during the working range of temperature.

27. Ans: (a)

Sol: Reversible process is an ideal process which consumes least and deliver the most work. Reversible process is that process which can be reversed without leaving any trace on system or surrounding.

28. Ans: (a)

Sol: $P = \rho RT,\quad \frac{P}{\rho} = \text{slope}$

So, $T_1 > T_2$ (Since slope is greater)

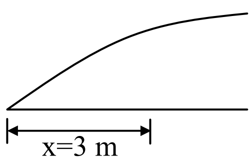
29. Ans: (c)

Sol: From first law of thermodynamics, $Q - W = \Delta U$. If heat is added and the value of $Q - W$ becomes negative (magnitude of work done by system is greater than magnitude of heat supplied) then $\Delta U < 0$.

$\Rightarrow$Temperature decreases.

30. Ans: (c)

Sol:



Dimensionless temperature gradient at the wall = 1000

Nu = 1000

$$\frac{h \times x}{k} = 1000$$

$$\frac{h \times 3}{0.024} = 1000$$

$$h = \frac{1000 \times 0.024}{3} = 8 \text{ W/m}^2\text{.K}$$

31. Ans: (d)

Sol: **Configuration** **Equivalent emissivity**

Infinite parallel plate – $\dfrac{1}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1}$

A small body completely enclosed in a large enclosure – ϵ_1

Concentric spheres – $\dfrac{1}{\frac{1}{\epsilon_1} + \left(\frac{r_1}{r_2}\right)^2 \left(\frac{1}{\epsilon_2} - 1\right)}$

Concentric cylinders – $\dfrac{1}{\frac{1}{\epsilon_1} + \frac{r_1}{r_2}\left(\frac{1}{\epsilon_2} - 1\right)}$

32. Ans: (d)

Sol: Heat transfer coefficient is inversely proportional to fouling factor.

$$\frac{1}{UA} = \frac{1}{h_i A_i} + \frac{R_{f_i}}{A_i} + R_w + \frac{R_{f_o}}{A_o} + \frac{1}{h_o A_o}$$

R_w = wall thermal resistance

R_f = fouling factor

i = inside,

o = outside

33. Ans: (c)

Sol: For constant heat flux condition :

Nu = 4.36 (only for laminar flow)

$Nu = 0.023 Re^{0.8} Pr^n$ (turbulent flow)

$$\frac{L_{e,h}}{D} = 0.05\, Re_D$$

$$\frac{L_{e,t}}{D} = 0.05\, Re_D \,.Pr$$

$$\frac{L_{e,t}}{L_{e,h}} = Pr$$

If Pr > 1

(thermal entrance length) > (Hydrodynamic entrance length)

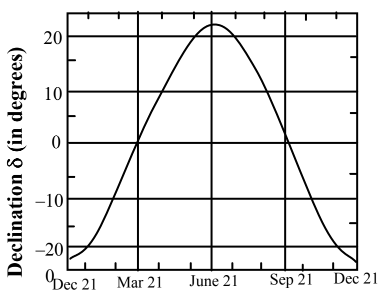
If Pr < 1

Thermal entrance length < Hydrodynamic entrance length

34. Ans: (b)

Sol: Declination of beam radiation is highest during June 21 and it is 23.45°. On June 27 it should be near to 23.45°.

$$\delta = 23.45 \sin\left[\frac{360}{365}(284+n)\right]$$



Variation of Declination over the year

35. Ans: (d)

Sol: On horizontal surface, incidence angle is equal to zenith angle, and solar altitude angle is complement of zenith angle.

36. Ans: (d)

Sol: Wave energy and biomass are non conventional energy sources.

37. Ans: (d)

Sol: The incident radiation on a flat plate depends on angle of tilt but not height of the panel, location of the plate.

38. Ans: (b)

Sol:

- There is decrease in volume during melting of ice slab at 273 K. Therefore, negative work is done by ice-water system on the atmosphere or positive work is done on the ice-water system by the atmosphere.
- There is increase in internal energy due to heat absorbed by ice.

39. Ans: (a)

Sol: PV = constant ($\because$ T = 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: Entropy change of reservoir at 400 K

$$= -\frac{800}{400} = -2\,kJ/K$$

Net heat transferred to reservoir at 200 K

= 800 – 400 = 400 kJ

Entropy change of reservoir at 200 K

$$= \frac{400}{200} = 2\,kJ/K$$

Entropy generated during the process

= –2 + 2 = 0

41. Ans: (d)

Sol: Reversible work

$$= \left(1-\frac{300}{1200}\right)\times 500 = 375\,\text{kW}$$

Irreversibility rate = Reversible power – Actual power

= 375 – 180 = 195 kW

42. Ans: (c)

Sol: $\in = \eta \times \frac{A_s}{A_c}$

$$\frac{\in}{\eta} = \frac{A_s}{A_c} = \frac{PL}{A_c}$$

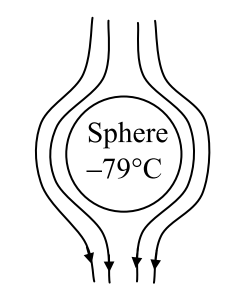
Effectiveness of the fin, $(\in) = \sqrt{\frac{Pk}{hA}}$

$$\in \propto \frac{1}{\sqrt{h}}$$

As *h* decreases, effectiveness ($\in$) increases. Fins will be more effective when it will be putted in lower heat transfer coefficient environment.

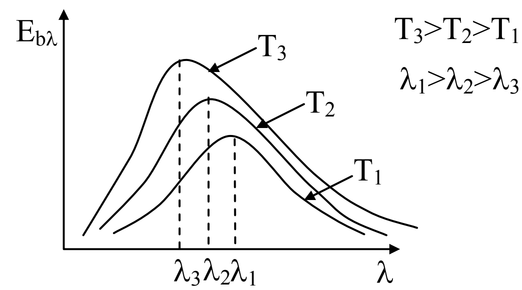
43. Ans: (c)

Sol: General direction of air for cooled sphere.



44. Ans: (b)

Sol:



45. Ans: (d)

Sol: Rough surfaces give diffused reflections, not specular reflection. Generally most of the engineering materials have rough surfaces.

46. Ans: (b)

Sol: A cell is like building block. So, we can add it according to the power requirement. As there is no mechanical work involved in the photovoltaic cell, it has no moving parts. These cells can work in both beam and diffused radiation.

47. Ans: (b)

Sol: $\frac{P_{avg}}{A} = 0.225\left(R^2 - r^2\right) MW/km^2$

$$\frac{2.7\times 0.3}{2500\text{x}10^{-6}} = 0.225\left(R^2 - 25\right)$$

$$R^2 - 25 = \frac{2.7\times 0.3}{2500\times 10^{-6}\times 0.225}$$

$$R^2 = 25 + 144$$

$\Rightarrow$ R = 13 m

48. Ans: (c)

Sol: $u_o = 15$ m/s, $u_2 = 6$ m/s

$CP = 4.a.(1-a)^2$

$$a = \frac{u_o - u_2}{2u_0} = \frac{15-6}{2\times 15} = 0.3$$

$= 4\times0.3(1-0.3)^2 = 0.4 \times 0.81 = 0.588$

49. Ans: (a)

Sol: Heat energy gain per day = (rate at which the system receives solar energy) × (collector area) × (efficiency)

$= (6.5 \text{ MJm}^{-2}) \times (8.36 \text{ m}^2) \times (0.7)$

We use the equation $Q = mc\Delta T$

$\Delta T = Q/(mc)$

$= (6.5 \text{ MJm}^{-2})\times(8.36 \text{ m}^2)\times(0.7)/(325 \text{ kg}\times4.18 \text{ kJ/°C})$

$= 28°C$

50. Ans: (b)

Sol: Critical point → Properties of saturated liquid and saturated vapor are same.

Sublimation → On heating solid changes to vapour state

Triple point → (Solid + liquid + vapour) coexist.

Melting → Phase change from solid to liquid.

51. Ans: (b)

Sol: By applying steady flow energy equation per unit mass flow rate at start and end of compressor

$h_1 + q = h_2 + w$

$\Rightarrow 100 - 60 = 200 + w$

$w = -160$

Power required = $2\times160 = 320$ kW

52. Ans: (a)

Sol:

- From 1st law of thermodynamics

$Q - W = \Delta U$

$Q = 0$ [Insulated tank]

$-W = C_v(T_2 - T_1)$

- W_{min} = Change in available energy

$= (U_2 - U_1) - T_0(\Delta S)$

$= C_v(T_2 - T_1) - T_0 C_V \ell n\frac{T_2}{T_1}$

- Irreversibility $= W - W_{min} = T_0 C_v \ell n\frac{T_2}{T_1}$

53. Ans: (c)

Sol: For lumped capacity analysis-

- Internal conductive resistance is negligible
- Biot number < 0.1
- Smaller body with higher thermal conductivity.

54. Ans: (b)

Sol: Heat generated = 180 W/cm^3

$$\text{Heat flux} = \frac{180W \times \frac{\pi}{4}d^2 \times L}{\pi dL}$$

$$= 180 \times \frac{d}{4}$$

$$= 180 \times \frac{0.3}{4}$$

$$= \frac{54}{4} = 13.5 \text{ W/cm}^2$$

55. Ans: (d)

Sol: For 1-D, steady state heat conduction equation without heat generation

$$\frac{\partial^2 T}{\partial x^2} = 0$$

Integrate with respect to x $\quad \frac{\partial T}{\partial x} = C_1$

Again integrate with respect to x

$T = C_1x + C_2$ ----------(1)

At x = 0, T = 40°C

$40 = 0 + C_2T$

$C_2 = 40$

At x = 0.15 m, T = 28°C

$28 = 0.15C_1 + 40$

$$C_1 = \frac{-12}{0.15} = -80$$

$T(x) = C_1x + C_2$

$T(x) = -80x + 40$

56. Ans: (d)

Sol: Generally thermal conductivity of liquid is independent of pressure except critical pressure.

For liquids:

As temperature increases → Thermal conductivity decreases

For gas:

$k \alpha \sqrt{T}$ as per kinetic theory of gas

As Temperature decreases → Thermal conductivity increases.

57. Ans: (d)

Sol: It is the angle on a horizontal plane, between the line due south and projection of the sun's ray on the horizontal plane. It varies from – 180° to 180°

58. Ans: (a)

Sol: Fill factor (FF) = $\frac{P_{max}}{I_{SCC}V_{OCV}}$

$$= \frac{18\times10^{-3}}{30\times10^{-3}\times1.2} = \frac{1}{2} = 50\%$$

59. Ans: (c)

Sol: Alkaline Fuel Cells have high energy density and KOH electrolyte in AFC's when exposed to atmosphere reacts with CO_2 to form K_2CO_3.They are used in space and military appliances.

60. 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.

61. 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.

62. Ans: (c)

Sol: Spontaneous processes are always irreversible.

63. Ans: (b)

Sol:

- μ = Joule – Thomson coefficient = $\left(\frac{\partial T}{\partial p}\right)_h$

  During throttling, pressure always decreases. Hence, for cooling $\partial T < 0$.

  Hence, Joule-Thomson coefficient is positive.
- During throttling process enthalpy remains constant.

64. Ans: (c)

Sol: Tidal power turbines run at 20-25 rpm which is 10 times lesser than speed of ship rotors.

65. Ans: (c)

Sol: AFC's have high energy density and efficiency. Their working temperature is 80-100°C.

66. Ans: (c)

Sol: Anaerobic respiration of Biomass produces methane gas which is dangerous and causes air pollution when exposed to atmosphere. Bio fuels are produced from fresh/decomposed organic matter.

67. Ans: (c)

Sol: Microwave ovens utilise electromagnetic radiation in the microwave region of the spectrum, 10^2–10^5, generated by microwave tubes called magnetrons.

These microwaves are reflected by the metal walls of the oven, transmitted through the glass or plastic containers of the food and absorbed by the water molecules present in the food. The electric energy convected to radiation in the oven eventually becomes part of the internal energy of the food. This fastens cooking which becomes more efficient and less power-consuming.

68. Ans: (a)

Sol: The heat transfer coefficient decreases sharply from the presence of this non-condensable gas. The non condensable gas like air not only blankets the cooling surface but also offers a high thermal resistance.

69. Ans: (c)

Sol: Thermal capacity = mC_p

$\because$ C_p valve of mercury is large.

$\therefore$ Thermal capacity of mercury is large. Hence response to temperature change is low

70. Ans: (a)

Sol: Wind flow is caused by uneven heating of the atmosphere by the solar rays falling on earth, the irregularity of earth surface and rotation of earth.

71. Ans: (a)

Sol: Position of sun in the sky is determined by hour angle and declination angle. So, there should be two degrees of freedom for the tracking mechanism.

72. Ans: (d)

Sol: Effectiveness of the fin ($\in$) = $\sqrt{\frac{Pk}{hA}}$

$$\in \propto \frac{1}{\sqrt{h}}$$

Fin will be more effective when it is provided in lower heat transfer coefficient environment.

So, in a liquid to gas heat exchanger, fins should be provided in gas side.

73. Ans: (d)

Sol: In forced connection

Nusselt number (Nu) = f(Re, Pr)

Heat transfer coefficient (h) = f(Re, Pr, k/l)

In free convection, Nu = f(Gr, Pr)

Heat transfer coefficient (h) = f(Gr, Pr, k/l)

74. Ans: (a)

Sol: When density of atmospheric air becomes equal to density of helium inside balloon, then balloon starts floating in air.

75. Ans: (c)

Sol: All reversible processes are quasi static, but all quasi static processes are not reversible.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ME
3 ME SAURABH
4 ME AMIT KUMAR RAI
6 ME ANKAN GUPTA
7 ME DHRUV JHA
9 ME ACHARAJ GUPTA
5 IN TOP 10 RANKS
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