Atmospheric and Oceanic Sciences (XE-H)

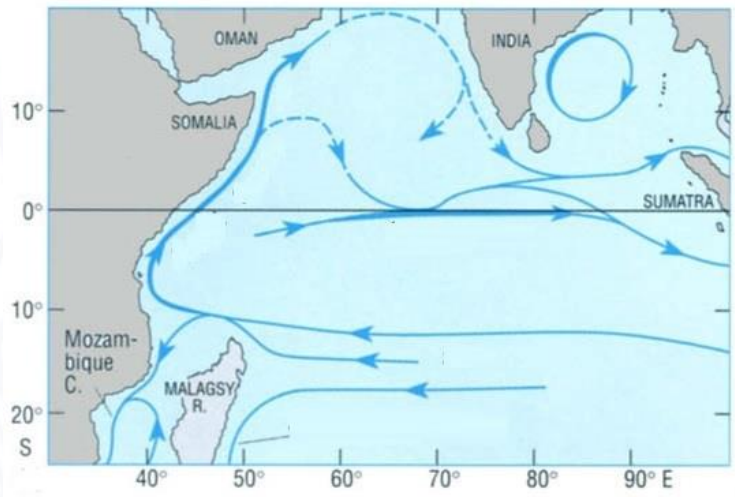
Q.1 – Q.5 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

Q.1	**Western Boundary Current in the ocean is primarily due to**
(A)	Ekman pumping.
(B)	rotation of the earth.
(C)	river water forcing.
(D)	ocean floor topography.

Q.2	**The relevant nondimensional number in deciding deepening of the thermocline driven by instability of ocean currents is**
(A)	Rossby number.
(B)	Reynolds number.
(C)	Richardson number.
(D)	Ekman number.

Q.3	**During July-August, the highest number of monsoon low pressure systems form over**
(A)	Arabian Sea.
(B)	Bay of Bengal.
(C)	South India.
(D)	Himalayan foothills.

Q.4	**CO_2 concentration in the Earth's atmosphere is increasing because 50% of the annual anthropogenic emissions are retained in the atmosphere. If nations agree to reduce annual CO_2 emissions by one Giga ton every year starting from 2021, then in which year will the CO_2 concentration in the atmosphere stop rising due to anthropogenic emissions?** **Take the anthropogenic CO_2 emissions in 2020 as 40 Giga tons.**
(A)	2020
(B)	2050
(C)	2060
(D)	2100

Q.5	**The figure shows a schematic of Indian Ocean surface circulation. This pattern is representative of the circulation in which month of the year?** 
(A)	January
(B)	July
(C)	May
(D)	November

Q. 6–Q. 7 Multiple Select Question (MSQ), Carry ONE mark each (no negative marks).

Q.6	**Over the open ocean, if the air sea temperature difference is zero, then which of the following statements is/are always true?**
(A)	Sensible heat flux is zero.
(B)	Latent heat flux is zero.
(C)	Momentum flux is zero.
(D)	Net energy flux is zero.

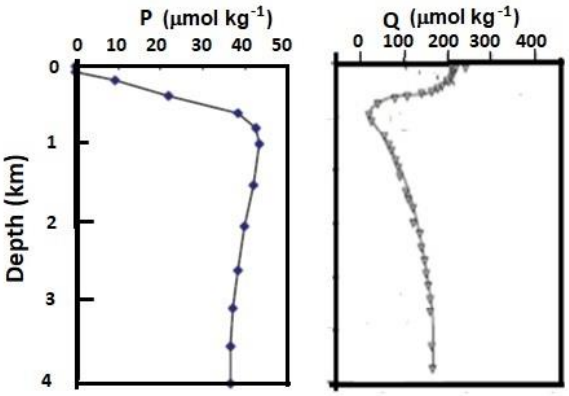
Q.7	**The psychrometric equation, which is useful in measuring humidity, is derived assuming the following process(es).**
(A)	Isobaric process
(B)	Isothermal process
(C)	Adiabatic process
(D)	Isentropic process

Q.8 – Q.9 Numerical Answer Type (NAT), carry ONE mark each (no negative marks).

Q.8	**The water vapour mixing ratio of an air parcel increases from 10 g kg^{-1} to 20 g kg^{-1} at a constant pressure of 1010 hPa and temperature of 300 K. The change in virtual temperature is _____ K (to one decimal place).**

Q.9	**The Ekman layer thickness, if turbulent diffusivity is 0.01 $m^2 s^{-1}$, is _____ m. Take Coriolis parameter to be 10^{-4} s^{-1}. Calculate to the nearest integer.**

Q. 10 – Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: – 2/3).

Q. 10	**The figure shows vertical variation of two chemicals P and Q measured in the Pacific Ocean. Identify the correct combination showing (P, Q) pair from the list below.** 
(A)	Oxygen, Nitrate
(B)	Oxygen, Neon
(C)	Nitrate, Oxygen
(D)	Neon, Nitrate

Q. 11 –Q. 15 Multiple Select Question (MSQ), Carry TWO marks each (no negative marks).

Q. 11	**Consider tropical high-level clouds and low-level stratus clouds with bases at 12 km and 1 km above the surface of the Earth, respectively. Which of the following statement(s) is/are correct?**
(A)	High clouds are composed of ice crystals.
(B)	High clouds have a larger albedo than low clouds.
(C)	High clouds have a net warming effect on climate.
(D)	Low clouds have a net warming effect on climate.

Q. 12	**Which of the following statement(s) is/are correct in the context of Sverdrup transport?**
(A)	Sverdrup transport is always in the meridional direction.
(B)	Sverdrup transport is always orthogonal to the wind direction.
(C)	Sverdrup transport depends on the variation of the Coriolis parameter.
(D)	Sverdrup transport is only due to ageostrophic currents.

Q.13	**Which of the following statement(s) is/are true with regard to the Hadley circulation?**
(A)	The ascending branch is narrower than its descending branch.
(B)	Thunderstorms are more frequent in the subsiding region of the Hadley cell than in its ascending region.
(C)	The lower level winds between the ascending and descending branches of the Hadley cell are north-westerly.
(D)	Latent heat is transported from the subsiding to the ascending region of the Hadley cell.

Q.14	**Which of the following statement(s) is/are true about the ocean circulation?**
(A)	Large-scale ocean surface currents are driven by winds.
(B)	Cold, dense and salty water forms in the North Atlantic Ocean.
(C)	Upwelling currents bring warm nutrient deficient water to the surface of the ocean.
(D)	Thermohaline circulation does not transport energy in the meridional direction.

Q. 15	**Coral reefs are found primarily in tropical and subtropical shallow seawaters. Which of the following statement(s) is/are correct?**
(A)	Corals require plenty of sunlight for photosynthesis and sunlight is abundant in the tropical and subtropical latitudes.
(B)	Corals grow optimally in seawater unsaturated in carbonate, which is found only in the tropical and subtropical oceans.
(C)	Corals grow optimally in fresh low-salinity water.
(D)	Corals grow optimally in water temperatures between 23^{o}C and 29^{o}C.

Q. 16 – Q. 22 Numerical Answer Type (NAT), carry TWO marks each (no negative marks).

Q. 16	**In an incompressible fluid, the horizontal divergence is $-0.01\ s^{-1}$. Then, the vertical velocity at 50 m above a flat surface is ____ $m\ s^{-1}$. Round off to one decimal place.**

Q. 17	**In an atmosphere, temperature (T) decreases linearly with height above the ground (z), i.e., $T(z) = T_o - \gamma z$, where γ is a constant. Surface pressure is 900 hPa. If the atmosphere is at rest, then the value of z at which the pressure decreases to half of that at the surface is _____ m (round off to the nearest integer).** **Take acceleration due to gravity $g = 10\ m\ s^{-2}$, gas constant $R = 300\ J\ kg^{-1}\ K^{-1}$, $T_o = 300$ K and $\gamma = 1/30\ K\ m^{-1}$, and the atmosphere behaves as an ideal gas.**

Q. 18	**In a local Cartesian system, a zonal jet has a form $u(y) = u_o (1 - y^2/L^2)$, for $-L \le y \le L$. Here, y is the meridional distance measured from the axis of the jet and is positive northward. The vertical component of vorticity of this flow at y=L/2 is _____ s^{-1}. Round off to 3 decimal places.** **Take $u_o = 50\ m\ s^{-1}$ and L = 5 km.**

Q.19	**An eastward flow with a speed of $10\ m\ s^{-1}$ goes from station M to station N, which are separated by a distance of 1 km. The temperature at station N is always higher than that at station M by 10 K. The absolute change in temperature due to advection at the mid-point between the stations in 50 s is _____ K (round off to nearest integer).**

Q.20	**Suppose, because of the doubling of atmospheric CO_2 concentration, an ocean water column receives an additional net energy input of $4\ Wm^{-2}$. If the entire water column of depth 1 km heats up uniformly, the water temperature will increase by 1 K in ____ years (round off to the nearest integer).** **Assume all the additional heat added is retained and not lost. Take density of seawater = $1000\ kg\ m^{-3}$; specific heat capacity of seawater = $4200\ J\ kg^{-1}\ K^{-1}$.**

Q.21	**Consider a layer of atmosphere between 5 and 6 km height. The downwelling longwave radiation at 5 and 6 km is 240 and 230 Wm^{-2}, respectively. The upwelling longwave radiation at these heights is 260 and 240 Wm^{-2}, respectively. The longwave heating rate in this layer is___ K per day. (Round off to one decimal place.)** **Take the average density of air in this layer to be 0.5 kg m^{-3}; Specific heat capacity of air at constant pressure = 1000 J kg^{-1} K^{-1}.**

Q.22	**A spherical asteroid, revolving around the sun in a circular orbit, is in radiative balance. Suddenly, the asteroid enters the shadow of a planet and solar radiation is cut off. Assuming that the asteroid emits as a blackbody in the longwave regime, the time taken to reduce the average temperature of the asteroid by 0.5 K is _____ seconds (round off to the nearest integer). Ignore the temporal change in radiation emitted by the asteroid during this cooling period.** **The physical properties of the asteroid are: diameter = 2 m, density = 3000 kg m^{-3}, specific heat = 2000 J kg^{-1} K^{-1} and albedo = 0.8 in shortwave radiation. Take the solar constant = 500 W m^{-2}, Stefan-Boltzmann constant = 5.67 x 10^{-8} W m^{-2} K^{-4}.**

END OF THE QUESTION PAPER