Question 1

(i) B

(ii) B

$$c = \sqrt{g \times d}$$

Shallow-water waves celerity equation

Tsunamis are always shallow-water waves because no ocean basin is deeper than half its wavelength up to 200km (The deepest ocean trench is only 11km)

$$c = \sqrt{9.81 \times 1000} = 99.04544412\ metre/seconds$$

$$1{,}000{,}000 \div 99.04544412 = 10096.37555\ seconds$$

$$10594.02877 \div 3600 = \mathbf{2.80454\ hours}$$

(iii) C

Date	Time	Height (m)	Date	Time	Height (m)
1	0252	1.8	3	0431	1.7
1	0837	2.6	3	1015	2.8
1	1541	0.8	3	1654	0.6
1	2254	2.5	4	0001	2.7
2	0352	1.8	4	0501	1.6
2	0933	2.7	4	1050	2.9
2	1622	0.7	4	1724	0.6
3	2333	2.6	5	No Data	No Data

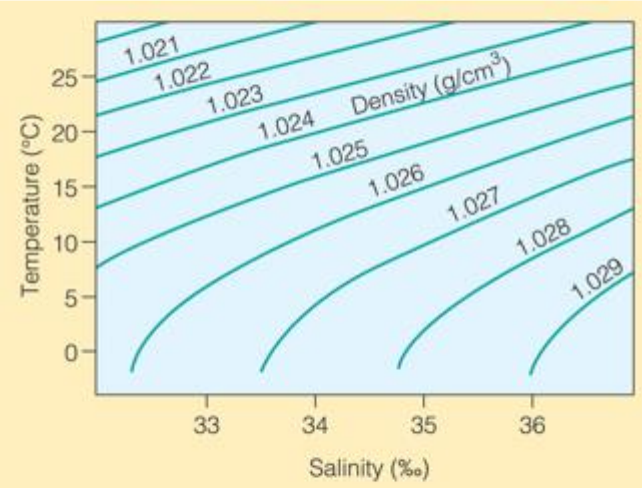
(iv) B

(v) A

Question 2

(a)

Density-temperature-salinity curve

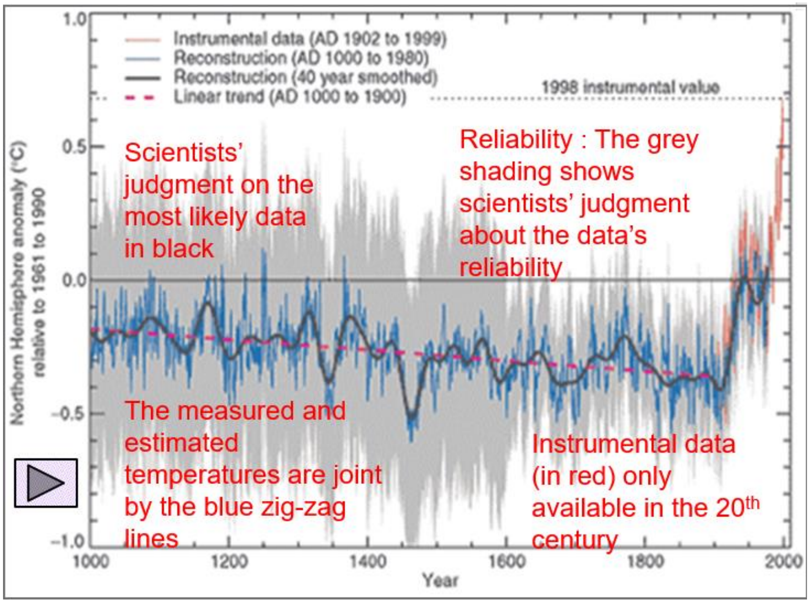


Water density primarily is a function of salinity and temperature. The density of seawater varies between 1020 to 1030 kg/m3. Seawater weights between 2-3% more than pure water at the same temperature. The density of seawater increases with (1) increasing salinity and (2) decreasing temperature. To put it simply, the colder the water, the heavier it sinks.

Assuming that the salinity of the sea water remains unchanged. The warming of the ocean water will directly affect the density of the seawater. When the ocean waters absorb the heat from the atmosphere (warming) it become less dense, resulting in the thermal expansion of the oceans. Warmer seawater has a greater volume than cold seater. The increased volume will cause the level of water in the oceans to rise.

(b)

Mann Hockey Stick



The Mann Hockey stick is a graph of global temperature over the past 10 centuries, which is a reconstruction of temperature over the past 100 years using tree rings, ice cores, coral and other records that act as proxies for temperature. The results revealed how global temperature gradually cooled over the last 1000 years with a sharp upturn in the 20th century. The inference based on the data of the plot that "the rise of temperature since ~ 1960 is anthropogenic" was not very valid as the hockey stick does not say anything about the warming is due to human activities. There were a lot of criticism received from the inference that Mann and some other scientist who succeeded him deduced from the data.

Question 3

(ai)

Assumptions apply to the equilibrium theory

(1) The ocean conforms instantly to the forces that affect the position of its surface.

(2) The ocean surface is always in equilibrium (balance) with the forces acting on it.

The limitation of the theory is that it assumes that the bulges are stationary, pointing steadily towards the moon or the sun, as Earth rotates beneath them. However, the moon does not stay directly over the Equator all the time. It moves 28.5° above and below the Equator, but the bulge will continue to follow the moon. This results in unequal high and low tides within a day. Apart from the moon, the sun also attracts the particles on Earth. On top of that, the equilibrium theory cannot accurately predict actual tides on earth, as tides cannot move fast enough (due to wave speed computed for a shallow-water wave) to match that induced by the celestial bodies. Moreover, the presence of land masses interferes with the tidal crest, diverting, slowing and complicating its movements.

(aii)

In order the equilibrium theory to be valid, the tides need to have a speed of 1670 km/hour, the ocean has to be approximately 22km

$$C = 1670km/h = \sqrt{gd}$$

$$\sqrt{9.81 \times d} = \frac{1670 \times 1000}{3600} = 463.89$$

$$d = 21936m \;\approx \boldsymbol{22km}$$

(bi)

Tsunamis are formed by the sudden vertical movement of Earth along faults also known as seismic sea waves. Usually the result of an earth below or near the ocean floor. Tsunamis can also be caused by landslides, iceberg falling from glaciers and volcanic actions.

(bii)

The characteristic of ocean depends on the relationship between their wavelength and water depth. This is because wavelength determines the size of the orbit of the water molecules, and water depth determines the shape. The reason why tsunamis are referred to as shallow water rather than deep water waves is mainly due to their wavelength. Tsunami is a very long wave with wavelength, L up to 200km. The deepest point of the ocean basin is only about 11km, making it much less than L/2 = 100km. In fact, most depth is less than L/20 = 10km, making tsunami a shallow-water wave.

Question 4

(i) C

(ii) C

(iii) D

(vi) B

(v) A

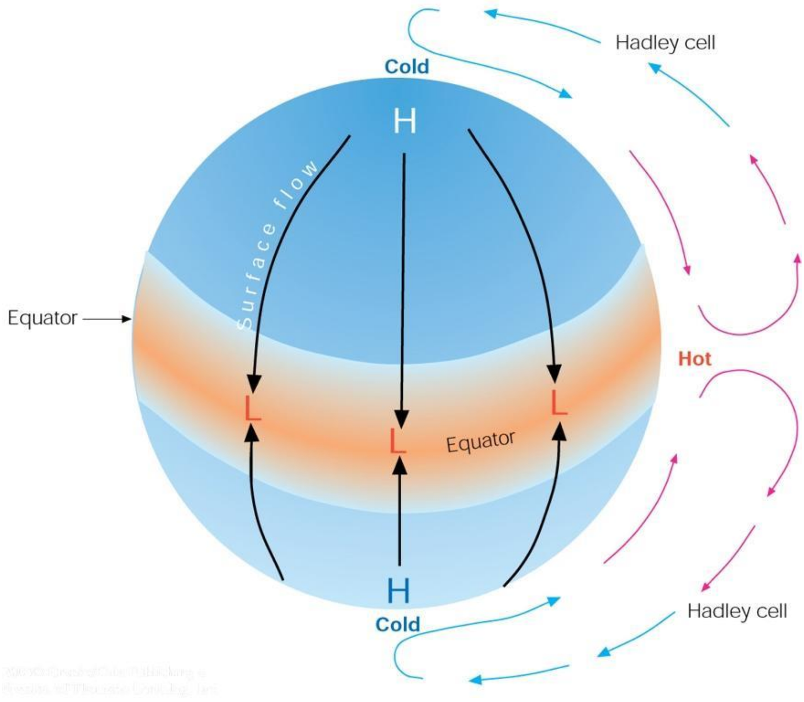
Question 5

(a)

Single-Cell Circulation Model (Assumptions)

1. Non-rotating – no Coriolis effect
2. Non-tilted – Sun always over the equator, no seasonal effect
3. Earth covered with ocean – No differential heating

(b)



As the earth is not tilted, the incoming sunlight shines on the earth most directly at the equator. The equator will become hotter than the poles. The warmer air is less dense, so it rises until it reaches the tropopause. From the tropopause, some of the warm air heads towards the North Pole and some heads towards the South Pole. When the air is heading to North and South Poles, the warm air cools, thus becoming denser and sinks. Once it sinks, it cycles back to the equator where it gets warmed again, and the cycle repeats. This creates one giant cell above each hemisphere.

(c)

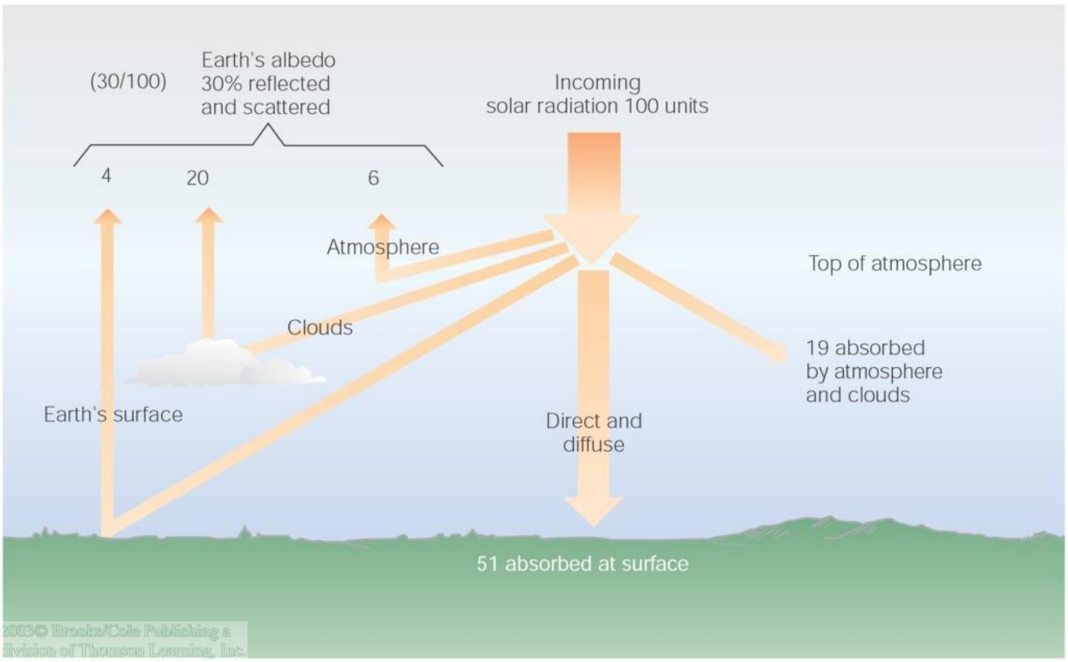
The general circulation of the atmosphere predicted by using the Single-Cell Model does not exist on Earth. Earth is a rotating planet, so we need to consider the Coriolis force in addition to the pressure gradient force. In the single-cell model, as upper level air flows from the equator toward the poles, it would be deflected by the Coriolis force. For example, in the northern hemisphere, this deflection would be toward the right resulting in a wind from west to east at upper levels. In this way, the air moving from the equator to the poles would never make it there because of the rotation of Earth.

Question 6

(a)

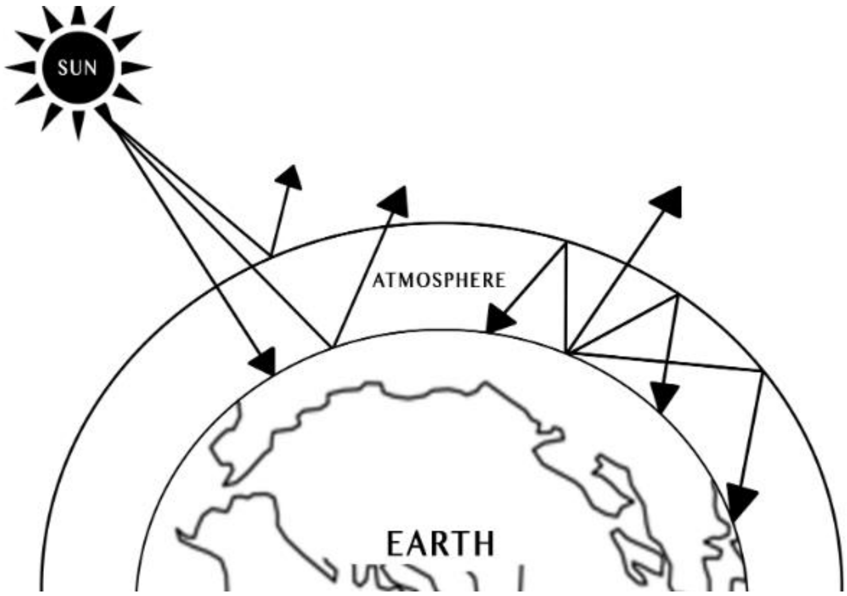
1. Carbon Dioxide
2. Methane
3. Nitrous Oxide
4. Fluorinated gases

(bi)



Solar radiation that is not absorbed or reflected by the atmosphere reaches the surface of the earth. Approximately 70% of the incoming radiation is absorbed by the atmosphere and the Earth's surface while around 30% is reflected back to space and does not heat the surface. Without greenhouse gases, the Earth's average surface temperature would be approximately -18^{o}C.

(bii)



Just as the major atmospheric gases (oxygen and nitrogen) are transparent to incoming sunlight, they are also transparent to outgoing thermal infrared. However, water vapor, carbon dioxide, methane, and other trace gases are opaque to many wavelengths of thermal infrared energy. When greenhouse gas molecules absorb thermal energy, their temperature rises, and radiate an increased amount of thermal infrared energy in all directions. Heat radiated upward continues to encounter greenhouse gas molecules; those molecules absorb the heat, their temperature rises, and the amount of heat they radiate increases. With them radiating heat in all directions, some of it spreads downward and ultimately comes back into contact with the Earth's surface, where it is absorbed. The temperature of the surface becomes warmer than it would be if it were heated only by directed solar heating.

Yap Quansheng
13th March 2021