20/21 SEM 2

MT1004 INTRODUCTION TO METEOROLOGY & OCEANOGRAPHY

1) Choose the most appropriate answer to the following MCQs:

i) On coasts with semi-diurnal, mixed tides, the tidal datum is the average of the _____ of the 2 daily _____ tides

a) Lower, low
b) Higher, low
c) Lower, high
d) Higher, high
e) None of the above

TIDAL DATUM

- On coasts with mixed tides, the tidal datum is the average of the lower of the 2 daily low tides (mean lower low water or MLLW)
- On coasts with diurnal or semidiurnal tides, it is the average level of all the low tides (mean low water, MLW)

Found in "Lecture 5_Tides" slide 41.

ii) A _____ wave generally forms on a _____ slope while a _____ wave forms on a _____ slope

a) spilling; steep; plunging; steep
b) plunging; gentle; spilling; steep
c) spilling; gentle; plunging; gentle
d) plunging; steep; spilling; gentle

iii) In order for tides to have a speed of 1,380km/hr, the depth of the ocean has to be approximately _____km.

(Hint: Celerity of a small amplitude wave = √(*gd*) , where *g* = gravitational acceleration; and *d* = water depth

a) 14,980km
b) 194km
c) 22km
d) 15km
e) None of the above

ANS:
Celerity = 1,380km/hr = √(*gd*) -- need to convert 'km' to 'm' and hour to seconds, *g* = *9.81*

Step 1 : √(*gd*) = √(9.81* *d*) = (1380 * 1000)/ 60*60

Step 2: √(9.81* *d*) = 383.333

Step 3: $d = 383.333^2 / 9.81 = 14{,}979.02\text{m} \approx$ **15km**

iv) The following table shows the tide levels on four days at a certain port. Based on the data, calculate the value of the mean higher low water?

Date	Time	Height(m)	Date	Time	Height(m)
14	0252	1.8	16	0431	1.7
14	0837	2.6	16	1015	2.8
14	1541	0.8	16	1654	0.6
14	2254	2.5	17	0001	2.7
15	0352	1.8	17	0501	1.6
15	0933	2.7	17	1050	2.9
15	1622	0.7	17	1724	0.6
16	2333	2.6			

a) 2.750m
b) 0.675m
c) 1.725m
d) 2.600m
e) None of the above

ANS: higher low means higher of the 2 low water level

Find higher of the 2 lower for each day and calculate average.

(1.8 + 1.8 + 1.7 +1.6) /4 = 1.725

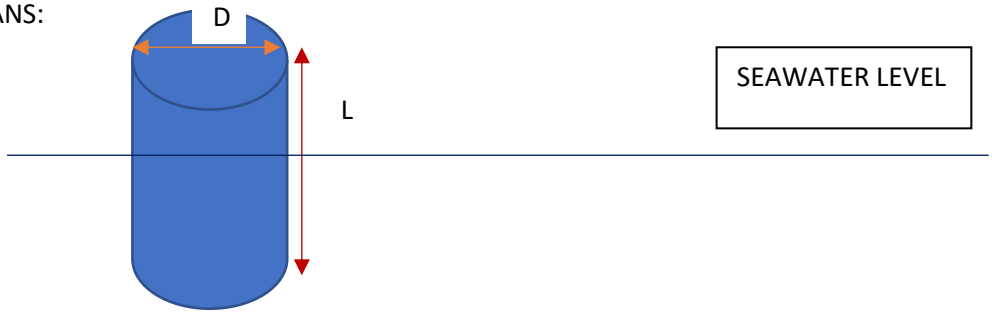
v) The stability of a wave form is dictated by the _____

a) Wave height
b) Wave length
c) Wave celerity
d) Wave steepness
e) Wave period

2a) The English idiom "tip of an iceberg" may be interpreted as "only a small portion of something much larger or more complex that cannot yet be seen or understood". From a scientific point of view, only the top of a floating iceberg is visible above the sea level. Considering a circular cylindrical iceberg with diameter D and length, *L* floating vertically in the ocean, prove that the length of the iceberg that is exposed above the sea level is 0.105*L*. You may assume that the densities of sea water and ice = 1025kg/m^3 and 917kg/m^3, respectively. (6M)

(Hint: Use Archimedes principle , which states that the buoyant force of a floating object = weight of the fluid displaced in your computation)

ANS:



Density of sea water : 1025kg/m^3

Density of ice: 917kg/m^3

Since buoyant force of a floating object = weight of fluid displaced in computation, to find out the length of ice submerged in water:

Density of ice/ density of seawater = （917kg/m^3 ） / （1025kg/m^3 ） = 0.89463 (this is the % of iceberg submerged in seawater)

Since length of cylinder given is *L*, 0.89463% of ice in seawater means length of iceberg submerged in seawater is 0.89463*L*

Thus, length of iceberg visible above sea level = *L* – 0.89463*L* ≈ **0.105 *L* (3s.f.)** ***(Proven)***

2b) Ekman spiral is a term used to describe the movement of surface currents. Explain with the aid of a sketch, what Ekman spiral is? Consequently, describe the Ekman transport. Arising from the Ekman transport, discuss how a large iceberg in the northern hemisphere may move relative to the prevailing wind. (14M)

ANS:

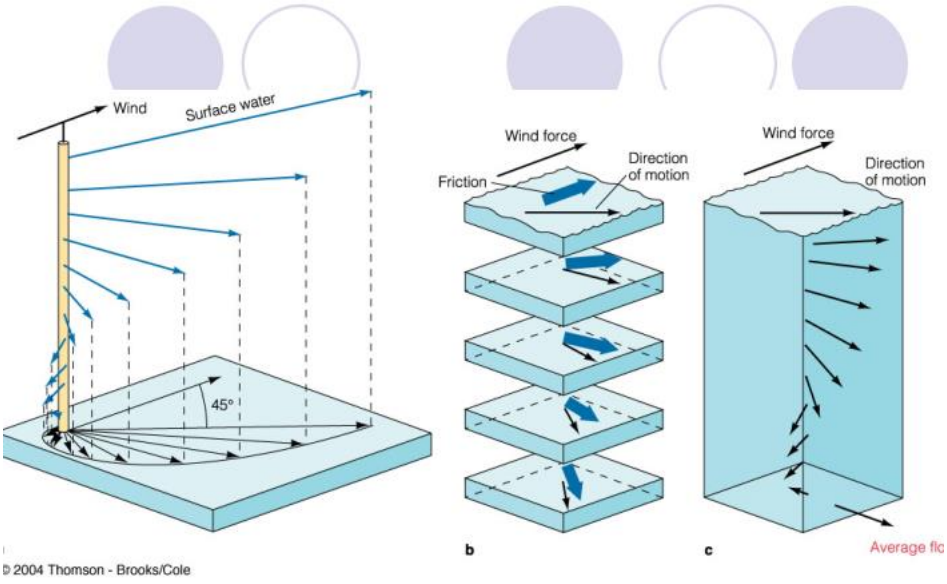


Fig 8-5, p.142

Sketch of Ekman spiral found in "Lecture 3_Ocean circulation" , slide 18

Ekman spiral is similar to a deck of cards where each layer slides horizontally over the one beneath it. Friction also comes into play in Ekman spiral as friction causes the lower layer to move slower than the layer above. This would result in the Ekman spiral where water at a particular layer is deflected at an angle to the right of the overlying layer above.

Ekman transport is an interesting but somewhat unexpected result where at a certain depth, the water flows in the opposite direction from the surface. The net motion of water down to about 100m is what we call Ekman transport. In theory, the direction of Ekman transport is 90^o to the right

and left of the wind direction in the northern and southern hemisphere respectively. However in actual cases, Ekman transport in gyre is less than 90^o and is only about 45^o.

A large iceberg in the northern hemisphere may move 90^o to the right of the wind direction and due to Ekman transport in gyre being about 45^o, the large iceberg would move towards the centre of the gyre.

3a) State the three factors that are used to classify ocean waves. (6M)

ANS:

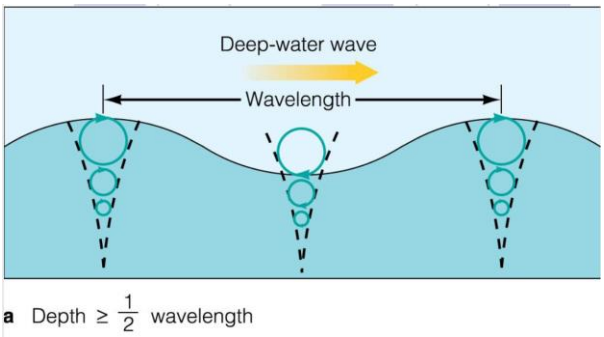
1. Disturbing force that creates the waves
2. Restoring force that flattens the waves
3. Wavelength of the different waves

3b) What is an orbital wave? With the aid of diagrams, discuss how the attributes of orbital waves, in terms of the shape and size of the orbits of the water molecules beneath the waves, change as the waves propagate towards the shoreline.(14M)

ANS:

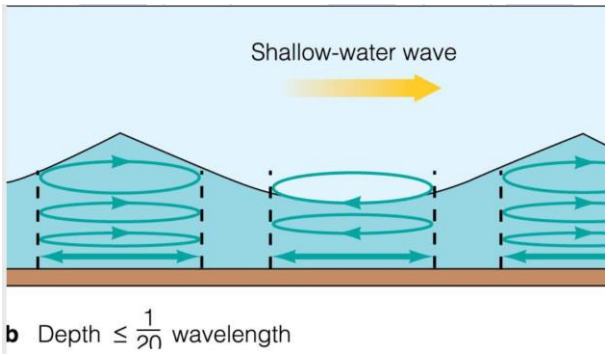
Orbital wave is formed as energy is transferred from one water particle to another in circular paths or orbits. Through this, wave energy is transmitted across the ocean surface and causes wave form to move, creating orbital wave. An orbital wave is a wave whose particles of the medium (water) move in closed circles as the wave passes. Orbital ocean waves occur at the boundary between air and water. Because its form moves forward, it is a type of progressive wave.

The characteristics of ocean waves depend 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.



Found in "Lecture 4_Waves", slide 26 Figure 1: Deep water wave

The orbit is circular only if the wave is travelling in deep water as seen in the drawing above. In deep water, the wave cannot "feel" the bottom as it moves through water deeper than ½ of its wavelength. Waves moving through such a situation are called deep-water waves.



Found in "Lecture 4_Waves", slide 28 ***Figure 2: Shallow water wave***

As the waves move closer and propagate towards the shoreline, the water depth reduces as seen in figure 2. The orbits of water molecules are then flattened by the bottom. In fact, the water adjacent to the seafloor cannot move in any circular (or elliptical) motion, it can only move forward and backwards. The waves in water shallower than 1/20 of their wavelength are close to shore and are known as shallow-water waves.

4) Choose the most appropriate answer to the following MCQs:

i) The most abundant gases in the earth's atmosphere by volume are:

a) Carbon dioxide and nitrogen
b) Oxygen and water vapor
c) Nitrogen and oxygen
d) Oxygen and helium

ii) The processes of condensation and freezing:

a) Both release sensible heat into the environment
b) Both absorb sensible heat from the environment
c) Do not affect the temperature of their surroundings
d) Do not involve energy transport

iii) If water vapor comprises 3.5% of an air parcel whose total pressure is 1000mb, the water vapor pressure would be:

a) 1035mb
b) 35mb
c) 350mb
d) 965mb

ANS:

Dalton's law of partial pressure

- The total pressure inside the parcel is equal to the sum of the pressures of the individual gases.
- If the total pressure inside the parcel is 1000 millibars (mb), and the gases inside include nitrogen (78%), oxygen (21%) and water vapour (1%), then the partial pressure exerted by nitrogen would be 780 mb and by oxygen 210 mb.
- The partial pressure of water vapour, called the actual vapour pressure, would be 10 mb (1% of 1000 mb).

Found in lecture 11, slide 48

Water vapor pressure = 3.5% * 1000mb = 35mb

iv) **If the outside air temperature is 27℃ and the air density is 1.2kg/m^3, the outside air pressure would be: (HINT: P = T*ρ*C, where P = pressure, T = temperature, ρ= density, C = constant = 2.87)**

a) 32mb
b) 93mb
c) 930mb
d) 1033mb

ANS: P = (27+273)* 1.2* 2.87 = 1033.2mb

- **Remember temperature S.I unit is in K**

v) **Buys-Ballot's law states that " In the Northern Hemisphere if you stand with your back to the surface wind, then turn clockwise about 30℃, lower pressure will be _____ ".**

a) To your right
b) To your left
c) Behind you
d) In front of you

5a) Define Meteorology and illustrate how this can be important to mankind and the economy. (10M)

Meteorology is the study of the atmosphere and its phenomena, and include the dynamics, physics and chemistry of the atmosphere.

Meteorology, the study of the atmosphere -- its patterns and variations --is a complex science that allows those skilled in the discipline the ability to analyze and interpret data, forecasting our weather.

Weather is a universal truth

Weather affects everyone! Even in space, light years away, NASA can detect solar flares and dust that reverberate and interact with Earth's magnetic systems.

Meteorology is international

One example of the meteorologist's important role in forecasting natural disasters and weather that can have serious implications for all--like hurricanes, tsunamis, and tornados -- is Hurricane Harvey. In 2018, this hurricane wreaked havoc on Houston, Texas in the United States. Meteorologists were able to forecast the storm with enough lead time so that people could be warned to evacuate and prepare for the worst. Predictive modeling and forecasting storms like this one demonstrates what a vital role meteorologists play in public health and safety.

Meteorology is interdisciplinary

As a meteorologist, you might be tasked with coming up with terms and phrases to describe never-before-seen or witnessed trends and weather events.

Accurate weather information is important

Communication with accurate information is key to disseminating meteorological information.

Point 1- Offers Protection

Consider surface temperatures:

- Without atmosphere (0^oF global average, large diurnal swings, similar to the Moon's Climate)
- With atmosphere (60^oF global average, moderate diurnal swing)

Point 2 - Offers Protection

Consider Surface Radiation

- Shields against harmful UV radiation

Consider Survival Time

Without Food

- few weeks

Without Water

- few days

Without Air

- few minutes

Necessary for a wide spectrum of features

- Oceans
- Clouds, Rain, Fresh Water
- Erosion by Water and Wind
- Life, Life on Land
- Blue Skies, Red Sunsets, Twilight
- Sound

Warning of severe weather

Agriculture

Timing of planting, harvesting, etc to avoid bad weather, hazards to livestock

Transport & services

Shipping, aviation, road gritting, flood warnings etc

Commerce

- Helps supermarket decide if they should order BBQs and ice cream, or umbrellas? (depending on weather forecast predictions etc)

5b) Draw a diagram showing how air temperature normally changes with height. Begin at the ground and end in the upper thermosphere. Clearly label the four main layers in your diagram. Give one important characteristic of each layer. Where will the top of Mt. Everest, the ozone layer, and the ionosphere be found in your diagram? (10M)

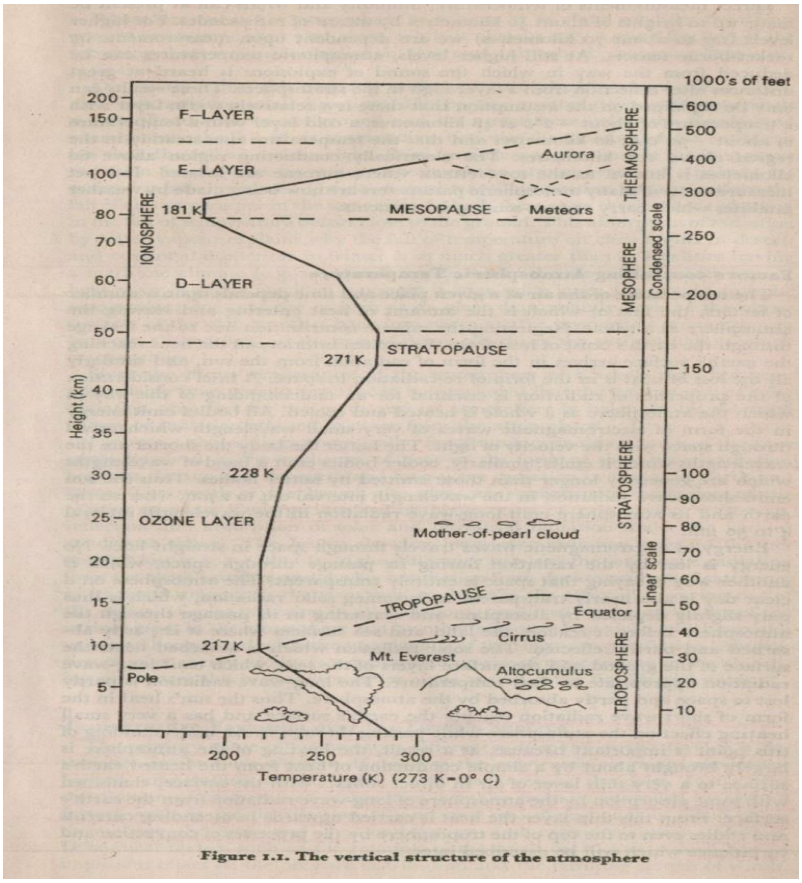


Figure 1.1. The vertical structure of the atmosphere

Can think of it like a `M' flipped 90^o to the left

- 4 main layers are Troposphere, Stratosphere, Mesosphere and Thermosphere

Troposphere

- Troposphere layer up to about 12 km. The height varies as higher at equatorial regions and decreasing poleward.
- Temperature decreases with height as sunlight warms earth's surface, and the surface warms the air above it.
- Rate decreases with height, known as lapse rate with average (standard) lower atmosphere at about 6.5 deg Celsius per 1000 metres (3.6 degree Fehrenheit per 1000 ft).

Stratosphere

- Stratosphere layer up to about 47 km.
- Temperature increase with height known as temperature inversion.
- Gas ozone found in large concentration here and important for absorbing energetic ultraviolet (UV) solar energy and warm the stratosphere layer thus creating the temperature inversion.(If no ozone gas, it will be colder with height).

Mesosphere

- Mesosphere layer up to about 80 km
- Air extremely thin and atmosphere pressure quite low average 1 mb, One over one thousand fraction of all atmosphere molecules and 99.9 percent of atmosphere mass are below it.
- Percentage of nitrogen and oxygen about similar to sea level. But humanly cannot survive caused by fewer oxygen molecules than sea level. Suffocation due to oxygen starving, condition hypoxia.

Thermosphere

- Thermosphere layer up to about 500 km
- The "hot layer "above mesosphere. The oxygen molecules absorb energetic solar rays, warming the air.
- A small amount of energetic solar energy can cause a large increase in air temperature.
- There are few molecules.

Top of Mount Everest can be found in the upper troposphere layer at about 9 km from ground level with air pressure of about 300 mb.

Ozone layer can be found in stratosphere layer where maximum ozone concentration can be found near 25km (mid latitudes).

Ionosphere layer can be found from about 60km to the top of the atmosphere.

6a) Explain how the stability of the atmosphere can affect the types of clouds formed. (10M)

An absolutely stable atmosphere occurs when the environmental lapse rate is less than the moist adiabatic rate. In a stable atmosphere, a rising air parcel is colder and more dense than the air surrounding it, and, if given the chance, it will return to its original position.

The atmosphere becomes more unstable as the environmental lapse rate steepens; that is, as the air temperature drops rapidly with increasing height. This circumstance may be brought on by either air aloft becoming colder or the surface air becoming warmer.

The cooling of the air aloft may be due to:
1. winds bringing in colder air (cold advection)
2. clouds (or the air) emitting infrared radiation to space
(Radiational cooling)

The warming of the surface air may be due to:
1. daytime solar heating of the surface
2. an influx of warm air brought in by the wind (warm advection)
3. air moving over a warm surface

Layered clouds tend to form in a stable atmosphere, whereas cumuliform clouds tend to form in a conditionally unstable atmosphere. Since air in an absolutely stable atmosphere strongly resists upward vertical motion, it will, *if forced to rise,* tend to spread out horizontally. If clouds form in this rising air, they, too, will spread horizontally in relatively thin layers and usually have flat tops and bases. We might expect to see clouds — such as cirrostratus, altostratus, nimbostratus, or stratus — forming in stable air.
Convective instability is associated with the development of severe storms, such as thunderstorms and tornadoes.

6b) List and discuss some of the atmospheric conditions that are needed for a thunderstorm to develop. (10M)

Atmospheric conditions needed for thunderstorms to develop are sources of moisture, instability and lifting mechanism. Moisture is very important in thunderstorm formation as it “fuels” the thunderstorm.

When the air parcel is warmer than the surrounding air, it will continue to rise until it reaches the same temperature as its environment. This creates instability and the air parcel when lifted will not return to its original position. Thus, air is said to be unstable if it continues to rise after being given a “push” upward.

Conversely, air is considered to be stable if it returns to its original position after being "pushed" upward due to the dry parcel of air cooling at a faster rate than Environmental Lapse Rate (ELR). As the air parcel cools faster than the Environment Lapse Rate, the air parcel will always be at a lower temperature when lifted from its position and will sink back to its original position. In order for thunderstorms to develop, air needs to be unstable. Air is most likely to be unstable when warm, moist air is present at the surface and cold, dry air is present aloft.

Lastly, lifting mechanism helps to give the air the initial "push" upward. There are several ways in which air can be lifted. Lifting primarily occurs along fronts. Air can also be lifted as it flows over hills or mountains.

Condensation will also produce a lot of latent heat, and this will continue to fuel the formation of thunderstorms as well. Atmospheric instability comes in then moisture comes in, just take note. Meaning air parcel will continue to rise even after a slight push and will not return to original position in unstable atmosphere. Afterwards, the moisture in the atmosphere and lifting mechanism would help in developing a thunderstorm.

Done by: Chia Chong Yew