Oxygen in Seawater and the Dissolved Oxygen Meter

The amount of a gas in seawater is a function of both physical and biological factors. In the case of oxygen, the biological processes of plant photosynthesis and respiration strongly affect the oxygen concentration. Two very simplified equations expressing these complex biological processes are:

Photosynthesis

$$6CO_2 + 6H_2O \rightarrow 6CH_2O + 6O_2$$

Respiration

$$6CO_2 + 6H_2O \leftarrow 6CH_2O + 6O_2$$

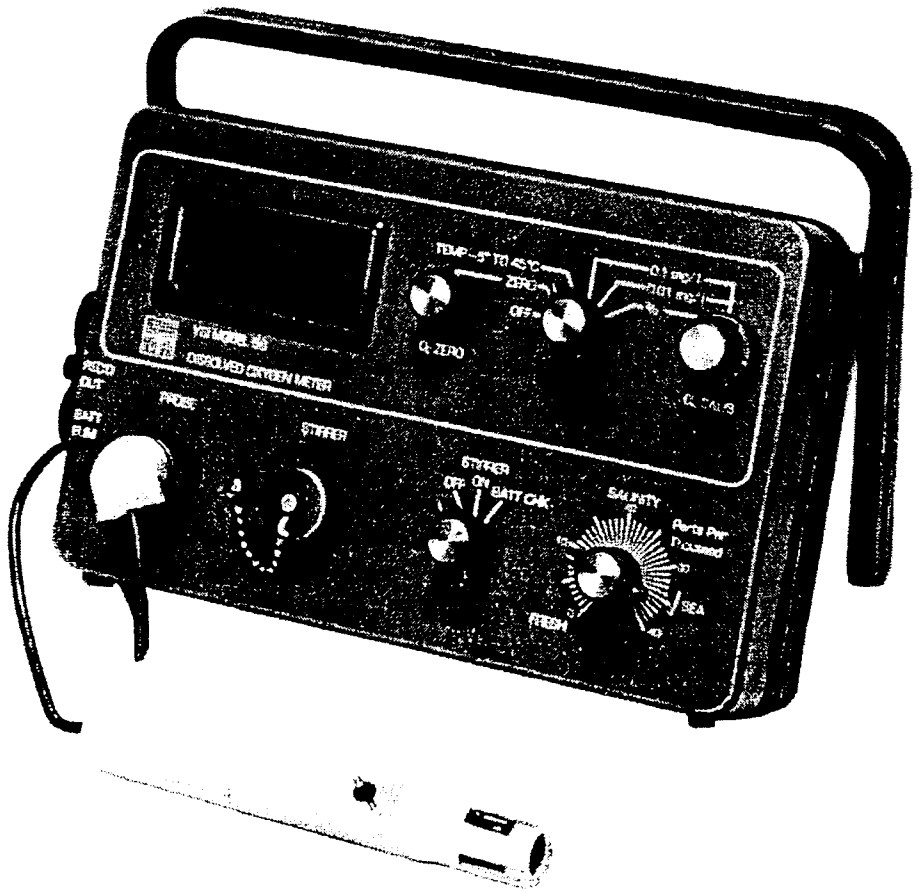
Carbon dioxide and water combine in the presence of light and chlorophyll to produce plant material and oxygen. In the process of respiration both plants and animals consume oxygen and release carbon dioxide.

The actual concentration of dissolved oxygen (DO) in seawater is affected by several biologically related factors, such as the number of photosynthetic organisms producing oxygen, the amount of respiration taking place, the amount of light available for photosynthesis, and the turbidity of the water. Several physical factors also affect the amount of oxygen dissolved in seawater. These include the state of the sea surface (calm or rough), salinity, temperature, and hydrostatic pressure.

The concentration of DO in seawater is greatest in well-mixed water near the surface and less in deeper waters. Yet even in the oxygen-rich areas the amount of oxygen is small, rarely exceeding 9 or 10 parts per million (ppm). In contrast, air-breathing animals obtain oxygen from an atmosphere which is 21%, or 210,000 ppm, oxygen. Since the supply of oxygen in sea water is so limited, even small changes in DO availability often seriously affect the well-being of marine organisms. Thus the concentration of oxygen is an important indicator in determining the "healthfulness" of water, especially in regard to pollution.

The most commonly used method for determining DO in fresh or seawater is the Winkler Titration method. This method is very accurate, but it is difficult to use in the field. It is often justifiable and much more convenient to use processes that may be less accurate, but that can readily be used in the field for on-the-spot analyses. The portable oxygen meter is such a convenience.

We will be using the YSI Model 58 Dissolved Oxygen Meter in the field and lab for measuring DO and temperature. Dissolved oxygen is indicated in mg/l. By switching meter modes, DO can also be indicated in % air saturation. This mode automatically corrects for temperature, and if the SALINITY control is adjusted for the correct value of the sample, the meter reading will indicate the degree of the saturation which would occur if the sample were saturated with air.



When the meter is to be used it must be turned on for at least 15 minutes to allow the probe to stabilize. If the meter is turned off or the probe is disconnected between readings, you must wait at least 15 minutes before making another reading. The tip of the probe must be kept moist at all times, so a bottomless plastic bottle with a moist sponge in the top is kept on the probe when the meter is not in use.

Each day before the DO meter is used it must be calibrated. Calibration consists of exposing the probe to a known oxygen concentration, such as air at 100% relative humidity or water of a known oxygen content, and then adjusting the **O_2 CALIB** control so the display shows a reading that matches the oxygen concentration of the known sample.

Air calibration is the quickest and by far the simplest calibration technique. The YSI Model 58 is air calibrated as follows:

1. Set function switch to % mode and allow 15 minutes for probe to stabilize. The probe tip should be in the bottomless plastic bottle with a moist sponge.

2. Set the function switch to **ZERO** and readjust display to read 0.00. Switch back to % air saturation mode.

3. When the display reading has stabilized, unlock the O_2 **CALIB** control locking ring and adjust the display to 100%. Relock the locking ring to prevent inadvertent changes.

4. The DO meter is now calibrated. Do not turn it off if readings are to be made within the next 15 to 20 minutes.

For accurate DO measurements, water movement of 1 foot per second or more is required so that the oxygen-depleted layer of the sample at the probe tip is flushed away and replenished. The simplest means of doing this is to move the probe through the sample by hand. Care must be taken, however, to avoid creating too much turbulence which will introduce additional oxygen into the sample.

Measurement of DO occurs as follows:

1. Determine the density of the water sample with a refractometer or hydrometer.

2. With the DO meter prepared for use and the probe calibrated, place the probe in the sample.

3. Turn the function switch to **TEMP** and read the temperature of the sample. If you are using a hydrometer to determine salinity, use this temperature value to determine the salinity of the sample.

4. Adjust the **SALINITY** control to the salinity of the sample.

5. Turn the function switch to O_2 **ZERO** and readjust if necessary.

6. Turn the function switch to **0.01 mg/l** readout mode and read the DO value when the meter reading has stabilized..

7. Next, turn the function switch to % mode and read the DO value in % air saturation when the meter reading has stabilized.

7. After you have finished your reading, rinse the tip of the probe with freshwater and replace the plastic bottle/moist sponge on the probe.

YSI Environmental

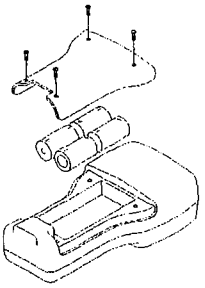
FEATURES OF THE YSI 550A

YSI 550A
Dissolved Oxygen Instrument

KEYPAD

⏻	Powers the unit on or off. The instrument will activate all segments of the display for a few seconds, and then will show a self-test procedure for several more seconds. During this power on self-test sequence, it is normal to error messages appear and disappear. If the instrument were to detect a problem, a **continuous** error message would be displayed.
☼	Turns the display backlight on or off. The light will turn off automatically after two minutes of non-use.
Mode	During DO calibration it allows the user to select between % and mg/L. After selection, it may be pressed several times to exit back to measurement mode without completing the calibration. During measurement, it switches the instrument display between DO %, DO mg/L, and salinity calibration.
▲ and ▼	Increases or decreases the value during calibrations.
▼ and Mode	Press at the same time to switch the temperature units between Fahrenheit (F) and Celsius (C).
▲ and Mode	Press at the same time to increase or decrease the resolution of the instrument in mg/L or % measurement mode.
↵	This is the Enter Key Button for execution of commands.

BATTERIES



The YSI 550A DO Instrument is powered by 4 C-size alkaline batteries. A new set of alkaline batteries will provide approximately 2000 hours of continuous operation. When batteries need to be replaced, the LCD will display a **"LO BAT"** message. When the message first appears, the instrument will have approximately 50 hours of life left, provided the back light is not used.

INSTRUMENT CASE

The waterproof instrument case is sealed at the factory and is not to be opened, except by authorized service technicians.

Caution: Do not attempt to separate the two halves of the instrument case as this may damage the instrument, break the waterproof seal, and will void the manufacturer's warranty.

GENERAL DESCRIPTION

The YSI 550A Handheld Dissolved Oxygen Instrument is a rugged, microprocessor based, digital instrument with a field-replaceable YSI dissolved oxygen probe. The YSI 550A DO Instrument is impact-resistant and waterproof.

The YSI 550A DO Instrument is designed for field use and is available with cable lengths of 12, 25, 50, or 100 feet (3.5, 7.5, 15, 30.5 meters). The body of the probe has been manufactured with stainless steel to add rugged durability and sinking weight. The large Liquid Crystal Display (LCD) is easy to read and is equipped with a backlight for use in dark or poorly lighted areas.

The YSI 550A DO Instrument can be easily calibrated with the press of a few keys. Additionally, the instrument's microprocessor performs a self-diagnostic routine each time the instrument is turned on. The self-diagnostic routine provides you with useful information about the function of the instrument circuitry and the quality of the readings you obtain.

The system displays temperature in either °C or °F and dissolved oxygen in either mg/L (milligrams per liter) or % air saturation. The system requires only a single calibration regardless of which dissolved oxygen display is used, and will calibrate in either mode. Salinity compensation values can be changed at any time without performing a new calibration.

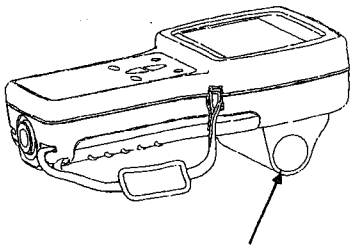
A detachable calibration chamber is mounted to the back of the instrument. A small sponge in the chamber can be moistened to provide a water saturated air environment that is ideal for air calibration. This chamber is also designed for transporting and storing the probe. When the probe is stored in the chamber, the moist environment will prolong effective membrane performance and probe life.

The YSI 550A DO Instrument is powered by 4 C-size alkaline batteries. A new set of alkaline batteries will provide approximately 2000 hours of continuous operation. If the backlight is used often, batteries will be depleted faster.

The YSI 550A case is waterproof with an IP-67 rating. The instrument is 100% corrosion proof and can be operated in a wet environment without damage to the instrument.

CALIBRATION/STORAGE CHAMBER

The YSI 550A DO Instrument has a convenient calibration/storage chamber that can be attached to the instrument's back. The calibration chamber can be used from either side of the instrument, by moving the rubber stopper to either end.



CALIBRATION CHAMBER

If you look into the chamber, you should notice a small round sponge in the bottom. Carefully put 3 to 6 drops of clean water into the sponge. Turn the instrument over and allow any excess water to drain out of the chamber. The wet sponge creates a 100% water saturated air environment for the probe. This environment is ideal for dissolved oxygen calibration and for storage of the probe during transport and non-use.

PRINCIPLES OF OPERATION

The sensor consists of a silver body as the anode and a circular gold cathode embedded in the end. In operation, this end of the sensor is filled with a solution of electrolyte containing a small amount of surfactant to improve wetting action.

A thin semi-permeable membrane, stretched over the sensor, isolates the electrodes from the environment, while allowing gases to enter. When a polarizing voltage is applied to the sensor electrodes oxygen that has passed through the membrane reacts at the cathode causing a current to flow.

The membrane passes oxygen at a rate proportional to the pressure difference across it. Since oxygen is rapidly consumed at the cathode, it can be assumed that the oxygen pressure inside the membrane is zero. Hence, the force causing the oxygen to diffuse through the membrane is proportional to the partial pressure of oxygen outside the membrane. As the oxygen partial pressure varies, so does the oxygen diffusion through the membrane. This causes the probe current to change proportionally.

DISSOLVED OXYGEN CALIBRATION

Dissolved oxygen calibration must be done in an environment with known oxygen content. The YSI 550A DO Instrument can be calibrated in either mg/L or % saturation. Sections below include instructions on how to calibrate in either mode.

BEFORE YOU CALIBRATE

To accurately calibrate the YSI 550A, you will need to know the following information:

- The approximate salinity of the water you will be analyzing. Fresh water has a salinity of approximately zero. Seawater has a salinity of approximately 35 parts per thousand (ppt). If you are uncertain what the salinity of the sample water is, use a YSI 30 Salinity-Conductivity-Temperature instrument to determine a salinity value.

- For calibration in % saturation mode, the approximate altitude (in feet) of the region where you are located is required. This information can be obtained over the internet or from a local airport or weather station. To convert from meters to feet, divide by 0.3048.

For best results:

- Check calibration with each use and recalibrate as necessary to prevent drift. Dissolved oxygen readings are only as good as the calibration.

CALIBRATION IN % SATURATION

1. Ensure that the sponge inside the instrument's calibration chamber is moist. Insert the probe into the calibration chamber.

2. Power the instrument on and allow readings to stabilize. This may take 5 to 15 minutes, depending on the age of the instrument and condition of the probe.

3. Press and release both the **UP ARROW** and **DOWN ARROW** keys at the same time to enter the calibration menu.

4. Press the **Mode** key until "%" is displayed on the right side of the screen for oxygen units. Press **ENTER**.

5. The LCD will prompt you to enter the local altitude in hundreds of feet. Use the arrow keys to increase or decrease the altitude. When the proper altitude appears on the LCD, press the **ENTER** key.

   EXAMPLE: Entering the number 12 here indicates 1200 feet.

6. **CAL** will now display in the lower left corner of the screen, the calibration value in the lower right corner and the current DO reading (before calibration) will be the main display. Once the current DO reading is stable, press the **ENTER** button.

7. The LCD will prompt you to enter the approximate salinity of the water you are about to analyze. You can enter any number from 0 to 70 parts per thousand (PPT) of salinity. Use the arrow keys to increase or decrease the salinity setting. When the correct salinity appears on the LCD, press the **ENTER** key. The instrument will return to normal operation.

CALIBRATION IN MG/L

1. Power the instrument on and allow readings to stabilize. This may take 5 to 15 minutes, depending on the age of the instrument and condition of the probe.

2. Place the probe in a solution with a known mg/L reading. Continuously stir or move the probe through the sample at a rate of at least 1/2 foot per second (16cm per second) during the entire calibration process.

3. Press and release both the **UP ARROW** and **DOWN ARROW** keys at the same time to enter the calibration menu.

4. Press the **Mode** key until "mg/L" is displayed on the right side of the screen for oxygen units. Press **ENTER**.

5. **CAL** will now display in the lower left corner of the screen and the current DO reading (before calibration) will be on the main display. Once the current DO reading is stable, use the up and down arrow keys to select the mg/L value of the known solution, then press the **ENTER** button.

6. The LCD will prompt you to enter the approximate salinity of the water you are about to analyze. Enter any number from 0 to 70 parts per thousand (PPT) of salinity. Use the arrow keys to increase or decrease the salinity setting. When the correct salinity appears on the, press the **ENTER** key. The instrument will return to normal operation.

SALINITY COMPENSATION CALIBRATION

1. Press the **Mode** key until salinity calibration is displayed on the screen.
2. Use the **UP ARROW** and **DOWN ARROW** keys to adjust the salinity value to that of the samples you will be measuring, 0-70 ppt.
3. Press the **ENTER** key to save the calibration.
4. Press **Mode** to return to dissolved oxygen measurement

PROBE OPERATION

NOTE: The YSI 550A DO Instrument should not be used in a purpose other than that specified by YSI Incorporated. See **Warranty** for details.

STIRRING

It is important to recognize that a very small amount of oxygen dissolved in the sample is consumed during probe operation. It is therefore essential that the sample be continuously stirred at the sensor tip. If stagnation occurs, measurements will appear artificially low.

Stirring may be accomplished by mechanically moving the sample around the probe tip, or by moving the probe through the sample. The YSI Model 550A has a flow dependence of <25%. The rate of stirring required is 1/2 foot per second (16cm per second).

MEASUREMENT PROCEDURE

1. Insert the probe into the sample to be measured.
2. Continuously stir or move the probe through the sample.
3. Allow temperature and dissolved oxygen readings to stabilize.
4. Observe/Record readings.
5. If possible, rinse the probe with clean water after each use.

Introduction to Oceanography
Laboratory Exercise

Name_____

DISSOLVED OXYGEN IN SEAWATER

This laboratory exercise is designed to study the effects of two physical factors, salinity and temperature, on the amount of dissolved oxygen in seawater. In the laboratory you will find none different water samples. Each of these solutions differs in salinity and temperature.

Use the Dissolved Oxygen Meter and the Refractometer or a Hydrometer to determine the temperature, salinity, and dissolved oxygen content of each water sample. Record these data in Table 1. Be certain to rinse the dissolved oxygen meter probe with distilled water after each reading.

TABLE 1

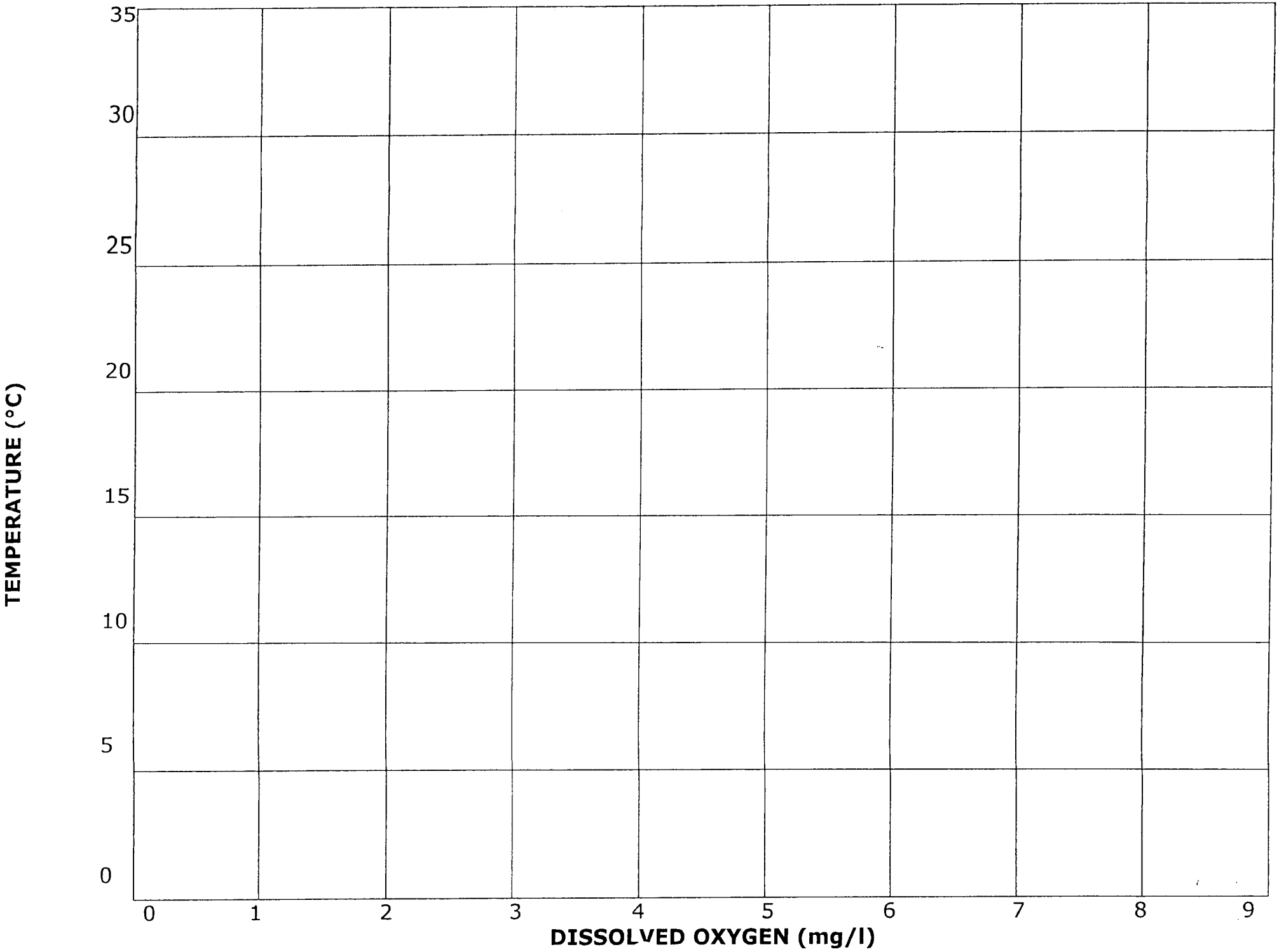
Sample #	Temperature (°C)	Salinity ($^0/_{00}$)	Dissolved Oxygen Content (mg/l)
1			
2			
3			
4			
5			
6			
7			
8			
9			

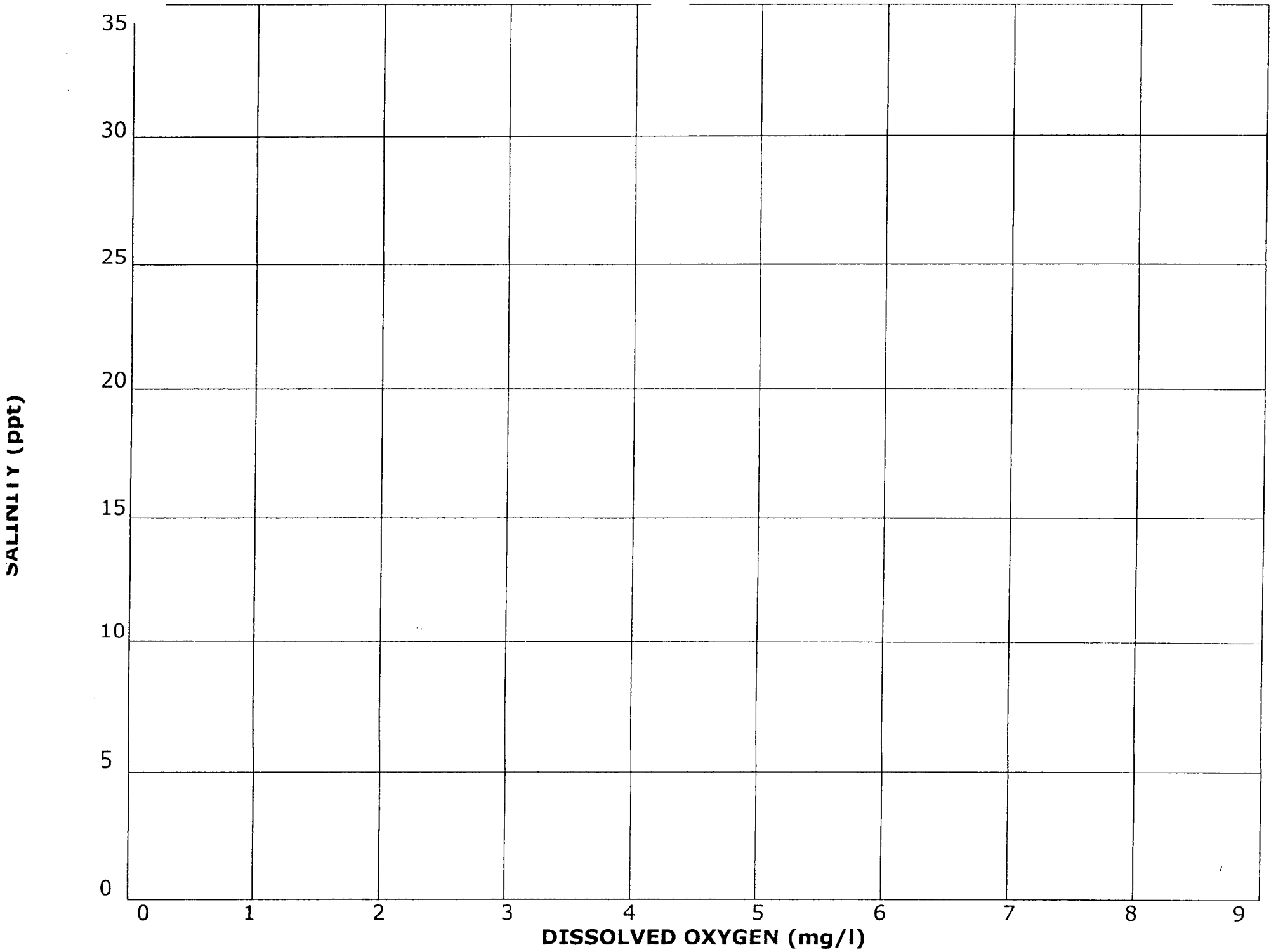
Plot the data in Table 1 on the graphs provided on the two following pages. Label each data point with the number of the water sample it represents.

On the Dissolved Oxygen vs. Salinity graph, draw lines connecting the data points of similar *temperature*.

On the Dissolved Oxygen vs. Temperature graph, draw lines connecting the data points of similar *salinity*. Label each of these lines with the appropriate temperature or salinity.

Answer the questions on the last page of this exercise utilizing the data you have plotted on the two graphs.


TEMPERATURE (°C)
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
DISSOLVED OXYGEN (mg/l)


SALINITY (ppt)
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
DISSOLVED OXYGEN (mg/l)

1. Carefully study the graphs you have constructed and compare the measured oxygen values for the water samples at different salinities. How do you think variations in salinity affect the amount of dissolved oxygen seawater can hold?

2. Study the graphs and compare the measured oxygen values for the water samples at different temperatures. How do you think variations in temperature affect the amount of dissolved oxygen seawater can hold?

3. Judging from the data you collected and plotted, which factor, temperature or salinity, would have a more important effect on dissolved oxygen concentrations in the open ocean? Explain your answer.