QUESTION #1. What is the principle of the gasoline engine?

ANSWER #1. A gasoline engine is a type of internal-combustion en-gine, so called because the fuel is burned within the cylinder of the engine. The conversion of the fuel into power is accomplished by atomizing the fuel, mixing it with air, and introduoing the mix-ture into the engine, where it is compressed and then ignited. When the compressed mixture is ignit[illegible] the resulting products of combustion expand very rapidly and force the piston down to the end of the cylinder, thus creating the power necessary to driv[illegible] the engine. When the piston has completed its stro[illegible] the gases are ejected from the cylinder. The up and down motion of the piston is converted into rotary motion by means of the connecting rod and crank.

QUESTION #2. What is a cycle?

ANSWER #2. The series of events occurring within the engine from the time of introduction of the curburized mixture into the cylinders until the products of combustion have been ejected therefrom is known as a "cycle" [illegible] complete cycle consists of:

1. Drawing the mixture into the cylinder. (Admission)
2. Compressing the mixture. (Compression)
3. Igniting the mixture and forcing the piston down with the pressure produced by the expan-sion of the burning gases. (Expansion)
4. Ejecting the burned gases from the cylinder. (Exhaust)

QUESTION #3. Describe in detail the principle of a two-cycle engi[illegible]

ANSWER #3. If the series of events which comprise a cycle is [illegible] complished during two strokes of the piston, the [illegible] gine is called a two-stroke cycle or two cycle eng[illegible] A two cycle engine of the ordinary type has no va[illegible] Admission and exhaust are regulated by the piston, which acts as a valve by uncovering, at the proper part of the stroke, ports in the cylinder walls. [illegible] ports communicate with the fuel supply and exhau[illegible] passages. The sequence of events in the three-po[illegible] two cycle type of engine is as follows: Consider t[illegible] engine at rest. In this condition there is no mixt[illegible] of gasoline vapor and air ready to be drawn into t[illegible] cylinder. To produce the initial power stroke the engine must be turned over either by hand or by mea[illegible] of an electric starter, As the engine is jacked over the piston moves up and down. The upward motion crea-tes a partial vacuum in the part of the cylinder be-low the piston and in the crank case. When the pis[illegible] has moved high enough for its lower edge to uncover admission ports, the crank case suction draws the

QUESTION #4. Describe in detail the principle of a four-cycle engine.

ANSWER #4. If the series of events which comprise a cycle is accomplished during four strokes of the piston, it is called a four-stroke or four cycle engine. In the four-cycle there is a power stroke in each cylinder for every two revolutions of the engine. In the four-cycle gasoline engine the admission of gaseous mixture to the cylinder from the carburetor and the expulsion of burned gases from the cylinder is controlled by valves. There are two valves in each cylinder. One controls the admission of the charge and is called the inlet valve and the other controls the expulsion of the burned gases and is called the exhaust valve. The actions of the valves are controlled by cams on a shaft driven from the crank shaft through gears, known as the timing gears The cam shaft is geared to revolve at one-half the speed of the crank shaft and carres a separate cam for each inlet and each exhaust valve. The cams are usually made integral with the cam shaft, so that if one valve is properly timed all valves are properly times. As a cam revolves it moves a rod called the push rod or valve tappet, which in turn moves the valve stem, either directly or through a rocker arm, and opens the valve. As the cam continues its revolution it releases its pressure on the push rod and removes the lifting force from the valve stem at the designed time. The valve then quickly closes, due to the action of the coil spring, which brings it back on its seat. The sequence of events which occur during the four strokes forming a complete cycle of a four-cycle engine is as follows: 1. Admission(down stroke). 2. Compression (up stroke). 3. Expansion (down stroke). 4. Exhaust (up stroke). In order to get a charge into the cylinder the engine will have to be turned over by hand or by means of an electric starter. When the engine is jacked the crank shaft turns and this sets the complete valve mechanism in operation. As the piston in one of the cylinders starts an admission stroke, the cam actuating the inlet valve quickly opens it. The piston continuing the down stroke creates a partial vacuum in the cylinder and, as the valve is open, a charge is drawn into the cylinder through the carburetor. The cam is so designed that as soon as a full charge has been drawn into the cylinder the pressure is released from the inlet valve stem and the spring closes it quickly. The admission stroke is now completed. During the entire stroke the exhaust valve in the cylinder has been held closed by its coil spring. The mixture now fills the cylinder but is under no pressure. The piston makes the succeeding upstroke, during which the charge is gradually compressed, the cam action being such that both the inlet and the exhaust valves are closed throughout the entire stroke. Just as the piston reached the top of its stroke and the charge is in the state of greatest

ANSWER #4. Continued.

compression a spark is produced between the terminals of the spark plug and the gases are ignited. At this stage of the cycle the compression stroke is ended and the expansion stroke is about to commence. When the charge is ignited it burns, and the heat thus generated causes the gases to expand very rapidly, producing a high pressure which forces the piston down. This is variously called the expansion firing, or power stroke. The cams actuate the valves so that the inlet valve is closed during the entire expansion stroke, and the exhaust valve is closed until just before the stroke is completed. As the piston nears the bottom of the expansion stroke a cam opens the exhaust valve and when the piston goes up the burned gases are forced from the cylinder. This last stroke of the piston is called the exhaust stroke. When it is completed the cam pressure on the exhaust valve is released, and the valve is closed by its spring. During this stroke the admission valve has been held shut by its spring

QUESTION #5. Why is a flywheel used on a gasoline engine?

ANSWER #5. A gasoline engine does not produce uniform rotation, but this condition is approached as the number of cylinders is increased. When there are less than three power strokes per revolution the torque is not continuous. For instance, in a one cylinder, four-cycle engine, power is exerted during only one of the four strokes. Means must therefore be provided to store up sufficient energy to cause the piston to make the other three strokes as well as to provide a continuous flow of power from the engine. This result is accomplished by means of the momentum of a heavy flywheel. To receive the intermittent power impulses from the pistons and to deliver them as nearly as possible in an even flow of power a flywheel is fitted to all gasoline engines, regardless of the number of cylinders.

QUESTION #6. Why are carburetors used on gasoline engines? Describe how they operate.

ANSWER #6. Before gasoline can be used in the cylinders of a gas engine it must be broken up into very fine particles and then mixed with air in such proportions as to form a very highly explosive mixture. The device used for this purpose is the carburetor. The carburetor is so arranged that it has two inlets, one from the gasoline supply and the other from the atmosphere. In the ordinary type of carburetor used on Navy engines the gasoline passes into the mixing chamber through one or more nozzles, the openings of which are controlled by needle valves. The nozzles atomize the gasoline so that it is drawn into the path of the incoming air as a fine spray. The movement of the piston in the cylinder creates a partial vacuum,

ANSWER #6. Continued.

which draws in the air from the atmosphere and the gasoline through the nozzles. The mixture of air and gasoline spray is effected in the mixing chamber and thence passes directly to the cylinder in the four-cycle type of engine or into the crank case in the two-cycle type. Ordinary commercial gasoline must be heated to effect proper vaporization. There are two methods of heating in ordinary use. One is to draw the incoming air to the carburetor through a stove heated by the exhaust manifold and the other is to pass the mixture that leaves the carburetor through a jacket heated by the exhaust gases, or in some cases by the circulating water discharge. In many engines a combination of both methods of heating is used.

QUESTION #7. What is meant by a rich mixture, lean mixture?

ANSWER #7. A rich mixture is one in which the proportion of vaporized gas is relatively large. A lean mixture is one in which the proportion of vaporized gas is relatively small. A good mixture is one in which the ratio of air to gas is about 16 to 1.

QUESTION #8. What happens and how can you tell when the mixture is (a) too rich? (b) too lean?

ANSWER #8. When the mixture is too rich, gasoline is wasted and the cylinders and spark plugs are fouled with carbon deposits. When the mixture is too lean a loss of power results. The mixture should be as lean as is consistent with proper combustion. If the mixture is too rich, the flame from an open pet cock will be a smoky red. If too lean, it will be a light yellow. If the mixture is correct, it will be a faint, light bl

QUESTION #9. Describe the ignition system of a gasoline engine.

ANSWER #9. The ignition of the gases in the cylinder of an internal combustion engine is accomplished by means of a high potential current which breaks down the air resistance between two points of a spark plug inserted in the top of each cylinder. When the resistance between the points of the plug is broken down, the current jumps across the gap and forms an arc which ignites the mixture. The necessary high-tension current is obtained from a storage battery and step-up coil or from a magneto. The ignition system requires an interrupter to make and break the primary low potential circuit; a condenser to protect the points of the interrupter and to increase the current in the secondary or firing circuit; and a distributer to direct the current to the spark plugs in their proper firing order. The time at which the spark occurs in a cylinder has a great effect on the proper running of the engine. The time for the spark to take place depends on the strength of the spark, the load on the engine, the speed of the engine, and the quality of

ANSWER #9. Continued.

the mixture. A manual means is provided to vary the time of the spark within certain limits, and in some ignition systems an automatic method is also provided. The spark is termed advanced or retarded, depending on whether it occurs early or late with relation to the time the piston is at the top of its stroke. In the description of the events which take place in an engine it is inferred that the spark occurs at the instant the piston reaches the top of the compression stroke. This inference whould be correct if when the spark occurred the charge burned simultaneously. However, the charge requires a small but nevertheless appreciable interval of time to burn. Consider this interval one two-hundredths of a second. In an engine making 600 revolutions per minute one revolution takes place in one-tenth of a second and one-twentieth of a revolution takes place in one two-hundredths of a second. In other words, the shaft would turn 18° before all of the charge becomes ignited. If the engine were making 1200 RPM the shaft would turn 36°. Still another factor enters into the time when the spark should occur. The greater the compression the charge is under, the more quickly it will burn and the more effective the power impulse will be. Therefore, to arrange for the power to be applied to the piston at the proper time and under the most effecient conditions the spark must occur at the instant when the charge is under the greatest compression, consistent with being fully ignited just as the piston reaches the top of the compression stroke. The spark must also be capable of being varied to suit the different conditons of engine operation. If the engine is running slowly, but little advance is necessary. As shown above, the greater the speed the more advanced the spark must be. If the load on the engine is heavy, such as, for instance, with a full power output, the engine requires a greater charge to produce a certain speed than it does when running under light load. For example, if one-quarter throttle opening is required normally to produce 600 RPM it may be found that under loaded conditions one-half throttle is necessary to obtain this same number of revolutions. When this greater charge in a cylinder is forced into the same space that a normal charge occupies it is therefore under greater compression than a normal charge would be. Consequently it burns more quickly and requires a more retarded spark than does normal operations. Other reasons for an advanced spark are: Too rich or too lean a mixture, slow burning mixture, worn piston rings, scored cylinders, leaky valves, loss of compression, weak spark. However, the spark must never be advanced so far that the mixture is completely ignited before the piston reaches the top of its stroke. That would causes a backfire and severely strains the engine. An unduly retarded spark will cause loss of power

QUESTION #10. Describe the cooling system of a gasoline engine.

ANSWER #10. An intense heat is generated by the explosions which occur during the operation of a gasoline engine, part of which is transmitted to the cylinder walls and heads. A cooling system must be installed on every engine to carry this heat away. The system generally consists of a pump and a water-circulating system. The pump is driven by the engine and takes suction from the water tank or other water-cooling source. To permit the circulation of this water, the engine cylinders and heads are fitted with water jackets, through which the water passes and then goes back through a radiator or similar device which cools the water. Strainers are fitted on the intake lines, and care must be exercised to see that they are always clear and that there are no obstruction in the line. If the circulating system fails, the engine will quickly heat up, causing an abnormal rise in the temperature of the cylinders. This intense heat soon destroys the lubricating oil film in the cylinders and the cylinder walls become scored, and in extreme cases a piston may expand to such an extent that it becomes too large for the cylinder inwhich it is operating. When this happens the piston is said to "freeze" To avoid trouble due to the lack of circulating water, an inspection to determine whether or not water is sent through the engine should be made every time the engine. Gasoline engines perform most economically at a temperature of about 180° F. and automobile engines are run at about this temperature. When salt water is being used for cooling purposes, the temperature should not be allowed to exceed 120° F as the salt water will form incrustations in the water jackets. In localities where the water is exceedingly cold it is good practice to throttle the intake valve so that a smaller amount of water will be taken in, as the extreme cold will cause too much of the heat generated to be absorbed by the cylinder walls and a loss of power will result.

QUESTION #11. Describe the characteristics of the Diesel crude-oil engine.

ANSWER #11. Internal-combustion engines that burn directly in the cylinder heavy liquid fuels of high boiling points, the fuel being injected into the compressed air shortly before or at the completion of the compression stroke, are termed oil engines. The distinguishing features of oil engines are that the fuel vapor is not absorbed by air before it is admitted to the cylinder and that inflammable mixture of vapor and air is compressed preceding its ignition. Oil engines compress air alone, and the heat of compression is used to ignite the fuel, which burns by consuming the oxygen of the air in the cylinder, the engine transforming the heat energy into work. To facilitate and speed up the burning of a liquid fuel, it must either be vaporized, atomized, or intimately

ANSWER #11. Continued.

mixed with air immediately preceding its ignition. Light, highly volatile liquid fuels, such as benzols, gasolines, alcohol, and distillates, offer no particular difficulties to vaporization; the air in its passage to the engine cylinder readily absorbs the fuel vapors and forms a combustible mixture which is ignited electrically in the cylinder. The process of charging the air with fuel vapors is called carburetion. The more volatile fuels, like gasoline, can be carbureted at ordinary atmospheric temperatures; that is, without previous heating of the air or fuel. Liquid fuels with higher boiling points may require heating of the air or the fuel or both to bring about their avaporation and absorption by the air preceding combustion. In the heavy oil engine the vaporizing of the fuel takes place inside of the engine. As a fuel with a high boiling point can not be evaporated at moderate temperatures, thorough mechanical division preceding ignition and combustion is necessary.

QUESTION #12. How many general types of liquid-fuel engines (crude oil engines) are there? How are they distinguished?

ANSWER #12. There are three general types of liquid-fuel (crude-oil) engines. They are distinguished according to the means used for atomizing the liquid fuels and igniting them. There are only two distinct types, the third being a combination of the two. In one type the entire fuel charge is sprayed against a highly heated surface in a chamber connected with the working cylinder. Contact with this highly heated surface gasifies the fuel, which is ignited and burns with explosion-like rapidity. Engines of this type are termed "explosion oil" engines, or engines in which the fuel is burned at constant volume. In engines of the other type the fuel to be converted is finely subdivided by air, and in this act of atomization is injected directly into the engine cylinder, where it is ignited automatically by the highly heated air in the cylinder. The combustion is not explosion-like, but is prolonged at constant pressure for the entire period during which the fuel is injected into the cylinder. This type of engine is universally known as the Diesel engine, being named after its inventor, Rudolph Diesel, of Munich, Germany. It is also termed the constant pressure oil engine. The third general type combines the features of the two types mentioned, in which the fuel is burned at both constant volume and constant pressure. Engines of this type are known as Sabathe engines. Any of these three types of engines may be classified as two-stroke or four-stroke, or single or double acting, depending on the mechanical arrangement.

QUESTION #13. How does a semi-Diesel differ from a true Diesel? How determine a semi-Diesel from the other types?

ANSWER #13. A semi-Diesel differs from a true Diesel in that its compression pressure is about half that occuring in a true Diesel, and all true semi-Diesels receive part of the heat of combustion at constant pressure and part at constant volume. One method of determining the right of an engine to be called a semi-Diesel is to study an indicator card from the engine; the proper classification can be determined, following the above definition, by the shape of the combustion line.

QUESTION #14. Describe the four-stroke cycle Diesel engine; the two stroke.

ANSWER #14. The four-stroke cycle Diesel engine consists of a piston in which is connected a connecting rod to a crankshaft. This piston is in a cylinder, in the head of which are several valves; the fuel injection valve, the air intake valves, the starting valve, and the exhaust valve. Another and smaller piston is connected to the connecting rod of the main piston by means of an arrangement of several connecting rods. This small piston compresses air. Connected to the air intake are the injection air bottle and the reserve air receiver. The sequence of events are as follows: The engine piston has started on its downward travel. The air intake valve is open to the atmosphere and lets air into the engine cylinder. On its return stroke the air intake valve and all other valves are closed, so that the piston compresses the air in the cylinder to a pressure of 450 or 550 pounds per square inch. As a result the air becomes heated, its temperature rising to about 1000° F, when the highest pressure is reached. When the piston is at its upper dead center the fuel injection valve is opened and liquid fuel in a volume proportional to the load of the engine is forced into the cylinder where, meeting the highly heated air, it automatically ignites and burns. When an automatically regulated supply of fuel has been delivered the fuel injection valve closes. Under the impulse of the expanding gases, the piston moves downward, transforming the heat energy of the fuel into work. Arriving at the lower dead center, the piston reverses its travel and begins a new upward stroke. The exhaust valve being open, the piston sweeps the products of combustion before it, expelling them through this valve into the atmosphere, thus completing the four-stroke cycle. This cycle is repeated when the air intake valve opens again and the piston starts on its downward stroke.

The two-stroke cycle Diesel engine differs from the Diesel in that it has a scavenging air pump and exhaust post, arranged around the cylinder walls, covered and uncovered by the piston in its upward and downward travel, and two or more admission

ANSWER #14. Continued.

valves in the cylinder head. The scavenging air pump is double acting and its air delivery is controlled mechanically by a piston valve. The air admission to the engine cylinder is mechanically controlled by two or more air valves in the cylinder head. The scavenging air is compressed to a pressure of 3 to 7 pounds per square inch. The air is admitted into the working cylinder as soon as the exhaust ports have been uncovered by the piston; the cylinder, full of the gaseous products of combustion, is cleared by the scavenging air, which sweeps out through the exhaust ports, leaving the cylinder full of a new charge of fresh air. As the piston on its return stroke closes all cylinder valves and exhaust ports, the air is compressed in the same manner as in the engine having a four - stroke cycle, and the fuel charge is injected on the completion of the compression stroke. During the next stroke the expanding gases give the piston its power impulse; with the opening of the exhaust ports and the discharge of the spent fuel gases the working cycle is complete. By employing a scavengin air pump for cleaning the cylinder of its combustio products and refilling it with fresh air a working impulse to every revolution is obtained, whereas two complete revolutions to a working impulse are required in an engine having a four-stroke cycle.

QUESTION #15. What are the important adjuncts of a Diesel engine?

ANSWER #15. The important adjuncts of the Diesel engine comprise a two stage air compressor, an air injection bottle a compressed air container, and a fuel oil tank.The pump is under the influence of the engine governor by which the volume of fuel delivered is proportioned to the load of the engine. The fuel oil stored in the tank flows by gravity to the pump which delivers a measured quantity of oil to the injector during the suction stroke of the engine piston whil the needle valve of the injector is closed. The fue injector is connected with the small air receiver, in which air under pressure of 700 to 900 pounds pe square inch is stored, and air at this pressure always fills the valve chamber around the valve stem of the fuel injector. The pump, in delivering its measured quantity of fuel to the injector must overcome the air pressure within the valve chamber. The pump is therefore designed to deliver the oil at a pressure of 100 to 200 pounds per square inch highe than the pressure of the air from the tank, or at a pressure of 800 to 1100 pounds per square inch. The fuel oil is delivered near the bottom of the fuel injector immediately above the neddle valve. When this valve is opened the injection air, which is at a pressure nearly double that of the compressed air in the engine cylinder at the completion of the compression stroke atomizes the fuel oil and carries it to the engine cylinder. The injection air thus ser-

ANSWER #15. Continued.

ves two important functions, namely, to inject the fuel into the cylinder and to subdivide it finely. The latter function is by far the most important, as on its efficiency greatly depends the success with which the heavy liquid fuels are burned. The fuel could be injected by direct pump pressure, but unless thoroughly atomized by highly compressed air it would burn only partly and after-ignition would resutl. The two stage air compressor furnishes the injection air; the intercooler cools the air from the low-pressure cylinder to atmospheric pressure before delivering it to the high-pressure cylinder; the aftercooler delivers cold air to the injection air bottle and the reserve air receiver; As previously mentioned, in the compressor the atmospheric pressure is brought to about a pressure of 700 to 1000 pounds per square inch. The reserve air receiver provides reserve air storage. Air is drawn from it whenever the engine is started and is delivered through the starting valve when the piston is at the upper center in position to receive a power impulse, air being the power medium for starting the engine. After the engine has been started the reserve air bottle is charged from the air injection bottle, by working the air compressor at its full capacity for 15 to 20 minutes. When desired air pressure has been restored in the reserve air receiver, all valves leading to and from the tank are closed. The air inlet pipe connects to the air intake valve. Starting a Diesel engine from no load to full load requires one to three minutes, depending on the size and construction of the engine.

QUESTION #16. Draw TM Transmitter.

ANSWER #16. See separate diagram.

USEFUL NOTES PERTAINING TO GASOLINE AND CRUDE OIL ENGINES.

Formula for finding the indicated horsepower of a two cycle engine:

$$\frac{1}{33000} \times \frac{pi}{4}d^2 \times P \times \frac{l}{12} \times n \times N$$

Where:	pi	equals	3.1416
	d	equals	Diameter in inches of cylinder.
	P	equals	Pressure in pounds per sq. in.
	l	equals	Length of stroke in inches.
	n	equals	Number of revolutions per minute.
	N	equals	Number of cylinders.

Formula for finding the indicated horsepower of a four cycle engine

$$\frac{1}{33000} \times \frac{pi}{4}d^2 \times P \times \frac{l}{12} \times \frac{n}{2} \times N.$$

The symbols in this formula are the same as above. The "n" (Number of revolutions per minute) is divided by "2" in this case because there is only one power stroke for every two revolutions.

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The brakehorsepower of an engine is measured by means of a dynamometer. The commonest form of this is the Prony Brake. Several wooden blocks are placed on the under side of the flywheel and are held there by means of a yoke circling the under part of the flywheel. The two ends of the yoke extend up vertically through the holes of a lever which extends out from the top of the flywheel. Several wooden blocks are placed on top of the flywheel and are held there be means of another yoke attached to the lever. The blocks are pressed against the face of the flywheel by the tension produced by the adjustable yoke on the bottom and the weight of the yoke on the top, thus applying a friction load to the flywheel as desire The pressure due to the energy absorbed by the brake is carried by the lever and a post to platform scales which are adjusted to just balance the load.

Formula for finding the brakehorsepower using a Prony Brake:

$$\frac{2piRNW}{33000}$$

Where:	2pi	equals	6.2832
	R	equals	Length of the brake arm in feet.
	N	equals	Revolutions per minute of flywheel.
	W	equals	Weight in pounds at distance R, measured by scales.

The value $\frac{2piR}{33000}$ is called the brake constant, and, for the same brake, is the same for all loads.

Before starting a test a zero reading of the brake is obtained, since the scales weigh not only the pressure due to the friction load on the lever, but also the weights of the brake and post. To determine the zero reading, the under yoke is loosed and the flywheel is turned by hand in one direction and scale read, in opposite direction and scale read. Adding the two readings and dividing by two gives the mean weight, which is the zero reading.