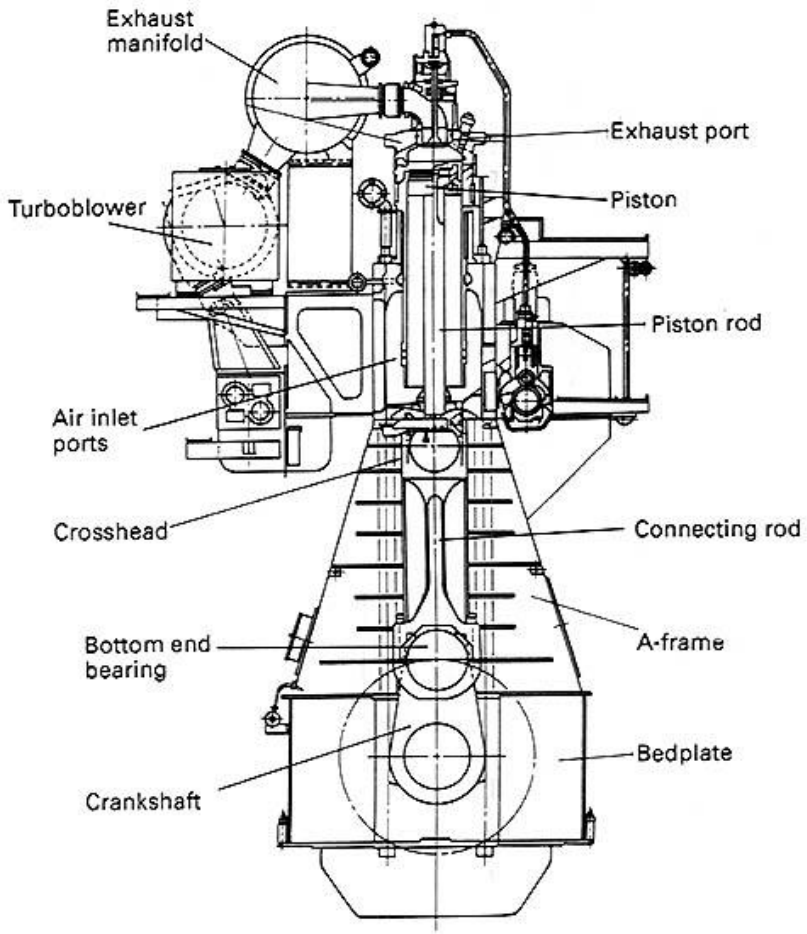
MARINE DIESEL ENGINES - THE BASICS

based on:

- A. Spinčić *English for Marine Engineers I.*
- *MarineDieselsCo.Uk.pdf*
- *http://www.splashmaritime.com.au/Marops/data/text/Med3tex/Engpropmed2.htm*
- *2 Stroke Marine Diesel Engine MAN-B@W – Operating Principle (YouTube)*

Marine diesel engine – cross section



Knowldege about marine diesel engines includes:

1. The 4 Stroke Diesel Cycle
2.
3.
4.
5.
6.
7.
8. The Air Start System

1. *The 4 Stroke Diesel Cycle*
2. *The 2 Stroke Diesel Cycle*
3. *The 2 Stroke Crosshead Engine*
4. *Uniflow and Loop Scavenging*
5. *The Cooling Water System*
6. *The Lubricating Oil System*
7. *Fuel Oil System*
8. *The Air Start System*

1. The 4 Stroke Diesel Cycle

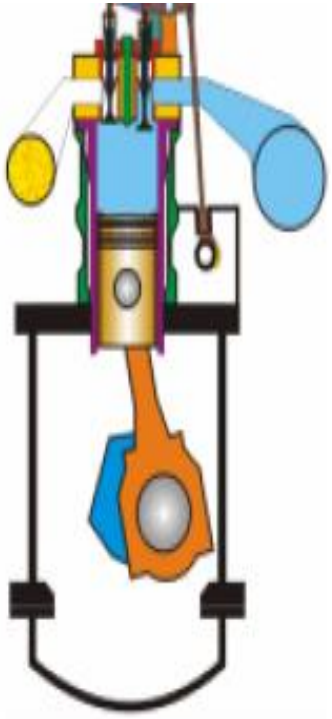
- main feature:

- the strokes:
  - "*suck, squeeze, bang, blow*."

The 4 Stroke Diesel Cycle

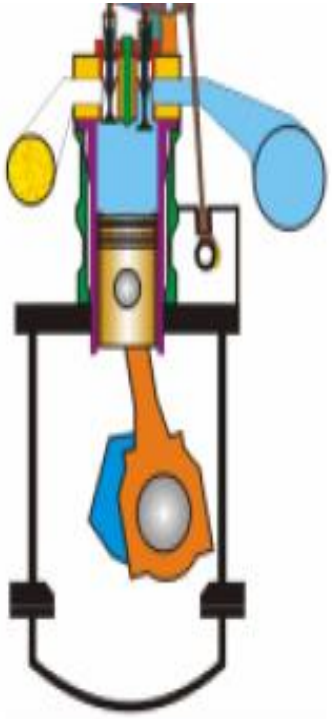
Stroke 1 - INDUCTION

The crankshaft is rotating clockwise and the piston is moving down the cylinder. The inlet valve is open and a fresh charge of air is being drawn or pushed into the cylinder by the turbocharger.



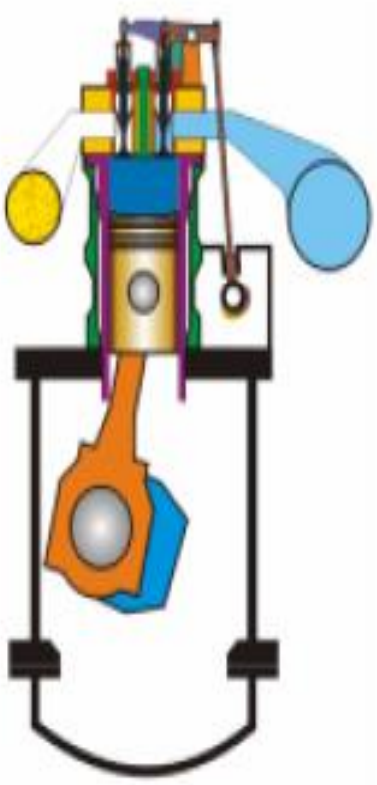
Supply the missing words: Stroke1 - INDUCTION

The crankshaft is _____ clockwise and the piston is _____ down the cylinder.
The inlet valve is _____ and a fresh charge of air is being _____ or pushed into the cylinder by the _____.



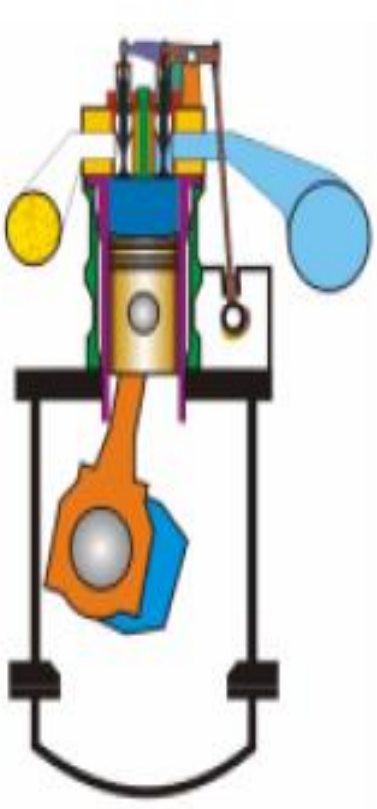
Stroke 2 - COMPRESSION

- The inlet valve has closed and the charge of air is being compressed by the piston as it moves up the cylinder. Because energy is being transferred into the air, its pressure and temperature increase. By the time the piston is approaching the top of the cylinder (known as Top Dead Centre or TDC) the pressure is over 100 bar and the temperature over 500°.



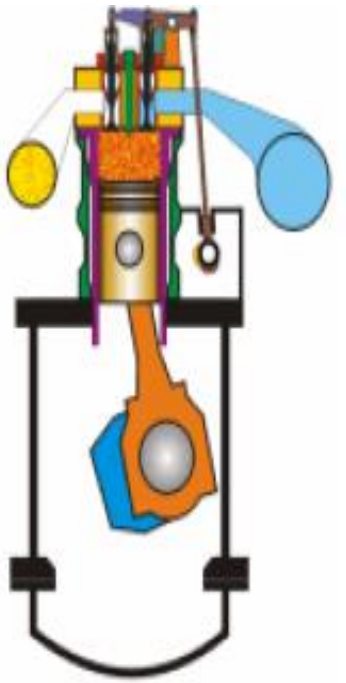
Supply the missing words: Stroke 2 - COMPRESSION

- The _____ has closed and the charge of air is being compressed by the piston as it moves up the _____ .
- Because energy is being transferrec into the air, its _____ and _____ increase.
- By the time the _____ is approaching the top of the cylinder (known as _____ or TDC) the pressure is over 100 _____ and the temperature over 500°.



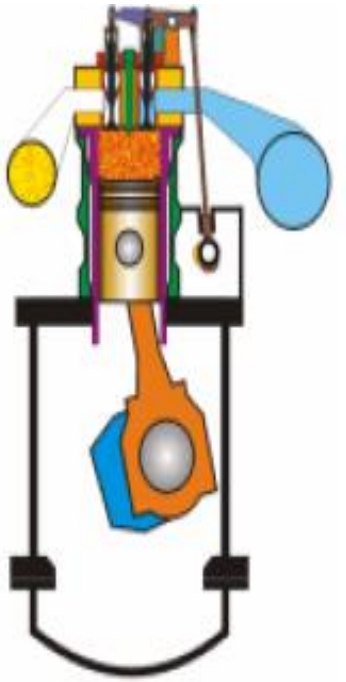
Stroke 3 - POWER

- Just before TDC fuel is injected into the cylinder by the fuel injector. The fuel is "atomised" into tiny droplets. Because they are very small these droplets heat up very quickly and start to burn as the piston passes over TDC. The expanding gas from the fuel burning in the oxygen forces the piston down the cylinder, turning the crankshaft. It is during this stroke that work energy is being put into the engine; during the other 3 strokes of the piston, the engine is having to do the work.



Supply the missing words: Stroke 3 - POWER

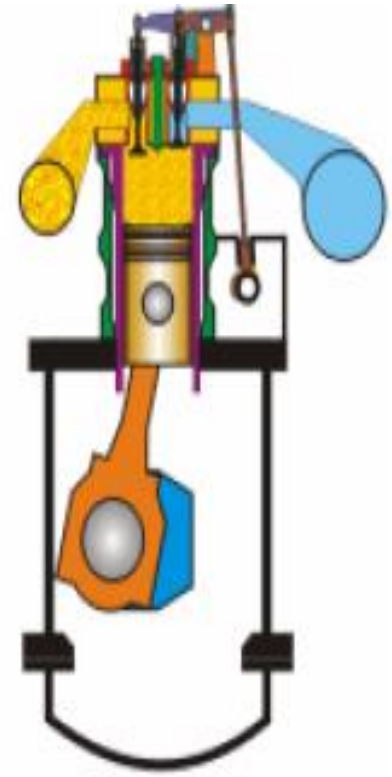
- Just before TDC fuel is _____ into the cylinder by the _____.
- The fuel is "atomised" into tiny _____.
- Because they are very small these droplets _____ very quickly and start to burn as the piston _____ over TDC.
- The expanding gas from the fuel burning in the _____ forces the piston down the cylinder, turning the _____.
- It is during this _____ that work energy is being put into the engine; during the other 3 strokes of the piston, the _____ is having to do the work.



Stroke 4 - EXHAUST

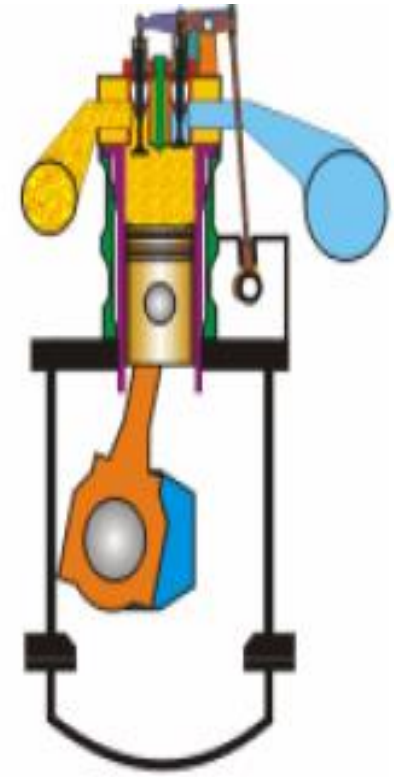
As the piston approaches the bottom of the cylinder (known as Bottom Dead Centre or BDC) the exhaust valve starts to open. As the piston now moves up the cylinder, the hot gases (consisting mostly of nitrogen, carbon dioxide, water vapour and unused oxygen) are expelled from the cylinder.

As the Piston approaches TDC again the inlet valve starts to open and the cycle repeats itself.

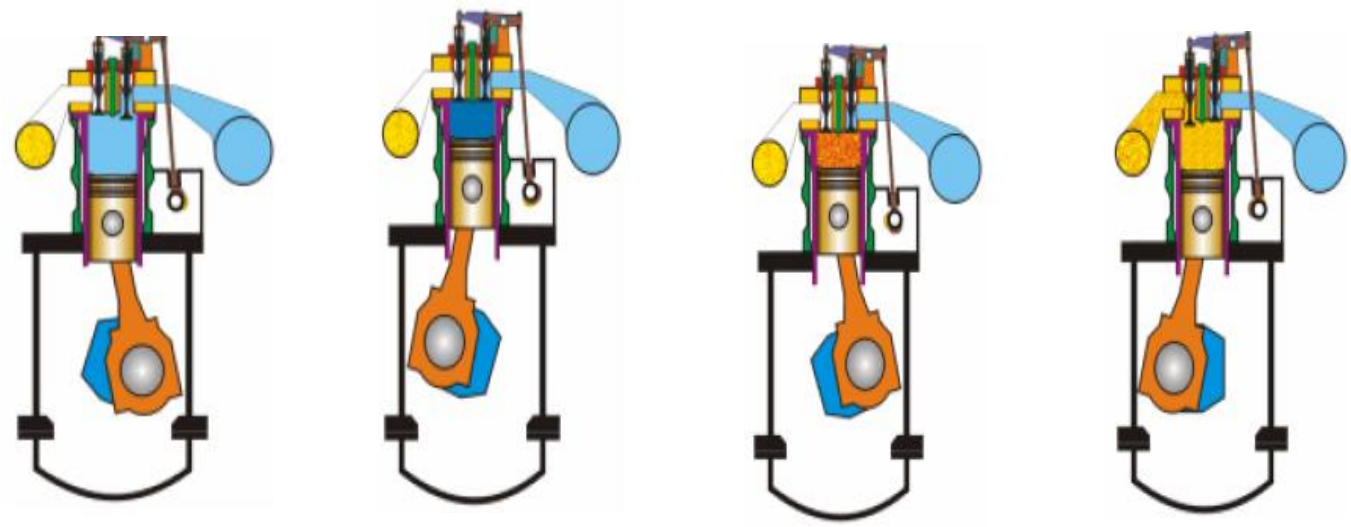


Supply the missing words: Stroke 4 - EXHAUST

As the piston _____ the bottom of the cylinder (known as _____or _____) the exhaust valve starts to open. As the piston now moves up the cylinder, the hot gases (consisting mostly of nitrogen, _____, water vapour and unused oxygen) are _____ from the cylinder. As the Piston approaches TDC again the _____ starts to open and the _____ repeats itself.



Writing skills: Write down the operation of the four-stroke diesel engine using the diagrams below



Speaking skills: Now work in pairs to decribe the operation of the four-stroke diesel engine using the diagrams below

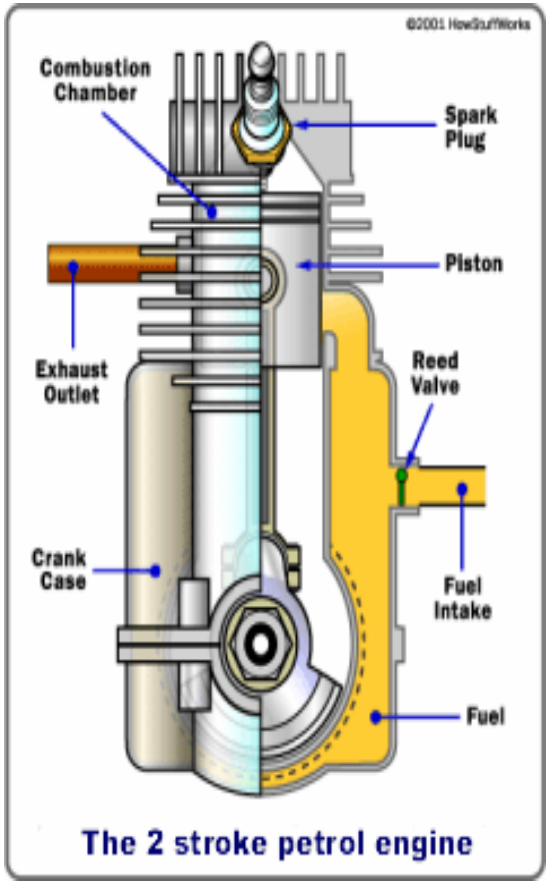
Match the definition with the name of the stroke	
Just before TDC fuel is injected into the cylinder by the fuel injector. The fuel is "atomised" into tiny droplets. Because they are very small these droplets heat up very quickly and start to burn as the piston passes over TDC. The expanding gas from the fuel burning in the oxygen forces the piston down the cylinder, turning the crankshaft.	***induction***
The crankshaft is rotating clockwise and the piston is moving down the cylinder. The inlet valve is open and a fresh charge of air is being drawn or pushed into the cylinder by the turbocharger.	***compression***
As the piston approaches the bottom of the cylinder (known as Bottom Dead Centre or BDC) the exhaust valve starts to open. As the piston now moves up the cylinder, the hot gases are expelled from the cylinder. As the Piston approaches TDC again the inlet valve starts to open and the cycle repeats itself.	***power***
The inlet valve has closed and the charge of air is being compressed by the piston as it moves up the cylinder.	***exhaust***

2.

The 2 Stroke Diesel Cycle

2. The 2 Stroke Diesel Cycle

- It may surprise you to learn that the biggest diesel engines in use operate on the two stroke principle. If you have experience of the two stroke **petrol eng**ine you will know that it causes more pollution than a four stroke petrol engine. This is because oil is mixed with the petrol to lubricate the crankshaft bearings, and a lot of unburnt petrol/oil/air mixture is discharged to the atmosphere.



The 2 stroke petrol engine

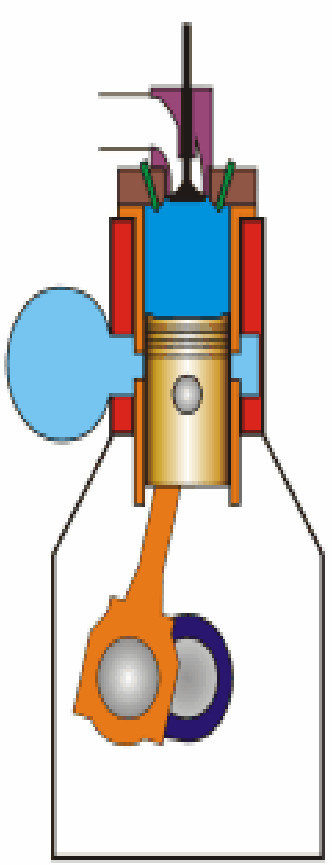
- The two stroke Diesel engine does not mix fuel or oil with the combustion air. The crankshaft bearings are lubricated from pressurised oil in the same way as a four stroke engine.
- The two stroke cycle is so called because *it takes two strokes of the piston to complete the processes needed to convert the energy in the fuel into work.*
- Because the engine is **reciprocating**, this means that the piston must move up and down the cylinder, and therefore the crankshaft must revolve once.

Complete the sentences below:

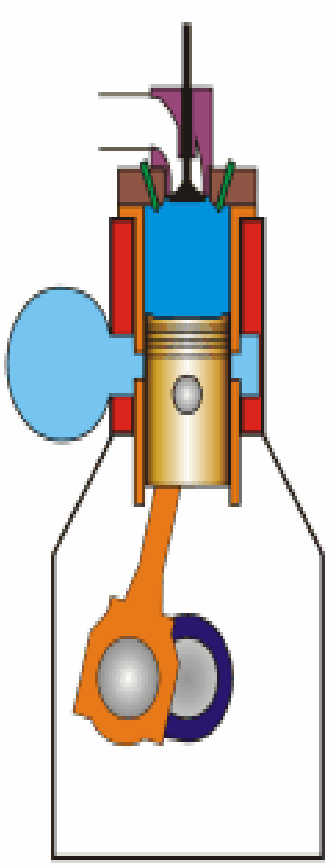
- The two stroke Diesel engine does not mix .....
- The crankshaft bearings are lubricated from pressurised oil in the same .....
- The two stroke cycle is so called because it..... needed to convert .....
- Because the engine is reciprocating, this means that the piston must ....., and therefore .....

1

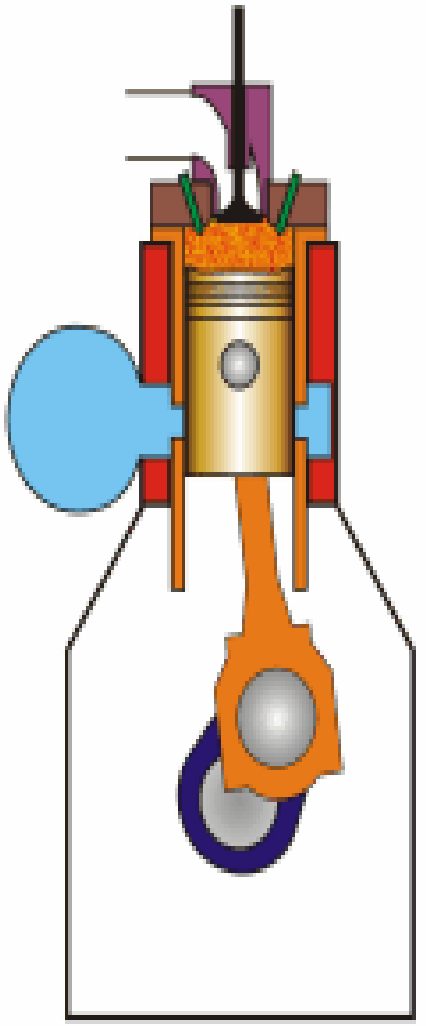
- 1. The crankshaft is revolving clockwise and the piston is moving up the cylinder, compressing the charge of air. Because energy is being transferred into the air, its pressure and temperature increase. By the time the piston is approaching the top of the cylinder (known as Top Dead Center or TDC) the pressure is over 100 bar and the temperature over 500°C.



- The crankshaft is revolving _____ and the piston is _____, compressing the charge of air.
- Because energy is being transferred into the air, its pressure and temperature _____.
- By the time the piston is approaching _____(known as Top Dead Center or TDC) the pressure is over _____ and the temperature over 500°C.

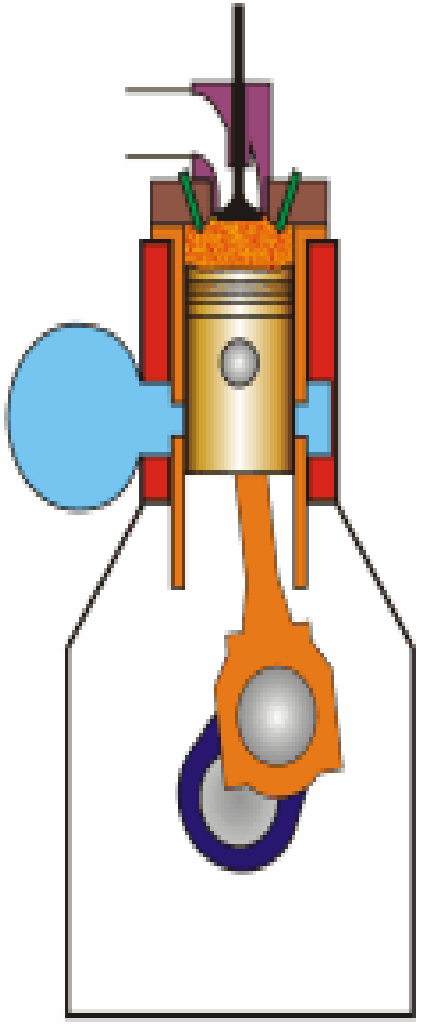


2. Just before TDC fuel is injected into the cylinder by the fuel injector. The fuel is "atomised" into tiny droplets. Because they are very small these droplets heat up very quickly and start to burn as the piston passes over TDC. The expanding gas from the fuel burning in the oxygen forces the piston down the cylinder, turning the crankshaft. It is during this stroke that work energy is being put into the engine; during the upward stroke of the piston, the engine is having to do the work.



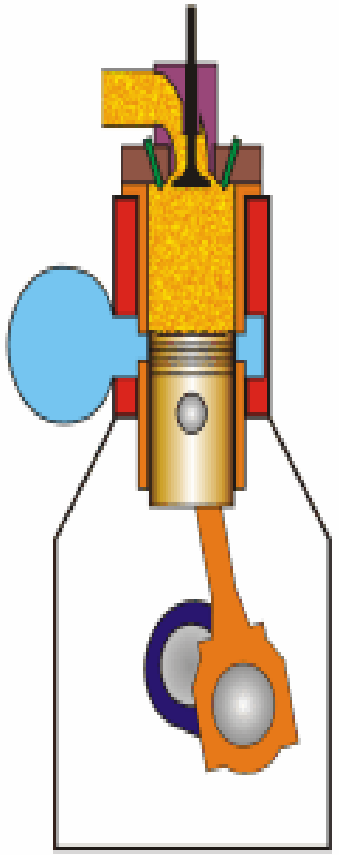
2

- Just _____ TDC fuel is injected into the cylinder by the fuel injector.
- The fuel is "atomised" _____ tiny droplets.
- Because they are very small these droplets heat up very _____ and start to burn _____ the piston passes over TDC.
- The expanding gas from the fuel burning in the oxygen forces the piston _____ the cylinder, turning the crankshaft.
- It is during this stroke _____ work energy is being put into the engine; _____ the upward stroke of the piston, the engine is having to do the work.

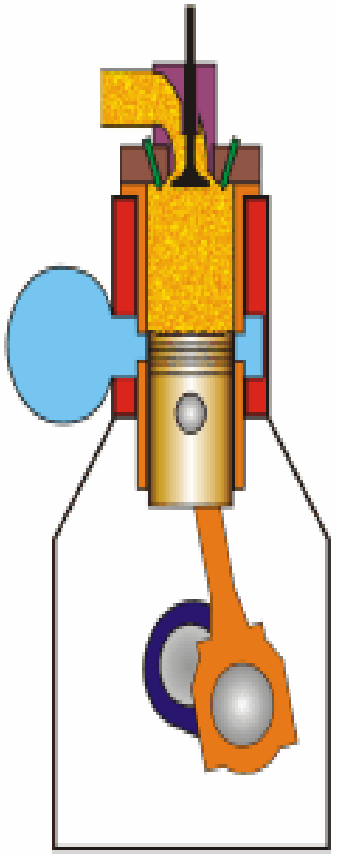


3

- 3. As the piston moves down the cylinder, the useful energy from the burning fuel is expended. At about 110° after TDC the exhaust valve opens and the hot exhaust gas (consisting mostly of nitrogen, carbon dioxide, water vapour and unused oxygen) begin to leave the cylinder.

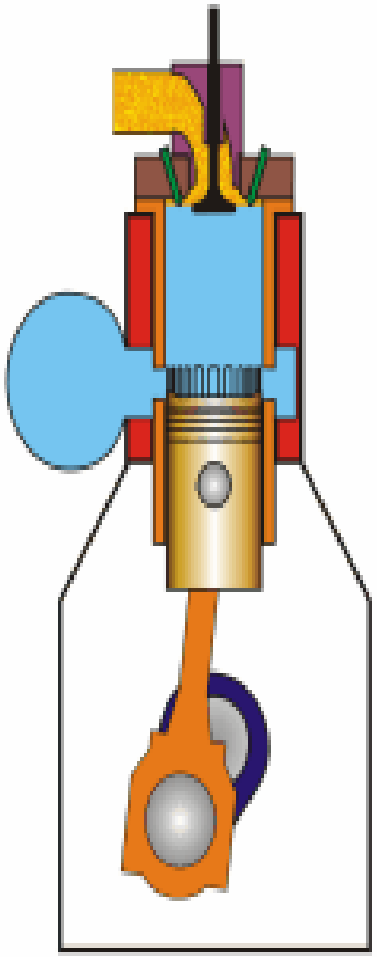


- 3. As ..... the useful energy from the burning fuel is expended.
- At about ..... the exhaust valve opens and the hot exhaust gas (consisting mostly of _____, _____, water vapour and unused _____) begin to leave the cylinder.

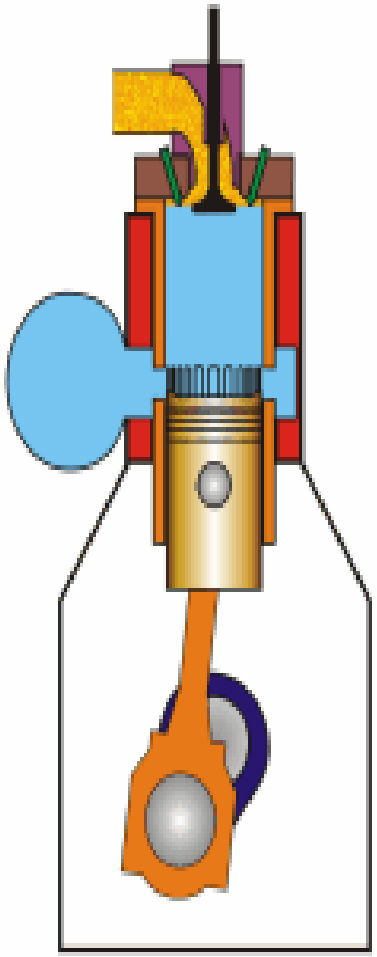


4

- 4. At about 140º after TDC the piston uncovers a set of ports known as **scavenge ports**. Pressurised air enters the cylinder via these ports and pushes the remaining exhaust gas from the cylinder in a process known as "scavenging".
- The piston now goes past Bottom Dead Centre and starts moving up the cylinder, closing off the scavenge ports. The exhaust valve then closes and compression begins.

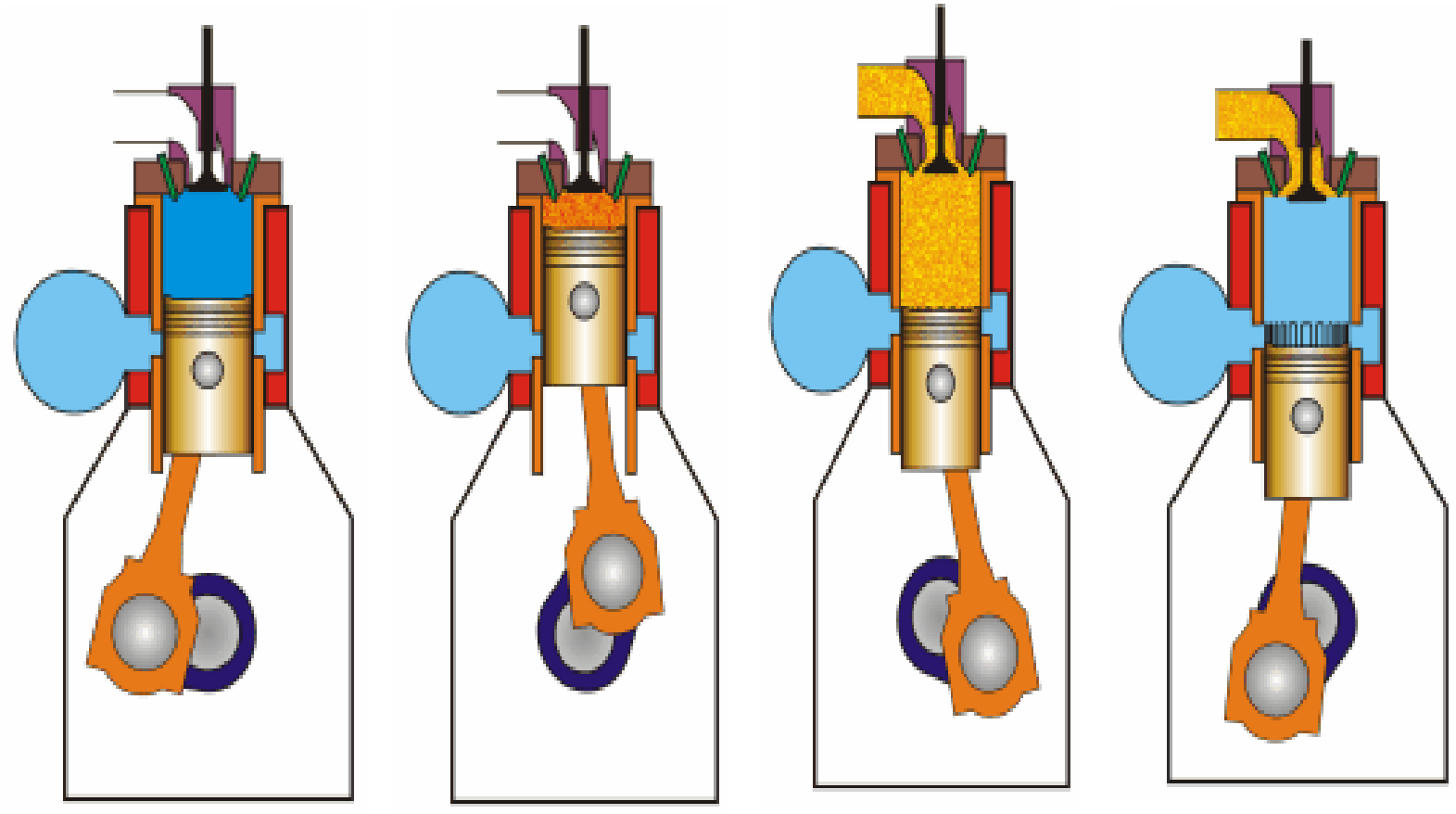


- At about 140º after TDC the piston uncovers a set of _____ known as scavenge ports.
- Pressurised air enters the cylinder via these ports and pushes the remaining _____ from the cylinder in a process known as " _____ ".
- The piston now goes past _____ and starts moving up the cylinder, closing off the _____.
- The exhaust valve then closes and _____ begins.



a) Writing skills: Describe the operation of a two-stroke diesel engine in writing

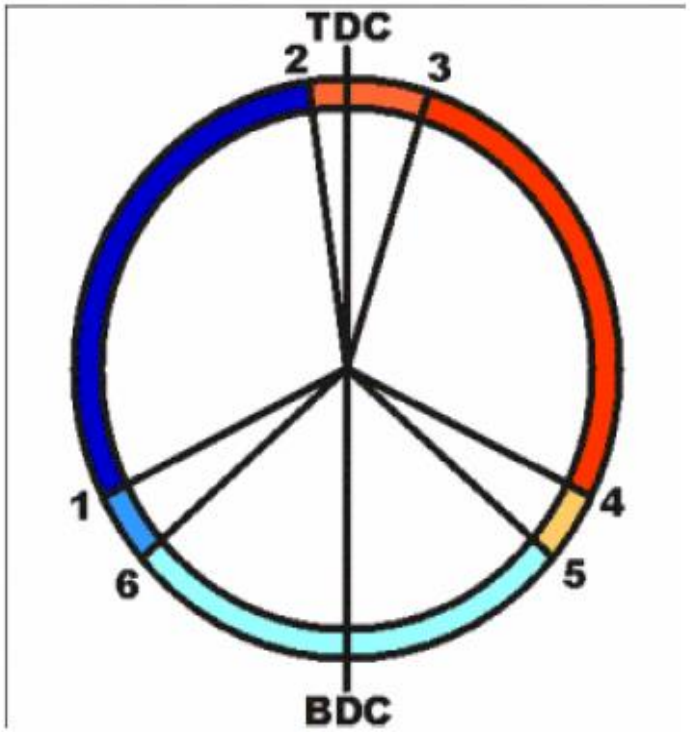
b) Speaking skills: present the operation of a two-stroke diesel engine to your colleague



Speaking and writing skills:

Describe the two stroke cycle using the diagram and data below

The two stroke cycle can also be illustrated on a timing diagram.

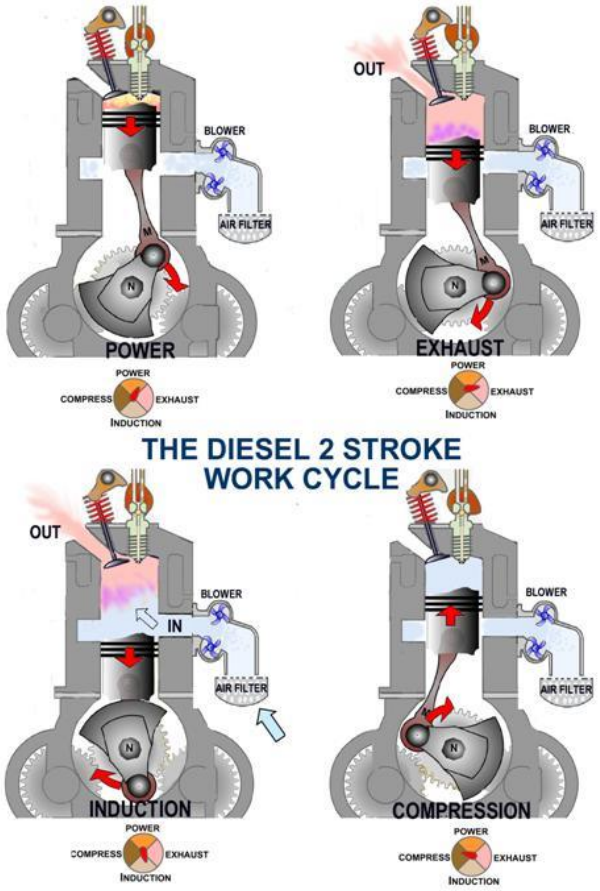


1 -2 Compression	1. approx 110° BTDC
2 - 3 Fuel Injection	2. approx 10° BTDC
3 - 4 Power	3. approx 12° ATDC
4 - 5 Exhaust Blowdown	4. approx 110° ATDC
5 - 6 Scavenging	5. approx 140° ATDC
6 - 1 Post Scavenging	6. approx 140° BTDC

Two stroke engine

Source:

http://www.splashmaritime.com.au/Marops/data/text/Med3tex/Engpropmed2.htm



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Power and exhaust operations-stroke 1

Just before tdc the piston is positioned above both inlet and outlet ports so sealing the cylinder with its pressurised charge of fuel/air mix. The crankshaft synchronises the timing that releases a high voltage impulse to the spark plug to explode the fuel/air mix. As the piston passes tdc, the burning gas expands, driving the piston toward bdc, rotating the crankshaft and its attached weighted flywheel.

Half way down its first stroke the piston uncovers the exhaust outlet port and directed by the piston's contoured head, exhaust gasses are partially ejected.

Induction and compression operations-stroke 2

The inlet port shown is a transfer port as it is open to both sides of the cylinder.
In the carburettor air and fuel are premixed and atomised. To improve the induction of fuel/air mixture into the crankcase, one-way valves (check valves, reed valves, or rotary valves) may be used in the intake port to allow the fuel air charge to get into the crankcase quickly, but prevent it leaking back out.

As the piston descends, the inlet port experiences a suction that inducts the fuel/air charge around the crankcase, in the process depositing a film of oil on the moving surfaces. Once past bdc and rising on its second stroke the piston pushes the charge up through the transfer port into the cylinder. This flow of the fuel/air charge into the cylinder forces any remaining exhaust out of the cylinder, a process called scavenging. Lastly, as the piston covers the inlet port, the fuel/air charge is compressed ready for the next power operation (ignition).

Power (exhaust and induction) operations-stroke 1

Just before tdc the piston is positioned above the inlet port and the exhaust valve is closed, so sealing the cylinder and its pressurised and heated air. The crankshaft driven timing synchronises the injector to release a spray of atomised fuel that explodes instantly on mixing with the super heated air.

As the piston passes tdc, the burning gas expands, driving the piston toward bdc, rotating the crankshaft and its attached weighted flywheel.

With the initial force of the expansion expended, three quarters of the way down its first stroke the exhaust valve opens and exhaust gasses begin to be ejected.

An instant later the piston exposes the inlet port and fresh air is sucked in, often under pressure from a blower (supercharger or scavenger blower). This rush of fresh air further pushes the exhaust towards the outlet valve (scavenging).

<u>Compression (exhaust and induction)</u> operations-stroke 2

After the piston passes bdc to begin the second stroke the fresh air compression completes the displacement of any remaining exhaust.

A quarter the way up the second stroke the piston covers the inlet port and next the exhaust valve closes. Now the air is fully compressed in the sealed cylinder ready for the next explosion.

Scavenging

Removal all burnt gases from the cylinder and replenishment with fresh charge (scavenging) is necessary to maintain the power and efficiency of the engine. The rapid operation of two strokes causes a flow of fresh air buffering against exhaust gasses to eject them. Improving the flow by careful design and a blower improves the scavenging efficiency. The cross flow type scavenging shown above uses a piston head profile directed towards the exhaust. Looped scavenging has inlets and outlets on the same side of the cylinder. Uniflow scavenging is arranged so the gasses all move centrally in the same direction towards the cylinder head outlet.

Engine designs with transfer inlet ports positioned evenly around the cylinder improve scavenging by allowing air to enter uniformly and push the exhaust towards the exhaust valve.

Air, blowers and after-coolers

Small engines are naturally aspirated purely by the suction created during the downward stroke of the piston. However more complex engines use additional blowers to force air into the cylinders and so increase their power and efficiency. Blowers may be the supercharger or turbocharger type.

Superchargers are driven directly by the engine and geared spin at up to twice the engine speed. A stream of air from a supercharger can also partially cool the hot running two-stroke.

Turbochargers are driven by a turbine which is powered by the engine exhaust and may spin at up to 100,000 r.p.m. Balance and lubrication is critical. At high speed turbo vanes reach high temperatures from the exhaust's blast of flame. If the engine is instantly shut down from high speed operation the rapidly spinning turbo will run-on for a substantial time after the engine driven lubricating system has stopped. The heat from the turbo vanes will conduct into the bearings with consequent damage. To prevent these problems, hot engines should be allowed to idle for about 5 to 15 minutes before they are switched off, to allow the engine and turbo to cool down.

Turbochargers also heat the inducted air by compression. An after-cooler may be fitted to cool and increase the density the air (providing more oxygen per unit of volume) before it enters the engine, so increasing efficiency and cool running.

1.4 Timing – valves, injection and ignition

Diesel engines

Timing methods vary widely in different engine designs, but all must be set exactly as even a small timing error can stop the engine or seriously damage it. Injection, and the opening and closing of the valves, is accurately timed in relation to the position of the piston, by the gear or chain drive from the crankshaft to the camshaft. The meshed teeth of the gears ensure that injection and valve operations occur at the correct point of each work cycle. At speed engines work cycles occur so rapidly that valve and injection has to be initiated prematurely to counter the miniscule delay in actuating mechanism.

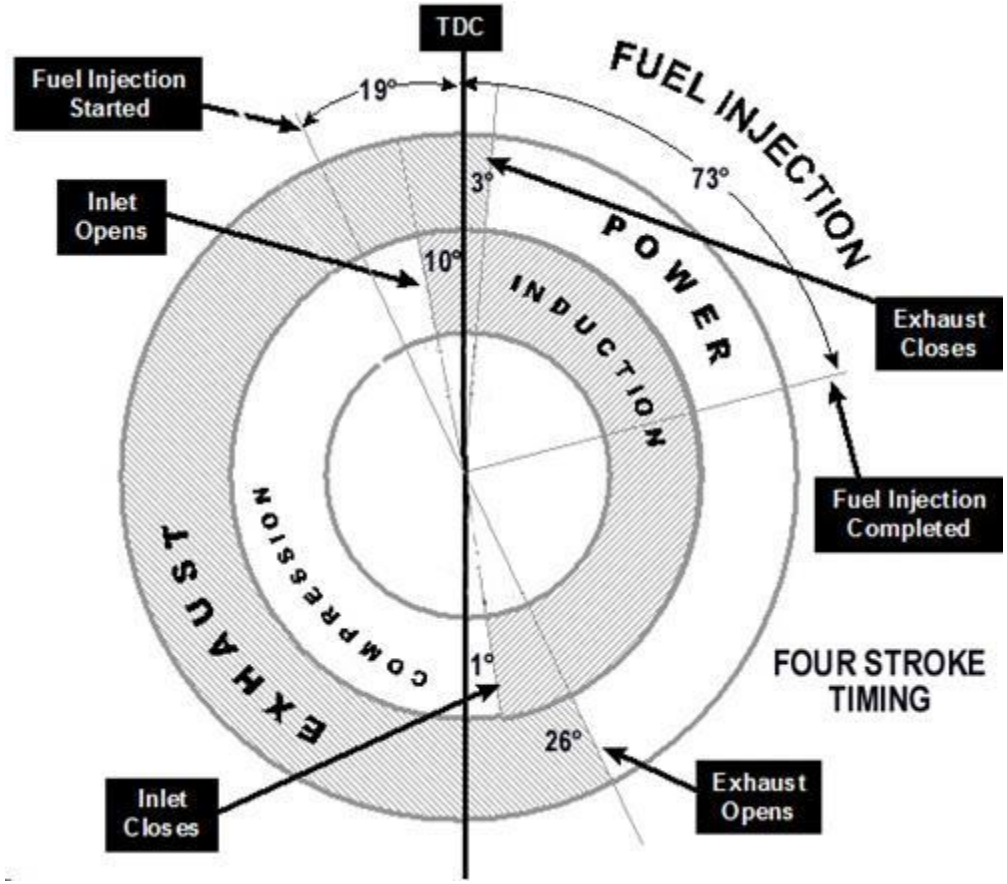
Four stroke engines have twice as many teeth on the camshaft gear (or sprocket) as there are on the crankshaft gear. This means the camshaft runs at half the speed of the crankshaft. The camshaft turns (injection and valves operate) only once for every two revolutions of the crankshaft.

With two stroke engines, injection occurs and the valves will open and close on each turn of the crankshaft. In two-stroke engines, the camshaft must run at the same speed as the crankshaft.

The specific opening and closing of the inlet and exhaust valves and the period of injection of the fuel can be taken from the engine manufacturers timing diagram. Examples are shown below:

Four stroke cycle diesel engine

The diagram below represents a Caterpillar turbo charged after cooled engine. The induction stroke commences when the inlet valve opens 10° before tdc when air is drawn into the cylinder as the piston moves down. The inlet valve closes 1° before bdc. The air is now trapped in the cylinder and as the piston rises on the compression stroke, the air is compressed. As the air is compressed, it rises in temperature. When the piston reaches 19° before tdc, the injection of fuel commences and continues until 73° after tdc.



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The heat in the compressed air ignites the fuel and combustion takes place. The gases expand forcing the piston down on the power stroke.

The **exhaust valves** opens at 26° before bdc and the exhaust gases are discharged as the piston rises on the exhaust stroke. Most of the exhaust gases have been discharged as the piston nears tdc. However, at 10° before tdc, the inlet valve opens and air enters the cylinder and helps discharge any remaining exhaust gases until the exhaust valve closes at 3° after tdc. The whole cycle is then repeated.

Both the **exhaust valve and inlet valve** are open from 10° before tdc to 3° after tdc, an overlap of 13°. This is referred to as “valve overlap” and ensures that all the exhaust gases are discharged from the cylinder and the cylinder receives a fresh charge of air to make it more efficient when combustion next takes place.
Therefore there is one power stroke for every cycle or two revolutions of the crankshaft.

Two stroke cycle diesel engine

The two strokes of power followed by compression are required to complete one cycle. The events of injection, combustion, expansion and compression of the gases takes place as the four stroke engine, but the exhaust of the burnt gases and the induction of air take place at the bottom of its stroke, this being a chief difference between the two stroke cycle and the four stroke cycle.

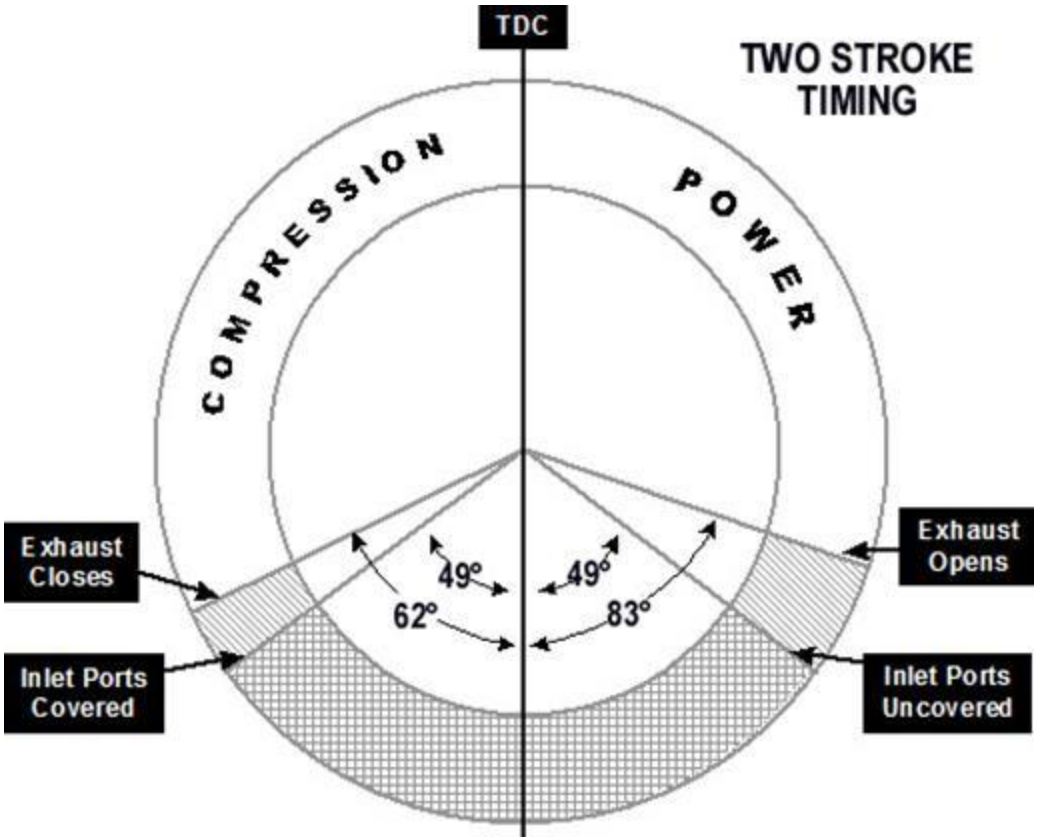
There are variations in two stroke cycle engines. The type described here is the most common to be found in marine engines. It has inlet ports and exhaust valves. The inlet holes or ports are in the lower section of the cylinder liner wall. The piston uncovers the inlet ports as it moves down the cylinder. The piston covers the inlet ports as it moves up the cylinder. This action has the same effect as a valve opening and closing. An engine driven scavenge blower is fitted and the incoming air is blown into the cylinder through the inlet ports when they are uncovered by the piston.

Complete the following sentences:

Two stroke cycle diesel engine

- The two strokes of power followed by compression are required to .....
- The events of injection, ... of the gases takes place as the four stroke engine, but the exhaust of the burnt gases and the induction of air take place at ..... , this being a chief difference between the two stroke cycle and the four stroke cycle.

- There are variations in two stroke cycle engines.
- The type described here is the most common to be found in marine engines. It has ..... and .....
- The inlet holes or ports are in the lower section .....
- The piston uncovers the inlet ports as .....
- The piston ..... as it moves up the cylinder.
- This action has the same effect as .....
- An engine driven scavenge blower is fitted and the incoming air is ..... through the inlet ports when they are ..... .



A. Spinčić; B. Priitchard

The above **timing diagram** represents a Detroit Diesel turbo charged inter cooled engine. Induction commences at 49° before bdc when the piston has uncovered the inlet ports. Air is forced into the cylinder by the scavenge blower as the piston moves down to bdc and back up again until it covers the inlet ports at 49° after bdc.

As the piston rises, the exhaust valve closes at 62° after bdc. The air is now trapped in the cylinder and as the piston rises the air is compressed and rises in temperature.
Fuel is injected before tdc and continues after tdc. Detroit Diesel do not specify the period of injection as this will vary depending upon the engine speed, the load and the size of the injectors. The camshaft contains the exhaust valve cams as well as the unit injector cams. Therefore, if the exhaust valve timing is correct, the unit injector timing will be correct providing the injector follower is adjusted to a definite height in relation to the unit injector. A special gauge is supplied to set this height.
The heat in the compressed air ignites the fuel and combustion takes place. The gases expand forcing the piston down on the power stroke.

The exhaust valve opens at 83° before bdc allowing the burned gases to escape into the exhaust manifold. However, at 49° before bdc, the inlet ports are uncovered by the piston and air enters the cylinder and helps discharge any remaining exhaust gases until the exhaust valve closes at 62° after bdc. The whole cycle is then repeated.
There is one power stroke for every revolution of the crankshaft.

Fill in the missing verbs:

The above **timing diagram** _____ a Detroit Diesel turbo charged inter cooled engine. Induction _____ at 49° before bdc when the piston has _____ the inlet ports. Air is _____ into the cylinder by the **scavenge blower** as the piston moves down to bdc and back up again until it _____ the inlet ports at 49° after bdc.

As the piston _____, the exhaust valve closes at 62° after bdc. The air is now _____ in the cylinder and as the piston rises the air is _____ and rises in temperature.
Fuel is _____ before tdc and continues after tdc. Detroit Diesel do not _____ the period of injection as this will vary depending upon the engine speed, the load and the size of the injectors. The camshaft _____ the exhaust valve cams as well as the unit injector cams. Therefore, if the exhaust valve timing is correct, the unit injector timing will be correct providing the injector follower is _____ to a definite height in relation to the unit injector. A special gauge is _____ to set this height.
The heat in the compressed air _____ the fuel and combustion takes place. The gases _____ forcing the piston down on the power stroke.

The exhaust valve _____ at 83° before bdc allowing the burned gases to _____ into the exhaust manifold. However, at 49° before bdc, the inlet ports are uncovered by the piston and air _____ the cylinder and helps discharge any

Discuss the terms highlighted in the text below

- In the 2 stroke **trunk piston engine**, the **side thrust** caused by the angularity of the connecting rod is transmitted to the liner by the **piston skirt** or trunk. It is therefore known as a 2 Stroke Trunk Piston Engine.
- The skirt of the piston also acts to **seal** the scavenge air ports when the engine is at TDC. This prevents the **scavenge air** from pressurising the **crankcase**.

Discuss the questions below

What are the disadvantages?

- Herein lies the disadvantage of this type of engine: although it has a low overall height, lubricating oil splashed up from the crankcase to lubricate the liner can find its way into the scavenge space, causing fouling and a risk of a scavenge fire. There is also the likelihood of liner and piston skirt wear, allowing air into the crankcase. This can supply the required oxygen for a crankcase explosion should a hot spot develop. The crankcase oil must have additives which can cope with contamination from products of combustion, and the acids formed during combustion due to the sulphur in the fuel.

Where are two stroke engines generally applied?

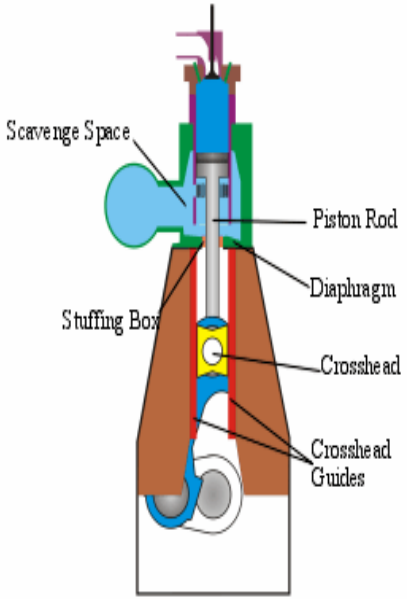
- This design of two stroke is generally only used for the smaller lower powered 2 stroke engines - up to about 5000kW for a V16 engine with a 280mm bore and 320mm stroke.

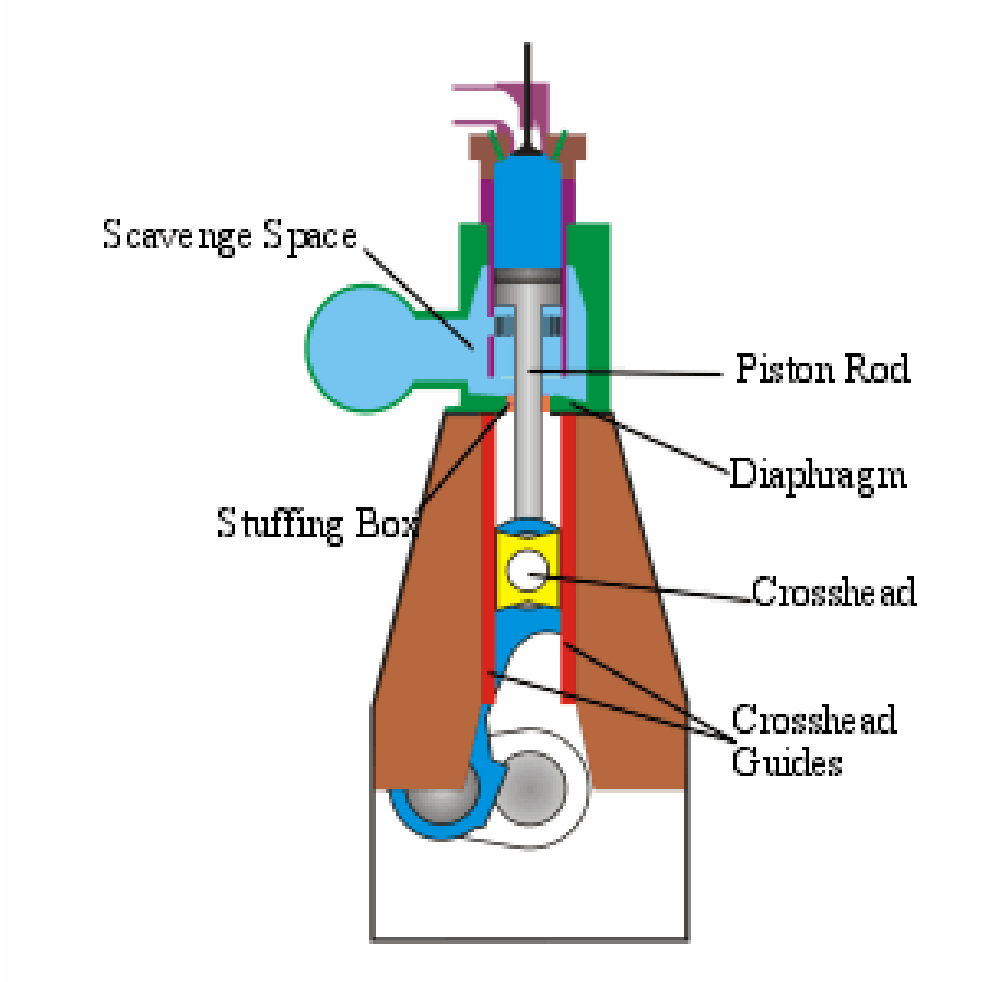
3.

The 2 Stroke Crosshead Engine

The 2 Stroke Crosshead Engine

- The 2 stroke diesel crosshead engine works on exactly the same principle and cycle as the 2 stroke diesel trunk piston engine.
- The disadvantages of the two stroke diesel trunk piston engine are that although it has a low overall height, lubricating oil splashed up from the crankcase to lubricate the liner can find its way into the scavenge space, causing fouling and a risk of a scavenge fire. There is also the likelihood of liner and piston skirt wear, allowing air into the crankcase. This can supply the required oxygen for a crankcase explosion should a hot spot develop. The crankcase oil must have additives which can cope with contamination from products of combustion, and the acids formed during combustion due to the sulphur in the fuel.




Scavenge Space
Piston Rod
Diaphragm
Stuffing Box
Crosshead
Crosshead
Guides

Guess the missing part of the sentences below (check your answer in the slide below; which clues have you used?):

- The majority of 2 stroke engines encountered at sea are of the _____ type.
- In this type of engine the combustion space (formed by the cylinder liner, piston and cylinder head), and the scavenge space are separated from the crankcase by _____.
- The piston rod is bolted to the piston and passes through a _____ mounted in the diaphragm plate.
- The stuffing box provides a seal between the two spaces, stopping oil from being carried up to the scavenge space, and scavenge air _____ into the crankcase.

- The majority of 2 stroke engines encountered at sea are of the "crosshead" type. In this type of engine the combustion space (formed by the cylinder liner, piston and cylinder head), and the scavenge space are separated from the crankcase by the diaphragm plate.
- The piston rod is bolted to the piston and passes through a stuffing box mounted in the diaphragm plate. The stuffing box provides a seal between the two spaces, stopping oil from being carried up to the scavenge space, and scavenge air leaking into the crankcase.

Complete the sentences below:

- The majority of 2 stroke engines encountered at sea are of .....
- In this type of engine the combustion space (formed by .....), and the scavenge space are separated from the .....
- The piston rod is bolted to the piston and passes through ..... mounted 00
- The stuffing box provides a ....., stopping oil from being carried up to the scavenge space, and scavenge air ..... .

- The foot of the piston rod is bolted to the crosshead pin. The top end of the connecting rod swings about the cosshead pin, as the downward load from the expanding gas applies a turning force to the crankshaft.
- To ensure that the crosshead reciprocates in alignment with the piston in the cylinder, guide shoes are attached either side of the crosshead pin. These shoes are lined with white metal, a bearing material and they reciprocate against the crosshead guides, which are bolted to the frame of the engine. The crosshead guides are located inbetween each cylinder.

Match the parts of the text below

1	**The top end of the connecting rod swings about the cosshead pin,**	**a**	**guide shoes are attached either side of the crosshead pin.**
2	The foot of the piston rod	b	which are bolted to the frame of the engine.
3	To ensure that the crosshead reciprocates in alignment with the piston in the cylinder,	c	as the downward load from the expanding gas applies a turning force to the crankshaft.
4	These shoes are lined with white metal, a bearing material and they reciprocate against the crosshead guides,	d	is bolted to the crosshead pin.

Provide the missing verb

- The foot of the piston rod is _____ to the crosshead pin.
- The top end of the connecting rod _____ about the cosshead pin, as the downward load from the expanding gas _____ a turning force to the crankshaft.
- To _____ that the crosshead reciprocates in alignment with the piston in the cylinder, guide shoes are _____ either side of the crosshead pin.
- These shoes are _____ with white metal, a bearing material and they _____ against the crosshead guides, which are _____ to the frame of the engine.
- The crosshead guides _____ inbetween each cylinder.

- The foot of the piston rod is bolted to the crosshead pin. The top end of the connecting rod swings about the cosshead pin, as the downward load from the expanding gas applies a turning force to the crankshaft.
- To ensure that the crosshead reciprocates in alignment with the piston in the cylinder, guide shoes are attached either side of the crosshead pin. These shoes are lined with white metal, a bearing material and they reciprocate against the crosshead guides, which are bolted to the frame of the engine. The crosshead guides are located inbetween each cylinder.

Multiple choice test (MCT)

- Using the crosshead design of engine allows engines to be built with very long (***covers, strokes, strapes***) - which means the engine can (**fire, exhaust, burn**) a greater quantity of fuel/stroke and develop more power.
- The fuel used can be of a lower (**blend, grade, viscosity**) than that used in a trunk piston engine, with a higher (**oxigen, nitrogen, sulphur**) content, whilst high alkalinity cylinder oils with a different specification to that of the crankcase oil are used to (**heat up, grease, lubricate**) the cylinder liner and piston rings and combat the effects of acid attack.

Based on your knowledge, experience and the previous text, answer the following questions

1. What is the most powerful type of diesel engines in the world?
2. What is their cylinder bore and stroke?
3. What is the maximum weight of the crankshaft and the entire engine?

- Using the crosshead design of engine allows engines to be built with very long strokes - which means the engine can burn a greater quantity of fuel/stroke and develop more power. The fuel used can be of a lower grade than that used in a trunk piston engine, with a higher sulphur content, whilst high alkalinity cylinder oils with a different specification to that of the crankcase oil are used to lubricate the cylinder liner and piston rings and combat the effects of acid attack.
- The most powerful diesel engines in the world are two stroke crosshead engines. Some of these engines have cylinder bores approaching 1metre with a stroke of over 2.5 metres. The crankshaft can weigh over 300 tons, with the engine weighing in excess of 2000 tons.

Jumbled texts

1. Using the crosshead design of engine allows engines to be built with very long strokes	a) are two stroke crosshead engines.	
2. The fuel used can be of a lower grade than	b) - which means the engine can burn a greater quantity of fuel/stroke and develop more power.	
3. The most powerful diesel engines in the world	c) 1 metre with a stroke of over 2.5 metres.	
4. Some of these engines have cylinder bores approaching	d) that used in a trunk piston engine, with a higher sulphur content.	
5. The crankshaft can weigh over 300 tons,	e) are used to lubricate the cylinder liner and piston rings and combat the effects of acid attack.	
6. High alkalinity cylinder oils with a different specification to that of the crankcase oil	f) with the engine weighing in excess of 2000 tons.	

4.
Uniflow and Loop Scavenging

4. Uniflow and Loop Scavenging

- Scavenging is the process whereby air at a pressure greater than that of atmospheric presuure is used to push the exhaust gas out of the cylinder of an engine. Unlike the 4 stroke engine, a two stroke diesel engine does not use the piston to push out the exhaust gas, instead, air enters the cylinder around bottom dead centre and sweeps or scavenges the exhaust gas from the cylinder.
- 2 stroke engines with an exhaust valve mounted in the cylinder head are known as uniflow scavenged engines. This is because the flow of scavenging air is in one (uni) direction.

4. Uniflow and Loop Scavenging

- Scavenging is the process whereby air at a pressure greater than that of atmospheric presure is used to push the exhaust gas out of the cylinder of an engine. Unlike the 4 stroke engine, a two stroke diesel engine does not use the piston to push out the exhaust gas, instead, air enters the cylinder around bottom dead centre and sweeps or scavenges the exhaust gas from the cylinder.
- 2 stroke engines with an exhaust valve mounted in the cylinder head are known as uniflow scavenged engines. This is because the flow of scavenging air is in one (uni) direction.

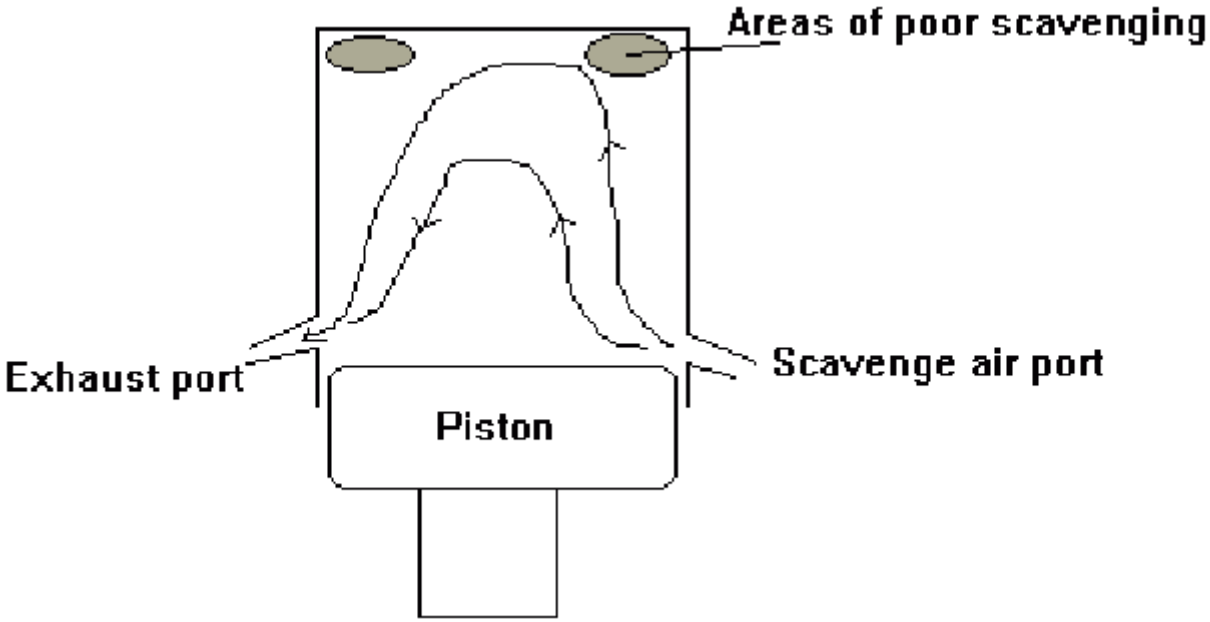
Supply the missing term

- Scavenging is the process whereby air at a pressure greater than that of _____ is used to push the _____ out of the cylinder of an engine.
- Unlike the 4 stroke engine, a two stroke diesel engine does not use the _____ to push out the exhaust gas.
- Instead, air enters the cylinder around bottom dead centre and sweeps or _____ the exhaust gas from the cylinder.
- 2 stroke engines with an exhaust valve _____ in the cylinder head are known as _____ engines.
- This is because the flow of scavenging air is in _____ (uni) direction.

Complete the sentences below

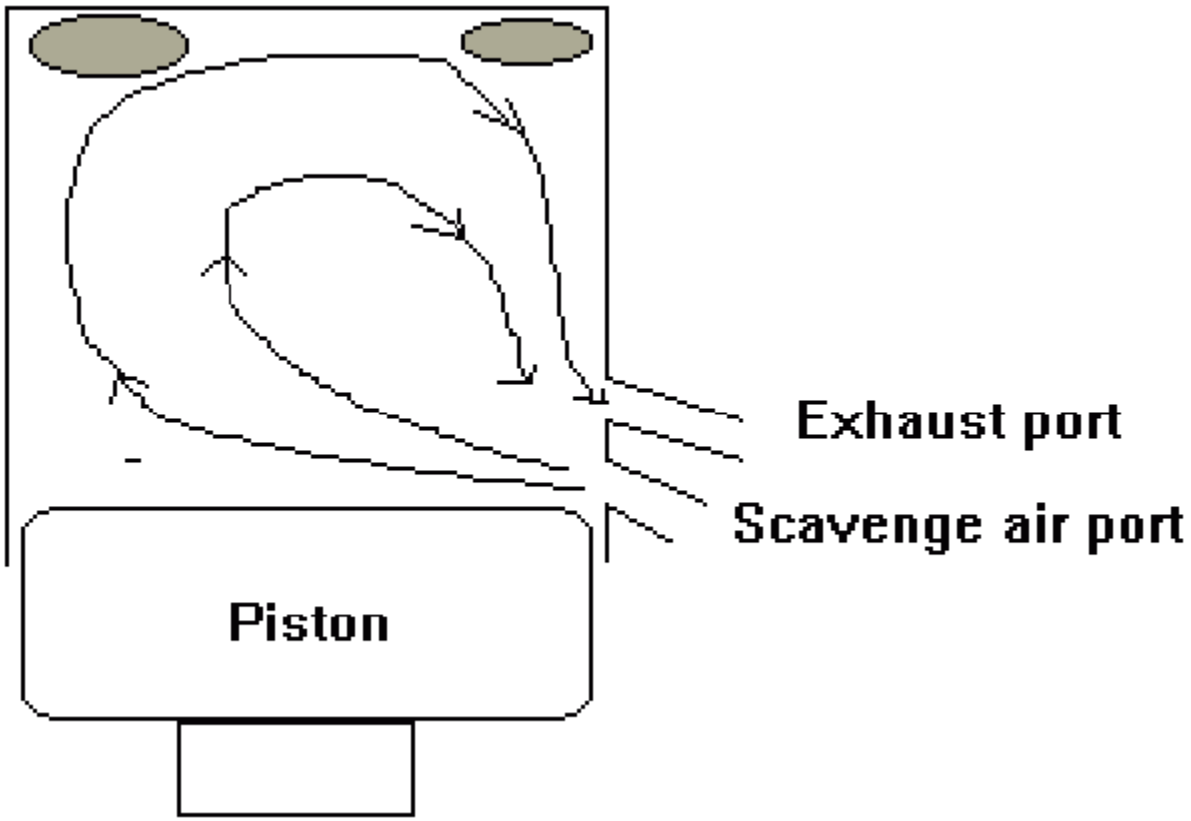
- Scavenging is the process whereby air at a pressure greater than that of atmospheric pressure is used to .....
- Unlike the 4 stroke engine, a two stroke diesel engine does not use .....
- Instead, air enters ..... and sweeps or scavenges the exhaust gas from the cylinder.
- 2 stroke engines with an exhaust valve ..... are known as uniflow scavenged engines.
- This is because .....

Cross flow scavenging



- After ignition of the fuel the piston travels down the liner uncovering firstly the exhaust ports. The exhaust gas at a pressure above atmospheric is expelled. This is often referred to as blowdown and its effect can be seen on the power card for all the types of scavenging as a rapid drop in cylinder pressure towards the end of the cycle.

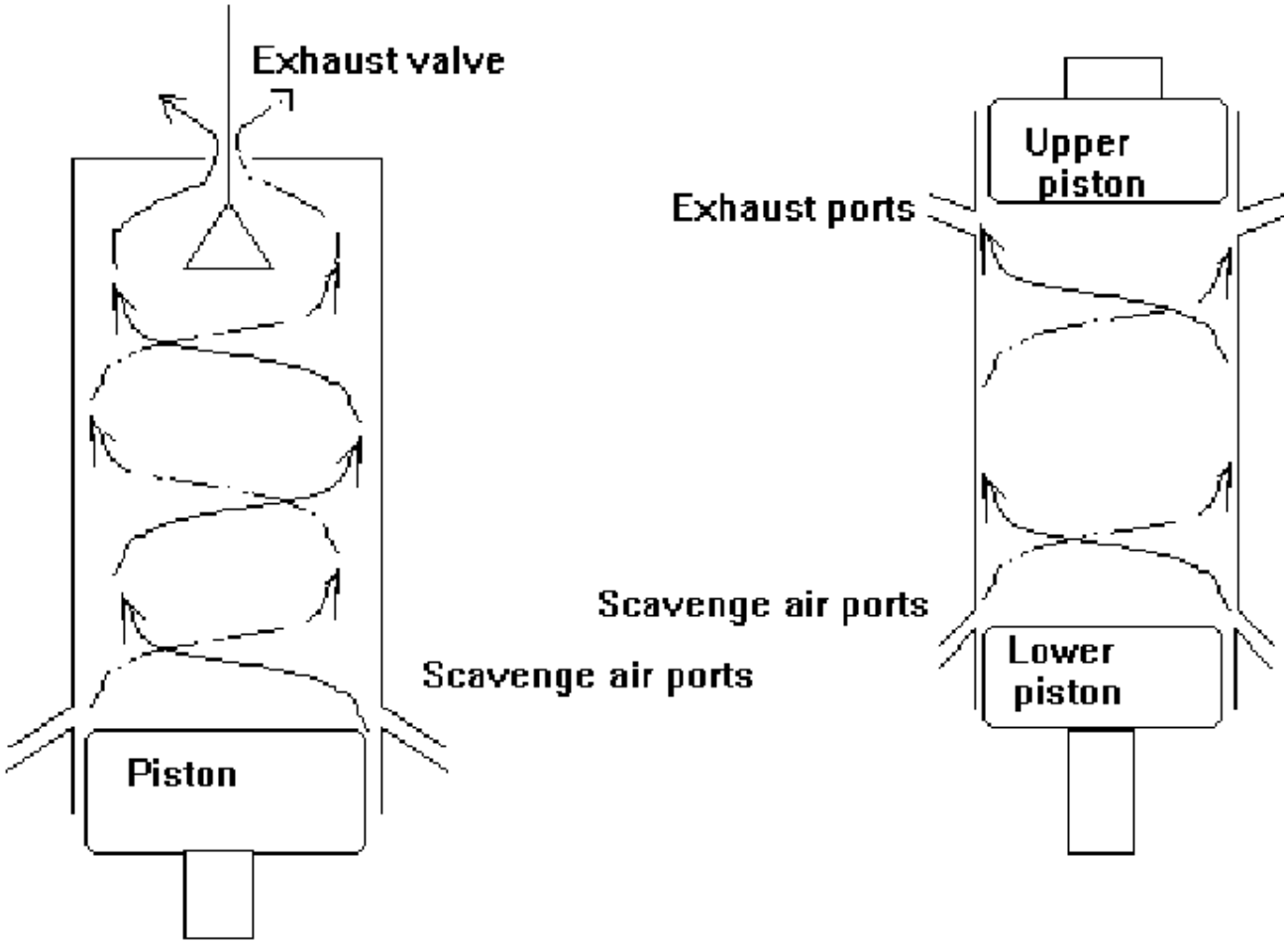
Uniflow scavenging



- The scavenge air enters through the scavenge ports in the lower part of the cylinder liner, the exhaust gas is expelled through the centrally mounted exhaust valve in the cylinder cover. The scavenge ports are angled to generating a rotational movement of the rising column of air.

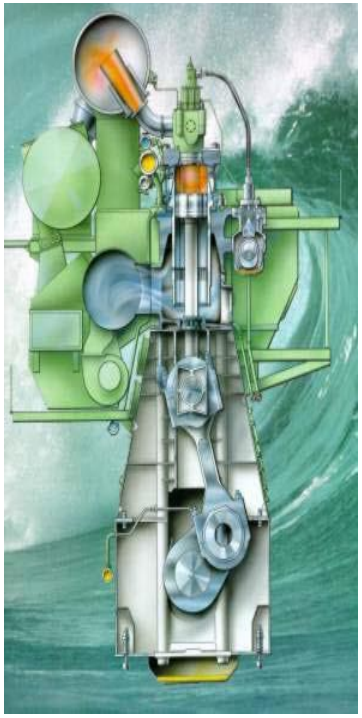
- Air is forced out of the cylinder by the rising piston leading to low flow resistance, the effect is often compared to squeezing the contents out of a tube.

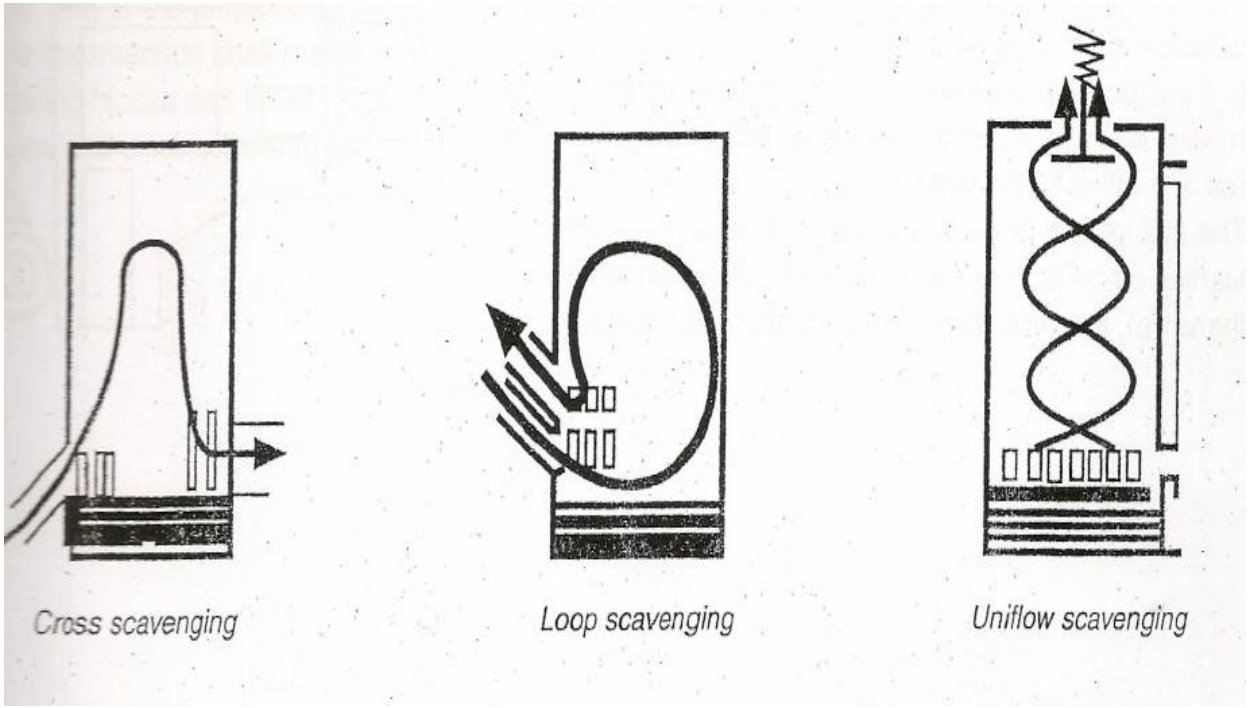
Loop scavenging



- The method of loop scavenging is similar to the cross flow except the exhaust and scavenge ports may be found on the same side
-

http://youtube.com/watch?v=TeDW1YFXiic




Cross scavenging
Loop scavenging
Uniflow scavenging

- Some 2 stroke engines do not have exhaust valves; As well as scavenge ports in the cylinder liner, they are fitted with exhaust ports located just above the scavenge ports. As the piston uncovers the exhaust ports on the power stroke, the exhaust gas starts to leave the cylinder. When the scavenge ports are uncovered, scavenge air loops around the cylinder and pushes the remaining exhaust gas out of the cylinder. This type of engine is known as a loop scavenged engine. Note that the piston skirt is much longer than that for a uniflow scavenged engine. This is because the skirt has to seal the scavenge and exhaust ports when the piston is at TDC.
- Although simpler in construction with less moving parts, these engines are not as efficient or as powerful as uniflow scavenged engines. The scavenging of the cylinder is not 100%, and thus less fuel can be burnt per stroke.
- All modern large 2 stroke crosshead engines now being built are of the uniflow scavenged type.

Supply the missing words below

- Some 2 stroke engines do not have _____;
- As well as scavenge _____ in the cylinder liner, they are fitted with _____ ports located just above the scavenge ports.
- As the piston uncovers the exhaust ports on the _____ stroke, the exhaust gas starts to leave the _____.
- When the scavenge ports are uncovered, scavenge air _____ around the cylinder and _____ the remaining exhaust gas out of the cylinder.
- This type of engine is known as a _____ engine.
- Note that the _____ is much longer than that for a uniflow scavenged engine.
- This is because the skirt has to _____ the scavenge and exhaust ports when the piston is at _____.

- Although simpler in construction with less moving parts, these engines are not as efficient or as powerful as _____ engines.
- The scavenging of the cylinder is not 100%, and _____ less fuel can be burnt _____ stroke.
- All modern large 2 stroke crosshead engines now being built are of the uniflow scavenged _____.

Writing skills:
Complete the sentences below

- Some ..... do not have exhaust valves.
- As well as ....., they are fitted with exhaust ports located just .....
- As ..... on the power stroke, the exhaust gas starts to leave the cylinder.
- When ....., scavenge air loops around the cylinder and ..... out of the cylinder.
- ..... is known as a loop scavenged engine.
- Note that the piston skirt is much longer than .....
- This is because the skirt has to ..... when the piston is at TDC.

Further exercises

II **The diagrams below illustrate the four strokes of the petrol/gasoline engine.** Name each of the strokes, are not given in the correct order, and describe what occurs in the cylinder. Make use of these hints:

Stroke	*Inlet valve/* **Exhaust valve**	*Piston motion/* **Piston position**	*Fuel mixture/ gas*
induction		*upwards*	*drawn in*
compression	*open*	*downwards*	*driven out*
expansion	*closed*	*TDC*	*compressed*
exhaust		*BDC*	

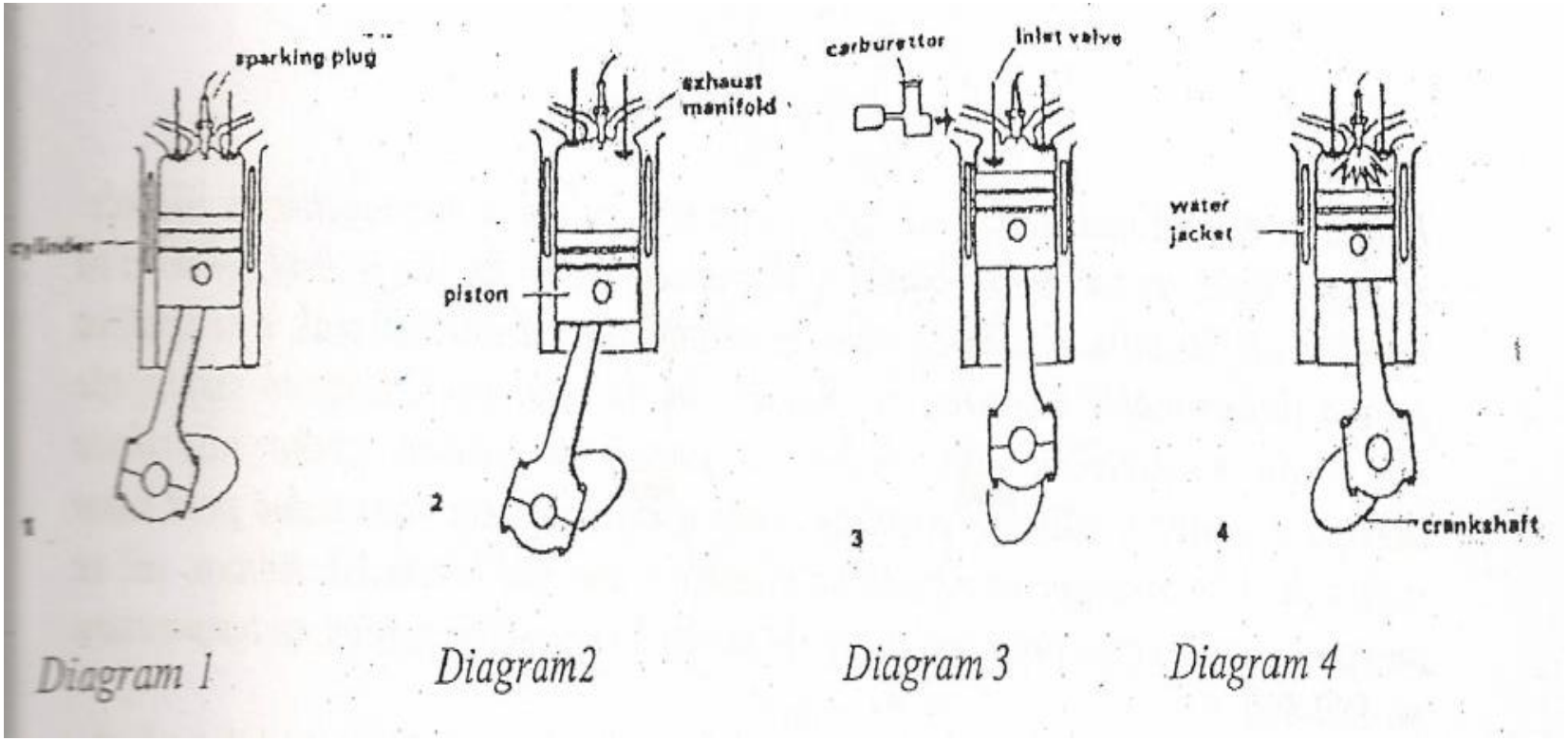


Diagram 1 *Diagram2* *Diagram 3* *Diagram 4*

Fig. 15 below shows the timing diagram of the four-stroke engine. The numbers refer to the angle of crank at which each operation takes place, while the arcs between the numbers give the period of operation.

Now do the following:

a) label the diagram with the terms and expressions given below;

b) arrange them in the correct sequence of events.

inlet valve opens (IVO) — *inlet valve closes (IVC)*

exhaust valve opens (EVO) — *exhaust valve closes (EVC)*

top dead centre (TDC) — *bottom dead centre (BDC)*

valve overlap (i.e. both valves are open)

fuel injection begins — *fuel injection ends*

suction — *completion of suction,*

compression power — *firing exhaust*

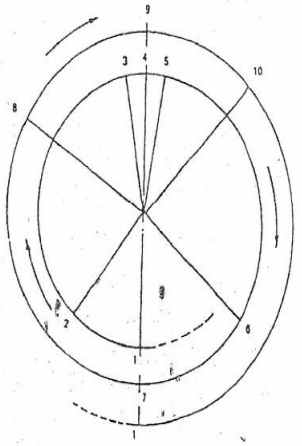


Fig. 15 Timing diagram

IV Translate into English:

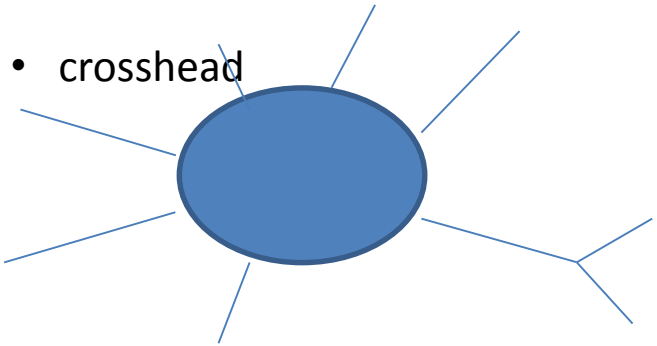
Rad dizel-motora

*Rad dizel-motora razlikuje se od rada benziskog motora, a bitne razlike su sljedeće: za pogon dizel- motora upotrebljava se teže tekuće gorivo kao što je dizel gorivo, a od nedavna i teška nafta. Pošto se u cilindre ovih motora usisava čisti zrak, a ne upaljiva smjesa **(inflammable mixture)**, ovi motori nemaju rasplinjača. Umjesto rasplinjača oni imaju visokotlačnu sisaljku koja u pogodnom trenutku preko rasprskača ubrizgava gorivo u cilindar, stvarajući tako upaljivu smjesu neposredno pred samo izgaranje. Uštrcano gorivo ne pali se svjećicom kao kod benzinskih motora, već se ono pali na užarenom **(hot)** zraku, koji je jakom kompresijom ugrijan na temperaturu do 500-600° C.*

Kod benziskih motora je izgaranje goriva trenutačno uz naglo povišenje tlaka, a kod dizel-motora izgaranje je postepeno, tj. gorivo izgara kako dolazi u cilindar. Pritom tlak ostaje približno stalan za cijelo vrijeme izgaranja.

III. Four-stroke and two-stroke engines

- **Write down as many terms as you know on the design and operation of <u>four-stroke</u> diesel engines. Add your words to the word spider below:**



- **Exchange your list with other student pairs in the class**
- **Discuss the results in the group**

III. Four-stroke and two-stroke engines

A cross-section of a four-stroke cycle engine is shown in Fig.16. The engine is made up of a piston which moves up and down in a cylinder covered at the top by a cylinder head. The fuel injector, through which fuel enters the cylinders, is located in the cylinder head. The inlet and exhaust valves are also housed in the cylinder head and shut by springs. The piston is joined to the connecting rod by a gudgeon pin.

The bottom end or big end of the connecting rod is joined to the crankpin which forms part of the crankshaft. With this assembly, the linear up-and-down movement of the piston is converted into rotary motion of the crankshaft.

The crankshaft is arranged to drive through gears the camshaft which, either directly or through pushrods operates the rocker arms which open the inlet and exhaust valves. The camshaft is timed to open the valves at the correct point in the cycle.

Underline the key terms relevant to four stroke-diesel engines. Then describe the engine using your terms (notes)

Four-stroke and two-stroke engines

A cross-section of a four-stroke cycle engine is shown in Fig.16. The engine is made up of a piston which moves up and down in a cylinder covered at' the top by a cylinder head. The fuel injector, through which fuel enters the cylinders, is located in the cylinder head. The inlet and exhaust valves are also housed in the cylinder head and shut by springs. The piston is joined to the connecting rod by a gudgeon pin.

The bottom end or big end of the connecting rod is joined to the crankpin which forms part of the crankshaft. With this assembly, the linear up-and-down movement of the piston is converted into rotary motion of the crankshaft.

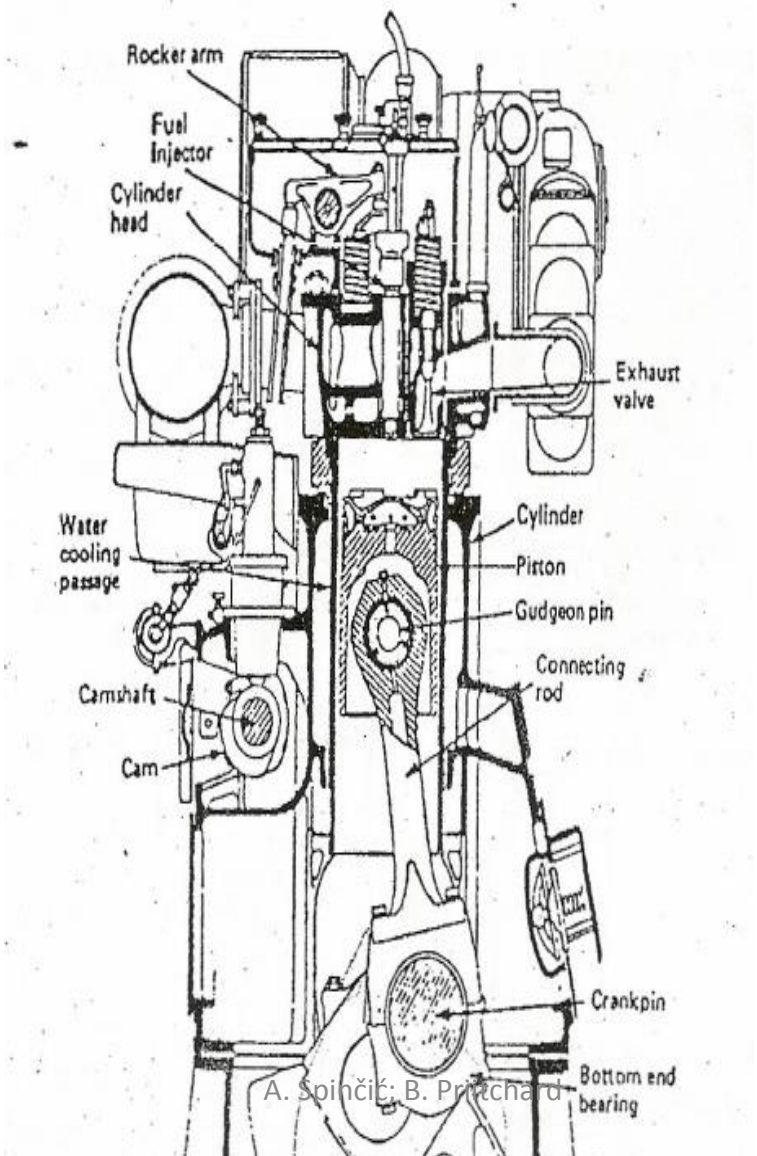
The crankshaft is arranged to drive through gears the camshaft which, either directly or through pushrods operates the rocker arms which open the inlet and exhaust valves. The camshaft is timed to open the valves at the correct point in the cycle.

Complete the sentences below:

Four-stroke and two-stroke engines

- A cross-section of a four-stroke cycle engine is shown in Fig.16.
- The engine is made up of a piston which moves .....in a cylinder covered .....
- The fuel injector, through which ....., is located in the cylinder head.
- The inlet and exhaust valves are ..... and are shut .....
- The piston is ..... by a gudgeon pin.

- The bottom end or big end of the connecting rod is joined to the crankpin which .....
- With this assembly, the linear up-and-down movement of the piston is converted into ..... .
- The crankshaft is arranged to ..... which, either directly or through pushrods operates the rocker arms which .....
- The camshaft is timed to open the valves ..... .


Rocker arm
Fuel Injector
Cylinder head
Exhaust valve
Water cooling passage
Cylinder
Piston
Gudgeon pin
Connecting rod
Camshaft
Cam
Crankpin
Bottom end bearing

What are the four-stroke diesel engines usually used for on board?

-
-
-
-

The four-stroke engine (usually rotating at medium speed, between 250 and 750 rev/min) is used for auxiliaries such as alternators and for main propulsion with gearbox to provide a propeller speed of between 90 and 120 rev/min

What are the differences between the 2- and 4-stroke diesel engines? – Write down your ideas in pair work

-
-
-
-
-

- Check your answers against the text of the two following slides !!!

The main difference between the four- and two-stroke cycle engines is the power developed. The two-stroke cycle engine, with one working power stroke every revolution, will, theoretically, develop twice the power of a four-stroke engine of the same swept volume. However, inefficient scavenging and other losses, reduce the power advantage to about 1.8.

For a particular engine power, the two-stroke engine is considerably lighter, a matter of great importance for ships. Nor does the two-stroke engine require the complex valve operating mechanism of the four-stroke engine. The four-strake engine, however, can operate efficiently at high speed which offsets power disadvantages. It also consumes less lubricating oil.

Each type of engine has its application which on board ship have resulted in the slow speed main propulsion diesel operating on the two-strake cycle. At low speed the engine requires no reduction gearbox between it and the propeller.

The four-stroke engine usually rotating at medium speed, between 250 and **750** rev/min) is used for auxiliaries such as alternators and for main propulsion wih gearbox to provide a propeller speed of between 90 and 120 rev/min.

I **Fig. 17 below shows a cross-section of a two-stroke slow speed engine. Complete the labelling of the components 1-12.**

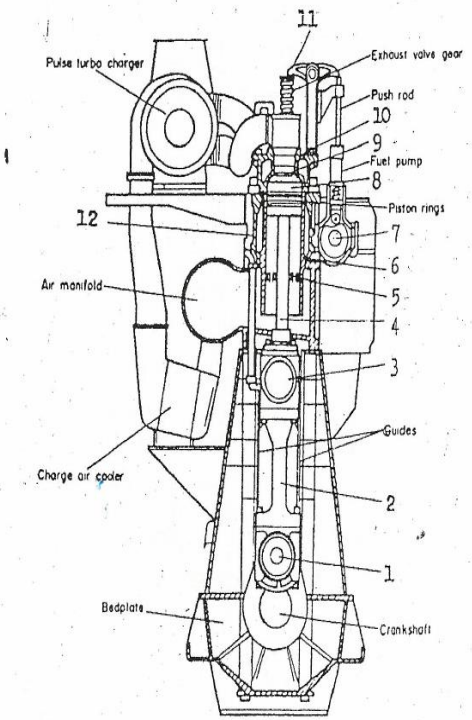


Fig. 17 Cross-section of a two-stroke slow-speed marine diesel engine

II

Four-stroke and two-stroke cycle

In common with all internal combustion engines the diesel operates with a fixed sequence of events, i.e. a cycle, which may be achieved either in four strokes or two, a stroke being the travel of the' piston between its extreme points. Each stroke is accomplished in half the revolution of the crankshaft.

The four-stroke cycle is completed in four strokes of the piston, or two revolutions of the crankshaft. In order to operate the cycle the engine requires a mechanism to open and close the inlet and exhaust valves.

Consider the piston at the top of its stroke, a position known as top dead centre (TDC). The inlet valve opens and fresh air is drawn into the cylinder by the partial vacuum created by the piston as it moves downwards, as shown in Fig, 11(a).

At the bottom of the stroke, i.e. bottom dead centre (BDC), the inlet valve closes and the air in the cylinder is compressed and raised in temperature as the piston rises. See Fig. 11(b).

Supply the missing term:

In common with all _____ the diesel operates with a fixed _____ , i.e. a cycle, which may be achieved either in four strokes or two, a _____ being the travel of the' piston between its extreme points. Each stroke is accomplished in half the revolution of the _____ .

The four-stroke cycle is completed in four strokes of the _____ , or two revolutions of the _____. In order to operate the _____ the engine requires a mechanism to open and close the inlet and _____ valves.

Consider the piston at the top of its stroke, a position known as _____(TDC). The inlet valve opens and fresh air is drawn into the _____ by the partial vacuum created by the piston as it moves downwards, as shown in Fig, 11(a).

At the bottom of the stroke, i.e. _____(BDC), the _____ closes and the air in the cylinder is compressed and _____ in temperature as the piston rises. See Fig. 11(b).

Supply the missing verb

Underline the noun with which it collocates

In common with all internal combustion engines the diesel engine ***operates*** with a fixed sequence of events, i.e. a cycle, which may be either in four strokes or two, a stroke being the travel of the' piston between its extreme points. Each stroke is in half the revolution of the crankshaft. (**accomplished, achieved, accomplished**)

The four-stroke cycle is in four strokes of the piston, or two revolutions of the crankshaft. In order to the cycle the engine requires a mechanism to and close the inlet and exhaust valves. (**operate, open, completed)**

the piston at the top of its stroke, a position known as top dead centre (TDC). The inlet valve and fresh air is drawn into the cylinder by the partial vacuum by the piston as it downwards, as shown in Fig, 11(a). (**moves, opens, consider, created**)

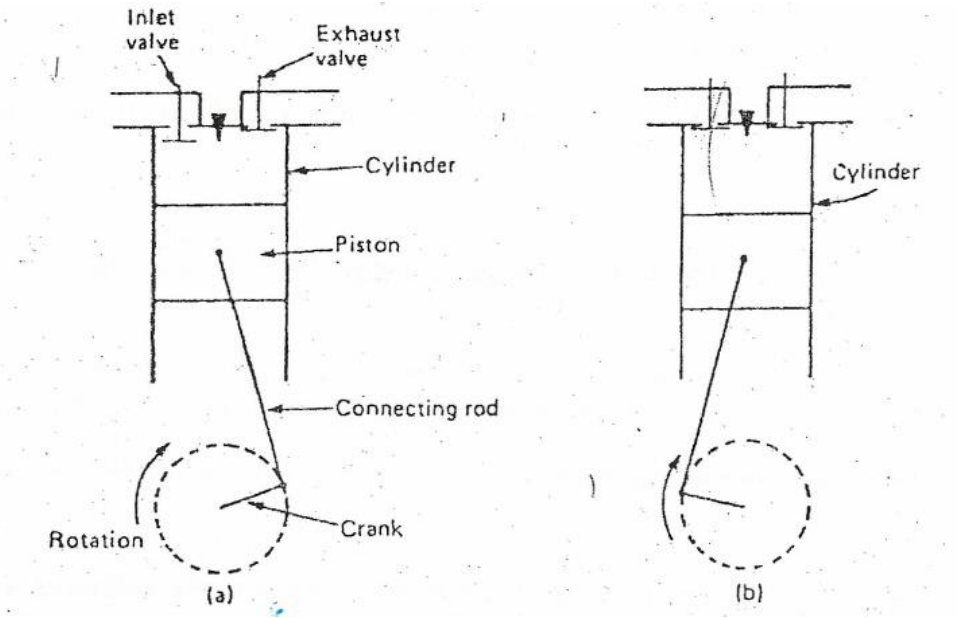
At the bottom of the stroke, i.e. bottom dead centre (BDC), the inlet valve and the air in the cylinder is and in temperature as the piston rises. See Fig. 11(b). (**compressed, closes, raised**)

The piston is now forced downwards by the gases and so supplies the power to the shafting through the connecting rod and crank, converting thus the downward push into rotary motion.

At the bottom dead centre the exhaust valve opens and the burnt gases are driven out as the piston rises to the top dead centre to complete the cycle, as illustrated in Fig. 12(d). The next stroke recommences the cycle of operation with the admission of air.

The four distinct strokes are known as inlet (or suction), compression, power (or working stroke) and exhaust.

Write down the verbs to show the sequence of events in the slide above. The write down the process using your notes (verbs)


Inlet valve
Exhaust valve
Cylinder
Piston
Connecting rod
Crank
Rotation
(a)
Cylinder
(b)

The two-stroke cycle is completed in two strokes of the piston or one revolution of the crankshaft. In order to operate this cycle, where each event is accomplished in a very short time, the engine requires a number of special arrangements. First the fresh air must be forced in under pressure. The incoming air is used to clean out or *scavenge* the exhaust gases and then fill or 'charge' the space with fresh air. Instead of valves, openings, known as 'ports', are used which are opened and closed by the sides of the piston as it moves.

Consider the piston at the top of its stroke where the fuel injection and combustion have just taken place (Fig. 13(a)).

The piston is forced down on its working stroke until it uncovers the exhaust ports (Fig. 13(b)).

Underline the key terms of your own choice in the slide above. Discuss them with your colleague and give their translations in your language:

English	Croatian
two-stroke cycle	dvotaktni radni ciklus

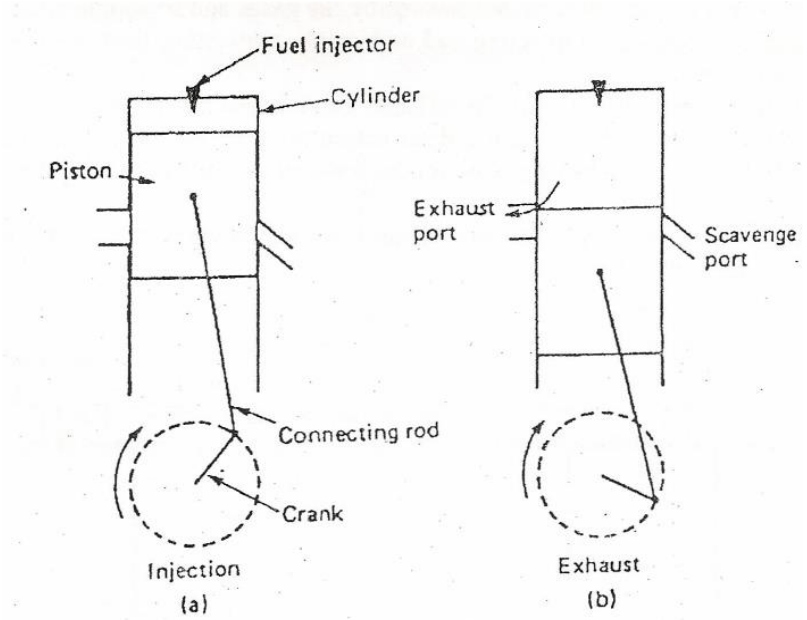


Fig. 13 The two-stroke cycle (a) injection and (b) exhaust

The piston is now forced downwards by the gases and so supplies the power to the shafting through the connecting rod and crank, converting thus the down ward push into rotary motion.

At the bottom dead centre the exhaust valve opens and the burnt gases are driven out as the piston rises to the top dead centre to complete the cycle, as illustrated in Fig. 12(d). The next stroke recommences the cycle of operation 'with the admission of air.

- inlet (or suction),
- compression,
- power (or working strake) and
- exhaust.

The four distinct strokes are known as:

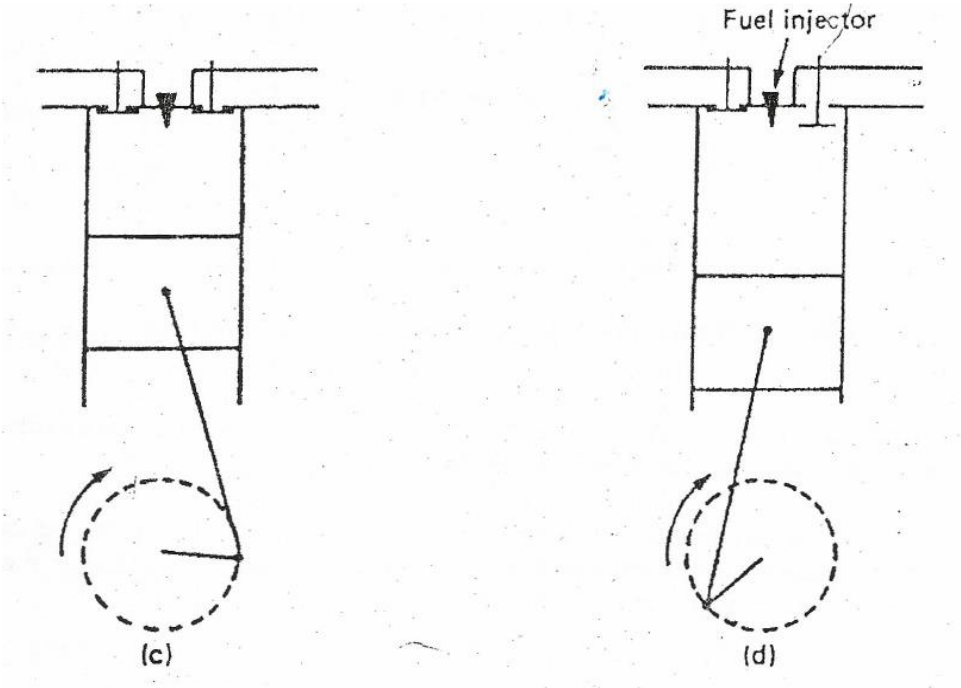
-
-
-
-

Discuss the function and meaning of the phrases highlighted in blue colour

The piston is *now* forced downwards *by the gases* and so supplies the power to the shafting through the **connecting rod** and **crank**, converting *thus* the down ward push into rotary motion.

At the bottom dead centre the exhaust valve opens and the burnt gases are driven out as the piston rises *to the bottom dead centre* to complete the cycle, as illustrated in Fig. 12(d). The next stroke recommences the cycle of operation *At the bottom dead centre* air.

- now: **time**
- *by the gases:*
- *thus:*
- *At the bottom dead centre:*
- *to the bottom dead centre:*
- *with the admission of:*


Fuel injector
(c)
(d)

The burnt gases then begin to exhaust and the piston continues downwards until it opens the inlet or scavenge ports as shown in Fig. 14(c).

Pressurized air enters and drives out the remaining gas. The piston, on its return stroke, closes the inlet and exhaust ports. The air is then compressed as the piston moves to the top of its stroke to complete the cycle. See Fig. 14(d).

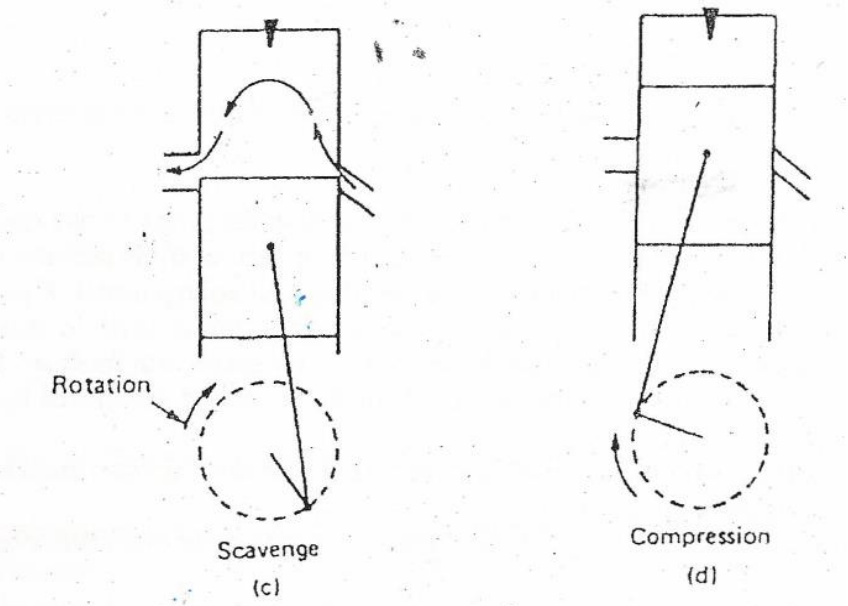


Fig. 14 The two-stroke cycle (c) scavenge and (d) compression

I. Questions

1. *What is the difference between petrollgas.oline engines and diesels?*
2. *What have diesels in common with other internal combustion engines?*
3. *Explain the rneaning oj the terms 'cycle' and 'strake '.*
4. *Name the events occurring in the operation oj internal combustion engines.*
5. *What difference is there between two-strake and four-stroke engines* ?
6. *What is the average compression temperature and the initial expansion pressure in diesel engines* ? .
7. *What is 'scavenging* '?
8. *What is meant by the term 'port* '? *What are ports and in what type oj engines can they be found?":*
9. *Say the common term used for ‘filling the cylinder with fresh air '.*