Applied Chemistry

Lubrication and Lubricants

1. Function of a Lubricant

A lubricant is a substance introduced between two surfaces in relative motion (such as the moving parts of a machine) in order to reduce friction and wear between them. Lubricants perform several important functions in machinery, including:

- Reducing friction between moving surfaces, thereby reducing the power lost in overcoming friction and improving the mechanical efficiency of the machine.
- Reducing wear and tear of contacting surfaces, by preventing or minimising direct solid-to-solid contact between them, thereby extending the working life of machine components.
- Carrying away the heat generated due to friction, helping to keep moving parts at a safe operating temperature and preventing overheating.
- Acting as a sealant, helping to prevent the entry of dust, dirt, and moisture into machine parts, and in some cases helping to prevent leakage of gases past pistons and seals.
- Protecting metal surfaces from corrosion, by forming a protective film that reduces direct contact between the metal surface and corrosive agents such as moisture and oxygen.
- Reducing noise and vibration produced by moving machine parts, by cushioning the contact between them.

2. Characteristic Properties of a Good Lubricant

A good lubricant should ideally possess the following characteristic properties:

1. An appropriate viscosity, suited to the operating speed, load, and temperature of the machine, neither too low (which fails to maintain an adequate separating film) nor too high (which increases frictional resistance).
2. Good oiliness, allowing it to adhere strongly to metal surfaces and maintain a protective film, particularly important under boundary lubrication conditions.
3. High thermal stability, allowing it to withstand the operating temperature of the machine without excessive decomposition or the formation of harmful deposits.

4. High chemical (oxidation) stability, resisting oxidation and chemical breakdown over the working life of the lubricant, without becoming excessively acidic or forming sludge.
5. A sufficiently high flash and fire point, for safety during storage, handling, and operation at elevated temperatures.
6. A sufficiently low pour point, allowing the lubricant to remain fluid and functional even at low ambient or starting temperatures, where relevant to the application.
7. Non-corrosive behaviour towards the metal surfaces it comes into contact with, and low volatility, so that it does not evaporate excessively during use.

3. Classification of Lubricants

Lubricants are broadly classified according to their physical state, as summarised below:

Class of Lubricant	Description	Examples
Solid Lubricants	Fine solid powders or coatings used to reduce friction between surfaces, particularly under conditions of high temperature, high load, or where liquid lubricants would be unsuitable	Graphite, molybdenum disulphide (MoS2), talc powder
Liquid Lubricants (Lubricating Oils)	Oils, either mineral (petroleum-based), vegetable, or synthetic in origin, used in the majority of general mechanical and automotive lubrication applications	Mineral (petroleum-based) lubricating oil, castor oil, synthetic ester-based oils
Semi-Solid Lubricants (Greases)	A thickened, semi-solid lubricant formed by combining a lubricating oil with a thickening agent (such as a metallic soap), used where a liquid oil would drain away too easily or where a sealing effect is also desired	Lithium-based grease, calcium-based grease, sodium-based grease
Gaseous Lubricants	Gases used as a lubricating medium in specialised, high-precision applications, particularly at very high speeds or extreme temperatures where conventional oils and greases would fail	Air, nitrogen, used in gas-lubricated bearings

4. Lubrication Mechanism — Hydrodynamic and Boundary Lubrication

Depending on the operating conditions (speed, load, and the thickness of the lubricant film maintained between two surfaces), lubrication is broadly classified into two main mechanisms or regimes:

Type of Lubrication	Description
Hydrodynamic (Thick-Film) Lubrication	A complete, continuous film of lubricant of substantial thickness is maintained between the two moving surfaces, generated by the relative motion of the surfaces themselves, which completely separates them and prevents any direct solid-to-solid contact; friction in this regime arises mainly from the internal viscous resistance of the lubricant film itself, rather than from surface contact.
Boundary Lubrication	Occurs when the lubricant film between the two surfaces becomes extremely thin, or is only partially maintained, such as at low speeds, high loads, or during starting and stopping, so that the surfaces come into partial direct contact at their microscopic high points (asperities); friction and wear in this regime depend strongly on the chemical and physical properties of thin, adsorbed lubricant films on the surfaces, rather than on bulk viscosity alone.

In practice, a machine may operate under hydrodynamic lubrication during normal, steady running at adequate speed, while briefly passing through a boundary lubrication regime during starting, stopping, or under sudden heavy loading, when a full hydrodynamic film cannot yet be established or is momentarily broken down.

5. Physical Properties of Lubricants

The suitability of a lubricant for a given application is assessed through several standard physical properties, described below:

Physical Property	Definition / Significance
Viscosity	A measure of a lubricant's internal resistance to flow, or its “thickness”; a lubricant must have a viscosity appropriate to its operating conditions — too low a viscosity fails to maintain an adequate separating film, while too high a viscosity increases frictional losses and resistance to motion.
Viscosity Index (VI)	A number that indicates the extent to which the viscosity of a lubricating oil changes with temperature; a lubricant with a high viscosity index shows relatively little change in viscosity over a range of temperatures, which is a desirable characteristic for maintaining consistent lubrication performance across varying operating temperatures.
Oiliness	The tendency of a lubricant to adhere strongly to a metal surface, forming a thin, tenacious film that resists being squeezed out under load, particularly important in boundary lubrication conditions where a continuous hydrodynamic film cannot be maintained.
Flash Point and Fire Point	The flash point is the lowest temperature at which the vapour given off by a lubricant momentarily ignites (flashes) on the application of a

	small flame, while the fire point is the lowest temperature at which the vapour continues to burn steadily for at least five seconds after ignition; both are important indicators of the fire safety of a lubricant during storage, handling, and use at elevated temperatures.
Cloud Point and Pour Point	The cloud point is the temperature at which a lubricating oil, on cooling, first begins to appear cloudy or hazy, due to the separation of wax crystals; the pour point is the lowest temperature at which the oil is observed to just flow (pour) under specified test conditions; both are important for selecting a lubricant suited to cold-weather or low-temperature operating conditions, since an oil with too high a pour point may fail to flow adequately in cold climates.

6. Chemical Properties of Lubricants

In addition to physical properties, the following chemical properties are also used to assess the quality and suitability of a lubricant:

Chemical Property	**Definition / Significance**
Coke Number (Carbon Residue)	The percentage of carbonaceous (coke-like) residue left behind when a lubricating oil is heated strongly in the absence of air until it evaporates and decomposes; a lower coke number is desirable, since a high carbon residue indicates a greater tendency of the lubricant to form harmful carbon deposits on hot engine or machine surfaces during use.
Total Acid Number (TAN) / Neutralisation Number	A measure of the total acidic content of a lubricating oil, expressed as the mass of potassium hydroxide (in milligrams) required to neutralise the free acids present in one gram of the oil sample; a lower total acid number is desirable, since a high acid content indicates oxidation or degradation of the oil and can promote corrosion of metal machine parts in contact with it.
Saponification Value	A measure of the amount of free fatty acids and esters present in a lubricating oil (particularly relevant for oils of vegetable or animal origin), expressed as the mass of potassium hydroxide (in milligrams) required to saponify (hydrolyse) one gram of the oil sample; it indicates the proportion of saponifiable (soap-forming) matter present, which is useful in distinguishing mineral oils (which have very low saponification values) from vegetable or animal oils (which have significant saponification values).

Together, these physical and chemical properties allow engineers to select the most appropriate lubricant for a given machine or operating condition, ensuring efficient, safe, and long-lasting lubrication performance.

7. Multiple Choice Questions (MCQs)

Answer the following questions by selecting the most appropriate option.

1. The primary function of a lubricant is to:

A) Increase friction between moving surfaces
B) Reduce friction and wear between surfaces in relative motion
C) Increase the temperature of moving parts
D) Corrode metal surfaces intentionally

2. Besides reducing friction, a lubricant also commonly serves to:

A) Increase noise in machinery
B) Carry away heat, prevent corrosion, and act as a sealant
C) Increase the wear of machine parts
D) Reduce the working life of a machine

3. A good lubricant should ideally possess:

A) High volatility and low stability
B) Appropriate viscosity, good oiliness, thermal stability, and chemical stability
C) A very low flash point
D) A tendency to corrode metal surfaces

4. Graphite and molybdenum disulphide are examples of:

A) Liquid lubricants
B) Solid lubricants
C) Semi-solid lubricants (greases)
D) Gaseous lubricants

5. Grease is best described as:

A) A purely gaseous lubricant
B) A semi-solid lubricant formed by thickening a lubricating oil with a thickening agent
C) A pure solid metal powder
D) A type of fuel

6. In hydrodynamic (thick-film) lubrication, the two moving surfaces are:

A) In direct solid-to-solid contact at all times
B) Completely separated by a continuous film of lubricant
C) Never separated by any lubricant
D) Always in a state of boundary lubrication

7. Boundary lubrication typically occurs under conditions of:

A) Very high speed and light load only
B) Low speed, high load, or during starting and stopping of machinery
C) Complete absence of any lubricant
D) Only in gaseous lubrication systems

8. Viscosity of a lubricant is best described as a measure of its:

A) Colour
B) Internal resistance to flow
C) Boiling point
D) Acidic strength

9. A lubricating oil with a high viscosity index shows:
A) A large change in viscosity with temperature
B) Relatively little change in viscosity over a range of temperatures
C) No viscosity at all
D) Constant colour regardless of temperature

10. Oiliness of a lubricant refers to its:
A) Tendency to evaporate quickly
B) Tendency to adhere strongly to a metal surface, forming a resistant film
C) Boiling point
D) Ash content

11. The flash point of a lubricant is the temperature at which:
A) The oil boils completely
B) The vapour given off momentarily ignites on application of a flame
C) The oil freezes solid
D) The oil becomes cloudy

12. The pour point of a lubricating oil is:
A) The temperature at which the oil first appears hazy
B) The lowest temperature at which the oil is just observed to flow
C) The temperature at which the oil ignites
D) The boiling point of the oil

13. The coke number (carbon residue) of a lubricant indicates its tendency to:
A) Dissolve in water
B) Form carbon deposits on hot surfaces during use
C) Evaporate at room temperature
D) Neutralise acids

14. The total acid number (TAN) of a lubricant is expressed in terms of:
A) Millilitres of water per gram of oil
B) Milligrams of KOH required to neutralise the free acids in one gram of oil
C) Grams of sulphur per litre of oil
D) Degrees Celsius

15. The saponification value of an oil is particularly useful for:
A) Measuring its flash point
B) Distinguishing mineral oils from vegetable or animal (fatty) oils
C) Measuring its viscosity index

D) Measuring its pour point

Answer Key

1. B) Reduce friction and wear between surfaces in relative motion | 2. B) Carry away heat, prevent corrosion, and act as a sealant | 3. B) Appropriate viscosity, good oiliness, thermal stability, and chemical stability | 4. B) Solid lubricants | 5. B) A semi-solid lubricant formed by thickening a lubricating oil with a thickening agent | 6. B) Completely separated by a continuous film of lubricant | 7. B) Low speed, high load, or during starting and stopping of machinery | 8. B) Internal resistance to flow | 9. B) Relatively little change in viscosity over a range of temperatures | 10. B) Tendency to adhere strongly to a metal surface, forming a resistant film | 11. B) The vapour given off momentarily ignites on application of a flame | 12. B) The lowest temperature at which the oil is just observed to flow | 13. B) Form carbon deposits on hot surfaces during use | 14. B) Milligrams of KOH required to neutralise the free acids in one gram of oil | 15. B) Distinguishing mineral oils from vegetable or animal (fatty) oils

8. Broad / Long Answer Questions

1. Explain the main functions of a lubricant in machinery.

2. Describe the characteristic properties that a good lubricant should possess.

3. Classify lubricants on the basis of their physical state, giving suitable examples of each class.

4. Explain hydrodynamic (thick-film) lubrication, describing the condition of the two surfaces during this type of lubrication.

5. Explain boundary lubrication, and state the conditions under which it typically occurs, distinguishing it from hydrodynamic lubrication.

6. Define viscosity and viscosity index of a lubricant, and explain why a high viscosity index is generally desirable for a lubricating oil.

7. Define oiliness of a lubricant, and explain its significance particularly in boundary lubrication conditions.

8. Define flash point and fire point of a lubricant, and explain cloud point and pour point, stating the significance of each in the selection of a lubricant.

9. Define coke number (carbon residue) and total acid number (TAN) of a lubricant, and explain the significance of each.

10. Define saponification value of a lubricant, and explain how it can be used to distinguish between mineral oils and vegetable or animal oils.