THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATION COUNCIL

DIPLOMA IN SECONDARY EDUCATION EXAMINATION

789 METAL WORKING AND MECHANICAL PRACTICE

Time: 3 Hours. **ANSWERS** **Year: 2019**

Instructions

1. This paper consists of **eight (8)** questions.

2. Answer **any five (5)** questions.

4. Cellular phones are **not** allowed inside the examination room.

5. Write your **Examination Number** on every page of your answer booklet

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1(a)(i) Give the meaning of the term 'fitting' as used in mechanical workshop activities.

Fitting refers to the process of assembling, shaping, adjusting, and finishing components so that they fit accurately together to form a mechanical assembly. It involves operations such as filing, scraping, sawing, reaming, drilling, tapping, and adjusting of mating parts to achieve the desired alignment and tolerance between surfaces.

In mechanical workshops, fitting is an essential stage that ensures parts manufactured separately can be joined with high precision. It focuses on accuracy, surface smoothness, and proper clearances between moving or mating parts so that the final product functions correctly and lasts longer.

Fitting also includes inspection and measurement of components using tools like vernier calipers, micrometers, and gauges to ensure the dimensions conform to specified limits. Without proper fitting, mechanical assemblies would suffer from misalignment, excessive wear, and reduced performance.

In short, fitting transforms roughly machined parts into usable components that work harmoniously in machinery and equipment by ensuring proper alignment, smooth operation, and exact dimensional accuracy.

1(a)(ii) Write five points to signify the proper use of a bench vice.

The first important point in using a bench vice is to mount it firmly and securely on the workbench. The base and bolts must be tight so that the vice does not shift when pressure is applied during work. A stable vice allows accurate operations and prevents accidents caused by slipping or sudden movement of the workpiece.

Secondly, the workpiece should always be clamped squarely and centrally between the jaws. Uneven clamping causes distortion or breakage of the jaws and can result in poor workmanship. Proper positioning ensures uniform pressure, keeps the work stable, and avoids vibrations that may affect accuracy.

Thirdly, it is essential to use soft jaw covers made of lead, copper, or leather when holding finished or soft materials. These covers prevent the hardened steel jaws from leaving marks or damaging the surfaces of delicate components. This practice is especially necessary when working on polished or non-ferrous metals.

Fourthly, never use the bench vice as an anvil or for hammering heavy objects. Striking the vice or using it to bend thick materials may crack the casting, loosen the base, or misalign the jaws. The bench vice is designed purely for holding, not for heavy impact loads, so such misuse shortens its lifespan.

Lastly, keep the vice clean, lubricated, and properly maintained. Metal filings, dirt, and rust can jam the screw or damage the threads. Applying a light oil film on the screw and guide surfaces ensures smooth operation and longer service life. Regular inspection of bolts and jaw alignment also maintains safety and efficiency in the workshop.

1(b) Explain how the metal chipping process is carried out in the workshop.

The metal chipping process begins by securing the workpiece firmly in a bench vice or on a worktable. Proper clamping is crucial because loose work can cause accidents or produce inaccurate cuts. The work surface must be at a comfortable height to allow steady control during the chipping or filing action.

Next, the operator selects the correct cutting tool for the job, such as a flat chisel, file, or hacksaw, depending on the material and the shape required. For harder metals, a sharper tool with the right cutting angle is chosen to ensure efficiency and safety.

During the process, controlled blows or strokes are applied to remove excess material. For chiseling, the chisel is held at an appropriate angle, and light hammer blows are delivered along the cut line. For filing, the operator pushes the file forward with pressure and lifts it during the return stroke to prevent blunting of the file teeth.

Another important step is to maintain proper cutting speed and direction. The tool should always move along the marked layout lines to achieve the desired dimension and surface finish. Constant checking using a square or measuring gauge ensures accuracy and helps detect any deviation early.

Finally, the surface is cleaned and inspected for accuracy and smoothness. Metal chips and burrs are brushed away using a file card or soft brush. If necessary, finer finishing operations such as scraping, polishing, or reaming are done to obtain a smooth and precise surface ready for assembly.

1(c)(i) Outline the advantages of using a power hacksaw.

The first advantage of using a power hacksaw is increased cutting efficiency. It uses an electric or mechanical drive that moves the blade at a constant speed and feed, allowing faster and more uniform cutting compared to manual sawing. This saves time, especially in large-scale or repetitive cutting tasks.

Secondly, it reduces operator fatigue. Since the machine performs most of the cutting work, the user only needs to set up the material and monitor the operation. This makes it ideal for heavy or thick metal sections that would be difficult to cut manually for long periods.

The third advantage is improved accuracy and consistency of cuts. Power hacksaws maintain uniform blade movement, producing straight and even cuts. The consistent feed and cutting pressure reduce human error, ensuring that each piece cut has the same length and smooth finish.

A fourth advantage is the ability to adjust blade speed and feed rate to suit different materials. Hard metals require slower speeds, while soft metals can be cut faster. This flexibility makes the machine versatile and effective across a wide range of workshop materials.

Lastly, power hacksaws enhance safety and tool life when used properly. They include guards and automatic shut-off mechanisms that reduce risk to the operator. Because cutting is steady and controlled, the blade experiences less wear and lasts longer than one used manually under irregular pressure.

1(c)(ii) Identify two materials which are commonly used for making hacksaw blades.

The first common material used is high-speed steel (HSS). HSS blades can withstand high cutting temperatures and retain sharpness for a long time. They are suitable for cutting hard metals such as steel, brass, and cast iron because they resist wear and maintain a smooth cutting action even under continuous use.

The second material is carbon steel, also called high-carbon tool steel. It is cheaper than HSS and suitable for cutting softer metals such as aluminum, copper, or mild steel. However, carbon steel blades tend to lose their hardness when overheated, so they are used mainly for light-duty or general workshop cutting tasks.

1(c)(iii) With examples, give four parameters which are used to determine the size of a hand hacksaw.

The first parameter is the length of the blade, usually measured in millimeters or inches. Common lengths are 250 mm, 300 mm, or 350 mm. Longer blades can cut larger sections, while shorter ones are used for precision work. For example, a 300 mm blade is commonly used for cutting mild steel bars.

The second parameter is the number of teeth per inch (TPI) on the blade. Fine-toothed blades (e.g., 24–32 TPI) are used for thin materials and hard metals, while coarse-toothed blades (e.g., 14–18 TPI) are used for thicker and softer materials. For example, 18 TPI is suitable for cutting brass rods.

The third parameter is the frame size or adjustment range. A hacksaw frame can be fixed or adjustable to accommodate different blade lengths. Adjustable frames allow the user to fit blades of varying sizes, making the tool more versatile for different cutting tasks.

The fourth parameter is the depth of the throat or frame clearance, which determines the maximum width of the material that can be cut. A deeper frame allows larger sections to pass under the blade, while a shallow frame is lighter and better for confined spaces. For example, deep-throat hacksaws are used when cutting wide plates or pipes.

2(a) Briefly explain four points to be kept in mind in order to get good results in the hand filing operation.

The first point is to choose the correct type and grade of file according to the nature of the work and the material being filed. Coarse files are suitable for rapid material removal on rough surfaces, while smooth or second-cut files are used for finishing operations. Using the correct file type prevents over-cutting and ensures a better surface finish.

The second point is to secure the work firmly in a bench vice at a comfortable height. If the workpiece is not held tightly, it may move during filing, leading to inaccurate surfaces and possible injury. The vice should grip the work without distortion, and the operator should stand with feet apart to maintain balance during each stroke.

The third point is to use the correct filing technique and pressure. Pressure must be applied on the forward stroke only, and the file should be lifted slightly during the return stroke to avoid dulling the teeth. The strokes should be long, even, and straight across the workpiece to maintain flatness and achieve uniform removal of material.

The fourth point is to keep the file clean and regularly remove metal filings using a file card. Clogged teeth cause scratches on the work surface and make filing more difficult. Files should also be handled carefully to prevent dropping, as any damage to the teeth affects accuracy and finish.

2(b) Give three methods of filing.

The first method is cross filing (also called straight filing). In this method, the file is moved forward in a straight path across the surface, usually at an angle of about 45°. It is mainly used for quickly reducing material thickness and flattening large surfaces.

The second method is draw filing, in which the file is held with both hands across its width and moved side to side across the work surface. This method produces a smoother finish and is commonly used for fine finishing after cross filing has been completed.

The third method is lathe or curved filing, used when filing curved or round surfaces such as shafts or pipes. The file follows the contour of the surface and removes small irregularities, giving a smooth and accurate curve.

2(c) Describe the following features in connection with files: (i) Size of the file (ii) Cut of the teeth (iii) Grade of cut of the file (iv) Shape of the file.

The size of a file refers to its overall length, usually measured from the point to the heel, excluding the tang. Common sizes range from 100 mm to 450 mm. Larger files remove more material and are used for heavy work, while smaller files are better for precision finishing.

The cut of the teeth refers to the pattern of the teeth on the file. A single-cut file has one set of parallel teeth, producing a smoother finish, while a double-cut file has two crisscrossing rows of teeth, which remove material faster but leave a rougher surface. Rasp-cut files have large, widely spaced teeth and are used for wood and soft metals.

The grade of cut indicates how coarse or fine the file teeth are. The main grades are rough, coarse, bastard, second-cut, and smooth. Rough and coarse grades are used for quick material removal, while second-cut and smooth grades are used for finishing and fine fitting work.

The shape of the file is designed to suit different types of surfaces. Common shapes include flat, square, round, triangular, and half-round. For example, a flat file is used on flat surfaces, a round file on holes or concave surfaces, and a triangular file for angles and corners.

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2(d) Draw a hand file and show its eight parts.

A hand file consists of eight main parts. These are:
(1) The tang, which is the pointed end inserted into the handle.
(2) The shoulder, where the tang meets the file body.
(3) The heel, which is the start of the toothed section near the handle.
(4) The face, which is the flat surface covered with teeth used for cutting.
(5) The edge, which may be toothed or smooth depending on the type of file.
(6) The point, which is the opposite end of the file, tapering to a narrow tip.
(7) The body, which is the main working length of the file between the heel and the point.
(8) The handle, usually made of wood or plastic, provides grip and safety while filing.

3(a) Write four advantages of braze welding.

The first advantage of braze welding is that it allows joining of dissimilar metals such as copper to steel or brass to cast iron. This makes it useful where normal fusion welding would fail due to different melting points of metals.

The second advantage is that the base metals do not melt, only the filler metal does. This means less distortion and residual stress in the joint, maintaining the original mechanical properties of the base materials.

The third advantage is the joints are smooth, strong, and leak-proof, making braze welding suitable for pipe work, thin sheets, and components that require airtight or watertight joints.

The fourth advantage is the process can be done with simple equipment such as a torch, flux, and filler rods, making it inexpensive and convenient for both workshop and field repairs.

3(b) In four points, give the importance of borax flux for welding process.

The first importance is that borax flux cleans the metal surfaces by dissolving oxides and impurities. Clean surfaces ensure better wetting and adhesion of the filler metal to the base metal.

Secondly, it prevents re-oxidation during heating. When metals are exposed to high temperature, they form new oxides; the flux covers the surface, acting as a barrier against air and preventing further oxidation.

The third importance is that borax flux promotes smooth flow of molten filler metal. It reduces surface tension and helps the filler spread evenly across the joint, filling gaps completely.

Finally, it lowers the melting temperature of oxides and slag, making it easier to remove unwanted residues from the joint. This results in cleaner, stronger, and more uniform welds.

3(c) Briefly explain two factors that influence the effectiveness of brazing operations.

The first factor is cleanliness of the surfaces to be joined. Any dirt, grease, paint, or oxide on the surface will prevent proper bonding because the filler metal cannot wet the surfaces evenly. Cleaning with a wire brush, solvent, or pickling acid ensures a strong joint.

The second factor is proper temperature control during heating. The base metal must reach the correct temperature for the filler to flow by capillary action without overheating. Too little heat prevents flow and causes weak joints, while too much heat burns the flux and weakens the filler.

3(d) Classify the brazing alloys into two essential categories as used in welding.

The first category is silver-based brazing alloys, which contain silver mixed with copper, zinc, or cadmium. They have low melting points and excellent flow characteristics, producing strong joints for steel, copper, and brass components.

The second category is copper-based brazing alloys, such as copper-zinc or copper-phosphorus types. They are cheaper and suitable for joining copper and its alloys, especially where high strength and electrical conductivity are required.

4(a) Explain the term ‘electric arc welding’.

Electric arc welding is a fusion process where an electric arc is created between an electrode and the base metal. The heat of the arc melts the edges of the workpieces and the filler metal, forming a fused joint after cooling. The arc temperature can exceed 3000°C, which is sufficient to melt almost all common metals.

4(b)(i) To which flow of an electric energy is the arc welding based on?

Arc welding is based on the flow of electric current through an ionized gas medium (the electric arc). The current can be direct current (DC) or alternating current (AC). The flow of electrons produces intense heat at the arc, which melts both the electrode tip and the base metal at the point of contact.

4(b)(ii) Write the hazards of ultraviolet rays and suggest ways to prevent them.

Ultraviolet rays from the arc can cause serious eye injuries such as arc-eye or photokeratitis, which is a painful inflammation of the eyes due to UV exposure.

They also cause skin burns similar to sunburn when the skin is exposed to the arc for prolonged periods.

To prevent these hazards, welders should wear a protective welding helmet with a dark lens, long-sleeved clothing, leather gloves, and high-collar jackets.

In addition, welding curtains or shields should be used to protect nearby workers from indirect exposure to the bright arc.

4(c) Sketch a neat diagram with six labeled parts to demonstrate the coated electrode in working process.

A coated electrode in working process consists of six key parts:
(1) Power source supplying current.
(2) Electrode holder gripping the electrode.
(3) Coated electrode core wire serving as filler metal.
(4) The electric arc between electrode tip and workpiece generating heat.
(5) The molten weld pool where metals fuse.
(6) The flux coating which burns to form shielding gas and protective slag covering the weld bead.

4(d) Outline five criteria to be considered during an electrode selection.

The first criterion is the type of base metal. The electrode composition should be similar to the base metal to ensure compatibility and prevent brittle welds.

The second criterion is the required mechanical properties of the joint such as strength, ductility, and toughness. Electrodes with matching tensile strength are chosen for high-stress joints.

The third criterion is the welding current and polarity. Some electrodes work only with AC, others with DC-positive or DC-negative polarity, depending on coating and core type.

The fourth criterion is the welding position. Certain electrodes are designed for flat or horizontal welding only, while others (all-position electrodes) can be used vertically or overhead.

The fifth criterion is the coating type and ease of slag removal. Basic coatings provide deep penetration and strong welds, while rutile coatings give smoother finishes and easier slag cleaning.

5(a) Outline three basic types of chip produced when cutting metals.

The first type is continuous chip, formed when cutting ductile metals like copper or mild steel at high speeds. These chips appear long and ribbon-like, providing a smooth surface finish but may tangle around the tool if chip breakers are not used.

The second type is discontinuous chip, produced when machining brittle materials such as cast iron or at low speeds. The chips break into small fragments due to poor plastic flow, resulting in a rough surface.

The third type is serrated or segmented chip, formed during machining of hard alloys such as titanium. These chips show alternating shear zones and form under conditions of high cutting temperature and pressure.

5(b) How are anvils and swage blocks used in connection with metal cutting?

Anvils are solid steel blocks used to support the workpiece during chipping, hammering, or shaping operations. The flat top surface absorbs hammer blows and provides a stable working platform.

Swage blocks are heavy cast-iron or steel blocks containing various shapes, grooves, and holes. They are used to support metal when cutting or shaping curved sections, bending rods, or forming angles, ensuring the workpiece retains its desired shape.

5(c) Explain the term threading and give five requirements of correct threading.

Threading is the process of producing helical ridges called threads on the external or internal surface of a workpiece to form screw-like features used for fastening or transmitting motion.

The first requirement is accurate pitch and lead so that mating threads fit perfectly without play or binding.

The second is correct thread form or profile, ensuring the flank angles and depth match standard specifications such as ISO or metric thread forms.

The third requirement is smooth and clean surface finish, free from burrs and roughness to prevent wear and ensure easy assembly.

The fourth is proper alignment and concentricity of the threaded portion with the axis of the workpiece to avoid cross-threading.

The fifth requirement is accurate diameter control, both major and minor, so that internal and external threads engage properly and maintain sufficient strength.

5(d) Draw a flat chisel in a cutting position and show the important geometry angles.

A flat chisel in a cutting position has four main geometrical features.
(1) The cutting edge — the sharpened tip that removes material by shearing action.
(2) The clearance angle — a small angle between the tool's bottom face and the work surface to avoid rubbing.
(3) The bevel angle — typically between 60° and 90°, depending on material hardness; smaller for soft metals, larger for hard ones.
(4) The included angle — formed by the two faces of the cutting edge, which determines the chisel's strength and sharpness.

When held correctly, the chisel's bevel faces the direction of cutting, and controlled hammer blows remove chips efficiently while maintaining a smooth cut line.

6. (a) Explain the function of each of the following:

(i) The angle plate
An angle plate is a precision tool used in the workshop to hold or support a workpiece at a right angle during marking out, machining, or inspection. It is usually made of cast iron or steel and has two flat faces that form a perfect 90-degree angle. The main function of the angle plate is to ensure

that the workpiece is accurately aligned when drilling or milling at right angles. This helps in maintaining accuracy, stability, and proper alignment in various operations, such as setting up jobs on milling machines or surface plates.

(ii) Vee blocks

Vee blocks are special holding devices used to support round, cylindrical, or irregular workpieces during marking out, drilling, or machining. They contain a V-shaped groove that securely holds the circular object without slipping or movement. The function of the Vee block is to ensure the workpiece is held steady and in the correct position for accurate marking or machining. They are often used together with clamps to hold the work firmly, preventing vibrations and ensuring precision during work operations.

(b) Explain the general procedures of marking out a workpiece.

The first step in marking out a workpiece is to clean the surface thoroughly to remove grease, rust, or dirt, ensuring clear and accurate markings. A clean surface prevents measurement errors and allows marking tools to work smoothly.

Next, a thin, even layer of marking medium, such as engineer's blue or chalk, is applied to the surface. This colored film provides a visible contrast for the scribed lines, helping the craftsman to see the layout clearly.

After that, accurate measurements are taken using tools such as a steel rule, calipers, or a height gauge, depending on the size and precision required. The layout lines are then scribed on the surface using a scriber or marking knife. These lines guide the machining or cutting process.

Finally, all measurements and markings are carefully checked for accuracy before any cutting or machining begins. This verification step ensures that no errors will occur in the subsequent stages of fabrication, saving time and materials.

(c) Outline the requirements for laying out lines using a surface gauge or a vernier height gauge.

The first requirement is that the surface plate used as a reference base must be flat, clean, and free from any debris. Any dirt or roughness can cause errors in marking.

Secondly, the surface gauge or vernier height gauge must be properly set and adjusted to the desired height, using a precise measuring tool or vernier scale. Accuracy in setting ensures that the scribed line is correctly positioned on the workpiece.

Thirdly, the workpiece must be securely held or clamped in position on the surface plate to prevent movement during marking. Any shift can result in incorrect layout lines.

Lastly, the scribing point should be sharp and properly aligned with the measuring scale. It must be moved smoothly along the surface to produce a clear, straight, and fine line. Proper technique ensures consistent and accurate markings suitable for precision machining.

7. (a) (i) Explain cutting speed as used in workshop practice.

Cutting speed refers to the distance that a point on the circumference of a rotating workpiece travels in one minute during a machining process, such as turning, drilling, or milling. It is usually expressed in meters per minute (m/min) or feet per minute (ft/min). Cutting speed determines the rate of material removal and the quality of the surface finish. Maintaining an appropriate cutting speed ensures efficient machining, prevents tool wear, and produces an accurate finish.

(ii) Calculate the cutting speed, given that the work diameter is 14 mm and the rotation speed (N) is 8 rev/m; take $\pi = 3.142$.

Formula:

Cutting speed (V) = $\pi \times D \times N / 1000$

Substitute: $V = 3.142 \times 14 \times 8 / 1000$

$V = 351.9 / 1000$

V = **0.352 m/min**

Therefore, the cutting speed is approximately **0.352 meters per minute**.

(iii) Calculate the change gears to cut R.H. thread of 10 T.P.I.

To calculate the change gears, use the formula:

Gear ratio = Lead screw pitch / Thread pitch required

If the lathe has a standard lead screw of 8 T.P.I., then:

Gear ratio = 8 / 10 = 0.8

Therefore, the ratio of the driver to driven gears should be **0.8 : 1**, meaning the driver gear should have 80% of the teeth of the driven gear to cut a right-hand thread of 10 T.P.I.

(b) (i) Outline the factors that limit the use of the maximum feed to the workshop machine.
The first factor is the rigidity of the machine and workpiece. Weak or flexible setups can cause vibrations, poor surface finish, and tool chatter when using high feeds.

Secondly, the material hardness affects the feed rate. Harder materials require lower feed rates to avoid tool wear or breakage.

Thirdly, the cutting tool's geometry and material limit the feed rate. Dull or unsuitable tools cannot withstand heavy feeds and may fail prematurely.

Lastly, the desired surface finish influences the feed choice. A rough surface is acceptable for roughing cuts, but fine finishing requires a lower feed to achieve a smooth and accurate surface.

(ii) What is the pitch, depth, minor diameter, width of crest, and width of root for M6 × 1.0 thread? Given that: D = 0.54127P, Crest = 0.125P, Root = 0.25P.
Given: P = 1.0 mm

Pitch = 1.0 mm
Depth = 0.54127 × 1.0 = 0.541 mm
Width of crest = 0.125 × 1.0 = 0.125 mm
Width of root = 0.25 × 1.0 = 0.25 mm
Minor diameter = 6 – (2 × 0.54127) = 6 – 1.08254 = **4.917 mm**

Therefore, Pitch = 1.0 mm, Depth = 0.541 mm, Minor diameter = 4.917 mm, Width of crest = 0.125 mm, and Width of root = 0.25 mm.

8. (a) How can the drilling of large diameters in sheet metal be done satisfactorily?
Drilling large diameters in sheet metal can be done satisfactorily by first drilling a small pilot hole using a small-diameter drill bit. This pilot hole guides the larger drill and prevents wandering.

Afterward, a step drill or a hole saw should be used to enlarge the hole gradually to the required diameter. This method prevents tearing and distortion of the thin metal.

Additionally, using a backing plate under the sheet metal helps support it during drilling, reducing vibration and ensuring a clean edge.

Finally, applying cutting fluid reduces friction and heat, prolonging the life of the drill bit and improving the surface finish of the hole.

(b) What are the four causes for the defect of making oversize hole when drilling?
The first cause is the use of a worn or dull drill bit, which causes uneven cutting and enlarges the hole beyond the desired size.

The second cause is excessive feed or high drilling speed, which leads to tool deflection and hole enlargement.

Thirdly, improper alignment of the drill bit or incorrect clamping of the workpiece causes the drill to wobble, resulting in an oversized hole.

Lastly, uneven pressure or poor machine maintenance can lead to vibration during drilling, causing inaccuracies and producing holes larger than required.

(c) Write two purposes of reamers left hand helix.
The first purpose of a left-hand helix reamer is to prevent the reamer from pulling itself into the hole while cutting. This ensures smooth, controlled operation and prevents damage to the workpiece.

The second purpose is to push chips back out of the hole rather than pulling them in, which provides a cleaner internal surface finish and reduces the chance of clogging inside the hole.

(d) Give the purpose for each of the following in metal works:

(i) Counterbore tool pilot
The counterbore tool pilot is used to guide the cutting edge of the counterbore tool accurately into the existing hole. It ensures the counterbore is concentric with the hole, creating a flat-bottomed recess for the bolt or screw head.

(ii) Chamfer
A chamfer is a beveled edge made at the end of a hole or component. Its purpose is to remove sharp edges, make assembly easier, and guide bolts or screws into the hole smoothly. Chamfers also improve appearance and reduce the risk of injury during handling.