Study unit 1

Introduction to Human Factors and Ergonomics (HFE)

In your own words, explain what Human Factors and Ergonomics (HFE) is

The word ergonomics is derived from the Greek word ergo (work) and nomos (laws). European ergonomics has its roots in work physiology, biometrics and workstation design. Human factors, on the other hand originated from research in experimental psychology, where the focus was on human performance and systems design. Despite the differences between human factors and ergonomics in the type of knowledge and design philosophy, the two approaches are coming closer. The primary purpose of human factors and ergonomics is design.

Helander defines human factors and ergonomics as:

- Considering environmental and organisational constraints,
- Use knowledge of human abilities and limitations,
- To design the system, organisation, job, machine, tool, or consumer product
- So that it is safe, efficient, and comfortable to use.

Explain the two principles or guidelines, namely that the primary purposes of HFE are the design of tools and workstations and that an interdisciplinary approach is necessary in the design and analysis of tools or systems.

Interdisciplinary knowledge is required in HFE design for the following reasons:

- To formulate systems goals
- To understand functional requirements
- To design a new system
- To analyse a system
- To implement a system

Discuss the focus of HFE

Ergonomics is that applied field of Industrial and Organisational Psychology that focuses on the interaction between human beings and the:

- Products
- Equipment
- Facilities
- Procedures
- Physical environment and
- Psychological environment

Used at work and in everyday living.

Discuss the goals of HFE

The main objective of HFE is to change (improve) the facilities people use and the environments in which they use them to correspond with their capabilities, limitations and needs. The three sub-objectives of ergonomics can be distinguished, namely:

- Increased safety of the user or operator
- Enhanced productivity
- Operator satisfaction

The goal of safety – with regards to the goal of safety, the limitations of the operator should be taken into consideration when designing tools, equipment or systems.

The goal of productivity – increase the efficiency and effectiveness with which work and other activities are performed, thereby increasing productivity. Safety must be considered when focusing on productivity; there is usually a trade-off between the two.

The goal of operator satisfaction – The ultimate goal of ergonomics is to improve and maintain the wellbeing of the individual worker. At the same time, the wellbeing of the organisation will also be improved and maintained. Ergonomics has certain advantages for the individual worker, such as an improvement in the following:

- Health
- Safety
- Comfort
- Satisfaction
- Convenience

For the organisation, there will be an improvement in:

- Performance
- Productivity
- Effectiveness
- Efficiency
- Quality of the product or service

Explain the holistic approach followed in the design of work environments and facilities

A holistic approach, where all aspects in the work environment are addressed, should be followed when ergonomics is applied to the design and layout of work environments and facilities.

Explain with the aid of an applicable illustration the human-technology-workspace-environment model and relate this to practical settings

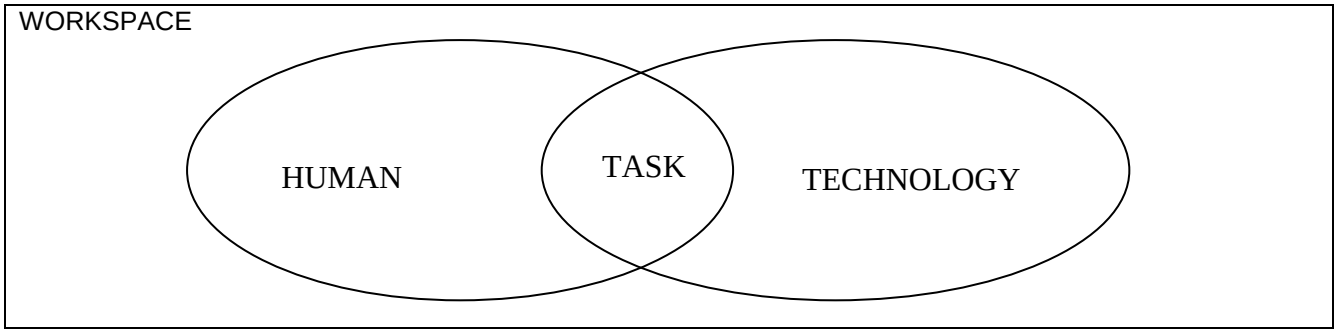
Whenever a person uses a product, equipment or tool, this interaction is referred to as a human-technology system.

- A system comprises a number of parts or components that interact with each other so that movement in one part of the system leads in a predictable way to movement in other parts.
- Systems are open to environmental inputs and as a result are continually fluctuating

Given the two points above about what a system is an example of a human-technology system, is a person working on a computer. From a mechanical point of view, the person receives information, based upon which he or she takes certain actions.

The interaction between person and technology always takes place in a certain workspace which is located in a certain physical and psychological environment; Illustrated below. The characteristics of the workspace and the environment will affect the task performance of the person.

WORK ENVIRONMENT



The workspace is described in terms of the size and layout of chairs, tables, desks, consoles and other equipment. Factors like size and layout will have an effect on the body position, body posture and reach distances of the expected user population and consequently on their comfort and efficiency.

The environment can be described in physical terms such as temperature, lighting, noise and vibration, or ambient environment. The ambient environment may also include the presence and effect of chemical and biological agents. The organisational environment can also include psychological aspects such as teamwork, management structure, shift conditions and psychological factors.

The human-technology-workspace-environment model is useful in identifying the factors that will have an effect on comfort, task performance and safety.

Describe communication between human and machine

Communication between a human and machine can be explained best by an example of a person working on a computer.
The person can use a mouse, keyboard or remote control to give instructions to the computer on what to do.
The computer can display data on the screen or print information on a printer for the person to see the output.

Explain the human-technology-workspace-environment model and relate this to practical settings.

If we take the human-technology system where a person is working on a computer, for an example, aspects of workplace will include the size, height and layout of the desk and chair, legroom underneath the desk, keyboard and mouse on the desk work surface. These factors will have an effect on the body position, body posture, viewing distance, viewing angle and the reach distance of the user and consequently on his or her comfort and efficiency.

Study unit 2

The reality of HFE in organisations

Explain why a cost-benefit analysis is needed in the human factors and design.

10 Marks

A redesign or change in a system will only occur because of a perceived need or benefit that can be achieved. Even if there is a strong perceived need for redesign or reengineering it is important not to just start with the redesign, because redesign will cost money.

It is important to investigate the benefits thoroughly and weigh them against the costs. If the benefits such as improved productivity, quality, safety and worker comfort outweigh the costs, then the effort of redesign might be worth it.

To investigate the costs and benefits of a redesign it is important to obtain information from different sources such as the following:

- Discussion with management
- Plant walk-through, inspection and not taking
- Discussion with operators
- Discussion with first-line supervisors
- Measurements in the plant or office of illumination, noise and the design of the workstation

These measurement values should be recorded and documented in a systematic fashion, so that comparisons can be made between different workstations and before and after comparison can be made.

Identify and discuss sources of information needed to conduct a HFE investigation

To investigate the costs and benefits of a redesign it is important to obtain information from different sources such as the following:

- **Discussion with management** – they can give more details about what the focus of the study should be and explain what the problem is from their perspective.
- **Plant walk-through, inspection and not taking** – from this information about how the manufacturing is and how the material flow is organised can be obtained.
- **Discussion with operators** – How they perform their tasks? How long does it take to learn a new task? What are the problems that newly employed workers have?
- **Discussion with first-line supervisors** – Often these are able workers who have been promoted. They are a great source of information.
- **Measurements in the plant** of illumination, noise and the design of the workstation.

Explain what usability testing entails and also

- **Indicate what the main benefits of usability testing are, and**
- **List the positive effects of usability testing for an organisation**

Usability testing is a method for reducing the difficulty and time for performing a task on a computer.

Main benefits of usability testing

- Usability testing can dramatically improve the quality of the work with respect to productivity and also with respect to job satisfaction.
- A task that has an easy and smooth work flow is simply more interesting and more satisfying to perform.

Positive effects of usability testing for an organisation

- Product design and product performance will improve.
- User satisfaction will increase
- Since usability errors can be detected much earlier in the systems development cycle, the development time ant he development cost for the interface will be reduced.
- As a result of the improved software design, sales and revenue will increase.
- Because interface is easier to handle it will take less time to train employees.
- There will also be reduced maintenance costs, reduced personnel costs, and improved user productivity.

Study Unit 3

Designing for vision and illumination

Explain how vision influences design in the workplace and the implications vision has for safety and the design of a safe workplace.

It is difficult to see in dim light. The adaptation process, or the reduction of the light threshold, is a function of time. Only after the first 10 minutes do the rods take over: The rods are the parts of the retina that are more sensitive to low light than cones. This process is completed in about half an hour (30 to 40 minutes).

This must be considered when designing jobs, if we expect a person to move rapidly from bright sunshine into a dark work area it must not be expected of them to be able to see and hence work properly in that environment for about 30 minutes. Physiologically speaking, they will need time to adapt. We have to make provision for this by designing our indoor dark areas in such a way that either accurate vision is not necessary or that sufficient time is available for adaptation.

Discuss the structure of the eye and the influence of ageing on the eye.

The eye is a slightly irregular sphere with a diameter of about 2.5 cm. In the front of the eye, covering the eye pupil, is the cornea. The cornea protects the eye. It has a high refractive index, which is helpful for focusing images on the retina. Between cornea and the pupil there is a fluid substance called aqueous humor. The pupil size ranges from a small diameter of 2 mm to a large diameter of 8 mm.
The ciliary muscle is a ring muscle that goes around the lens. It can contract or it can relax, and by doing so it either pushes the lens, so that it bulges, or it pulls the lens, so that it becomes flatter.

The inside of the eyeball is lined by the retina. This is a paper-thin layer of light sensitive cells. All the cells are connected to the optic nerve, which transmits the information to the visual cortex, the main location for visual information processing. The visual axis extends from the cornea to the fovea, which is the central part of the retina. In the fovea there are mostly cones, which are responsible for the colour vision of the eye. The light sensors in the peripheral vision are mostly rods. The rods are not sensitive to colour but rather to black and white.

For older individuals there are several physical changes in the eye. The most important is the loss of focusing power (accommodation) of the lenses in the eye. This is because with increasing age the eye lenses lose some of their elasticity, and therefore cannot bulge or flatten as much as before.

Describe how the eye focuses, the different refractive errors and how they influence vision.

To look at close objects, the lens has to bulge, thereby increasing the refractive power, while for distant objects it flattens out and reduces the refractive power. 70–80% of the refractive power is in the cornea, and the rest, 20–30%, is fine tuning which is performed by the lens. There are two lenses of the eye: the cornea and the lens.

There are four refractive errors that happen in the eye:
Myopia (*near-sightedness*) – The image is projected in front of the retina. Negative lenses are used to project the image on the retina.
Hyperopia (*far-sightedness*) – The image is projected in back of the retina. Positive lenses are used to project the image on the retina.
Astigmatism (*the vision along vertical axis is different from the horizontal axis*) – May occur because of irregularities in the curvature of the cornea.
Presbyopia (*changes due to age*) – Results in blurred images. With increasing age, the lens of the eye gets harder, so that it cannot accommodate, or bulge in and out.

Describe some of the main aspects that determine how we perceive colour, how we adapt to darkness and how to measure visual acuity (how big writing should be), and the implications of these for design.

Visible light ranges in wavelength from 380 nanometers (nm) to 760 nm. This corresponds to the colours violet, indigo, blue, green, orange, and red.

All colours are only perceptible at a certain level of illumination. As the illumination get less everything tends to become greenish, then grey, and just before it becomes so dark that nothing is visible, we tend to see only in black and white.

The design implications of this are as follows:
Use large letters (objects) if working under poor illumination
Avoid colour coding when illumination is low (for instance red warning signs)
Use dark adaptation goggles if needed

Define the following terms:

- **Illumination**
- **Luminance**
- **Contrast**
- **Contrast ratio**

Illumination is

Light falling on a surface

Measured in lux

Luminance is

Reflected illumination

Light emitted by a computer screen

Measured in candela per square metre (cd/m^2) or nits

Contrast is

The difference in luminance between two objects next to each other

Contrast ratio is

A ratio of the luminance of area A and area B

Explain the role illumination plays at work 5 Marks

A well-designed illumination system is important for industrial productivity and quality, as well as operator performance, comfort, and convenience. Improved illumination is not just a matter of installing more lights, but also of how this is done. There are several ways of improving the quality of illumination; for example, by using indirect lighting. Such lighting can be important since it reduces the amount of glare. Visual inspection can be enhanced by using special-purpose illumination, which makes flaws more visible.

Explain how to use indirect or reflected lighting in the workplace.

The use of indirect lighting minimizes both direct glare and indirect glare. It minimises direct glare because the light is directed towards the ceiling rather than the operator's eyes, and it minimises reflected glare because the light reflected from the ceiling is not directional, and will therefore generate so-called diffuse reflection.

Indirect lighting is mostly suitable for offices and clean manufacturing workplaces where the ceilings do not become soiled. Indirect lighting would probably not be effective for dirty manufacturing processes, since the light sources and light fixtures become covered with dirt and it is necessary to clean luminaries and paint ceilings at regular intervals.

Study Unit 4

Human information processing

State the implications of the large amounts of information that people are exposed to

In HFE reaction time (RT) is used to measure how complex decisions are. Complex decisions take a long time and easy decisions take a short time. RT is used to reformulate or redesign decisions so that they become easier, quicker, and more reliable.

Hick's law stipulates that the reaction time is a function of the number of choices in a decision. It seems that the brain is wired to respond linearly to the number of bits of information.

This is a very useful finding, since it makes it possible to predict the information processing time. The more information a person has to process the slower the decision and if the person is not given sufficient time to process all the information the decisions can also be less reliable.

Explain the potential problems with information.

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Explain how people transform, reduce, store, recover and use information (information processing)

People sense the environment through seeing and hearing, then make decisions, and finally action on the decisions.
The diagram below illustrates the human information processing cycle, as conceived by Card, Moran, and Newell. There are three processors in this model:

1. A perceptual processor (to see and hear)
2. A cognitive processor (to think)
3. A motor processor (to act)

The average time to process information in the 3 processors is as follows: 100 ms for perception; 70 ms for cognition; and 70 ms for action. These numbers depend upon the task; a complex target with many details takes a longer time to process than a simple target. For motor processors, however, the variability in time is not so large; once a decision has been made, it takes a relatively short time to act upon it.

At the top of the figure is the long-term memory (LTM). The LTM supposedly has unlimited storage capacity. The mode of information in LTM is semantic; that is, it consists of concepts. Most people store and retrieve information from LTM in terms of concepts.
The LTM supports the working memory (WM), also called short-term memory (STM). The WM is what we use when we perform a task. The half-time (HT) of the working memory is 7 sec. This means that the working memory fades away very quickly, and after 7 sec, half of the information has been forgotten. The WM is like a pull-down menu in a computer system. Once we get into a situation we can select and execute the appropriate strategies. Information in WM gets updated from LTM as it becomes useful. WM is also referred to as “running memory”.
As people learn tasks, they form large chunks – a chunk can be a group of letters or a situation. Therefore experienced operators are more efficient than inexperienced operators. The mode of information storage in the working memory is acoustic or visual. The more chunks of information there are, the quicker the information dissipates. The halftime (HT) for 1 chunk of information is about 100 sec, and for 3 chunks of information it is about 7 sec.

Perceptual processors

When we make decisions, we first perceive information, then extract features of the information. The perceptual processors send data from the eyes and the ears to two data banks, then visual image store and the auditory image store. The data in these banks decay very quickly. The HT for the visual image store is 200 ms; for the auditory store HT is 1500 ms.
The visual image store is also called iconic memory. It has a capacity of about 17 letters.
The auditory image store also referred to as echoic memory. It stores sound impressions, and its HT is about 1500 ms. during this 1.5 s we can still “hear” what was said, which is why this type of memory is called echoic memory. The HT of the echoic memory is much longer than for the iconic memory. This makes it possible to listen to the words together in a sentence and comprehend them as an entire sentence, rather than as isolated words.

Explain the effects on people of too much information

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Discuss what information theory entails

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Explain how people make decisions using rules of thumb, and the views of various heuristics practitioners.

Heuristics save us from overloading the brain; cognitive limitations force decision makers to construct simplified models of their problems. Heuristics enable fast, frugal, and accurate decisions.

Below are the well known heuristics:

Salience Bias
The operator pays the most attention to salient information, such as bright signs, loud noise, large lettering, top of the page, and so forth.

As if Heuristic
The operator acts as if all information were equally valuable.

Ignoring arithmetic calculations
In multiplying 147 x 52 we take short cut and multiply 150 x 50.

Availability heuristic
High probability events are favoured over low probability events.

Confirmation bias
One person comes in and immediately makes a bad impression. You will then be biased to keep searching for confirming negative information throughout the interview and deemphasize the positive information.

Reverse causal reasoning

A implies B also means that B implies A. Increased temperature leads to increased pressure in a pressure cooker – true. Increased pressure leads to increased temperature – not true; but this is the type of mistake we may make in reasoning about the process.

Overconfidence in diagnosis

A football fan may say the chances of his team winning are very good whereas the statistics of recent matches may be against the chances of his team winning.

Overestimation of small numbers and underestimation of large numbers

It is difficult to judge small probabilities. A driver may expect that the probability of a police speed control is 0.02 (2%). In reality, speed controls are much rarer, but since we think of them as being significant events, the number is exaggerated.

Differentiate between the classical school of decision making and the naturalistic decision making approach.

Classic school of decision making

A reasonable decision maker is supposed to choose an alternative that maximises the expected value. The expected value of a decision is offered by the normative school as the gold standard for good decision making. This means that the optimum decision would consistently produce the maximum value if repeated many times.

In recent years, there has been a departure from formal decision making to a more opportunistic approach. There is a realisation that alternatives are difficult to formulate, and an optimal solution may not exist. It is difficult to fully diagnose the entire situation, assign probabilities and values, and consider all possible outcomes.

Naturalistic decision making

In every situation, decisions are embedded in large tasks. Decisions research in the laboratory tends to lose the greater perspective of a meaningful context. In natural settings, making a decision is usually not an end in itself, but a means to achieving a broader goal.

Discuss the factors that characterise decision making in naturalistic settings

Characteristics of natural decision making:

Ill structured problems

When a task is ill-structured, the decision maker may not fully understand the problem, yet she needs to generate an appropriate response.

Uncertain dynamic environment

The environment of the task may change rapidly. This results in an unstable situation where the conditions for decision making also change.

Shifting, Ill-defined, or Competing goals

The decision maker may be guided by many different goals, some of which may be unclear or in conflict with other goals. Thus the decision maker has to trade off different goals.

Exploring alternative actions

In a naturalistic setting, a decision maker may take a long time assessing the situation, and the final decision is composed of several smaller decisions that take place over time.

Stress

Decisions makers who are under high levels of personal stress are often tired and unmotivated. Under these conditions, they may use incomplete strategies to arrive at a decision.

High stakes

In real situations, the outcomes of a decision often involve real stakes that matter to the decision maker, who will therefore take an active role in ensuring a good outcome.

Multiple players

In a team, individuals assume different roles. Problems arise when they do not share the same goals.

Organisational goals and norms

The organisation may impose general goals and standards operating procedures which individuals have to comply with. These may be in conflict with the personal goals of the employee.

Explain the three models developed in naturalistic settings

Rasmussen's model

Jens Rasmussen distinguished between Skill-Based, Rule-Based, and Knowledge-Based decision making and task performance.

A person may enter a situation that is very familiar and the way he performs the task is automatic an there are usually not many decisions. This is referred to as Skill-based decision behaviour. There is no need for formal decisions and the execution of the task is automatic.

The next level is called Rule-based decisions. This is no longer automatic. In this case there are several well-understood rules for decision making.

- If situation A, then I do X,
- If situation B, then I do Y,
- If situation C, then I do Z,

Rule-based decisions are usually very effective, since they are quick and they can deal with a variety of conditions.

Knowledge-based decisions are typically for complex environments and for unfamiliar tasks. With training and experience, many knowledge-based tasks are turned into rule based tasks and rule-based tasks into skill-based tasks.

Norman's gulfs of execution and evaluation

Norman's Gulfs of execution and evaluation model has been used extensively in human-computer interaction. According to this model the user of an interface must be able to do several different things: formulate her goal; formulate her intention; specify her action; execute the action; perceive the system state; interpret the system state; and evaluate the outcome. In order to make this happen, a designer of an information system needs to consider carefully how she can design the interface so that:

- The system state and the action alternatives are visible
- There is a good conceptual model with a consistent system image
- The interface has useful mappings that reveal relationships between stages
- The user receives continuous feedback on his actions

Norman's model is clearly more focused on systems design.

Recognition-primed decision making

The model of Recognition-primed decision making (RPD) was developed by Klein (1989) and Klein et al. (1993). RDP has similarities to Rasmussen's rule-based behaviour: if situation A, then do X; if situation B, then do Y; and so forth.

In RPD there are three different decision situations.

1. The first situation is where operators recognise a situation and act like they have acted before.
2. Sometimes the situation may be a little different from past situations, and the operator will then go through a mental situation of what could happen if he decided to act according to the familiar pattern. Only then may he decide to accept the common routine action.
3. An operator simulates the action again, but decides that a routine action is no longer appropriate.

One important distinction of RPD is that decision makers do not go through all possible alternatives before they make a decision. They use reliable heuristics and in most cases they are correct.

Explain the three decision situations and distinguish between micro-cognition and macro-cognition.

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Micro-Cognition and Macro-Cognition

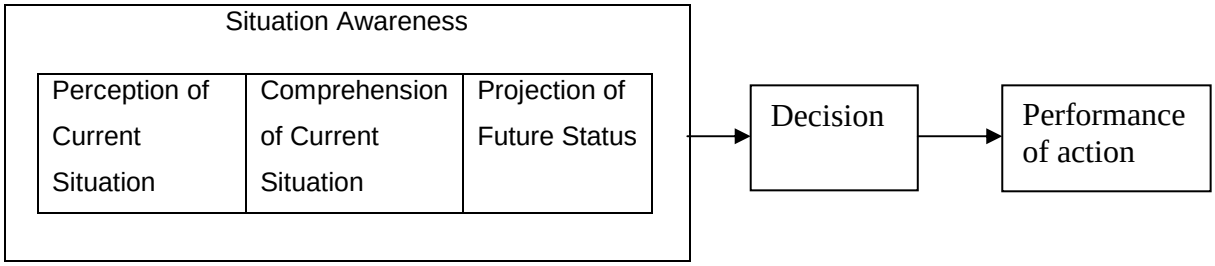
Micro-cognition is typical for cognition in an experimental situation in a psychology lab: puzzle solving, searching a problem space, selective attention, choosing between options, and estimating uncertainty values.

Macro-cognition is typical of real life situations, such as planning and replanning, problem detection, building courses of action, attention management, recognising situations, and managing uncertainty. These types of problems are difficult to model quantitatively, and the analysis is qualitative.

Explain the situation awareness model developed by Endsley (1995)

The model of situation awareness was developed by Endsley (1995). It has been used extensively for analysis and design of systems. She provided the following definition: “Situation awareness is the perception of the elements in an environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future.”
The main concept is a human information model, with three steps as follows:

1. Perception of elements in the current situation
2. Comprehension of the current situation
3. Projection of future status



Based on these the person makes a decision and performs an action. Prediction is essential in all human-machine interaction and HCI tasks; if a user understands what is coming up, then it is easier to plan future action. Fewer errors will be committed and performance times will decrease.
Situation awareness is difficult to measure. One cannot just ask people if they have situation awareness; they wouldn’t know if there are aspects that they are unaware of.

Explain the signal detection theory paradigm

According to the signal detection theory (SDT), there are two possible states of the world: either there is a signal or there is no signal or signal or noise. The operator may respond in two ways: “Yes” (there is a signal) or “No” (there is no signal). If there is a signal and the operator says yes, the situation is referred to as a hit. False alarm is a situation where there is no target but the operator says “Yes”. If there is no signal and the operator says “No”, we have a correct rejection. Finally the operator may miss the signal, thereby resulting in a miss.

There are many applications of signal detection theory in real life.

A radiologist examines an x-ray to determine if a tumour is malignant (signal) or benign (noise).
A nuclear power plant supervisor decides whether the present alarms mean that there is a malfunction in the power plant (signal) or that the situation is still normal (noise).
A polygraph expert determines whether the data from a polygraph indicates that a person has lied (signal) or told the truth (noise).
Aircraft maintenance personnel trying to find cracks in the aircraft frame.
Airport security inspectors looking at an image of the contents of a carry on bag, and deciding whether there is a concealed weapon (signal) or other objects (noise).

Explain how employees whose jobs involve looking at displays can sustain their vigilance and attention.

People's vigilance remains adequate for some time, but starts dropping after 20 to 30 minutes. The loss in performance over time is called the vigilance decrement, whereas the steady state level of vigilance performance is called vigilance level. The problem with vigilance increases if the signal has low strength; if there is spatial or temporal uncertainty, meaning that one cannot predict where or when the signal will occur; and if only a few events happen in the background.

To reduce vigilance decrement, one can do many things:

- Show examples of targets on the screen and thereby increase mental availability.
- Increase target salience – for example, the size of the target.
- Remove social isolation.
- Add irrelevant tasks to increase the physiological activation level, such as playing games.
- Provide trial testing with feedback on hits, correct rejections, false alarms, and misses.
- Schedule work and rest periods so as to reduce fatigue.
- Present the signal in two modes or channels at the same time, such as visual and auditory.
- Drink coffee and take other stimulants.

Study Unit 5

Design of controls, displays and symbols

Explain that one of the major thrusts of HFE is improving the design of controls, displays and symbols

Much research is undertaken by companies to support the design of controls, displays and symbols.
In a manufacturing plant, operators handle a variety of objects, including controls, hand tools, and parts to be assembled. The design principles derived for controls may be applied to most things that an operator uses; in fact, they apply to anything that an operator touches with his hands, such as parts used for assembly work.
The coding of controls principles can also be extended to the coding of parts manufacturing.

Explain the principles underlying the design of controls

Appropriateness of manual controls

Manual controls should be selected so that they are appropriate to the task and intuitive to use. Some controls can make a task easy to perform, whereas others make a task difficult.
Controls can be classified by the number of settings and by the force required to manipulate the control. For example, if a control does not require much force and there are only two discrete settings, the recommended types are goggle switch, pushbutton, or key lock. If there are several control settings, a rotary selector would be a good choice.
If a large actuation force is necessary, one should select a control where it is easy to apply force. Hand pushbuttons, foot pedals, levers, or cranks could be used.
Presently many controls are programmed and they have become inexpensive, for example male urinals with sensors for flushing, if the sensor is put too high it might not pick up that someone just used the urinal and not flush, therefore height adjustment must be appropriate.

Standardisation of controls

Over the years many controls have become standardised. In driving a can we are so accustomed to steering wheels and foot pedals, that it would be difficult to imagine any other arrangements. Examples of standardised controls include:

- Steering wheel for steering
- Joystick for airplanes
- Foot pedals for braking and acceleration
- Manual lever for aircraft throttle
- Lever control for gear shift

A user would be confused and annoyed to find other types of controls.
With technological advancement, some systems are no longer controlled manually. You do not have to manually turn on some water taps. If there are hands in front of them they open the water.

Selection of computer input devices

There has been much research on the design of input devices, such as the mouse, the track-ball, the joystick, the touch screen, the light pen, and the graphics tablet.

Different input devices have different advantages and disadvantages. For touch screens and light pens, one has to point with a finger or a stylus; this provides excellent hand-eye coordination. Pointing is a very direct way of expressing preference. This is such basic behaviour that training is not necessary. Touch screens and light pens are therefore the most direct devices. There are, however, disadvantages. The pointing will partly obscure the view of the display, and the input resolution is poor. For the touch screen the resolution is the width of the finger, and for the light pen it is the width of the pen.

Touch screens are particularly appropriate for use in public environments, such as information displays at train stations and ticket vending machines at airports. This type of device has no moving parts, and it is sturdy and robust.

The mouse, the track-ball, and the joystick have the best input resolution; therefore they are the best for accurate pointing. This is because the input resolution can be programmed by changing the gear ratio between the device movement and the cursor movement.

For some devices there is flexibility with respect to placement on the work table. The track-ball and joysticks are excellent in this respect, because they are small and easy to move. One disadvantage with the mouse and the graphics tablets is that they occupy prime table space to the right of the keyboard, in the space where users like to write.

Operators of touch screens and light pens sit with an extended arm, which could induce muscle fatigue.

Control movement stereotypes

People have expectations about what to do with controls. In the U.S., a light switch is moved upwards to turn on the light. For a person raise in SA, it is the opposite expectation – the switch is turned down. Control movement stereotypes are trained expectations, and many have been learned since childhood.

The stereotype for opening the traditional tap is always to turn the control counter clockwise, and to turn the control clockwise to close the tap.

Control-response compatibility

The problem with the design of the stove top is that there is no clear control response compatibility. Ideally, there should be a one-to-one relationship between the controls and the responses (burners). It would be easy to redesign the stovetop so that there is control-response compatibility. For example, the rear burners can be offset slightly to the side. The controls can then be lined up one-to-one with the burners, and the association is immediate.

The stovetop represents a familiar and common problem in control-response compatibility. In manufacturing, it would be expected that workstations should be designed with similar considerations. In designing a workstation for manual assembly one must line up part bins so that they are compatible with the assembly process.

Coding of controls

Controls can be coded by adding features to them. This makes them easier to distinguish. There are six common types of control coding:

1. Location
2. Colour
3. Size
4. Shape
5. Labelling
6. Mode of operation

These principles apply to controls in automobiles and airplanes, as well as industrial and office environments

Coding by location

Coding by location is the most powerful principle e.g. in a car.

Coding by colour

In colour coding, items are coloured differently depending upon the function and the task. One potential problem with colour coding is that it only works in a well illuminated environment.
Colour coding requires a longer reaction time than location coding, since it is first necessary to reflect on the meaning of the colour before the task can be performed. This typically involves a double reaction time.

Coding by size

To distinguish easily between different controls, size can be one coding option.

Coding by shape

Controls can be coded by shape. The best control design is when the control shape resembles the control function. In an airplane the flap control resembles the flap and the landing gear resembles a wheel so that the association is immediate.

Coding by labelling

A label may be used to describe a control. The label can be put above, underneath, or on top of the control. The location of the label does not really matter as long as it is clearly visible and the wording reads from left to right.
As with colour coding and shape coding, the use of label coding implies a double reaction time; the label has to be read and understood before action can be taken.

Coding by mode of operation

Controls can also be coded by the mode of operation. This implies that each control has different feel or that each control has a unique method of operation. A car driver can distinguish between the accelerators and brake because they have different control resistance, dampening, and viscosity. The same principles may be used for controls in industrial settings.

Coding of other items touched by the hand; hand tools and parts in manufacturing

Coding principles can be applied to any items that are touched or held; it could be parts to be assembled as well as hand tools. Hand tools and parts can be coded by location, colour, and labelling. Hand tools are often coloured with different colours. This makes it easier to find them.

Explain the guiding principles for the organisation of items at a workstation

All items in a workstation that require handling need to be organised efficiently. This includes controls, hand tools, parts to be assembled and part bins. Some guiding principles are clearly needed, especially ergonomics-related principles, as described below.

Keep the number of items touched by the hand to a minimum

Minimise the number of hand tools, the number of different parts, and the number of controls. It is important for product designers to understand the implications of their designs in terms of manual labour. Why use five varieties of screw when two are enough?

Arrange the items (controls, hand tools and parts) so that the operator can adjust his or her posture frequently.

Sometimes the location of items ties up workers in impossible work postures. For example, in using an industrial punch press the operator must hold the work item with both hands and press the foot control to initiate the pressing action. Using just one foot causes one-sided strain that is likely to lead to back problems. It must be possible to move the foot control so that it can be operated with either foot at the worker's convenience.

Consider preferences in hand movement and handedness

People can move their hands both faster and with much better precision in an arc than horizontally or vertically.

Handedness is important in the design of hand tools, particularly those intended for tasks which require skill and dexterity. Assembly tasks do require skill and dexterity, and thus hand tools for left-handed individuals are needed.

Explain the principles that guide the designing of symbols and labels

Symbols

Symbols are often used in industry to identify controls, machine functions, and states of processes. Symbols are also widely used as traffic signs and for public information at airports and train stations. The idea is that a picture can convey a 1000 words, so a symbol can be more succinct than a label with many words. The other assumed advantage is that symbols do not have to be translated and can be understood by individuals throughout the world.

Some symbols are difficult to understand, particularly those that relate to abstract machine functions that may be had to visualise or recall. In such instances, it is better to use a label.

Labels

The main constraint in designing labels is that the message must be short; otherwise it will not be read. Broadbent pointed out that an affirmative, active statement is easier to understand than a passive statement. Negative statements require a double reaction time, since the user must first understand what not to do, and then, only by inference, is the appropriate action clear.

Explain the stages in the processing of information on warning signs

There are several distinct stages in processing information on warning signs. An individual is first exposed to a warning sign. There are several factors that make people look at a sign. The size of the sign is clearly important: the bigger the better. Location is also important. One should position a sign where people tend to look.

Having processed the sign, we would expect that the semantics of the sign will make it possible for the worker to draw a clear conclusion. The individual must also agree with the conclusion. If there is no agreement he will not take any action. Following a agreement, the individual must select and execute one of many alternative responses. This selection of response depends largely on experience; an experienced individual has a greater response repertoire.

Attention and active processing

Individuals will attend to a sign if they perceive that the sign is relevant. Unfortunately, many individuals regard warning signs as irrelevant. Because the hazard is not perceived, the warning sign is not read. This is also one of the basic problems in motivating workers to work safely: the hazard is simply not perceived, so there is no need to work differently.

It is possible that workers develop strong coping mechanisms that make them underestimate hazards, particularly if these hazards are inherent in their own job. The warning contradicts the worker's mental model of what is safe and unsafe. The same basic problem prevails in safety training. Participants feel the training is directed at others but not at themselves.

Another basic problem is that accidents happen fairly infrequently and, therefore there are not enough current warning examples. This is more of a problem for young workers who may have never seen an accident. Older workers are more perceptive and motivated to comply with safety instructions. One could make something happen that could reinforce the sense of hazard.

Comprehension and agreement

In comprehending the meaning of words, there is a trade-off between detailed description and the use of simple words. Simple words may not be illustrative enough, whereas detailed descriptions will not be read. Wogelter et al. (1985) suggested that there should be four fundamental elements in warning signs:

- Signal word: to convey the gravity of the risk; for example, “Danger”, “Warning” or “Caution.”
- Hazard: the nature of the hazard.
- Consequences: what is likely to happen if the warning is not followed?
- Instructions: the appropriate behaviour required to reduce the hazard.

The main reason for a short warning is the limited capacity of the human short-term memory. Typically, the short-term memory can store about seven “chunks” or concepts. But short-term memory is constantly upgraded to include current items, and half of the memory is therefore replaced in 3 – 4 sec.

Selecting and performing a response

An individual may have fully comprehended a warning sign and may also be in full agreement, but may select to do something different because there is a cost of compliance. Employees often select not to be safe. Safety glasses, steel-toed boots, respirators, and other personal protective equipment are perceived of as being inconvenient and uncomfortable. The cost of compliance is too high, unless the company decides to change the cost equation by enforcing safety rules.

Another issue is whether the action implied by a warning sign can be incorporated in the regular work task.

Study unit 6

Anthropometry in workstation design

Discuss the concept of anthropometrics and its implications for HFE and specifically refer to individual and group differences, including cultural ones.

Anthropometry is a branch of ergonomics that deals with the measurement of human body dimensions and certain other physical characteristics of the body. Such measurements are vital conceptual data used in the design and assessment of facilities or products that people use. Anthropometry is a widely applied scientific discipline used in measuring and assessing body dimensions and proportions of the world's population groups. Body dimensions are very important in the design of workstations, tools and equipment.

Just as people from various countries and various racial groups differ in language, culture and habits, they also differ in body dimensions and body proportions. Helander (2006, p147) points out that a car that would fit the population of the USA would fit only 10% of the population of Vietnam. In a similar context Wickens, Lee, Lui and Becker 2004, p 245) refer to a study by Ashby that found that "if a piece of equipment was designed to fit 90% of the U.S. male population, it would fit roughly 90% of Germans, 80% of Frenchmen, 65% of Italians, 45% of Japanese, 25% of Thai, and 10% of Vietnamese".

This type of problem also occurs in industrially developing countries. Specialist mining equipment is imported from other continents and used "as is". Within weeks the operator have adapted the equipment with old sponges, duck tape and wire. What at first looks like vandalism is nothing more than the operator's attempt at ergonomic design to improve the equipment.

Therefore, it is very important to define the likely range of people who will be using the relevant workstation or equipment. For example, the end-users must be identified and their body dimensions (anthropometric data) should be used in the design of the work station or equipment.

Discuss the problems associated with anthropometric databases

Anthropometric surveys are time-consuming and expensive and as Wickens, Lee , Liu and Becker (2004, p250) mention "most anthropometric surveys were done with special population, such as pilots or military personnel". This is also a reason why military data is often used for civilian populations, although there are differences between the two groups, that the HFE practitioners should take note of when designing for civilians.

Explain normal distribution and percentiles in a HFE context

Within any sizeable group, body dimensions are distributed along a bell-shaped configuration (normal curve), where a small number of measurements appear at either end of the scale, but most are grouped within the middle positions. It is common in ergonomics solutions to design for 90% of the upper population and to exclude the 5% above and the 5% below the average.

The population can be divided into 100%ge categories, ranked from least to greatest, according to some specific type of measurement, in this case body measurement. If we divide a body of data equally into a hundred groups, then each group is a percentile. Percentile values provide a convenient means of describing the range of body dimensions to be accommodated in the designs. This makes it easy to locate the percentile equivalent of the measured body dimension. For example, 5^{th} percentile stature is a value whereby 5% of the population are short and 95% are taller. 50^{th} percentile stature is the median stature, where 50% of the population are short and 50% are tall. And 95^{th} percentile stature is the value whereby 95% of the population are shorter than the 5% who are tall. There is no individual who is 5^{th}, 50^{th} or 95^{th} percentile. Percentile refers to one body dimension only. 50^{th} percentile does not mean both 50^{th} percentile stature and 50^{th} percentile sitting height.

Explain the use of anthropometric data in the design or improvement of equipment, work environment and products.

Evaluate and criticise equipment, facilities and products that do not meet the basic ergonomics requirements of the South African user population and environment

Discuss the different body dimensions and anthropometric measures of relevance for workplace design (refer specifically to table 8.3 and figure 8.5)

Apply anthropometric data to the design and evaluation of a workstation

Discuss why three-dimensional models for anthropometric design are preferred by designers

Discuss what advantage can be gained by using 3D measurement, compared to the traditional two-dimensional methods

Discuss what aspects you have to take into account when designing for the seated operator

Apply ergonomics principles to the practical design and layout of a computer workstation

Discuss the body dimensions regarded as important when designing, buying or evaluating a workstation; give reasons why the body dimensions you have chosen are important; and take into consideration the range of possible users of the workstation

Explain the difference between the traditional office and the modern office, and identify the equipment generally used in the modern office.

Explain what constitutes a good ergonomic office chair

Explain the meaning of “free posturing”

Explain why computers are especially useful for the physical handicapped

Describe which environmental factors have to be taken into consideration when designing workstation

Discuss the most prevalent myths concerning computer workstations

Study Unit 7

Work posture, or designing to fit body posture

Discuss the problem(s) that users often face when engineers had been in charge of the design process

Many engineers tend to focus on the engineering aspects; the work station, if even considered, is designed as an afterthought.

One conventional engineering solution is to use an industrial height workstation with a 92 cm high work table. This can accommodate both sitting and standing operators. The working height for the standing operator is about 92 cm, and a sitting operator can use a high industrial chair with a ring support or a footrest. Such flexibility in a workplace is indeed desirable; however, the use of a conventional industrial height workstation can also create problems. It is not an appropriate design solution for dedicated seated tasks.
When designing if there is no reason to consider a standing work posture, a regular table should be used. This would have the benefit that the operator can put his or her feet on the floor, which improves comfort.
In focusing on the technical aspects of the problem, engineers often forget the critical aspects of human performance. It seems that the greater the technological challenge, the greater the likelihood that the human element will be forgotten in engineering design.
In some cases machines are not designed with maintenance ability in mind.

To avoid these types of problems, engineers must expand their responsibilities and consider human factors engineering and ergonomics when they design manufacturing processes and workstations. Ergonomic problems are unproductive as they introduce human errors and result in costly quality defects.

Explain the different body postures found in the world of work and the problems associated with them. Use practical examples to illustrate your answer

Type of Posture	Location of complaint	Example
Standing	Feet, lower back	Security guard
Sitting without lower back support	Lower back	Cashiers
Sitting without back support	Central back	Cashiers
Sitting without proper foot support	Knees, legs, lower back	Short typist without a height adjustable chair
Sitting with elbows on a high surface	Upper back, lower neck	Typist
Unsupported arms or arms reaching up	Shoulders, upper arms	Mechanic
Head bent back	Neck	Painter
Head bent forward	Lower back, central back	Typist without a document holder
Cramped position	Muscles involved	Welder
Joint in extreme position	Joints involved	Mechanic

Discuss common complaints that are linked to different types of work posture

Type of Posture	Location of complaint
Standing	Feet, lower back
Sitting without lower back support	Lower back
Sitting without back support	Central back
Sitting without proper foot support	Knees, legs, lower back
Sitting with elbows on a high surface	Upper back, lower neck
Unsupported arms or arms reaching up	Shoulders, upper arms
Head bent back	Neck
Head bent forward	Lower back, central back
Cramped position	Muscles involved
Joint in extreme position	Joints involved

Explain the HFE considerations associated with body postures such as sitting, standing and sit-standing at work

Depending on the type of task, it is advantageous for an operator to stand, sit, or sit-stand.

- If there is frequent handling and lifting of heavy objects it is preferable to stand up. However sit-standing may be an option.
- For packaging, or other tasks where objects must be moved vertically below the elbow height, it is preferable to stand or sit-stand. A sitting posture would not be feasible since the hands are reaching downwards and the table cannot be put at a sufficiently low level without interfering with the operator's legs.
- If the task requires extended reaching, it is sometimes preferable to stand or sit-stand, as the operator can then reach further.
- Light assembly work with repetitive movements is common in industry, and sitting is preferred.
- For fine manipulation and precision tasks the operator must support the underarms. Sitting is definitely preferred.
- Visual inspection and monitoring is best done sitting.
- If the work task involves a variety of subtasks and also frequent moving around, it may be preferable to sit-stand, since the operator does not have to get in and out of the chair.

Discuss which position is the most suitable for various tasks or activities

Sit-standing workplaces have become increasingly common in industry during the last ten years. Sit-standing is convenient for many tasks, and there are biomechanical advantages since the pressure on the spine and the lower back is about 30% lower for sit-standing and standing as compared to sitting.

Explain the importance of correct body posture at a workstation in task performance

Correct body posture increases the comfort of users and as a result ensure optimal performance and maintain good health.

People who work in awkward spaces and with awkward postures tend to have accidents and complaints about painful feet, lower back, knees, shoulders, neck, muscles involved and joints involved.

To avoid these types of problems, engineers must expand their responsibilities and consider human factors engineering and ergonomics when they design manufacturing processes and workstations. Ergonomics problems are unproductive as they introduce human errors and result in costly quality defects.

Explain what one has to take into consideration when determining or calculating table or work surface height.

There are standard recommendations in the ergonomics literature for table height for seated and standing workplaces. To arrive at a suitable hand position the work table must be put at a lower height for a tall product and higher height for a short product.

Demonstrate your ability to calculate the correct height of a work surface

To calculate the recommended table height one has to take the following factors into consideration:

- Individual's preferred posture
- Elbow height above the floor
- Handling height of the product or object

Draw up a check list that you can use to evaluate the suitability of a conveyor belt layout. Include possible remedial actions for design faults

CRITERIA	CHECK
The height of the conveyor belt must be different at different locations	
The conveyor height must be convenient for manual work	
The conveyor height should depend on the size of the object that is being handled.	
If the work along the conveyor is performed sitting, the hand height should be the same as for other sitting workplaces	
There must be leg room and knee room as with other seated workplaces	
The conveyor must be thin so that it can fit in the space between the thighs and underarms	
The conveyor must be accessible from both sides so that two people can work together	
It is important to provide crossing points or gates where people and material can be brought through	
It should be possible to slide assemblies along the conveyor rather than to lift them	
Products typically weigh more when they come off the conveyor line after the assembly therefore precaution should be taken to prevent back injuries caused by overexertion	
The conveyor speed must be less than 10 m/min because if it is greater than that operators can develop nausea and dizziness	
Operators must not seat sideways to the conveyor so as to perceive the conveyor motion in the peripheral vision because that might cause nausea and dizziness	

Discuss the subjective and objective methods for the assessment for musculoskeletal problems in the workplace and the ergonomic implications of work posture.

There are two types of methods for assessing musculoskeletal problems: subjective assessments performed by employees, and objective assessments performed by an analyst.

Subjective methods

There are two methods that can be used by employees to evaluate musculoskeletal problems:

- A part discomfort scale and
- The use of questionnaires

Body part discomfort scale

The amount of discomfort is linearly related to the amount and the duration of a particular force. The longer the force is held, the greater discomfort reported. To specify the location of the discomfort the body map is used. The body is divided in segments and the person is asked to rate the amount of comfort on a seven (or five) point scale, where 0 corresponds to no discomfort and 7 to extreme discomfort.

Often the discomfort will be localised to a few areas of the body. It is then possible to ask about the discomfort in those locations and ignore the other locations.

Questionnaires

Several questionnaire evaluation methods have been developed and validated. One popular method is the Nordic questionnaire for evaluation of musculoskeletal problems. This is s multiple-page questionnaire. Another tool developed at the Swedish National Board of Occupational Safety and Health is a single-sheet analysis for identifying musculoskeletal problems. This tool is self-explanatory and can be used for example to make before and after comparisons to demonstrate the effectiveness of ergonomic improvements.

Objective methods

There are two objective measures of work posture:

- OWAS and
- RULA.

OWAS method

The OWAS method was developed in Finland. By using OWAS one can code work postures using a three-digit code, to which three more numbers are added to describe the amount of force and the work phase. An experimenter observes the worker, makes an assessment of the posture, and records the result on the data sheet. The results from all work phases are then assembled, and an assessment is made whether there is a need to take immediate action to improve the design of the work station or the task. Such immediate action

would be prompted if, for example, the person works with a bent and twisted back or with bent knees for more than 70% of the time.

RULA Method

Rapid upper limb assessment (RULA) is similar to OWAS. Postures are evaluated using numbers; the greater the number, the worse the posture. Values of force are then estimated.

Study unit 8

Manual materials handling

Describe the human cost and the economic consequences that manual materials handling may inflict

In the U.K., for the period 2001 – 2002, 27% of all reported accidents involved manual handling. An estimated 12.3 million workdays were lost. Manual handling and lifting are the major causes of work-related back pain.

However, back pain, and in particular low back pain, is also common in other work environments such as seated work, where there is no lifting or manual handling. In fact, back pain is extremely common. During a lifetime, there is a 70% chance of developing low back pain, and there is a 1 in 7 chance that any individual will be suffering from back pain presently.

Explain lifting techniques, and how the size of the object may invalidate a technique

The guidelines for correct lifting techniques – straight back, bent knees – have become quite controversial in recent years. The first observation is that this technique only applies to small compact objects that can be held between the legs while lifting. Large boxes, for example, are too large to lift with the straight back, bent knees technique. For many lifts, this technique is simply difficult and awkward and it will not be used by workers. Furthermore, Garg and Herrin calculated disc compressive force and concluded that stoop lifting (bent back, straight knees) is sometimes superior to squat lifting (straight back, bent knees).
Other correct lifting techniques are:

- Squatting while lifting
- Carrying weight with straight arms
- Arms remaining straight while lifting
- Using leg muscle to lift items.

Explain work, environment and personal factors to be considered in a workstation organisation.

1. **Characteristics of the Load**

The manual handling of a load may present a risk, particularly of back injury, if it is

- too heavy or too large
- unwieldy or difficult to grasp
- unstable or has contents likely to shift
- positioned in a manner requiring it to be held or manipulated at a distance from the trunk, or with a bending or twisting of the trunk
- likely that its contents and/or consistency would result in injury to workers in the event of a collision.

2. **Physical effort required**

A physical effort may present a risk, particularly of back injury, if it is

- too strenuous
- only achieved by a twisting movement of the trunk
- likely to result in a sudden movement of the load
- made with the body in an unstable posture.

3. Characteristics of the working environment

The characteristics of the work environment may increase a risk, particularly of back injury, if

- there is not enough room, in particular vertically, to carry out the activity
- the floor is uneven, thus presenting tripping hazards, or is slippery in relation to the worker's footwear
- the place of work or the working environment presents the handling of loads at a safe height or with good posture by the worker
- there are variations in the level of the floor or the working surface, requiring the load to be manipulated on different levels
- the floor or foot rest is unstable

4. Requirements of the activity

The activity may present a risk particularly of back injury if it entails one or more of the following requirements:

- over-frequent or over-prolonged physical effort involving in particular the spine
- an insufficient bodily rest or recovery period
- excessive lifting, lowering, or carrying distances
- a rate of work imposed by a process which cannot be altered by the worker.

5. Individual risk factors

The worker may be at risk if he/she

- is physically unsuited to carry out the task in question
- is wearing unsuitable clothing, footwear, or other personal effects
- does not have adequate or appropriate knowledge or training

Discuss guidelines and standards for lifting

NIOSH guidelines

In developing the present guidelines, three criteria of lifting were considered: biomechanical, physiological, and psychophysical.

The biomechanical criterion was based on calculating the compressive forces in the L5/S1 disc. Several studies have indicated that, during lifting, the largest moments are created in the trunk area and the L5/S1 disc is at greatest risk.

The physiological criterion evaluates the metabolic stress and muscle fatigue that may develop during lifting. The criterion is most important for frequent lifting. To limit muscle fatigue the maximum aerobic work was set to 9.5 kcal/min.

The psychophysical criterion, took into consideration the acceptability of lifts to workers. This type of criterion is based on subjective judgement among workers; the chosen limit for lifting should be acceptable to 75% of female workers and 99% of male workers.

The NIOSH equation for calculating the recommended weight limit (RWL) represents a compromise between the three different criteria.

European Community guidelines

The Council of the European Communities has also formulated qualitative requirements for manual handling of loads “where there is a risk of back injury to workers”. This directive mandates employers to organise workstations to make manual handling a safe activity.

Work, environment, and Personal Factors to be Considered in Workstation Organisation.

6. **Characteristics of the Load**

The manual handling of a load may present a risk, particularly of back injury, if it is

- too heavy or too large
- unwieldy or difficult to grasp
- unstable or has contents likely to shift
- positioned in a manner requiring it to be held or manipulated at a distance from the trunk, or with a bending or twisting of the trunk
- likely that its contents and/or consistency would result in injury to workers in the event of a collision.

7. **Physical effort required**

A physical effort may present a risk, particularly of back injury, if it is

- too strenuous
- only achieved by a twisting movement of the trunk
- likely to result in a sudden movement of the load
- made with the body in an unstable posture.

8. **Characteristics of the working environment**

The characteristics of the work environment may increase a risk, particularly of back injury, if

- there is not enough room, in particular vertically, to carry out the activity
- the floor is uneven, thus presenting tripping hazards, or is slippery in relation to the worker's footwear
- the place of work or the working environment presents the handling of loads at a safe height or with good posture by the worker
- there are variations in the level of the floor or the working surface, requiring the load to be manipulated on different levels
- the floor or foot rest is unstable

9. **Requirements of the activity**

The activity may present a risk particularly of back injury if it entails one or more of the following requirements:

- over-frequent or over-prolonged physical effort involving in particular the spine
- an insufficient bodily rest or recovery period
- excessive lifting, lowering, or carrying distances
- a rate of work imposed by a process which cannot be altered by the worker.

10. **Individual risk factors**

The worker may be at risk if he/she

- is physically unsuited to carry out the task in question
- is wearing unsuitable clothing, footwear, or other personal effects
- does not have adequate or appropriate knowledge or training

Safety and Health Commission Guidelines from the U.K.

The Health and Safety Commission in the U.K. developed consultative guidelines for material handling.

Guidelines for lifting according to the Health and Safety Commission (1991)

TABLE 10.8 Page. 203

The criterion for the development of the guidelines was to consider a boundary "beyond which the risk of injury is sufficiently great to warrant a more detailed assessment of the work system." The guidelines are for lifts performed less than once per minute "under relatively favourable conditions." This implies a stable load which is easy to grasp and an upright work posture with a non-twisted trunk. Under such circumstances the guideline figures are assumed to provide reasonable protection to nearly all men and between one-half and two-thirds of women. There are also correction factors for stooping and twisting the body.

Explain the methods that can make materials handling affordable and manageable

The planning for materials handling and smooth transportation should start at the product design stage. One important aspect of product design is “design for ease of handling and transportability.” Thus a product could have a smooth bottom, which makes it easier to transport on conveyor belts. The product can also be equipped with handholds to simplify manual lifting.
Just-in-time (JIT) manufacturing may also be implemented. JIT manufacturing is to structure the transportation activities. According to this philosophy, smaller quantities of parts are delivered to a manufacturing plant and then distributed to workstations, just in time for processing and assembly. The need for storage of parts and products is reduced. The manufacturing plant can be made smaller, and the cost of buying land is also reduced.

Describe the various materials handling devices and their possible uses

- Conveyor
- Snake conveyors
- Ball transfer table
- Carts
- Carousels
- Turntables
- Cranes
- Hand trucks
- Gravity feed conveyors/slides

Refer table 10.9

Explain the difference between horizontal and vertical transportation

Horizontal transportation is transportation from one horizontal point to another without any upwards movement.
Vertical transportation is transportation of an item from one vertical point to another for an example transporting an item from the ground to the table.

Study unit 9

Repetitive motion injury and design of hand tools

Describe the causes of cumulative trauma disorders or repetitive motion injury

Inappropriate work methods

- Repetitive hand movements with high force
- Flexion and extension of hand
- High force pinch grip
- Uncomfortable work postures
- Lack of experience of manual work
- New job
- Back from vacation

Inappropriate leisure activities

- Insufficient rest due to working in a second job
- Knitting, playing musical instruments, playing tennis, bowling,
- Home improvement work

Pre-existing conditions

- Arthritis, bursitis, other joint pain
- Nerve damage
- Circular disorders
- Reduced oestrogen level
- Small hand/wrist size

Explain the guidelines for reducing cumulative trauma disorders or repetitive motion injury

Guidelines for hand posture

- Watch out for sudden flexion or extension of the hand or fingers
- Avoid extreme ulnar deviation and radial deviation
- Avoid operations that require more than 90 wrist rotation
- Keep forces low during rotation or flexion of the wrist
- For operations that require finger pinches keep the forces below 10 N; this represents 20% of the weaker operators' maximum pinch strength.

Guidelines for hand tools

- Cylindrical grips should not exceed 5 cm in diameter
- Avoid gripping that spreads the fingers and thumbs apart by more than 6 cm

- Use hand tools that make it possible to maintain the wrist in a neutral position
- Guidelines for workstation design
- Keep the work surface low to permit the operator to work with elbows to the side and wrists in a neutral position
- Avoid sharp edges on the work table and part bins that may irritate the wrists when the parts are procured; keep reaches within 50 cm from the work surface so that the elbow is not fully extended

Guidelines for process engineering

- Allow machinery to do repetitive tasks and leave variable tasks to human operators
- Provide fixtures that hold parts together during assembly, and which can present the assembly task at a convenient angle to the operator
- Minimise time pressure or pacing pressure by allowing operators to work at their own paces.

Guidelines for product design

- Minimise the number of screws and fasteners used in the assembly
- Minimise the torque required for screws
- Locate fasteners and screws at “natural” angles so they are easy for the operator to insert
- Design a product with large parts to permit gripping with fingers and palm instead of pinching.

Explain design guidelines for hand-tool design

For precision grip

- Grip between thumb and finger
- Grip thickness 8 – 13 mm
- Grip length minimum 100 mm
- Tool weight maximum 1.75 kg
- Trigger activated by distal phalanges of finger(s) with fast-release
- Locking mechanism

For power grip

- Grip with entire hand
- Grip thickness 50 – 60 mm
- Grip length minimum 125 mm
- Grip force maximum 100 N
- Grip shape non-cylindrical, preferably triangular with 110 mm periphery
- Tool weight maximum 2.3 kg, preferably about 1.2 kg
- Trigger activated by thumb with locking mechanism

General guidelines

- Grip surface smooth, slightly compressible and non-conductive
- Avoid vibration, particularly in the range of 50 – 100 Hz
- Design handles for use by either hand
- Keep the wrist straight in handshake orientation
- Tool weight balanced about the grip axis
- Eliminate pinching hazards

Study unit 10

Noise and vibration

Explain the harmful effects of noise on people and also on human performance

There are no clear-cut effects of noise on performance. The existing studies simply do not cover a sufficient range of noise and task conditions to be able to draw firm conclusions and formulate a viable theory. Helander draws the following guarded conclusions about the effects of noise:

1. Visual functions, such as visual acuity, eye focusing, and eye movements are little affected, if at all, by noise.
2. Motor (manual) performance is rarely affected by noise.
3. For the performance of simple, skill-based, routine tasks, noise may have no effect.
4. For rule-based tasks where the individual makes quick choices between different alternatives, noise may have some effect, particularly if the noise is louder than 95 dBA.
5. The detrimental effects of noise seem to be associated primarily with knowledge-based tasks, where operators must apply their knowledge of different scenarios, think hard, and make tentative conclusions.

Explain how noise can interfere with communication

Noise can have a psychological impact on the individual. There are instances when we are irritated by noise: noise emitted by a plane taking off; noise by others while we are watching the news or our favourite TV programme.

A huge truck that emits excessive nose passes by while you are on the phone; a fellow learner makes a noise in a classroom or discussion class while the learning facilitator or another learner is speaking.

Describe the two types of hearing protectors

There are two types of hearing protectors that are commonly used in industry: ear plugs and ear muffs.

The plugs are designed to occlude the ear canal and are available in many types of material. Cotton has traditionally been used, but unfortunately, it affords no protection. Ear plugs made out of rubber, neoprene, glass down, and plastics offer good protection. Custom-moulded ear plugs are also available. They are made individually to fit the ear canal and offer excellent protection.

Ear muffs are designed to cover the entire external ear. They consist of ear cushions made of soft spongy material or specially filled pads to ensure a smug fit.

Ear plugs provide a sound attenuation of between 15 dB for low frequency sounds and 35 dB for higher frequencies. At frequencies above 1000 Hz, muffs provide about the same protection as plugs. At frequencies below 1000 Hz, certain muffs provide more protection than plugs. Ear plugs and ear muffs may be worn together in intense situation. This combination provides an additional attenuation of approximately 5 dB.

Describe the methods for the reduction of noise in manufacturing plants

In a manufacturing plant one can take many different measures to reduce the noise. The noise can be controlled at the noise source, by reducing the structure-borne transmissions of noise, and by reducing the airborne transmissions of noise.

Several measures have been taken to reduce noise, including the following; using vibration isolation mounts, placing heavy vibrating equipment on a separate rigid structure, and using air intake muffler with laminar flow of air. The structure-borne transmissions have been reduced, for example, by use of flexible pipe on the air intake and sound isolating joints between the vibrating equipment and the floor. Finally the airborne transmission has been reduced by using sound absorbing ceilings and shields, and by enclosing noise sources in a control room and in the basement.

Explain the two types of vibration and the consequences of exposure to the two

There are two major kinds of vibration: whole-body vibration and hand vibration (commonly referred to as segmental vibration).

Whole-body vibration

A common source of whole-body vibration is from transportation vehicles where drivers are exposed to a vibration generated by the vehicle and the roadway.

Laboratory studies have confirmed that vibrations between 3 and 5 Hz are likely to be physically uncomfortable at an acceleration level of approximately 0.1 g, to be painful and distressing at intensities of about 1 g, and to cause injuries if the acceleration exceeds 2 g.

In addition to the discomfort effects of vibration, there are several reputed health effects, such as various spinal, anal-rectal, and gastrointestinal disorders.

Exposure to vibration also induces physiological responses. The most basic physiological response to a moderate level of vibration is an increase in heart rate, about 10 – 15 beats/min above the resting level. The heart rate returns to its normal level after the vibration ceases. Blood pressure can also increase, particularly for vibration frequencies around 5 Hz. Some investigations have revealed a slightly increased breathing rate and oxygen consumption.

Another notable finding is that at vibrations of about 10 – 25 Hz, the vision acuity level decreases.

Whole-body vibration also effects both cognitive and motor performance. Sherwood and Griffin noted that whole-body vibration impairs learning.

Segmented vibration (hand vibration)

Hand –tool vibration can cause vibration injuries. There are two common types of vibration injuries: Reynaud's disease (or white finger disease) and Dart's disease.

Reynaud's disease is caused by hand-tool vibration in the frequency range 50 – 100 Hz. The white fingers are caused by a reduction in blood flow to the hand and to the fingers, which is due to constriction of the smooth muscles of the blood vessels in the hand and fingers. Both the nerves and the blood vessels in the hand are permanently damaged. The reduction in blood flow causes stiffness and numbness of the fingers and gradual loss of muscle control of the hand.

Dart's disease is less common. This disease is caused by vibration frequencies around 100 Hz. In Dart's disease, blood pools in the hands, which become blue, swollen and painful.

One way of reducing the transmission of vibration is to use a vibration attenuating handle.

Study unit 11

Accidents, human errors and safety

Discuss the definitions of an accident, also referring to the different approaches followed by different professions.

- Something without an apparent cause
- An unexpected unintentional act
- A mishap
- A chance occurrence
- An act of God

Explain the interactive model of accidents, after briefly referring to the energy exchange model, the chain of events and the systems safety approach to accidents

Energy Exchange model

Schutzinger claimed that accidents result from the integration of a constellation of forces. Hadden thought of accidents as an occurrence of an “unexpected physical or chemical damage” to living or non-living structures. Injuries are produced by energy transfer and exchange of mechanical, thermal, or electrical energy.

The energy exchange model does not attribute causes to accidents, but the model can be useful to suggest effective barriers to accidents, such as soft road sides, seat belts, airbags, and removal of roadside trees. Through these measures the energy is distributed over a greater area and absorbed over a longer time.

Chain of Events

Arbour and Kerrick considered an accident an “unplanned event in a chain of planned or controlled events.” According to this model each accident is the result of a series of chain of events. No singular cause exists; many factors influence the accident.

System safety

We learn from this model that accidents have multiple causations, and must be analysed as such. There are no simple answers to accident causation.

First there is exposure to hazardous situation. The victim must then be able to perceive the hazard, understand the gravity of the hazard, make a decision to avoid, and finally take the correct action. But there is still a chance that the action that is taken will not be enough.

Interactive Model of Accidents

The state of the accident scene can be described using several different factors. None of these factors has precedence over the others. The accident was caused by interactivity among the factors – not by a single cause.

The constant blaming of the operator represents an oversimplification of causality. A problem with interactive accidents is that the number of factors and the number of interactions and potential causes becomes very large, and therefore accidents become difficult to analyse and describe.

Discuss human error, especially referring to the aspects that lead to accidents

Human error is a primary cause of 60 – 90% major accidents. Accidents happen because of the operator's misinterpretation, wrong decision, lack of knowledge, or silly mistake. This does not mean that humans must be held responsible for the errors they commit. Human errors are very frequent in daily life and they appear in all walks of life. There are many reasons for errors, including poor discriminability, memory lapses, and communication breakdown.

Poor visual discriminability
When an operator cannot see instructions or signals he is likely to make mistakes.

Memory lapses
A system with mode control can be difficult to control, and sometimes a user selects the wrong mode. The system operates so that one action is appropriate in one mode of operation, and another action in another mode; in Mode A the operator must take action X, in mode B he must do Y, and so forth. The problem with mode controls is that people are easily distracted and forget what mode they are in.

Communication breakdown
There may be several reasons for a communication breakdown; one common reason is the difference in status. Sometimes the boss is dominating and the subordinate is submissive. The submissive subordinate may be scared to warn the boss that he is making a mistake that might lead to an accident.

Discuss James Reason's error model in detail, making use of the relevant diagram

Figure 18.5 Page 337.

Discuss errors in an organisational context

Human errors in organisation may be blamed on organisational deficiencies. Accidents, because they are so visible, are often analysed, but less visible organisation errors are not analysed. Accidents represent the tip of the iceberg. Underneath the surface there are many organisational deficiencies that limit productivity as well as quality. Such deficiencies may be due to poor communication policies and poor operating procedures. The same organisational characteristics that cause unsafe acts and accidents will also decrease productivity and quality.

Many of the errors that people commit in operating equipment systems are the results of poor design and poor organisational structure, rather than irresponsible action. Before the human error occurred there were several mechanical and organisational errors. But the organisational errors are more difficult to identify. They are abstract and not so visible. Environment must be designed for human beings, taking into account all their vulnerabilities and competencies – if not, the system is not appropriately designed.

Explain the role ergonomics plays in accident prevention

Human factors and ergonomics are highly related to industrial safety. If workers can perceive hazards, if there are relevant warning signs, if controls are easy to use, if work postures are acceptable, if noise and other environmental stressors are reduced, if there is collaboration between workers and management based on mutual understandings, and if there is good housekeeping, then safety will improve. Ergonomics safety measures focus on the operator and are different from the conventional approach taken in industrial safety. Ergonomics can improve safety through worker's attitudes, perception, decision-making, and risk taking.

Briefly describe different safety programmes and also refer to their effectiveness

Studies were done on different safety programmes and their effectiveness in preventing accidents and the findings are discussed below:

Technological interventions

These studies had a average effect size of 29%. They focused on accident prevention for robots and automation. Automation and robots bring about new types of workplace injuries. For example, a robot can catch an operator in its work envelope and press him against a structure. Thus, robots may require specific safeguards, such as sensors in the floor and on the robot itself.

Behaviour modifications

The effect size was 38.6%. A typical program consisted of basic safety information and training in safe behaviour. This was followed by a period of observation and feedback.

Comprehensive ergonomics

The effect size was 51.6%. Most of the studies involved a redesign of the work place or equipment to improve the work conditions. Employees actively participated in the program. One study emphasized the safety climate or safety culture.

International Safety Rating System (ISRS)

The effect size was 17%. This is safety audit program that addresses many topics, including management and employee training, planned inspections, task analyses, group meetings, personal communication, and accident analysis.

For this approach, operations personnel met voluntarily to discuss safety issues and problems, and to develop action plans for safety improvement.

Behavioural Safety

There is a realisation that effective safety programs can be formed if there is a consensus among workers and management. Behavioural safety is participatory approach to safety that is based on group consensus and feedback.

Study unit 12

Conducting a HFE investigation

Describe the three different investigative research methods or types of studies that are commonly used in HFE, that is to say descriptive studies, experimental research and evaluation research. Describe each briefly by referring to their definition, objectives, purposes or procedures. Also give an example of each type of research study to show that you know the difference between them.

Use an ergonomics check list to assess a workstation or any human-technology system in the real world of work to solve HFE problems.