Motion Study and Work Design

Sections:

1. Basic Motion Elements and Work Analysis – **part 1**

2. Micromotion Analysis – **part 1**

3. Principles of Motion Economy and Work Design – **part 2**

Definitions

- **Motion study** - *analysis* of the basic hand, arm, and body *movements* of workers *as they perform work*
- **Work design** - *design* of the *methods and motions* used to perform a *task*
- Includes:
  - Workplace layout and environment
  - Tooling and equipment used in the task

Motion Study and Work Design

3. Principles of Motion Economy and Work Design

Principles of Motion Economy

- Developed over **many years of practical experience** in work design

- **Guidelines** to help determine
  - **Work method**
  - **Workplace layout**
  - **Tools**, and **equipment**

- Objectives:
  - **maximize efficiency** and
  - **minimize worker fatigue**

Three Categories of Principles

1. Principles that apply to the **use of the human body**

2. Principles that apply to the **workplace arrangement**

3. Principles that apply to the **design of tooling and equipment**

1. Use of Human Body

1. Design work to **fully utilize both hands**
   - Natural tendency of most people: **use** their **preferred hand*** to accomplish most of work
   - **Other hand: minor role**, e.g. holding object, while preferred hand works on it
   - first principle:
     both hands should be used **as equally as possible**
2. The two hands should **begin** and **end** their motions **at the same time**
   - follows from 1
   - Sometimes must design method so work is **evenly divided** between **right-hand** & **left-hand side** of workplace
   - In this case, **division of work** should be organized according to following **principle** (**3**)

1. Use of Human Body

3. **Hand** and **arm motions** should be **symmetrical** and **simultaneous**
   - i.e. **minimize** amount of **hand-eye coordination** required by worker
   - since **both hands**: doing **same movements** at **same time** ⇒ **less concentration required** than if 2 hands had to perform different & independent motions
4. Design work to **favor preferred hand**
   - Preferred hand: **faster**, **stronger**, more practical
   - If the work to be done cannot be divided evenly between 2 hands ⇒ **take advantage of worker's best hand**
   - e.g. work units should:
     - enter workplace on side of worker's preferred hand
     - & exit workplace on the opposite side**

1. Use of Human Body

5. Worker's two hands should **not** be **idle at the same time**
   - **Avoid** periods when **neither hand is working**
     - It may not be possible to completely balance workload between the right & left hands
     - but it should be possible to avoid having both hands idle at the same time
   - The **exception** to this principle: during **rest breaks**
   - Work cycle of worker-machine system also exception
     - if worker is responsible for **monitoring machine** during its automatic cycle,
     - and monitoring involves using worker's **cognitive senses** rather than hands*

1. Use of Human Body

Next 5 principles of motion economy attempt to utilize **laws of physics** to assist **use of hands and arms** while working

6. Method should consist of:
   - **smooth continuous curved motions**
   - rather than **straight motions** with **abrupt changes in direction***
     - Reason behind this principle:
       - **straight-line path sequence** includes start and stop actions (accelerations, decelerations) ⇒ **consume** worker's **time & energy**
       - Motions consisting of **smooth continuous curves: minimize lost time** in starts & stops

1. Use of Human Body

7. **Use momentum** to facilitate task
   - When **carpenters strike nail with hammer** ⇒ they're using momentum ($\boldsymbol{mass} * \boldsymbol{velocity}$)
     - Imagine applying static force to do this!
   - When work situations provide opportunity to use momentum (like above): use it
     - Previous principle (**smooth continuous curved motions**) shows **beneficial use of momentum** to make a task easier
8. Take advantage of **gravity** – Don't oppose it
   - **Less time & energy** required **to move heavy object** from higher **to lower elevation** than to move object upward
   - Principle usually implemented by **proper layout and arrangement** of the workplace

1. Use of Human Body

9. Method should achieve a **natural rhythm** of the **motions** involved
   - Rhythm: motions that have **regular recurrence and flow** from one to the next
   - Basically, the **worker learns** rhythm & performs motions **without thinking**
   - Like **natural** & instinctive motion pattern in walking

1. Use of Human Body

10. Use **lowest** classification of **hand and arm motion** (five classifications)
    1) **Finger only**
    2) Finger and **wrist**
    3) Finger, wrist, and **forearm**
    4) Finger, wrist, forearm, and **upper arm**
    5) Finger, wrist, forearm, upper arm, and **shoulder**

- For **lower classification**, worker perform hand and arm **motion**: **more quickly** & with **less effort**
  - $\Rightarrow$ **work method**: should be composed of motions at **lowest classification level possible**
- Accomplished by: **locating** parts & tools **as close** together **as possible** in workplace

1. Use of Human Body

Two remaining human body principles of motion economy (11 and 12): recommendations for using **body members other than hands and arms**

1. Use of Human Body

11. **Minimize eye focus** and **travel**

- ***Eye focus*** occurs when eye must **adjust to change in viewing distance**
  - e.g. from 25 in. to 10 in., with little or no change in line of sight
- ***Eye travel*** occurs when eye must **adjust to a line-of-sight change**
  - e.g. from one location in the workplace to another, but the distances from eyes are same
- Since **eye focus and eye travel** each **take time,**
  - $\Rightarrow$ desirable to minimize need for worker to make these adjustments as much as possible
  - Accomplished by **minimizing distances between objects** (e.g. parts and tools) used in workplace

1. Use of Human Body

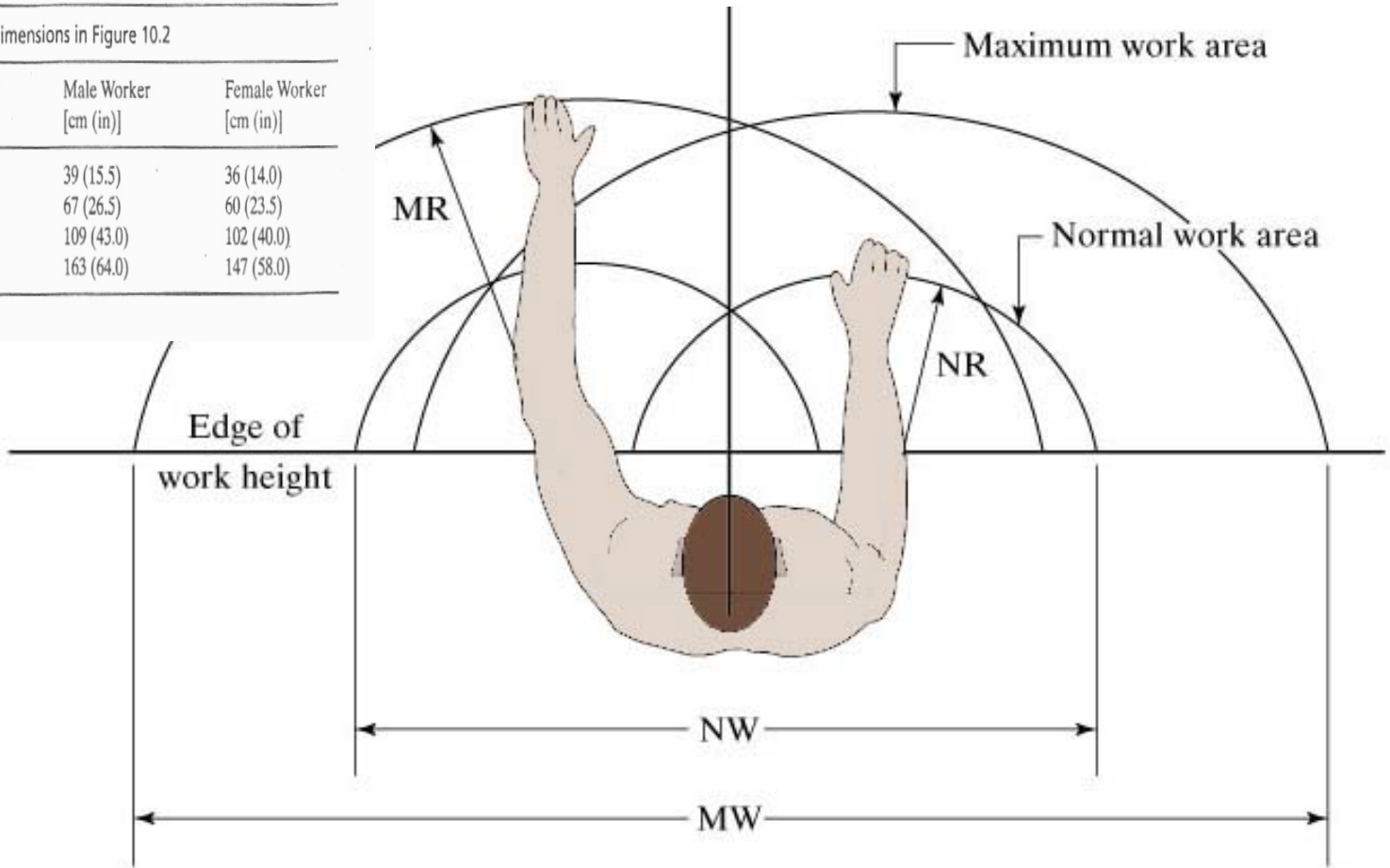
12. Design method to utilize **feet and legs** where appropriate
    - **Legs**: **stronger** than arms, although feet are **not** as **practical** as hands
    - **Work method** can sometimes be designed to **take advantage** of greater **strength of legs**
        - e.g.: in **lifting** tasks

2. Workplace Arrangement

- **Normal and maximum working areas** in the workplace

TABLE 10.6 Normal and Maximum Working Area Dimensions in Figure 10.2

Symbol in Figure 10.2	Dimension in Working Area for Worker Seated at Worktable	Male Worker [cm (in)]	Female Worker [cm (in)]
NR	Normal radius of arm reach	39 (15.5)	36 (14.0)
MR	Maximum radius of arm reach	67 (26.5)	60 (23.5)
NW	Normal width of arm reach	109 (43.0)	102 (40.0)
MW	Maximum width of arm reach	163 (64.0)	147 (58.0)



2. Workplace Arrangement

- First 3 principles:
  - Deal with **immediate work area**
  - Lead to **natural rhythm** in workplace
- Remaining principles (4 – 7):
  - Deal with **use of gravity**, and
  - **General conditions** of the workplace

2. Workplace Arrangement

1. Locate tools and materials in **fixed positions within the work area**
   - "a place for everything & everything in its place"
   - Worker eventually learns **fixed locations**,
     - $\Rightarrow$ allowing him to **reach for object**,
     - **without wasting time** looking & searching

2. Workplace Arrangement

2. Locate tools and materials **close to where they are used**
   - Helps **minimize distances** worker must move (**TE** and **TL**) in workplace
   - Any **equipment** controls should also be located in **close proximity**:
     - Refers to **normal & maximum working area** (Fig. 10.2)
     - Desirable to **keep parts & tools** used in within **normal working area** (for each hand & both hands working together
   - If method requires worker to **move beyond maximum working area:**
     - ⇒ worker must move > than just arms & hands
     - ⇒ more **energy**, more **time**, more worker **fatigue**

2. Workplace Arrangement

3. Locate tools and materials to be **consistent with sequence of work elements**
   - Items should be arranged in **logical pattern** that matches sequence of work elements
     - Those items that are used **first in cycle** should be **on 1 side of work area**
     - Items used next should be next to first, and so on
   - Alternative: **locate** items **randomly** in the work area
     - $\Rightarrow$ **increases** amount of **searching** required
     - & **detracts** from **rhythm** of work cycle
   - **Fig. 10.3**: shows top view of workplace layout that illustrates 1st **3 principles**
     - Note, layout in (b)
       - locates bins in **more accessible pattern**
       - **consistent** with **sequence** of work elements

Illustration of First Three Principles

Figure 10.3: Two workplace layouts.

(a) Poor arrangement of parts and tools in workplace

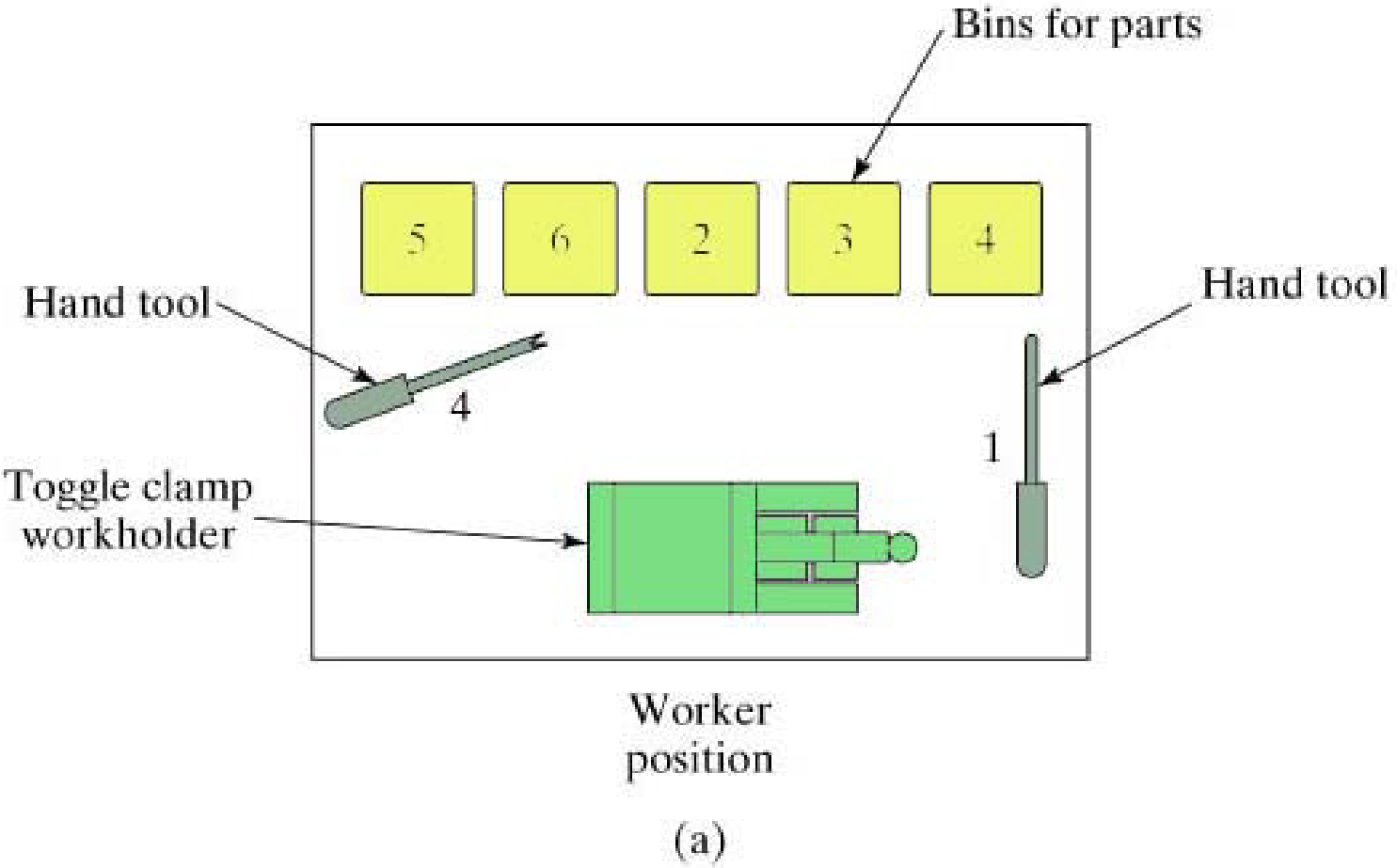
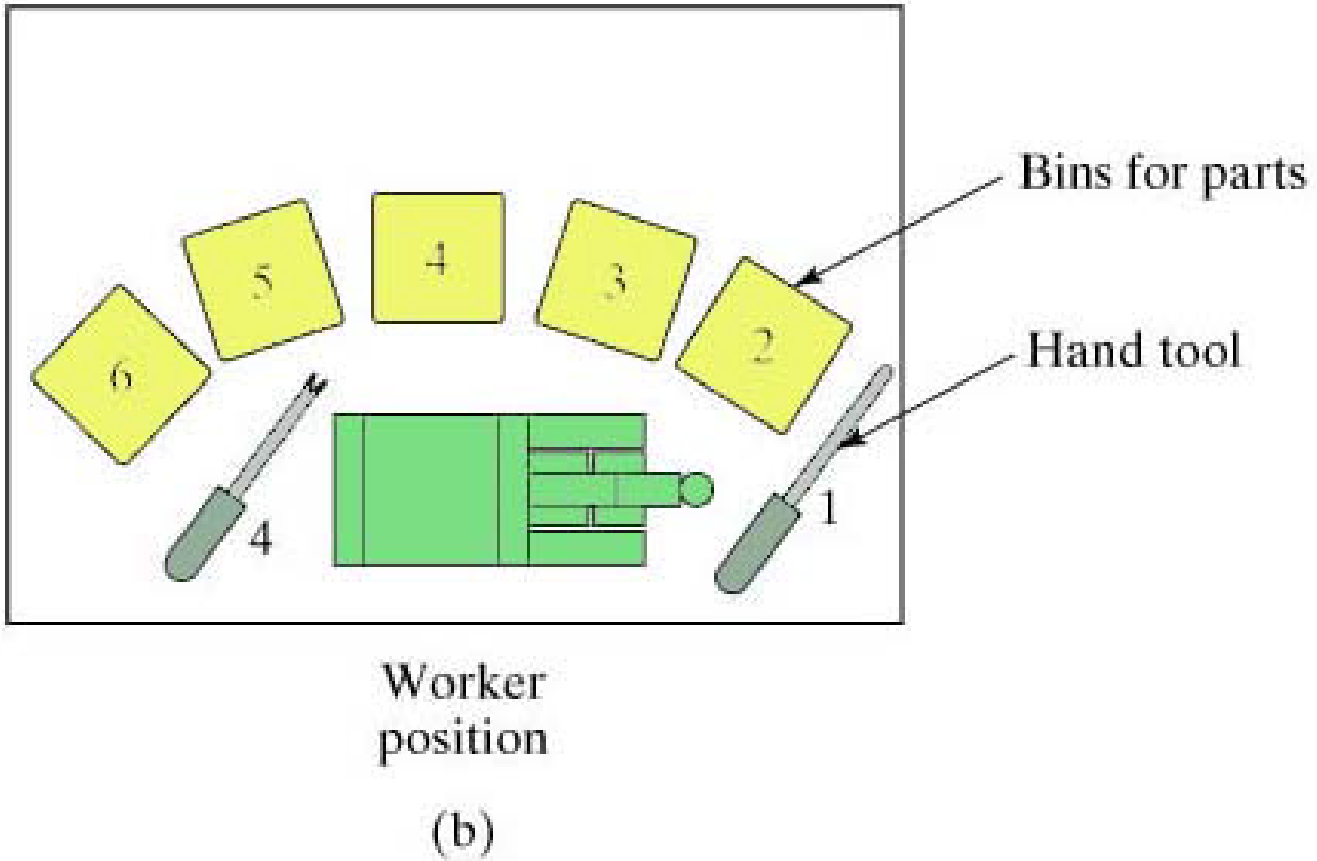


Illustration of First Three Principles

(b) Good arrangement of parts and tools in workplace

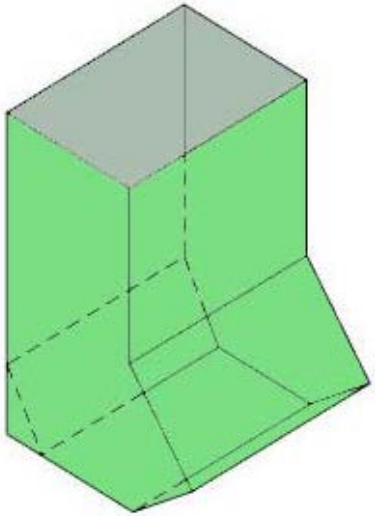


(b)

2. Workplace Arrangement

4. Use **gravity feed bins** to deliver small parts and fasteners

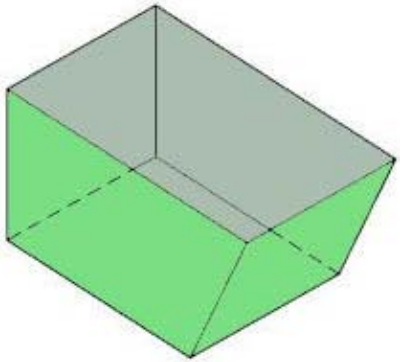
- **Two types of bins** used for small parts and fasteners in the workplace:



(a)

a) gravity feed bin

This's a container that uses gravity to move items in it to a convenient access point for the worker



(b)

b) conventional rectangular bin

slower acquisition of items than gravity feed bin

2. Workplace Arrangement

5. Use **gravity drop chutes for completed work units** where appropriate
   - Drop chutes **should lead to container adjacent to worktable**
   - **Entrance** to gravity chute should be located **near normal work area**
     - ⇒ allows worker to dispose finished work unit quickly & conveniently
   - Most **appropriate for lightweight work units** that are not fragile

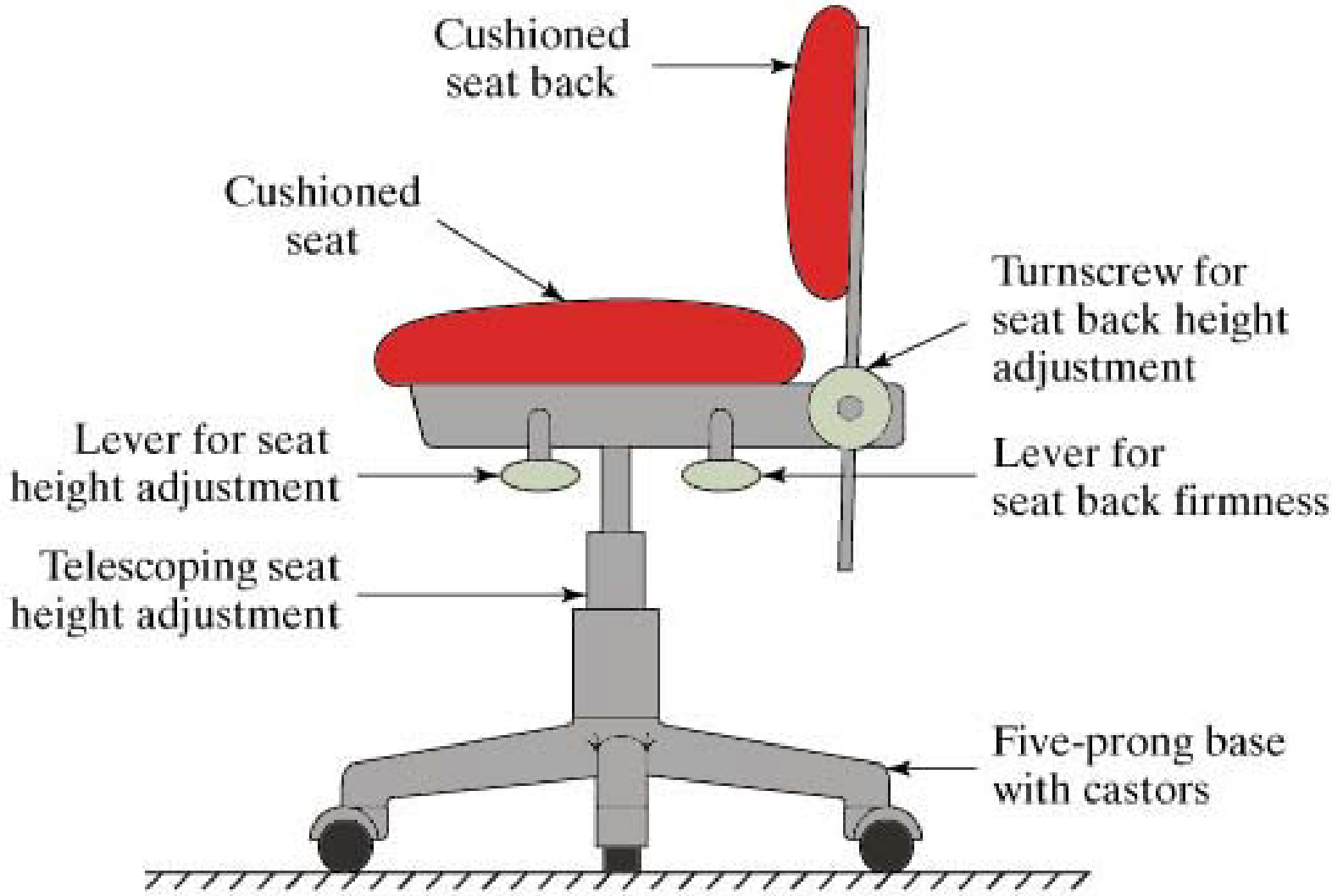
2. Workplace Arrangement

6. Provide **adequate illumination**
   - Issue of illumination is normally **associated with ergonomics**
   - Also long known to be important factor in **work design**
   - Illumination: especially important in **visual inspection tasks**

2. Workplace Arrangement

7. A **proper chair** should be provided for the worker:
   - **Adjustable** to the size of the worker
   - Seat **height and back adjustments**
   - **Padded** seat and back
   - Means of increasing & decreasing amount of **back support**
   - **Chair height** should be in proper relationship with **work height**
   - Adjustable chair for workplace: next slide

Adjustable Chair for Workplace



3. Design of Tooling and Equipment

1. **Workholding devices** should be designed for the task
   - **Mechanical workholder** with fast-acting clamp
     - permits work unit to be **loaded quickly**, and
     - **frees both hands** to work on the task productively
   - **Typical** workholder: must be **custom-designed** for work part processed in task

3. Design of Tooling and Equipment

2. Hands should be relieved of work elements that can be performed by the feet using **foot pedals**
   - Foot pedal controls **instead of hand controls**
     - to operate **certain types of equipment**
     - e.g. **Sewing machines**, foot pedals used as integral components in operation of equipment
   - **Training: often required** for operator to become proficient in use of foot pedals

3. Design of Tooling and Equipment

3. Combine **multiple functions into one tool** where possible
   - Many common **hand tools** implement this principle
     - e.g. **claw hammer**: designed for both striking and pulling nails
     - e.g. **nearly all pencils** are designed for both writing and erasing*
   - **Less time usually required** to **reposition** such a double-function tool than to put one tool down and pick another one up

3. Design of Tooling and Equipment

4. Perform **multiple operations simultaneously** rather than sequentially
   - **Work cycle**: usu. conceptualized as **sequence of work elements** or steps
   - Steps are **performed one after the other** by worker and machine
   - In some cases: **work method can be designed** so steps are **accomplished at same time** rather than sequentially*
   - **Special tooling** and processes can often be designed to **simultaneously accomplish multiple operations**

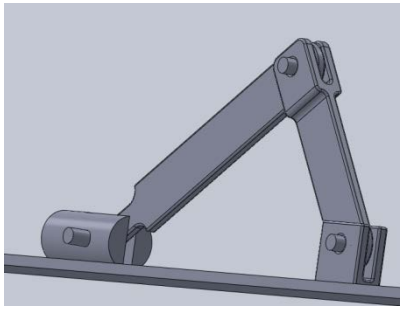
3. Design of Tooling and Equipment

5. Where feasible, perform operation on **multiple parts simultaneously**
   - Usu. applies to cases involving use of **powered/ machine tool**, e.g.:
     - **drilling of holes** in a printed circuit board (PCB)
     - PCBs are **stacked 3 or 4 thick**
     - NC drill press drills each hole through entire stack in **one feed motion**

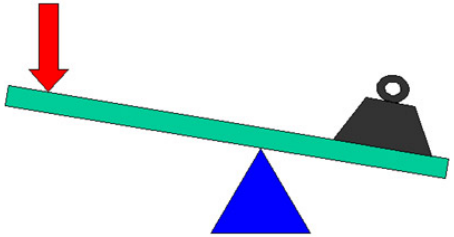
3. Design of Tooling and Equipment

6. Design **equipment controls** for **operator convenience** and **error avoidance**

- Equipment controls include **devices that regulate operation of the equipment**
  - Dials
  - Cranks
  - Levers
  - Switches
  - Push buttons, etc.



- All controls needed by operator should be **located within easy reach**
  - $\Rightarrow$ **minimize body motions** required to access & activate them



3. Design of Tooling and Equipment

7. Hand tools and portable power tools should be designed for **operator comfort and convenience**
   - e.g. tools should have **handles/grips**: **slightly compressible**
     - $\Rightarrow$ can be held & **used comfortably** for duration of shift
   - **Location** of handle/grip relative to working end of tool:
     - should be designed for **max. operator safety, convenience, and effectiveness** of tool
     - If possible, tool should accommodate both **right-handed & left handed** workers

3. Design of Tooling and Equipment

8. Mechanize or automate manual operations if economically and technically feasible

- $\Rightarrow$ this will almost always **outperform worker** in terms of **speed**, **repeatability**, and **accuracy**
- $\Rightarrow$ results in **higher production rates** & **better quality** products
- **Economic feasibility** depends on quantities produced:
  - **Higher quantities**: likely to **justify** investment in **mechanization** & **automation**