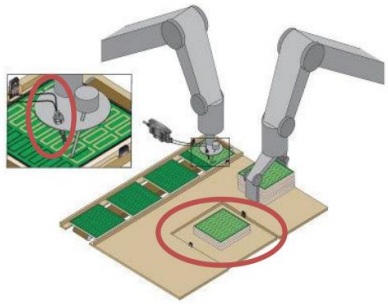
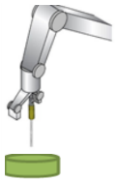
1. **(6 pts) Choose suitable sensors for the following application. (a) sensor (positioned near where the robot applies the adhesive and can be adjusted for different adhesive layouts) to verifies that adhesive is applied to the IC wafer (b) sensor to detect the level of filled wafer trays (so when tray reaches preset level, robot arm will take it away) Explain the reasons for your choices in a) and b).**



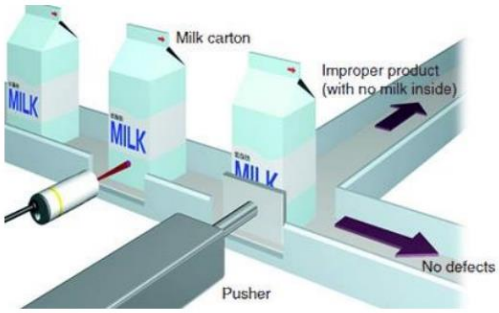
a) Laser sensors. It is suitable for precision position and detecting tiny objects. Other sensors do not have comparable competence.
b) Thru-beam sensor. It is often used for sense object presence and absence. For example, when it reaches a specific height which is designated, the sensor will detect and report it to user.

2. **(3 pts) Select a sensor type to detect the distance from the end of the robotic arm to the surface of the part and justify your selection.**



Ultrasonic sensors

3. **(5 pts) Choose a sensor to detect if there is milk inside the carton. Justify you answer**



Capacitive sensors. It uses electrostatic field to detect the variation of capacitance between the sensor and the object. When the milk of the carton is not as the same level as others, it would detect it, so this is suitable for such application.

4. **(a) (4 pts) Explain the differences between inductive sensors and capacitive sensors. Give at least two differences.**

Capacitive sensors can be divided into variable pitch, variable area and variable media types. In general, they can be used for a **wider range** of materials to be measured.

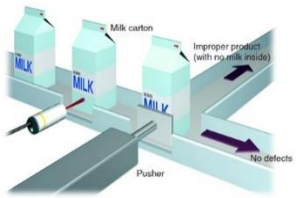
Inductive sensors can only be used for metallic objects.

But on the other hand, **capacitive sensors** need to ensure that the measured **environment** is free from contamination, such as dust, oil and water, because these factors can change the dielectric constant and thus change the measurement results.

(b) (3 pts) Give an application example that an inductive sensor can be used. Use sketches.

Inductive sensor to detect if washer is present by sensing the distance between inductive sensor and object.

(c) (3 pts) Give an application example that a capacitive sensor can be used. Use sketches.



- **Use capacitive sensor to detect if milk canton with milk in it**

5. **(6 pts) What are the major differences between photoelectric reflective sensors and pyroelectric infrared sensors?**

Photoelectric reflection sensors detect visible light with wavelengths from 400nm to 780nm. In contrast, pyroelectric infrared sensors can sense infrared light with wavelengths exceeding 780 nm. Therefore, the range of light detection is the most important difference between the two sensors.

6. **(6 pts) Why are capacitive sensors sensitive to temperature and humidity? What are the main advantages of capacitive sensors?**

This is because capacitors are sensitive to temperature and humidity. Capacitance varies with temperature depending on the relationship between dielectric constant and temperature. In addition, humidity also affects the capacitance size. Water vapor condenses on the surface of the capacitor and is absorbed, causing the insulation resistance of the capacitor to drop and generating leakage and flying arcs. The dielectric constant increases and the dielectric loss increases. Capacitive sensors have two main advantages. First, it has a relatively simple structure, which means it is easy to produce and quite economical. In addition, it has a very high intrinsic frequency and a very short response time. Therefore, it is suitable for measuring high speed and high frequency motion.

7. **(6 pts) What are the main advantages of using Radar sensors over ultrasonic sensors?**

Radar emits electromagnetic waves. It does not require a transmission medium. Ultrasound is an acoustic wave, a mechanical wave. It is emitted by the vibration of a piezoelectric substance and

therefore cannot be used in high pressure or negative pressure environments. It is generally used only in atmospheric pressure environments.

8. (6 pts) For a given joint in a robot, what is the accuracy? What determines its accuracy?

Accuracy is the ability to reach a specified point in space that defined by an x-y-z or other coordinate system. It's determined by how close the TCP is to the point described by the program or visual system

9. (8 pts) In a machine loading and unloading application,

(a) (2 pts) What are the advantages of a dual gripper design over a single gripper design?

Handle object size variation
Deal with two workstations
Reduce cycle time
Increased productivity
Increase efficiency

(b) (3 pts) Describe the similarities of the design and motion of these abovementioned in two kinds of grippers.

(c) (3 pts) Describe the differences of the design and motion of these abovementioned in two kinds of grippers.

10. (5 pts) Describe harmonic drive and give an application example of using harmonic drive.

It is based on elastic dynamics and utilizes the flexibility of metal. It consists of circular spline, flexspline, wave generator.
No backlash, high compactness, high precision, wide range of gear ratio in a small package size.
EX: Robot joints. Use Harmonic drive for waist, shoulder, and elbow joint

11. (5 pts) What is an actuator? Briefly describe how to select an actuator for a given joint or end effector.

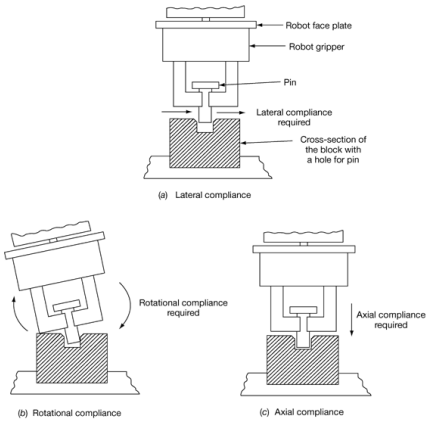
Device used to **produce motion or action**, usually produce **physical changes** such as linear or angular displacement.
Motor: Speed range, torque-speed variations, reversibility, operating duty cycle, starting torque, and power required
Solenoids: Used when a small, light and quick linear motion is desired, not very controllable
Relays: are used to **make or break mechanical contact** between electrical leads.

12. (8 pts) Design a robot gripper or gripper mechanism to pick and place wine glasses as shown below. Describe how it works. And what factors do you consider in designing such gripper? Please use sketches to illustrate your gripper design

Soft finger grippers can be used to pick and place wine glasses.
Driven by a hollow rubberlike cylindrical body, it has a smooth surface on one side and a ribbed surface on the opposite side.
I consider that it is good for the geometry of the wine glasses, has the controllable force gentleness in designing.

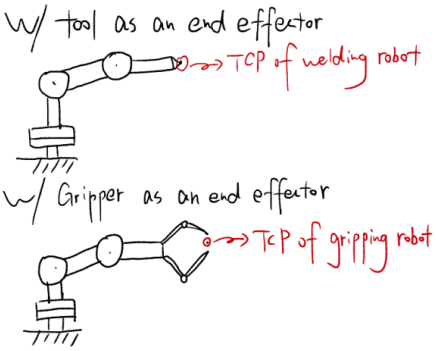
13. (5 pts) What is compliance tooling? Use sketch to explain why we use it for assembly applications?

Compliance tooling is used to handle **fragile materials** or **Facilitate assembly.**
Flexible connection provide three compliances in lateral, rotational, and axial



14. (7 pts) What is Tool Center Point (TCP)? Why knowing such point is critical in robot applications? Use two sketches to illustrate the TCP for a welding gun and for a two-finger gripper.

TCP is the point of action for the end effector mounted to the robot tool plate. If no tool attached to the wrist, TCP is the center of standard tool plate defined by robot manufacturer.
Offset must input into robot program to make sure the real tool center is the TCP.



15. (9 pts) (a) What is cycle time of a robot application? (b) Give at least three factors that affect the cycle time?

(a) It is the time needed to achieve a cycle of motion that the robot is expected to finish

(b) i) Joint actuators ii) Overall size of the robot iii) Payload.

16. (6 pts) For an application of using robot to assemble laptop circuit boards, what are the top three robot selection criteria you would use? Explain why.

Accuracy: Laptop circuit board consists of many different parts. Good accuracy assure that robots could position every part in correct position so that the board can be applied.

Repeatability: The same circuit will be manufactured repeatedly. High repeatability enables the robots to manufacture the circuit board again and again.

Speed: There will be a large number of circuit boards to be manufactured in the assembly. High speed could confirm the efficiency.

- Ex: Machining application: repeatability, work envelop size, arm configuration, DOF, wrist configuration, are critical measures
- Ex: Electric circuit assembly: positioning, accuracy, repeatability, speed, downward force, are critical factors
- Ex: Material handling: arm configuration, wrist flexibility, payload, work envelope, are the critical measures

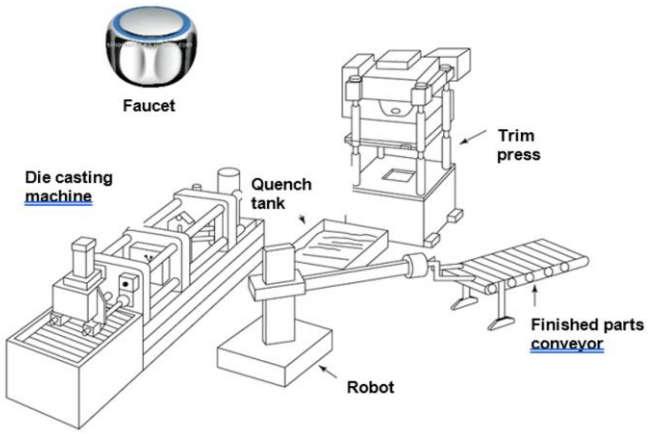
17. (6 pts) During the process of selecting or designing grippers for a given application, why is knowing the part or object crucial or what factors do you consider on the part or object to help you make gripper selection/designing decisions? Explain. Use sketches if necessary.

i) Payload: The payload determines whether the selected robot can withstand the weight of four faucet knobs at the same time; the larger its value, the higher the robot's expectation of completing the task.

ii) Accuracy: The higher the maximum reach distance, the higher the robustness of the adjustable distance between the robot and the die casting machine, quench tank and finished part conveyor.

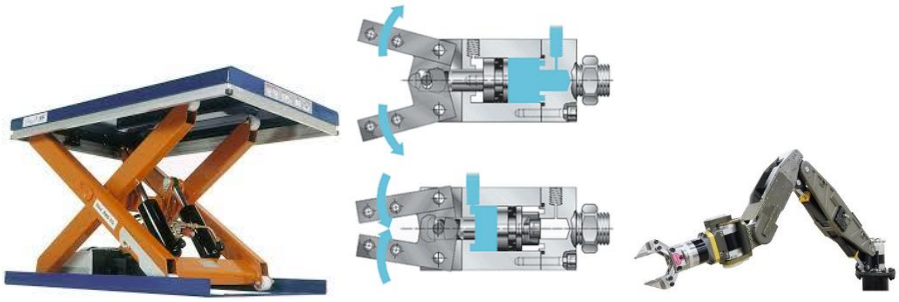
iii) Repeatability: The higher the repeatability, the higher the ability of the robot's wrist to move back and forth between different positions such as die casting machine, quench tank and finished part conveyor.

Die-casting application:



18. (4 pts) What type of motors will be a good choice for a base joint in an articulated robot? Explain.
Stepped motor.
Characteristics: Rotate in both directions. Move in **precise angular increments (steps)** for every voltage pulse

19. (9 pts) Use sketches to illustrate three ways or three methods to actuate a gripper for an open and close actions.



20. (a) (3 pts) What are the applications of using three finger grippers? Use sketches.
large round parts

(b) (3 pts) What are the applications of using four finger grippers? Use sketches.
center parts in horizontal vertical directions large irregylar shaped parts

21. (10 pts) The vacuum plate below picks up a layer of carton boxes that weight 50 pound. If the vacuum is 0.70 bars behind the gripping surface, how many 1/2-inch holes will be required to lift the boxes?

1bar≈14.5psi
0.7bars=0.7*14.5psi=

22. (8 pts) Determine the diameter of vacuum cups (six) for lifting window glass that weighs 20 pounds. Assume a vacuum of .70 atmospheres.

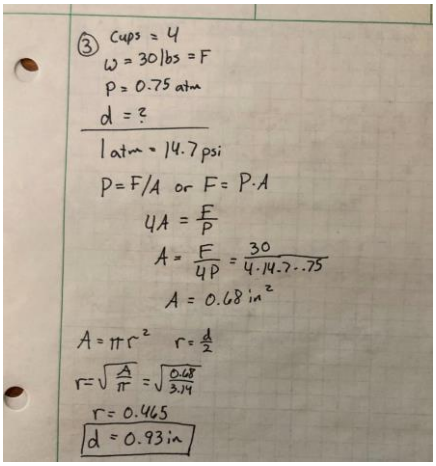
P=6*0.7atm=4.2atm
4.2 ATM=4.2bar=4.2*14.5psi

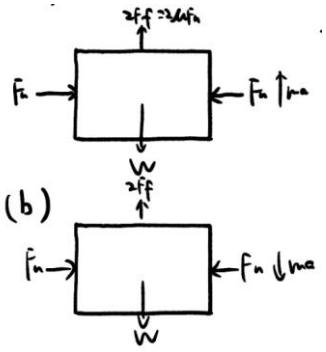
23. (10 pts) A parallel gripper is used to keep a 30 pound part from slipping when the robot tooling accelerates upward and at a rate of 8 feet per second squared. The coefficient of static friction is 0.70.

(a) (4 pts) Draw FBD or Kinetic diagram to show gripper holding the part.

(b) (4 pts) Determine the friction force needed for the gripper design.

(c) (2 pts) Determine the minimal normal force required for the gripper.





24. (12 pts) A robot loads and unloads a CNC turning machine from a central conveyor. The following average robot operation times apply:

Pick up part from conveyor (including average wait time in pickup position)- --3.0 sec

Move robot hand from conveyor to machine ----------1.7 sec

Load part into machine and back hand away from machine so the machine can start -1.1 sec

Unload part from machine ----------0.8 sec

Move robot hand from machine to conveyor ----------1.7 sec

Deposit part onto conveyor ----------0.5 sec

Suppose the turning machine operations cycle requires 8 seconds, and 100% efficiency,

(a) (3 pts) What is the cycle time if a single gripper is used? Calculate the production rate per hour.

(b) (5 pts) What is the cycle time if a dual-handed gripper is used, and why? Calculate production rate per hour.

(c) (4 pts) How much improvement of production rate from a dual gripper design over a single gripper design? Do you recommend using single gripper design or dual gripper design for this application? Why

machine time: 8 sec

Single gripper design

Cycle time: $T_c = 3+1.7+1.1+0.8+1.7+0.5+8 = 14.1$ sec

Production ratio $= \frac{1}{T_c} = \frac{1}{14.1\,\text{sec}} \times 60\frac{\text{sec}}{\text{min}} \times 60\frac{\text{min}}{\text{hr}} \times 8\frac{\text{hr}}{\text{shift}} = 2042$ unit/shift

Dual gripper design

Cycle time

If machine busy: $T_c = 8+0.8+1.1 = 9.9$ sec

If robot busy: $T_c = 3+1.7+1.1+0.8+1.7+0.5 = 8.1$ sec

$9.9 > 8.1$ So cycle time is 9.9 sec.

Production ratio: $\frac{1}{T_c} = \frac{1}{9.9\text{sec}} \times 60 \times 60 \times 8 \times 0.8 = 232$ unit/shift

Production rate improvement

$\frac{2327-2042}{2042} \times 100\% = 13.96\%$