Okay, let's break down the three types of robot work cells described in your text and then tackle the exam-style scenario.

Here is a summary table highlighting the key differences:

|  |  |  |  |
| --- | --- | --- | --- |
| **Feature** | **1) Robot-centered Work Cell** | **2) In-line Robot Work Cell** | **3) Mobile Robot Work Cell** |
| **Robot Placement** | Approx. center of the cell | Along an in-line conveyor/transport system (can be one or more robots) | Mounted on a mobile base (floor tracks or overhead railing) |
| **Equipment Arr.** | Arranged in a partial circle around the robot | Arranged linearly along the transport system | Stations may be geographically separated, not necessarily close |
| **Material Handling** | Supply/Delivery conveyors, part-feeders, pallets within robot reach | In-line conveyor or transport system | Robot itself transports between stations (via mobile base) |
| **Part Presentation** | Known location/orientation (often static at pickup/place points) | Presented by the transport system (can be moving or stopped) | Delivered to/picked up from fixed points at each station |
| **Part Movement** | Robot moves parts between peripheral equipment | Transport system moves parts between robot stations | Robot moves itself between stationary stations with parts |
| **Transfer Types** | N/A (Robot is the transfer) | Intermittent, Continuous, Non-synchronous | N/A (Robot's mobility is the transfer) |
| **Complexity (Robot Control)** | Generally straightforward (often interacts with static parts) | Varies significantly (simple with intermittent/non-synchronous stops, complex "tracking" with continuous) | Requires coordinating robot motion with base movement and station interaction |
| **Flexibility** | Flexible within robot's radial reach | Varies (Non-synchronous > Intermittent > Continuous) | Flexible to service widely separated stations |
| **Typical Apps** | Assembly, machine tending (loading/unloading multiple machines) | Welding lines (spot welding), processing parts on a line | Servicing multiple machines with long cycles, large workpieces |
| **Key Advantage** | High robot utilization by serving multiple points from central location | Processing parts as they move along a line (especially welding) | Servicing stations beyond a single robot's fixed reach, time-sharing tasks |

Now, let's create a scenario and choose the appropriate work cell type.

**Exam Scenario:**

A manufacturing company needs to automate the loading and unloading of three different CNC milling machines. Each machine has a long cycle time (ranging from 30 to 60 minutes per part). The machines are currently located in a linear arrangement approximately 10 meters apart from each other on the factory floor due to space constraints and workflow considerations. The parts are relatively large and heavy (around 15-20 kg), making manual handling ergonomically challenging. Finished parts need to be placed on a pallet near the last machine. Raw parts are delivered on a cart to the vicinity of the first machine. The goal is to maximize machine uptime by ensuring they are continuously loaded and unloaded.

**Chosen Work Cell Type:** **3) Mobile Robot Work Cell**

**Drawing/Description:**

*(Since I cannot draw, I will describe the layout)*

Imagine three CNC milling machines arranged in a line with significant space (approx. 10m) between Machine 1, Machine 2, and Machine 3. A Mobile Robot Work Cell would be implemented as follows:

* A heavy-duty industrial robot arm is mounted on a **mobile base**.
* This mobile base runs on a **floor-mounted track** that extends in front of all three CNC machines. The track covers the distance from the first machine, past the second, and to the third, potentially extending slightly beyond Machine 3 to reach the finished goods pallet and the raw material cart area near Machine 1.
* Each CNC machine has a designated **loading/unloading point** accessible from the track.
* Near Machine 1, there is a **pickup point** for raw materials from the cart.
* Near Machine 3, there is a **drop-off point** for finished parts onto a pallet.
* The mobile robot's path on the track would involve moving between the raw material pickup, each of the three CNC machines, and the finished goods drop-off point.

**Reasons for Choosing this Work Cell Type (Justification):**

The Mobile Robot Work Cell is the most suitable choice for this scenario for several key reasons, directly addressing the requirements and constraints:

1. **Servicing Widely Separated Stations:** The scenario explicitly states the three CNC machines are approximately 10 meters apart. A standard fixed-base robot (like in a Robot-centered cell or typical In-line cell without a mobile base) would not have sufficient reach to service all three machines from a single location. The Mobile Robot Work Cell's defining feature is its ability to move between stations that are "geographically separated by distances greater than the robot’s maximum reach." This perfectly matches the need to cover 10-meter gaps between machines.
2. **Servicing Stations with Long Processing Cycles:** The CNC machines have long cycle times (30-60 minutes). This is a characteristic explicitly mentioned as suitable for Mobile Robot Work Cells, as the robot can spend its time traveling between machines and performing other tasks while a machine is busy with a long process. This prevents the robot from being idle for long periods waiting for a short cycle to finish, unlike if it were fixed at one station or if all stations had very short, synchronized cycles.
3. **Maximizing Equipment Utilization (Machines):** By having a mobile robot dedicated to loading and unloading, the CNC machines can run almost continuously with minimal downtime waiting for manual intervention. As the text states, mobile robots "help keep machines working non-stop, using them more efficiently and reducing idle time" for the *machines*. The robot can serve Machine 1, then travel to Machine 2 while Machine 1 is running, then travel to Machine 3, and repeat the cycle, ensuring each machine is attended to as soon as its cycle finishes.
4. **Time-Sharing Tasks:** The long cycle times allow the robot to effectively time-share its efforts across the three machines. It can pick up a raw part, deliver it to Machine 1, then move to unload Machine 2 (which has finished its long cycle), load it with a new part, then move to unload Machine 3, and so on. This scheduling of tasks across multiple stations is a core benefit of mobile robot cells and directly addresses the need to maximize machine uptime.
5. **Handling Material at Different Points:** The scenario involves picking up raw materials near Machine 1 and dropping off finished goods near Machine 3. The mobile robot on a track can easily incorporate these distinct pickup and drop-off points into its path, integrating material handling across the distributed layout.

In contrast, a Robot-centered cell would only be feasible if the machines could be clustered within the robot's fixed reach, which the scenario explicitly prevents. A standard In-line cell is designed for sequential processing along a line, and while it could potentially use a long conveyor, a fixed robot would still only be able to reach a limited section. Using multiple robots in an In-line cell would be an option, but a single mobile robot is likely a more cost-effective solution when machines are spaced far apart and have long cycles suitable for time-sharing.

**Scenario 2: Robot-centered Work Cell**

**Exam Scenario:**

A manufacturer of small electronic devices needs to automate a series of post-molding operations on a plastic casing part. The tasks involve:

1. Loading the part into a small press for trimming.
2. Removing the trimmed part from the press.
3. Placing the part into a fixture for a simple component insertion.
4. Removing the part from the assembly fixture.
5. Presenting the finished part to a vision inspection system. The cycle times for these operations are relatively short (trimming: 15 seconds, insertion: 10 seconds, inspection: 5 seconds). The parts arrive in bulk bins, and finished/inspected parts need to be placed into separate collection bins. Space is limited, and the company wants to achieve high throughput in a compact area.

**Chosen Work Cell Type:** **1) Robot-centered Work Cell**

**Drawing/Description:**

*(Since I cannot draw, I will describe the layout)*

Imagine a central area where the robot is placed. Around this central robot, arranged in a partial circle within its reach, would be:

* A small **trimming press**.
* An **assembly fixture** with a mechanism for presenting components (e.g., a vibratory feeder).
* A **vision inspection station** (camera and light source, with a pad or fixture to place the part).
* A **raw material delivery point** (e.g., a conveyor or simple tray where parts from the bulk bin are presented in a known orientation, possibly using a part-feeder).
* A **finished parts collection point** (e.g., a chute or conveyor leading to a bin).

The robot sits in the middle and can easily rotate and reach each of these stations/points.

**Reasons for Choosing this Work Cell Type (Justification):**

The Robot-centered Work Cell is the most suitable choice for this scenario for the following reasons, aligning with its described characteristics and advantages:

1. **Multiple Operations within Limited Space:** The scenario involves performing several distinct tasks (trimming, assembly, inspection) on a single part. The Robot-centered layout is designed for a single robot to service "other components and equipment arranged in a partial circle around the robot," allowing these multiple operations to be placed compactly within the robot's work envelope.
2. **High Robot Utilization with Short Cycles:** While the individual cycle times are short (15s, 10s, 5s), the *combined* work for the robot involves picking, placing, waiting for short machine cycles, picking again, etc., across all stations. The central placement allows the robot to quickly pivot and move between these short-duration tasks at different points, thereby maximizing its "high utilization of robot" by minimizing travel time between operations. It keeps the robot constantly busy.
3. **Parts Presented at Known Locations:** The description notes that parts must be presented in a "known location and orientation." This is crucial for any robot cell, but the Robot-centered layout relies on the surrounding equipment (press, fixture, inspection station, part feeder) consistently presenting parts at fixed, predictable points around the central robot, which is a standard requirement for this cell type, often using the methods mentioned like part-feeders and fixtures.
4. **Efficient Material Flow within the Cell:** Raw materials are delivered to one point within the circle, and finished parts are collected from another. The robot handles all the transfers between these points and the processing stations, creating an efficient internal material flow loop contained within the cell's compact footprint, reducing the need for extensive external conveyors linking individual machines.

In contrast, an In-line cell is typically better suited for sequential operations on a part moving *along* a line, which isn't the core requirement here (parts are processed step-by-step *by the robot* at different stations). A Mobile Robot cell is overkill for this compact layout and short-cycle process; its benefit is servicing stations spread over large distances, which isn't the case here.

**Scenario 3: In-line Robot Work Cell**

**Exam Scenario:**

An automotive assembly plant needs to automate the application of numerous spot welds onto car body sub-assemblies (e.g., door frames or floor panels). The sub-assemblies move down a conveyor line. Multiple spot welds are required along the length of the assembly as it passes through a specific zone. The process is sequential and must occur precisely as the assembly moves along the line. The application requires multiple welding guns working simultaneously or in rapid succession along the moving part.

**Chosen Work Cell Type:** **2) In-line Robot Work Cell**

**Drawing/Description:**

*(Since I cannot draw, I will describe the layout)*

Imagine a production line with a conveyor belt or a similar material transport system running in a straight line. The In-line Robot Work Cell would be implemented along a section of this line:

* A **conveyor belt or transfer system** carries the car body sub-assemblies continuously or intermittently through the work cell area.
* **One or more industrial robots** equipped with spot welding guns are positioned **alongside** the conveyor. The number of robots depends on the cycle time, the number of welds, and the length of the workpiece section needing welds.
* The robots are mounted on fixed bases next to the conveyor.
* Safety barriers surround the robot work zone along the conveyor line.

The sub-assemblies enter this zone on the conveyor, the robots perform their welding tasks, and the assemblies continue down the conveyor out of the work cell.

**Reasons for Choosing this Work Cell Type (Justification):**

The In-line Robot Work Cell is the most suitable choice for this scenario for the following reasons, directly leveraging its described characteristics and typical applications:

1. **Sequential Processing on a Moving Line:** The core requirement is performing operations (spot welding) on a workpiece as it moves along a production line. This is the defining characteristic of an "In-line Robot Work Cell," where robots are "located along an in-line conveyor or other material transport system" and "work is organized so that parts are presented to the robots by the transport system."
2. **Suitable for Continuous or Intermittent Flow:** Spot welding can be performed with either an intermittent (stop-and-go) or a continuous transfer system. The text lists these as the primary transfer types for In-line cells. If the welding can be done while the part is stopped (intermittent), robot control is simpler. If the process requires welding *while* the part is moving (continuous), the robots can be equipped with tracking capabilities ("robot(s) has to perform the tasks as the parts move along"). This adaptability to different linear flow types fits the potential needs of a welding line.
3. **Typical Application (Welding Lines):** The text explicitly mentions "Typical applications such as in welding lines used to spot-weld car body frames, usually utilizes multiple robots" as an example for In-line Robot Work Cells. This directly matches the scenario provided.
4. **Handling Large or Long Workpieces:** In-line systems are ideal for workpieces that are too large or long to be easily manipulated in a compact, centralized cell. The workpiece moves, and the robots work on segments of it, which is typical for car body sections.
5. **Facilitates Multiple Robots:** As noted in the text and common in automotive welding, the linear nature of the line makes it straightforward to position multiple robots along the line to share the workload on a single large workpiece or to increase throughput.

In contrast, a Robot-centered cell is unsuitable because the large, linear workpiece and sequential process don't fit a radial arrangement around a single fixed robot. A Mobile Robot cell *could* potentially move along a large workpiece, but In-line systems with fixed robots alongside a conveyor are the standard, proven solution for high-volume, sequential processes like automotive welding on a line.