

**The sample answer hints have been provided for clarification. The answer approach to some of the question has also been provided. The learners must use them for reference only and do not rote them as the actual exam scenario will be different and these answers may not be applicable. Learners must see the answer approach and use same/similar or better approach when answering the questions in actual exams.**

## **Section A**

**Carefully analyze the following scenario and answer to the 5 questions in context with given scenario only. Any generic or irrelevant response will not be accepted by the examiner**

### **Workplace Situation/ Scenario**

“Silk Aviation Suppliers Pvt. limited Company” is a reliable supplier for aviation components, hardwares and chemicals to a number of airlines in the region. The company employs 3000 workforce including supervisors, managers and directors. Their business strategy is to be amongst top 10 suppliers (in terms of business revenue) in the region within next 5 years. They maintain huge inventory of aviation parts and deliver those parts to their customers using 3<sup>rd</sup> party courier service. The courier company staff is often required to pick some heavy products directly from the warehouses using their own manpower and necessary equipment. The company has 10 huge warehouses which are used to store various inventory items based on their sizes, chemical properties, fragility etc. The retrieval of the items from the warehouses require the manual as well as mechanical operations which are often done simultaneously creating various safety hazards for the workers. There are certain health hazards as well while working in the chemical warehouse or pulling/pushing the inventory on manual carts. The pushing of carts to or from the warehouse becomes very tedious as ramps are used to approach the warehouses. Latest regulatory limit for pushing force for the cart has been set to 50 Lbs. however, it has been observed that workers are required to use force beyond the legal limit when they push the cart on a ramp.

The company has previously trialed a semi-automated storage and retrieval system without the need for workers to physically store or retrieve the loads but it caused delays in delivery. The company has now planning to redesign the ramps so lesser pushing force is required for storage/ retrieval manually through the carts in order to be regulatory compliant.

Another problem with the chemical warehouse is that it is used to store a number of chemicals under the same roof. Although the company ensures that short term and long term exposure limits (STEL and LTEL) for various hazardous airborne chemicals should be complied yet there have been instances when workers had health issues due to the exposure with airborne chemicals. The company has put a time bar on every worker (Reduced from 8 hours to 6 hours) beyond which the workers cannot be in the chemical warehouse but again this practice has caused delays in the deliveries. Moreover, the production managers

found it very difficult to ascertain the exact time for which the workers remain present inside the warehouse as it requires frequent movements between the warehouse and the packing/delivery point by each worker which cannot be documented in real time.

**All 5 questions carry 10 marks each (Total 50 Marks)**

Keeping in view the above mentioned scenario, please answer to the following questions;

**Question 1-** Calculate the suitable ramp angle for a maximum of 100 lbs. load on the cart so the required pushing force remain under 50 lbs.?

**10 Marks**

## **Answer**

Force required to start or stop a cart/ trolley/ wheel chair etc. is higher than the force required to keep them in motion. Let's assume that 25 LBS. force is required to keep the trolleys (Having 100 LBS. load on it) in motion on a level ground with smooth wheels. But when there will be ramp, the pushing force required will be higher and will depend on the angle of the ramp. Lower the angle, lesser force will be required and higher the angle of ramp, more force will be required to push the carts/ trolleys.

We can solve this problem with a simple right angle triangle formula as follows;

force required to push a mass  $m$  up a frictionless incline is equal to Load  $\times \sin \theta$

**( $\theta$  = Angle of the ramp in degrees)**

Force Required = Load on Cart  $\times \sin \theta$

Force Required/ Load on Cart =  $\sin \theta$

$\sin \theta$  = Force Required/ Load on Cart

$\sin \theta$  =  $50/100$  (50 LBS. we want maximum pushing force and 100 LBS. is load on the cart)

$\sin \theta$  = 0.5

$\theta$  = Inverse  $\sin 0.5$  (Check the value of Inverse  $\sin 0.5$  on google or scientific calculator)

$\theta$  =  $30^\circ$

So at 30 degrees, the pushing force will be 50 LBS. if the load on the cart is 100 LBS.

The friction of wheels with the ramp has not been taken into account.

**Note: The learners should try the following question using same formula;**

**What will be the required pushing force for a load of 100 LBS on cart with a ramp angle of  $50^\circ$**

**Question 2-** Why do you think there have been ill health issues at the chemical warehouse if the STEL and LTEL limits are being complied? What additional measures will you take to eliminate/mitigate the risk of ill-health in the given scenario. **10 Marks**

## Answer Hints

- 1- Mixed exposure of the chemicals may affect the health even if the STEL and LTEL limits of individual airborne chemicals are being complied.
- 2- Some physiological factors e.g. age, gender, smoking habits, alcohol consumptions, may influence the health.
- 3- Daily dose for which workers are exposed may be higher for some workers depending upon how much time they remain within the chemical warehouse.
- 4- Environmental factors e.g. temperature, humidity can worsen the health condition in an airborne chemical environment
- 5- Manual handling coupled with chemical exposures can also influence the health of workers

### Additional Measures

- 1- Forced ventilation system should be installed in chemical warehouse (Engg Control)
- 2- Overtime should not be allowed in Chemical warehouse (Admin Control)

**Question 3-** What control measures you may wish to take (without any financial implications) in the prevailing circumstances in order to increase the OHS performance. **10 Marks**

## Answer Hints

- 1- Storage of items should be done during a specific time separated from the time when items are retrieved. For example storage should only be done during the night shift
- 2- Better storage management with spacious aisles. Each worker or team of workers should be allocated with specific aisles so they work in co-ordination with other team members to avoid risk of injury due to movement of powered vehicles.
- 3- Courier company should be given access to a certain area outside the warehouses so their work does not conflict with the workers of the organization.
- 4- Abolish overtime working for workers in chemical warehouse/ manual handling jobs. Workers should be cross trained so they may work elsewhere within the organization so the dose exposure/ manual handling load is distributed amongst the workers.

- 5- 5S (Sort, Set in Order, Shine, Standardize, Sustain) philosophy should be implemented within the warehouses through a systematic process. This requires a behavioral and cultural change supported by the management.

**Question 4-** What technological solution you may advise to the management in order to ensure that each worker does not remain inside the chemical warehouse beyond 6 hours during their 8 hours shift and an additional 4 hours over-time duration? You must explain the technical details along with the cost implications of the proposed solution.

**10 Marks**

## Answer Hints

- E-Tag should be pasted on each worker's front pocket. This should have a unique ID for each worker.
- An E-Tag reader should be placed at the entrance of the warehouse which will record the entrance and exit time of each work
- The Electronic processing unit will calculate the total number of hours and minutes a worker has been inside the chemical warehouse.
- Once a pre-set limit (for example 6 hours) is reached for any worker, a notification will be sent to the supervisor who will stop that worker from further entering into the chemical warehouse.
- The total cost of this solution is almost 1100 US\$ as follows
  - o Card reader 200 US\$
  - o Computing system 300 US\$
  - o Software system specifically designed 500 US\$
  - o E-Tags @1 US\$ each for 100 workers 100 US\$

**Question 5-** What technological options will you suggest for fully automated storage and retrieval system? You must explain the technical details of the proposed solution in terms of the process flow including the use of Information technology tools where applicable.

**10 Marks**

## Answer Approach

Please watch Amazon Automated Warehouse by clicking the following Youtube link to understand how automated storage and retrieval system works. As a learner, you are required to understand this and apply this system in the given exam scenario.

<https://www.youtube.com/watch?v=IMPbKVb8y8s>

## Section B

Carefully analyze the following scenarios and answer to the question/s in context with given scenarios only. Any generic or irrelevant response will not be accepted by the examiner.

### Workplace Situation/ Scenario

A large textile company “Star Textiles” has its own weaving, dying, stitching and packaging units employs 6500 workforce at different administrative and functional levels. The company operates in 3 shifts on weekdays and 2 shifts on weekends. There are 6 separate buildings as follows;

- 1- Admin block (4 storey building) with the capacity of 150 people on each floor.
- 2- Weaving and stitching unit (2 storey building) with capacity of 500-600 workers on each floor
- 3- Dying Unit (single storey) with capacity of 300 workers in each shift
- 4- Packaging unit (Single storey) with capacity of 350 workers in each shift
- 5- Raw materials warehouse (2 storey) with capacity to accommodate 50 workers in each shift
- 6- Maintenance unit (single storey) with capacity to accommodate 60 workers in each shift

Each building/ storey has an entrance and a separate exit doors (each 10 foot wide).

The company believes in “Equal Opportunity” and therefore 50% of the manpower is female. There are 10 workers who have hearing impairment while 7 workers have mobility issues. The administrative building is a 4 storey building where lifts are used however, 10 feet wide stairs have been made available as well.

**Question 6 -** Write down a comprehensive “Fire Evacuation Plan” as per the given scenario requirements.

**20 Marks**

## Answer Hints

Fire evacuation plan is a comprehensive document which outlines duties and responsibilities at each level within the organization to ensure that evacuation in case of fire is 100% effective without the risk of injury or ill health.

Keeping in view the above mentioned scenario, the fire evacuation plan must cover the following ;

- 1- Action in case of discovering the fire
  - a. Who needs to take action? **Assign responsibilities and document it**
  - b. Fire alarm positioning at suitable locations. **Decide where these alarms need to be installed and communicate their location to the ones who are required to take action**
  - c. Centrally monitoring of fire alarms to check which area/workplace has discovered fire. **Arrange for centralized monitoring**
  - d. Isolation of electrical connections for that specific area depending upon nature and spread of fire. **Assign responsibilities and document it**
  - e. Priority evacuation of workers from that specific area if the situation necessitates. **Avoid a situation which may create panic**

- f. Employees training and awareness (What they are supposed to do when they hear fire alarm? **Decide the frequency of training and rehearsals.**

**2- Who needs evacuation (Your procedure must separately address them)**

- a. Routine workers (**How many? Calculate the time of evacuation during the rehearsals and design plan keeping in view the maximum number of people which can possibly be present**)
- b. Fresh employees (**They may not be conversant with organization's evacuation strategy**)
- c. Maintenance workers (**As they often carry out work activities at various locations within the organization and may not react as effectively as routine workers**)
- d. Contractors (**May not know what to do in case of fire**)
- e. Members of public (**For example a study visit**) **How will they be managed? What arrangements must be done?**
- f. Disabled workers **What specific arrangements will be in place to evacuate vulnerable persons? How will they know if there is a fire occurrence? Who will assist them for evacuation?**

**3- Identification of evacuation routes**

- a. Escape route characteristics (**Marking, specific coloring, directional arrows, wide and clear from obstructions, well lighted and ventilated, shortest possible, doesn't cross another escape route, doesn't get narrow, workers are aware about it**)

**4- Assembly point/s**

- a. Closer to all (**Decide a suitable place/s within organization, Mark it prominently, let all know its location**)
- b. Arrangements for ensuring that every person has evacuated. **Roll Call/ head count etc.**
- c. Arrangements for tracing the missing workers. **Who will do it and how it will be done. You may use E-Tag system for automated counting**

**5- Return to work**

- a. Who will decide if it is safe to return to the workplace (**Assign responsibilities**)

Foresee Risks and take measures with Fire Evacuation plan;

- 1- Foresee any situations which may create panic resulting stampede
- 2- What if the alarm system is not functional? Any alternative arrangements?
- 3- What if the person responsible for certain duties are absent? Is the situation covered in Fire plan?
- 4- What could go wrong during evacuation? For example Power breakdown resulting dark environment making it difficult to escape for the workers
- 5- What if the exit door or escape route has caught fire? Are there any alternative escape routes already planned and communicated to the ones who are supposed to occupy the premises
- 6- Any temporary immobility issues of workers e.g. muscle spasm, fracture etc.

**Note: Above are the guidelines and approach to writing a “Fire Evacuation Plan” and is not a Plan itself. The learners must write the full plan using the above guidelines. This plan does not cover fire extinguishing and control as that is not the question’s requirement.**

### **Workplace Situation/ Scenario**

A large construction company utilizes various lifting equipment for the transportation of men and materials on large storey under construction buildings. Lately there have been an accident when a material lifting equipment failed resulting free fall of the lifting platform and collapse of the whole assembly. Fortunately there have been no injuries but the incident alarmed the regulatory body as well as the management who are concerned with the safety of people. You are working as safety manager in the construction company head office and has been assigned to carry out a technical investigation.

**Question 7 -** Establish the scope of the investigation for the perusal of Safety Director and the management?

**10 Marks**

## **Answer Hints**

### **Scope of investigation**

“ Carry out the technical investigation regarding the collapse of lifting equipment as per the following scope”;

- 1- Document your initial finding about the accident
- 2- Identify the root cause/s of the accident
- 3- Suggest suitable corrective and preventive actions to avoid the same or similar accidents in future
- 4- Identify other locations within the organization’s projects where same or similar equipment is being used and provide the level of assurance regarding their safe operations
- 5- Present a report to the management within stipulated number of days

**Question 8 -** Based on the scope of the investigation, establish a checklist as per the following format;

**10 Marks**

## **Answer Hints**

Sr#	Potential Cause of the Accident	Evidences you wish to collect to “Establish” or “Rule Out” the potential cause
1	Operational Procedure violation	Interview the operators about their understanding of the operation and the hazards related to procedure violations.

2	Design Failure	The findings will be shared with the manufacturer and designers to seek their opinions. Their responses will be reviewed to ensure if the cause of accident can be due to design failure
3	Overloading	The document showing the load limits and comparison with the load which was being lifted
4	Maintenance issues	What were manufacturer's recommended maintenance? Were those being complied? Inspection reports, calibration records
5	Equipment malfunction	Which instruments/ equipment were responsible for failure. The pattern of failure, visual inspections and utilization of other inspection techniques. The evidence of instrument/equipment failure e.g. a ruptured hydraulic hose, a burst valve etc.
6	Improvisation	Any unauthorized maintenance performed e.g. welding, bolting, joining or steel ropes unauthorized uses. It will be ensured through visual inspection, maintenance log etc. The interview with the witness and operators will reveal many things related to the incident and failure.
7	Environmental conditions	Was the lifting equipment exposed to environmental conditions beyond their design limitations. For example certain sensitive electronic equipment may malfunction in extremely hot environment. Or there was any storm on the day of incident or the days before the incident
8	Work politics	Were there 2 or more operators for this equipment? How is their relationship? Do they blame each other's for the incident. Does it benefit some workers if other worker is blamed e.g. in terms of promotion, job retention etc.
9	Intentional Damage	Any operators/ workers has shown any concerns lately regarding the organization's policies e.g. pay rise, vacations, holidays, overtime etc. The visual inspection followed by detailed NDT and Destructive inspections will provide clues if the failure was initiated by an individual or it happened due to some other reasons.

### Scenario

The recent Corona Virus Pandemic has affected the whole world. It caused business and life disruptions all over the world. There were various administrative measures taken by each and every country to curtail the spread of the virus but the efforts were mostly not very effective as to-date, there are thousands of people being affected daily. The situation alarmed the scientists, politicians as well as the citizens who urged the need for more scientific development in the field of public health. The Health and Safety Officer have also been observing the impacts of Pandemic and the way it is being managed. They have also been discussing the limitations of prevailing technological options which could not effectively work to reduce the spread of Corona Virus.

**Question 9** - Which technological invention you wish to have in near future which may curtail the spread of virus or increase the effectiveness of existing control measures? Propose a single specific



product/service (Except the vaccine) and explain in detail how it will be used in order to control the spread of similar or more deadly viruses in future.

**20 Marks**

## Answer Hints

The learners must figure out themselves as the answer relates to the individual's aspiration and wishes about the technological developments.

### **Workplace Situation/ Scenario**

An oil refinery company "Silverline Oil Refinery" had deployed various engineering controls for its process safety to eliminate the risk of explosion. There have been lately an occurrence when a "Pressure Release Valve" could not maintain the required pressure flow resulting huge pressure build-up within the system. The abnormal situation was observed by the vigilant staff of main control room who brought the pressure "under control" by shutting down the process (administrative Controls) which resulted in heavy financial losses to the refinery. The refinery has carried out a technical investigation and the cause of the failure was identified as "Equipment Failure" i.e. the subject valve failed to perform its intended function although it was calibrated and tested only a week ago.

**Question 10 -** Why Engineering controls cannot be 100% reliable and Which factors influence their performance?

**10 Marks**

## Answer Hints

### **Are Engineering Control Fail-Safe?**

The answer to this question is simply no. We cannot rely 100% on engineering controls even if they are effectively designed. We have studied earlier a number of reasons for ineffectiveness of engineering controls. Those reasons may contribute to failure of engineering controls. One may ask that why do we invest huge resources in engineering controls if they do not give us a sense of 100% protection. The answer is probability of failure or accidents with engineering controls is very less if designers and/or manufacturers' recommendations are complied.

We have witnessed the accidents where the probability of accident was 0.0001% but the accidents took place. For example, a passenger aircraft has 4 engines. If 3 engines fail, the 4<sup>th</sup> engine still can safely land the airplane. But we have seen the air accidents where only one engine failure resulted into crash landing of the plane.

The designers although have latest tools and testing equipment available with them but still forecasting what will go wrong is a difficult task. We come across a number of new reasons for the accidents and/ or

material failures. The good thing however is that we are learning lessons from these accidents. The latest technologies and materials are being developed to cope with accidents from material failure or human error. Similarly, the development of rescue and escape equipment and personal protective equipment is in progress to minimize the consequences of accidents. It is being believed that human lives have more worth than the materials and equipment.

### **Effectiveness of engineering controls**

It is not imperative that all engineering controls will be effective. The effectiveness of engineering controls relies on a number of factors which have been outlined as follows:-

- The selection of engineering control options for a specific hazard is very important factor for the effectiveness of engineering controls in occupational safety and health. Consider a workplace with significant chemical agents present but a local exhaust ventilation (LEV) system has been purchased which has very low capacity. The required suction rate should have been 100 m<sup>3</sup>/min but the selected LEV has the capacity of only 25 m<sup>3</sup>/min. So the capacity of engineering controls is an important factor in their effectiveness. In simple words, engineering controls should be suitable and sufficient for specific hazards.
- The second aspect in selection of engineering controls is their use in a specific work environment. For example a proximity sensor may have limitations due to the type of environment. A sensor may not work well in a chemical or corrosive environment so engineering controls should be selected for correct rating so that they may be used with effective output in a specific type of environment.
- Engineering equipment installed and commissioned as engineering controls against certain hazards will require maintenance after a certain period of time. Engineering controls may not serve their intended function if not maintained as per the manufacturer recommendations and/or requirements as per the workplace environment. The engineering controls will remain effective only if they are properly maintained. Certain monitoring and detection sensors and equipment as part of engineering control may also require calibration after specific period. If the calibration is not carried out, the results from sensors or other such equipment will be dubious and engineering control effectiveness will be compromised.
- Another factor in engineering control is their fool proofing or tamper proofing. The employees have tendency to bypass engineering controls to expedite the productions.

They may alter the engineering controls if the provision may allow. The effectiveness of engineering controls will thus be compromised if the workers can alter or change the way the engineering controls have been installed. A simple example is a fixed guard installed on the machine. The worker may prefer to uninstall the guard to avoid wastage of time in frequent installations due to requirements of maintenance in a machine.

- Engineering controls should be robust for the type of environment in which they are being used and the competency and risk perception of the people who will be beneficiary of the engineering controls. An unintentional change in the engineering control by the worker or accidental damage to the engineering controls can compromise the effectiveness of the engineering controls. For example, a damaged fixed guard may collide with moving parts of the machinery and create more hazards for the workers etc.
- Engineering controls may fail due to the failure of some part or equipment i.e. material failure. We have discussed in preceding elements about the material failure reasons. If any such failure occurs, the engineering controls will not work for the intended function.
- Any modifications and alterations in the engineering controls without suitable authorizations and testing may also lead to ineffectiveness of engineering controls. Some engineering controls have provisions for expansions while others do not. It should be ensured that the modification or alteration in engineering control should only be carried out by competent professionals and the authorization should be taken from the designers.

**Question 11** - The management has decided to deploy redundant engineering control for the subject process. An additional “Pressure Release Valve” will be installed in parallel so if one fails, the other will take over. If the reliability of existing valve is 93% and for additional valve, its 97% then what will be the combined availability of the system during next one year?

**10 Marks**

## Answer Hints

The formula to calculate the combined availability of a parallel system is'

$$= 1 - (1 - \% \text{age availability of valve 1}) \times (1 - \% \text{age availability of Valve 2})$$

$$= 1 - (1 - 0.93) \times (1 - 0.97)$$

$$= 1 - (0.07) \times (0.03)$$

$$= 1 - 0.0021$$

$$= 0.9979 \text{ or } 99.79 \% \text{ age}$$

To calculate in days

$$= 365 \times 0.9979 = 364.2335 \text{ Days or } 364 \text{ days} + 5 \text{ Hours} + 36 \text{ Minutes}$$

### **Workplace Situation/ Scenario**

A local theme park "Joy City" has installed a range of joy rides including a roller coaster. The company carries out frequent inspections (mostly visual inspections) using its own staff to ascertain the integrity of the structures and its components. The company also has a 3<sup>rd</sup> party annual inspection contract with a renowned inspection body who certifies them against the given criteria. During a routine daily pre-use inspection, one of the worker accidentally found 2 large bolts supposedly disengaged from the roller coaster and reported to you (safety manager). The matter was discussed with the management who were alarmed to foresee the potential impact on public safety and the business had it not been timely reported.

**Question 12** - What do you think are the issues with the existing inspection scope, method or criteria?

**10 Marks**

### **Answer Hints**

- The situation reveals ineffectiveness with the existing inspection process as the anomaly was not detected unless the bolts were disengaged and accidentally found.
- The inspection scope is limited to visual inspections only which is not commensurate with the nature and level of potential risks
- Visual inspection methods need further elaboration in terms of acceptance and rejection criteria. The inspection staff must have clearly defined acceptance and rejection criteria for each inspection
- A general visual inspection may mislead the inspection staff so there must be equipment specific inspection criteria instead of general criteria
- Keeping in view the scenario, robust weekly, fortnightly or monthly inspections should also be planned and these inspections should take into account the conflict of interest of inspection staff. It is very unusual for a routine worker to spot an anomaly due to complacency or other human limitations.

**Question 13** – Which different inspection methods can be used to ascertain the structures integrity without dismantling them?

**10 Marks**

## Answer Hints

- X- rays inspection
- Ultrasonic Inspection
- Penetrant testing
- Torque measurement on bolts using Torque wrenches

Inspection criteria must be approved by a competent level 3 certified inspection engineers in the specific testing methods.

End of Question Paper