SCHEME OF EVALUATION

Revision: R (15)

Course code : 6026

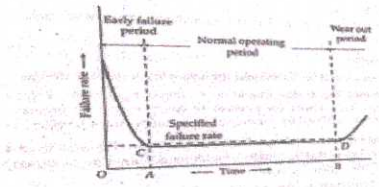
COURSE TITLE: MAINTENANCE ENGINEERING

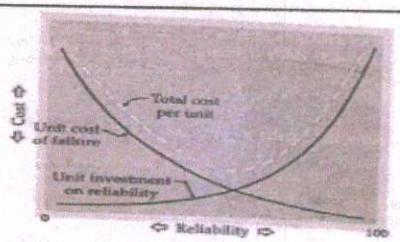
Qst.No	Scoring Indicators	Split up score	Sub total	Total
I (1)	1) Breakdown maintenance, 2)Preventive maintenance, 3) Predictive maintenance, 4) Condition based maintenance, 5) Routine maintenance, 6) Corrective maintenance, 7) Opportunistic maintenance.	0.5x4=2 (any four)	2	2
I (2)	Condition monitoring (CM) is determining the health and condition of the equipment, machines and systems by obsorving,checking, measuring and monitoring certain parameters and signals.It is also called equipment health monitoring (EHM).	2	2	2
I (3)	The MTBF is the mean (average) time between successive failures of a product.This definition assumes that the product in question can be repaired and placed back in operation after each failure.	2	2	2
I (4)	1) Temperature crayons, 2) Thermometers and optical pyrometers, 3) Thermocouples and fusible plugs, 4) Infrared meters, 5) Thermography, 6) Bimetallic strips, 7) Thermistors, 8) Vapour pressure in bulbs.	0.5x4=2	2	2
I (5)	**Ferrography** is a specialized type of oil analysis used to study particle wear on machine components through analysis of contaminants in lubricating oil. It can be used to predict and diagnose errors occurring on machinery. Ferrography is related to tribology, which is the study of friction between interacting surfaces.	2	2	2
II (1)	1) Friction and wear control: To minimize friction at the point of contact of mating components, by maintaining a separating layer of lubricant between the mating surface. 2) Corrosion control: To protect precision finish of contact surfaces of components from being corroded. 3) Temperature control: Lubricant absorbs and dissipate the heat at the point of generation. 4) Contamination control: Prevent foreign matters like dust, dit, water etc entering at the mating surface.	1.5x4=6	6	6
II (2)	**Successful maintenance planning follows these 6 Principles:** 1) Have a separate department for planners. 2) Focus on future work. 3) Component level file keeping. 4) Estimate the job based on planner expertise. 5) Recognize the skills of the crafts man. 6) Measure the performance with work sampling.	1x6=6	6	6
II (3)	λ = 0.00001/hour T = 10000 hr, Ri = e-λT = e^{-0.00001X 10000) = e-0.1 = 0.90483 = 90.48%	6 (equation-2marks,correct substitution -2 marks,Answer-2 marks	6	6

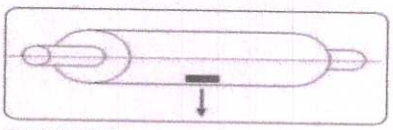
II (4)	1) Corrosion coupons (weight loss measurement). 2) Electrical resistance test.(ER) 3) Linear polarization resistance (LPR) 4) Galvanic (ZRA) 5) Hydrogen penetration 6) Microbial 7) Sand/ Erosion	1x6=6	6	6
II (5)	Techniques of wear debris analysis: 1) Sources of wear debris. 2) The distinction between amount, size, shape and chemical break down. 3) Spectrometric or spectroscopic oil analysis 4) Direct reader ferrography. 5) Visual method analysis. 6) Filter debris analysis. 7) Scanning electron microscope. 8) Magnetic plug method. 9) Lab tests. 10) Lubricant contamination control.	1x6=6	6	6

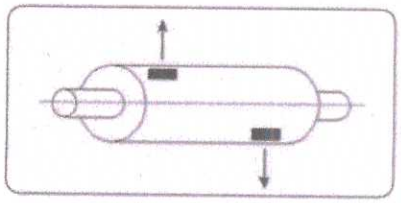
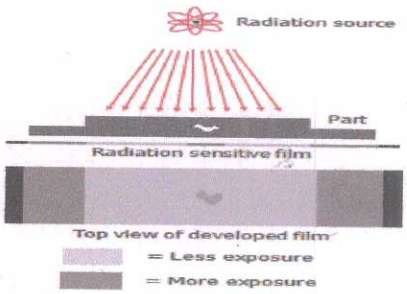
II (6)	* The reliability of a system, product, or equipment is an important aspect of quality for its consistent performance over its expected life span. * Uninterrupted service and hazard free operation is the essential requirement of large complex systems like Electric power generation and distribution plants or communication network of raiways,aeroplane,automobiles etc * Failure of an assembly or even a single component results in health hazard, accident or interruption in continuity of service. * So maintaining reliability of a product is highly important, hence consideration should be given during product design, control of quality during manufacture, acceptance inspection, field trials,life testing etc.	2x3=6	6	6
II (7)	• An infrared thermometer is a thermometer which infers temperature from a portion of the thermal radiation sometimes called black-body radiation emitted by the object being measured. * By knowing the amount of infrared energy emitted by the object and its emissivity, the object's temperature can often be determined within a certain range of its actual temperature. * Infrared thermometers are a subset of devices known as "thermal radiation thermometers. *The design essentially consists of a lens to focus the infrared thermal radiation on to a detector, which converts the radiant power to an electrical signal that can be displayed in units of temperature after being compensated for ambient temperature. *This permits temperature measurement from a distance without contact with the object to be measured. *A non-contact infrared thermometer is useful for measuring temperature under circumstances where thermocouples or other probe-type sensors cannot be used or do not produce accurate data for a variety of reasons.	6	6	6
III(a)	Predictive maintenance: *In this technique it uses regular evaluation of actual operating condition of plant equipment,production system,and plant management function to optimise total plant operation. *Predictive compare the trend of measured physical parameters for the purpose of decting, analysing and correcting the problem before the failure occurs. Condition monitoring and condition based maintenance are two essential components of predictive maintenance. Advantages: 1) Cost effective in many capital intensive processes. 2) Flexibility allowsfor the adjustment of maintenance periodicity. 3) Increased component life cycle. 4) Energy saving. 5) Reduce equipment or process failure. Disadvantages: 1) Catastrophic failures still likely to occure. 2) Labour intensive. 3) Includes performance of un needed maintenance. 4) Potential to incidental damage due to unneeded maintenance.	Expl- 4 marks Adv-2 marks Disadv-2marks	8	8

III (b)	1) Listing the condition of equipments/components. 2) Selecting critical equipments/ machines and systems. 3) Identify components/ items. 4) Fixing condition parameters. 5) Fixing monitoring techniques. 6) Monitoring schedule and freequency. 7) Trend monitoring. 8) Repair schedule and exicution. 9) Follow-up	1x7=7	7	7
IV (a)	The following are the main condition monitoring techniques applied in the industrial sectors: • Vibration analysis and diagnostics. • Lubricant analysis • Acoustic emission (airborne ultrasound) • Infrared thermography. • Ultrasound testing (material thickness/flaw testing). • Motor condition monitoring and motor current signature analysis (MCSA) • Model-based voltage and current systems (MBVI systems) 1.**Vibration Analysis** refers to the process of measuring the vibration levels and frequencies of industrial machinery, and using that information to determine the "health" of the machine, and its components. When an industrial machine (such as a fan or pump) is operated, it generates vibration. 2.**Oil analysis** (OA) is the laboratory analysis of a lubricant's properties, suspended contaminants, and wear debris. OA is performed during routine predictive maintenance to provide meaningful and accurate information on lubricant and machine condition. By tracking oil analysis sample results over the life of a particular machine, trends can be established which can help eliminate costly repairs. The study of wear in machinery is called tribology. Tribologists often perform or interpret oil analysis data.	list- 4marks Expl-4 marks	8	8
IV (b)	The main steps to be followed in maintenance planning are 1.knowldge base : The planner should have through understanding of work order requirement. 2.Job investigation at site: It gives clear perception of total job. 3.Identify and document the work: A complete work or job list is prepared. 4.Development of repair plan: Preparation of step by step procedure which would accomplish the work in most economical use otime, man power and material. 5.Preparation of tools, tackles and facilities: This can be done in the plan sheet itself. 6. Estimation of time required to do the job 7. Work order feedback form/plan: Two types of feedback form are used, one for supervisor of planner to approve the plan and other for scheduler to report after completion.	1x7=7	7	7

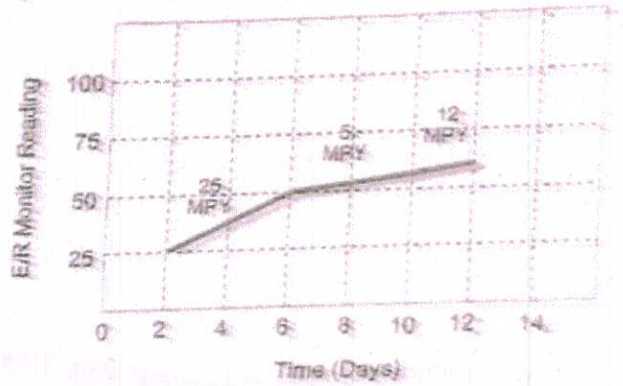
V (a)				
	Complex products often follow a familiar patternof failure. When failure rate is plotted againest continuous time scale, the resulting chart is called bath tub curve. Three zones of bath tub curve are 1. **Infant mortality period**: the is charecterised by high failure rates. * It begins when the equipment starts operation and continues maintenance and repairs, the elimination of marginal parts initially defectivethough not inoperative * Commonly, these are early failure resulting from defects in manufacturing. 2. **The constant failure rate period:** Upon replacement of all prematuely failing items, the failure rate will have reached a lower value(poin C). From this point thefailure rate remains fairly constant. * These are chance failures which may result from the limitations inherent in the design plus accidents caused by usage or poor maintenance or hidden defects which escape inspection. * The period from A to B is the normal operating periodin which the average failure rate	fig-3 marks Expl-5 marks	8	8
V (b)	A system or a complex product is an assembly of a number of parts or components. The components may be similar or dissimilar. Components connected in series: If the components of an assembly are connected in series the failure of any part causes the failure of assembly or a system. In this type of systems the reliability of the system is given by the product of reliabilities of individual components. Let, R1 (t) = reliability of component - 1 R2 (t) = reliability of component - 2 R3 (t) = reliability of component - 3 Then reliability of the system, Rs(t) = R1 (t) x R2 (t) x R3 (t) Let $R_1(t)$ = Reliability of component 1 $R_2(t)$ = " - 2 $R_3(t)$ = " - 3 The Reliability of the System $R_s(t) = R_1(t) \times R_2(t) \times R_3(t) \times \cdots R_n(t)$ Interms of failure Rate $R_i(t) = e^{-\lambda_i t}$ λ_i = failure Rate of i^{th} component. ie $R_i(t) = \int_{i=1}^{n} e^{-\lambda_s t} \times dt = e^{-\lambda_s t}$ ✱ λ_s = Summation of individual failure Rate.	Expl-3 marks formula & derivation 4 marks 3+4=7	7	7

VI (a)	 Fig. 13.4 Optimum reliability. * If the specified reliability is much lower than the optimum, the actual cost to the consumer may be high due to excessive repairs and maintenance. * On the otherhand if an unduly high reliability value is specified the total cost may still be excessive due to greater and strict requirements for components and assemblies. * Hence, both costs have to be balanced in such a way to ensure adequate reliability at an economic level. * Figure shows while the reliability increases the unit cost of failure decreases but the uni investment on reliability increases correspondingly. Both curve meet at a point, which is considered as the optimum value of total cost.	fig-4 marks Expl-4 marks	8	8
VI (b)	1. **Maintainability:** It is defined as the probability that adevice will be restored to its operational effectiveness with in the given period,when maintenance action is performed in accordance with the priscribed procedure. 2. **MTTR (Mean time to repair)**: It is the arathematic mean of time required to perform maintenance action MTTR = (Total maintenance time)/(Number of maintenance action ction) 3. **Availability:** The availability is the more appropriate measure than reliability. * Reliability is the measure of performing without failure. * Availability recognizes both reliability and maintainability.	2.5+2+2.5=7	7	7
VII (a)	**Misalignment** •Misalignment is created when shafts, couplings and bearings are not properly aligned along their centerlines. • The two types of misalignment are angular and parallel, or a combination of both. * Angular misalignment occurs when two shafts are joined at a coupling in a manner that induces a bending force on the shaft. • Parallel misalignment Parallel misalignment occurs when the shaft centerlines are parallel but displaced or offset. **Common causes of misalignment are:** Thermal expansion: Expansion or growth of a component due to the heating and cooling of that component. * Cold alignment: Most machines are aligned cold and heat as they operate. Thermal growth causes them to grow misaligned. • Alignment of components during coupling is not correctly achieved. Therefore, misalignment is introduced into the system during installation	3points of misalignment 3points of cause 2points of effects	8	8

	• Improper alignment due to imparted forces from piping and support members. Misalignment due to uneven foundation, shifting in foundation or settling. **Effects** Misalignment usually causes the bearing to carry a higher load than its design specification, which may cause bearing failure due to early fatigue. • Fatigue is the result of stresses applied immediately below the load carrying surfaces and is observed as spalling of surface metal. Effects on coupling in the form of damage to the coupling or excessive heat due to friction can also be seen.	effects (3+3+2=8)	8	8
VII (b)	1. Quick problem dectection without inturrupting service. 2. Prevention of premature failure and extension of equipment life. 3. Identify potentially dangerous or hazardous equipment. 4. Wide temperature range (-17deg. to 900 deg. cetigrade) 5. Can monitor target in motion and fragil target. ~~6.~~ 6. Temperature profile can be recorded and displied easily. 7. Can monitor high voltage equipments. 8. Can also monitor small and remote targets.	1x7=7	7	7
VIII (a)	A common indication of poor machine health is unbalance in the system. Unbalance can cause excessive forces that affect the machine. Unbalance occurs when the shaft's mass centerline does not coincide with its geometric centerline. In general, there are three types of unbalance: 1. Static unbalance 2. Couple unbalance 3. Dynamic unbalance			
	 Fig. 8. Static unbalance.			
	• **Static unbalance** With static unbalance, only one force is involved. For example, if you have a bicycle tire that has mud buildup on one area or portion of the tire, when stopped the wheel naturally settles with the clump of mud at the bottom of the wheel. Similarly, a rotor turns until the heavy spot is located at 6 o'clock . The term "static" implies that this type of unbalance can be observed at rest.	FIG - 3marks Expl-5 marks	8	8

	 *Fig. 9. Couple unbalance.* **Couple unbalance** * Unlike static unbalance, couple unbalance cannot be measured at rest. With couple unbalance, two equal forces (weights) are 180° from each other, which causes the rotor to appear balanced at rest. * However, when the rotor rotates, these forces move the rotor in opposite directions at their respective ends of the shaft. This causes the rotor to wobble, which produces a 180° out-of-phase reading from opposite ends of the shaft. **Dynamic unbalance** * In reality, most unbalance is dynamic. Dynamic unbalance is the combination of static and couple unbalance. * On simple machines, there is usually more static unbalance than couple unbalance. On more complex machinery, with more than one coupling or several areas on the rotor where unbalance can occur, couple unbalance is usually more prominent in the system.			
VIII (b)	1. They are extremely sensitive and may vary from person to person. 2. Those are often erratic. 3. Required long experience to judge. 4. Inexpensive (unless the equipment is remote). 5. Difficult to pass-on skill. 6. Distractions are a factor. 7. Basically a breakdown strategy.	1x7=7	7	7
IX (a)	In general, RT is method of inspecting materials for hidden flaws by using the ability of short wavelength electromagnetic radiation (high energy photons) to penetrate various materials. The intensity of the radiation that penetrates and passes through the material is either captured by a radiation sensitive film (*Film Radiography*) or by a planer array of radiation sensitive sensors (*Real-time Radiography*). Film radiography is the oldest approach, yet it is still the most widely used in NDT.  			

	Basic Principles In radiographic testing, the part to be inspected is placed between the radiation source and a piece of radiation sensitive film. The radiation source can either be an X-ray machine or a radioactive source (*Ir-192, Co-60, or in rare cases Cs-137*). The part will stop some of the radiation where thicker and more dense areas will stop more of the radiation. The radiation that passes through the part will expose the film and forms a shadowgraph of the part. The film darkness (*density*) will vary with the amount of radiation reaching the film through the test object where darker areas indicate more exposure (*higher radiation intensity*) and lighter areas indicate less exposure (lower *radiation intensity*). This variation in the image darkness can be used to determine thickness or composition of material and would also reveal the presence of any flaws or discontinuities inside the material. *Advantages* • Both surface and internal discontinuities can be detected. • Significant variations in composition can be detected. • It has a very few material limitations. • Can be used for inspecting hidden areas (*direct access to surface is not required*) • Very minimal or no part preparation is required. • Permanent test record is obtained. • Good portability especially for gamma-ray sources.	Expl.4 marks fig-2marks Advantages-2 marks	8	8
IX (b)	Corrosion monitoring techniques can help in several ways. 1) By providing early warning that damaging process conditions exist which may result in a corrosion induced failure. 2) It help to studying the corelation of changes in the process parameters and their on system corrossivity. 3) It ca diagnose particular corretion problem and can identify, the rate and cause etc. 4) It evaluate the effectiveness of corrosion control/prevention technique. 5) It provide management information related to the maintenance rquirements.	1.4x5=7	7	7
X (a)	Electric resistance probes provide a basic measurement of metal loss. Measured at any time, freequantly as required. * The electric resistane technique measures the change in ohmic resitsance of corroding metal element exposed to the process stream. * Due to corrosion the cross section area of the component decreases, hence a corresponding increase in its electrical resistance will be there. * The increase in resistance can be related directly to metal loss and metal loss as a function of time is the corrosion rate.The graph below shows the typical responce. The major advantages of ER method are, 1. Direct corresion rate can be obtained. Probe remains installed in line until the operational life has been exhausted. 3. They respond quickly to corrosion upsets and can be used to trigger an alarm.	Expl.- 5 marks figure-3 marks	8	8

					
X (b)	1. Compitability with previous or existing maintenance software. 2. Compitability with existing hardware or operating system. 3. Ease of implementation and ease of use. 4. general reputation of software and its vendor. 5. Integration with other commercial and technical software. 6. Already being used in sister concern or other department of same organization. 7. Cost of implementation, including cost of purchase and consultants. 8. Availability of local support and training facility. 9. Availability of local language version. 10. Extensive management reporting capabilities.		1×7=7	7	7