DHANALAKSHMI SRINIVASAN ENGINEERING COLLEGE
(AUTONOMOUS)
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Accredited by NBA – BME, ECE & EEE
PERAMBALUR - 621 212. Tamil Nadu.
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Course Code/Name	**U23MET42/THERMALENGINEERING**

Syllabus

UNIT I/ GASPOWER CYCLES	**No.of Periods:9**
Otto,Diesel,Dual,ConstantPressureJoulecycles-airstandardefficiency.Comparisonofefficiencies,meaneffectivepressureTheoretical and ActualPV diagrams.	
UNIT II / STEAMNOZZLESAND INJECTOR	**No.of Periods:9**
TypesandShapesofnozzles,Flowofsteamthroughnozzles,Criticalpressureratio,Variationof massflowratewith pressureratio.Effectof friction.Meta stableflow.	
UNIT III / STEAMANDGASTURBINES	**No.of Periods:9**
Types,Impulseandreactionprinciples,Velocitydiagrams,Workdoneandefficiency–optimal operating conditions. Multi-staging, compounding and governing. Gas turbine cycle analysis – openand closed cycle. Performance and its improvement - Regenerative, Intercooled, Reheated cyclesandtheircombination.	
UNIT IV / INTERNALCOMBUSTIONENGINES– FEATURESANDCOMBUSTION	**No.of Periods:9**
ICengine–Classification,working,componentsandtheirfunctions.Idealandactual:Valveand port timing diagrams, p-v diagrams- two stroke & four stroke, and SI & CI engines – comparison.Geometric, operating, and performance comparison of SI and CI engines. Desirable properties andqualities of fuels.Air-fuelratio calculation–lean and rich mixtures. Combustion in SI & CIEngines– Knocking– phenomenaandcontrol.	
UNITV/REFRIGERATIONANDAIRCONDITIONING	**No.of Periods:9**
Vapourcompressionrefrigerationcycle-superheat,subcooling–Performancecalculations,Principleand workingofAmmonia– Watervapourabsorptionrefrigerationsystem,Comparisonbetweenvapourcompressionandabsorption systems.Air conditioning system- Processes - Types and Working rinciples.- Concept of RSHF, GSHF,ESHF - Cooling Load calculations.	

Objective:

Themain learningobjectiveof this courseis to preparethestudents for:

1. Computetheappropriateenergytransfersandsystempropertiestoanalyzeclosedsystem processesand gaspowercycles.
2. Analyzingtheperformanceofsteamnozzle,calculatecriticalpressureratio.
3. Evaluatingtheperformanceofsteamturbinesthroughvelocitytriangles,understandthe needforgoverningandcompoundingofturbines.
4. AnalyzingtheworkingofICenginesandvarious auxiliarysystemspresentin ICengines.
5. Analyzinganddesigning thedifferent RACsystems.

(**Useof SteamTables withMollierChartand Refrigeration andAirConditioning tableswithpsychrometricchart ispermitted)**

TEXT BOOK

T1.Rajput. R. K., —Thermal Engineering‖ S.Chand Publishers, 2018.

T2.Kothandaraman.C.P.,Domkundwar.S,Domkundwar.A.V.,—Acourseint hermal Engineering",Fifth Edition, ‖Dhanpat Rai & sons , 2016.

ReferenceBook:

R1.Sarkar,B.K,Thermal Engineering TataMcGraw-HillPublishers,2007

R2.Arora.C.P,Refrigeration and AirConditioning,TataMcGraw-HillPublishers2017 R3. GanesanV.Internal Combustion Engines, Fourth Edition, Tata Mcgraw-Hill 2018 R4.Rudramoorthy, R, —Thermal Engineering —, Tata McGraw-Hill, New Delhi,2003

R5.Ramalingam.K.K.,"ThermalEngineering",SCITECHPublications(India)Pvt.Ltd.,2018.

U23MET42/THERMALENGINEERING

UNIT I – GAS POWER CYCLES

PART-A Questions with Answers

1. **What is an air standard cycle?**
   Air standard cycle is an ideal cycle in which **air is used as the working fluid and combustion process is replaced by heat addition**.

2. **Define thermal efficiency of a cycle.**
   Thermal efficiency is the **ratio of net work output to heat supplied** in the cycle.

3. **What is Otto cycle?**
   Otto cycle is the **ideal cycle for spark ignition engines** consisting of two isentropic and two constant volume processes.

4. **Write the efficiency of Ott**

5. **What is compression ratio?**
   Compression ratio is the ratio of **maximum cylinder volume to minimum cylinder volume**.

6. **Define mean effective pressure (MEP).**
   MEP is the **constant pressure which produces the same work as the actual cycle**.

7. **What is Diesel cycle?**
   Diesel cycle is the **ideal cycle for compression ignition engines** where heat is added at constant pressure.

8. **What is cut-off ratio?**
   Cut-off ratio is the **ratio of cylinder volume after combustion to volume**

before combustion.

9. **Define Dual cycle.**
   Dual cycle is a combination of **Otto and Diesel cycles**, where heat is added partly at constant volume and partly at constant pressure.

10. **What is Joule cycle?**
    Joule cycle is the **ideal cycle for gas turbine power plants**.

11. **List the processes in Otto cycle.**

- Isentropic compression
- Constant volume heat addition
- Isentropic expansion
- Constant volume heat rejection

13. **What is clearance volume?**
    The volume remaining in the cylinder **when piston is at top dead centre**.

14. **Define swept volume.**
    Volume displaced by piston from **TDC to BDC**.

15. **What is work ratio?**
    Ratio of **net work output to turbine work**.

16. **What is PV diagram?**
    Graph showing **pressure vs volume changes during a thermodynamic cycle**.

17. **Define indicated power.**
    Power produced **inside engine cylinder**.

18. **Define brake power.**
    Actual useful power **available at engine shaft**.

19. **What is air fuel cycle?**
    A cycle considering **actual combustion effects**.

20. **Why Otto cycle efficiency is higher than Diesel cycle?**
    Because **heat addition occurs at constant volume**, giving higher temperature rise.

PART-B Questions

Theory Questions

1. Explain **Otto cycle with PV and TS diagrams** and derive efficiency equation.

2. Explain **Diesel cycle with PV and TS diagram** and derive efficiency expression.

3. Compare **Otto, Diesel and Dual cycles** with efficiency expressions.

4. Explain **Joule cycle (Brayton cycle)** with diagram and derive thermal efficiency.

5. Explain **mean effective pressure and its significance**.

Problems

6.An air standard dual cycle has a compression ratio of 16, and compression begins at 1bar, 50°C. The maximum pressure is 70 bar. The heat transferred to air at constant pressure is equal to that at constant volume. Estimate (a) the pressures and temperatures at the cardinal points of the cycle, (b) the cycle efficiency and (c) the mean effective pressure of the cycle.

7.. compression ratio of an air standard dual cycle is 12 and the maximum pressure on the cycle is limited to 70bar. The pressure and temperature of the cycle at the beginning of compression process are 1bar and 300K. Calculate the thermal efficiency and Mean Effective Pressure. Assume cylinder bore = 250mm, Stroke length = 300mm, Cp=1.005KJ/Kg K,

Cv=0.718KJ/Kg K.

8. Derive an expression for the air-standard efficiency of Otto cycle. Explain why the efficiency of Otto cycle is greater than that of the diesel cycle for the same compression ratio.
9. An Otto cycle has an compression ratio of 7. The initial pressure and temperature at the beginning of compression stroke is 1 bar and 40 o C. The heat supplied is 2510 kJ/kg. Find (i) Maximum temperature and pressure, (ii) Work done per kg of air, (iii) Cycle efficiency and (iv) Mean effective pressure. Assume, C p and C v , R and γ suitably.

10.Air standard Diesel cycle has a compression ratio of 18. The pressure at the beginning of the compression stroke is 1 bar and the temperature is30 0 C. The heat supplied is 1800 kJ/kg. Determine: (i) Thermal efficiency, (ii) Pressure and temperature at salient points, (iii) Heat rejected, (iv) Mean effective pressure. Assume, C p and C v , R and γ suitably.

UNIT II – STEAM NOZZLES AND INJECTOR

2 Marks Questions and Answers (20)

1. **What is a nozzle?**
   A nozzle is a **device used to convert pressure energy of steam into kinetic energy**.

2. **What is the function of a steam nozzle?**
   To **increase velocity of steam by decreasing pressure**.

3. **What are the types of nozzles?**

   - Convergent nozzle
   - Divergent nozzle
   - Convergent–divergent nozzle

4. **Define critical pressure ratio.**
   It is the **ratio of exit pressure to inlet pressure when steam velocity becomes maximum (sonic velocity).**

6. **What is supersaturated flow?**
   It is the **condition where steam expands below saturation temperature without condensation**.

7. **What is metastable flow?**
   It is a **delayed condensation of steam during expansion in nozzle**.

8. **What is nozzle efficiency?**
   Ratio of **actual kinetic energy at exit to ideal kinetic energy**.

9. **Write nozzle efficiency equation.**

10. **What is the effect of friction in nozzle?**
    Friction **reduces exit velocity and increases steam dryness fraction**.

11. **What is choking of nozzle?**
    Choking occurs when **mass flow rate becomes constant even if exit pressure decreases further**.

12. **What is throat of nozzle?**
    The **minimum cross-sectional area of a nozzle**.

13. **Define mass flow rate of steam.**
    Amount of steam **flowing through nozzle per second**.

14. **What is steam injector?**
    Device used to **feed water into boiler using steam pressure**.

15. **Who invented steam injector?**
    Henri Giffard invented steam injector.

16. **What are the parts of injector?**

- Steam nozzle
- Mixing chamber
- Diffuser

17. **What is the function of diffuser in injector?**
    To **convert velocity energy into pressure energy**.

18. **What is condensation shock?**
    Sudden **condensation of steam droplets in nozzle flow**.

19. **What is the purpose of convergent-divergent nozzle?**
    Used to **produce supersonic velocity**.

20. **Where are steam nozzles used?**

- Steam turbines
- Jet engines
- Injectors

16 Mark Questions

Theory Questions

1. Explain **types of steam nozzles with neat sketches**.

2. Derive the **expression for maximum mass flow rate through nozzle**.

3. Explain **critical pressure ratio and choking of steam flow**.

4. Explain **metastable flow in steam nozzle**.

5. Explain **working of steam injector with diagram**.

Problems

6. Steam enters a nozzle at **10 bar and 300°C** with velocity **50 m/s** and leaves at **2 bar**.
   Calculate **exit velocity**.

7. Steam expands from **12 bar to 1 bar** in a nozzle.
   Determine **velocity at exit** if inlet velocity is negligible.

8. A steam nozzle receives steam at **15 bar and 350°C** and expands to **3 bar**.
   Calculate **mass flow rate if throat area is 5 cm^2**.

9. Steam flows through a nozzle from **8 bar to 1 bar**.
   Determine **throat pressure using critical pressure ratio**.

10. Steam expands in a nozzle from **10 bar to 0.1 bar**.
    If **nozzle efficiency = 90%**, calculate **exit velocity**.

11. Steam flows through a nozzle at an inlet pressure of 6 MPa and an inlet temperature of 250°C. The nozzle's exit pressure is 0.2 MPa, and the steam exits with a velocity of 90 m/s. Calculate the steam flow rate through the nozzle, given the nozzle diameter is 0.05 m

UNIT III – STEAM AND GAS TURBINES

2 Mark Questions and Answers (20)

1. **What is a steam turbine?**
   A steam turbine is a **prime mover that converts the thermal energy of steam into mechanical work**.

2. **What are the types of steam turbines?**

   - Impulse turbine

- Reaction turbine

3. **Who developed the impulse turbine?**
   Gustaf de Laval

4. **Who developed the reaction turbine?**
   Charles Parsons

5. **What is an impulse turbine?**
   A turbine where **steam expands completely in the nozzle and strikes the blades with high velocity**.

6. **What is a reaction turbine?**
   A turbine where **steam expands both in fixed and moving blades**.

7. **What is compounding in turbines?**
   Compounding is **splitting the total pressure drop into several stages** to reduce rotor speed.

8. **Types of compounding in impulse turbines?**

   - Velocity compounding
   - Pressure compounding
   - Pressure–velocity compounding

9. **Define blade efficiency.**
   Ratio of **work done on blades to kinetic energy supplied by steam**.

10. **Define stage efficiency.**
    Ratio of **actual work done in a stage to the isentropic energy drop**.

11. **What is nozzle efficiency?**
    Ratio of **actual kinetic energy at nozzle exit to ideal kinetic energy**.

12. **What is degree of reaction?**
    Ratio of **enthalpy drop in moving blades to total enthalpy drop in stage**.

13. **What is governing of turbines?**
    Controlling **steam flow rate to maintain constant speed**.

14. **Types of governing in steam turbines?**

- Throttle governing
- Nozzle governing
- Bypass governing

15. **What is carry over loss?**
    Loss due to **residual velocity of steam leaving turbine blades**.

16. **What is blade velocity coefficient?**
    Ratio of **actual blade velocity to theoretical velocity**.

17. **What is gas turbine?**
    A turbine where **high temperature gases drive the turbine blades to produce power**.

18. **What are the components of gas turbine plant?**

- Compressor
- Combustion chamber
- Turbine

19. **What is regeneration in gas turbines?**
    Process of **using turbine exhaust heat to preheat compressed air**.

20. **What is intercooling?**
    Cooling of air **between compressor stages to reduce work input**.

16 Mark Questions

Theory Questions

1. Explain **Impulse turbine with velocity diagrams** and derive work done equation.

2. Explain **Reaction turbine with velocity diagrams**.

3. Explain **types of compounding in impulse turbines with sketches**.

4. Explain **methods of governing of steam turbines**.

5. Explain **open cycle gas turbine with PV and TS diagrams**.

Problems

6.The velocity of steam, leaving the nozzle of an impulse turbine is 1000 m/s and the nozzle angle is 20°. The blade velocity is 350 m/s and the blade velocity of coefficient is 0.85. Assuming no losses due to shock at inlet, calculate for a mass flow of 1.5 kg/s and symmetrical blading.

1) Blade inlet angle. **(3)** 2) Driving force on the wheel. **(3)**

3) Axial thrust on the wheel and **(3)**

4) Power developed by the turbine. **(3)**

ii) Differentiate between impulse and reaction turbine. (4)

7.The following data refer to a single stage impulse turbine:
Isentropic nozzle enthalpy drops = 210KJ/Kg, Nozzle efficiency = 90%, Nozzle angle = 25 ˚, Ratio of blade speed to whirl component of steam speed =0.5, Blade velocity coefficient =0.9, The velocity of steam entering the nozzle = 30 m/s. Find (a) The blade angles at inlet and outlet if the steam enters the blades without shock and leaves the blades in an axial direction, (b) blade efficiency, (c) power developed and (d) axial thrust if the steam flow rate is 10Kg/sec.

UNIT IV – INTERNAL COMBUSTION ENGINES

2 Mark Questions and Answers (20)

1. **What is an Internal Combustion (IC) Engine?**
   An IC engine is a heat engine where **fuel combustion occurs inside the engine cylinder to produce power**.

2. **Classify IC engines.**
   - Spark Ignition (SI) engines
   - Compression Ignition (CI) engines
3. **What is a Spark Ignition (SI) engine?**
   An engine where **fuel–air mixture is ignited using a spark plug**.

4. **What is a Compression Ignition (CI) engine?**
   An engine where **fuel ignites automatically due to high compression pressure and temperature**.

5. **Give examples of SI and CI engines.**
   - SI engine: Petrol engine
   - CI engine: Diesel engine
6. **What is the function of a carburetor?**
   It **mixes air and fuel in proper proportion** for combustion.

7. **What is fuel injection?**
   Process of **injecting fuel directly into the combustion chamber**.

8. **What is knocking in SI engines?**
   Abnormal combustion **causing pressure waves and noise inside the cylinder**.

9. **What is knocking in CI engines?**
   Sudden **ignition of accumulated fuel causing pressure rise**.

10. **What is ignition delay?**
    Time between **fuel injection and start of combustion**.

11. **Define air-fuel ratio.**
    Ratio of **mass of air to mass of fuel in the mixture**.

12. **What is a rich mixture?**
    Mixture containing **more fuel and less air**.

13. **What is a lean mixture?**
    Mixture containing **more air and less fuel**.

14. **What is octane number?**
    Measure of **anti-knock property of petrol fuel**.

15. **What is cetane number?**
    Measure of **ignition quality of diesel fuel**.

16. **What is valve timing diagram?**
    Diagram showing **opening and closing of inlet and exhaust valves**.

17. **What is port timing diagram?**
    Diagram showing **timing of ports in two-stroke engines**.

18. **What are the strokes of a four-stroke engine?**

- Suction
- Compression
- Power
- Exhaust

19. **Define indicated power.**
    Power **generated inside the cylinder**.

20. **Define brake thermal efficiency.**
    Ratio of **brake power to heat supplied by fuel**.

16 Mark Questions

Theory Questions

1. Explain **working of four-stroke petrol engine with neat diagram**.
2. Explain **working of four-stroke diesel engine with diagram**.
3. Compare **SI and CI engines**.
4. Explain **combustion process in SI engines**.
5. Explain **knocking in SI and CI engines and methods of control**.
6. Explain in detail the working of battery ignition system and magneto ignition system with neat sketch.
7. b. What are the different methods of lubricating IC engine? Explain the pressure system of Lubrication with neat sketch.

Problems

8.The following observations were taken during a test on a single cylinder 4 stroke cycle engine having a bore of 300 mm and a stroke of 450 mm.
Ambient air temperature =22 ^{o} C
Engine speed = 300 rpm
Fuel consumption =11 kg/h
CV of fuel = 42000 kJ/kg.
Mean effective pressure = 6 bar
Rope diameter = 2 cm
Net brake load =1.0 kN
Brake drum diameter = 2 m
Quantity of Jacket cooling water = 590 kg/hr
Temperature entering cooling water = 22 ^{o} C
Temperature of leaving cooling water =70 o C
Quantity of air as measured =225 kg/h
Specific heat of exhaust of gases =1.005 kJ/kgK
Exhaust gas temperature =405 ^{o} C
Determine
indicated power,
brake power
mechanical efficiency and draw a heat balance sheet on hour basis.

9. Calculate the diameter and length of the stroke of a diesel engine working on four stroke constant pressure cycle from the following data.
IP=18.75 kW
rotation per minute=220
CR=14
fuel cut-off ratio=1/20 th of stroke, index of expansion=1.3,
index of compression=1.35,
L/D=1.5.
Assume the pressure and temperature of the air at inlet are 1 bar and 40˚C respectively
10. The following data refer for a 4 stroke, 4-cylinder diesel engine:
Diameter of the cylinder =35 cm, stroke =40 cm, speed of the engine = 315 rpm, indicated mean effective pressure = 7 bar, brake power = 260 KW, Fuel

consumption = 80 kg/h, calorific value of fuel = 43000KJ/Kg, Hydrogen content in fuel = 13% and remaining is carbon, Air consumption = 30kg/min, Cooling water circulated = 90kg/min, Rise in temperature of cooling oil = 23°C, Cp for cooling oil = 2.2 KJ/kg-K, Exhaust gas temperature = 322°C, Cp for exhaust gases = 1.1 KJ/kg-K, Ambient temperature = 22°C, Cp for the super-heated steam =2 KJ/kg-K, Latent heat of steam = 2520 KJ/Kg. Find (a) the mechanical efficiency and indicated thermal efficiency and (b) Draw up heat balance sheet on minute and percentage basis.

UNIT V – REFRIGERATION AND AIR CONDITIONING

2 Mark Questions and Answers (20)

1. **What is refrigeration?**
   Process of **removing heat from a low temperature region and transferring it to a high temperature region**.

2. **What is refrigerant?**
   A substance used in refrigeration system **to absorb heat during evaporation**.

3. **Examples of refrigerants?**

   - Ammonia (NH_3)
   - Freon
   - Carbon dioxide

4. **What is ton of refrigeration?**

1;TR = 3.5;kW

5. **Define Coefficient of Performance (COP).**

COP = Refrigeration effect/ work input

6. **What are the main components of vapour compression system?**

    - Compressor
    - Condenser
    - Expansion valve
    - Evaporator

7. **What is subcooling?**
   Cooling the refrigerant **below saturation temperature**.

8. **What is superheating?**
   Heating the vapour **above saturation temperature**.

9. **What is vapour absorption refrigeration system?**
   System where **heat energy replaces mechanical compressor work**.

10. **Working fluids in absorption system?**

- Ammonia–water
- Lithium bromide–water

11. **What is psychrometry?**
   Study of **properties of moist air**.

13. **What is dry bulb temperature?**
   Temperature measured by **ordinary thermometer**.

14. **What is wet bulb temperature?**
   Temperature measured using **wet cloth covered thermometer**.

15. **What is dew point temperature?**
   Temperature at which **moisture starts condensing**.

16. **What is sensible heat?**
   Heat that **changes temperature without phase change**.

17. **What is latent heat?**
    Heat that **changes phase without temperature change**.

18. **What is SHF (Sensible Heat Factor)?**
    Ratio of **sensible heat to total heat load**.

19. **What is air conditioning?**
    Process of **controlling temperature, humidity, purity and air motion**.

20. **What is cooling load?**
    Total heat **removed from the air conditioning space**.

Theory Questions

1. Explain **Vapour Compression Refrigeration System with diagram**.

2. Explain **Vapour Absorption Refrigeration System**.

3. Explain **psychrometric properties of air with chart**.

4. Explain **air conditioning processes on psychrometric chart**.

5. Compare **vapour compression and vapour absorption systems**.