

PAPER-1 COLOR CODE : PINK

**24th NATIONAL CERTIFICATION EXAMINATION
FOR**

ENERGY MANAGERS & ENERGY AUDITORS - SEPTEMBER, 2024

PAPER - 1 : GENERAL ASPECTS OF ENERGY MANAGEMENT & ENERGY AUDIT

Date : 28.09.2024 Timings : 09:30-12:30 HRS Duration : 3 HRS Max. Marks : 150

Section – I: OBJECTIVE TYPE

Marks: 50 x 1 = 50

1. **Which entity is responsible for implementing the Energy Conservation Act 2001?**
 - a) Ministry of Renewable Energy
 - b) **Bureau of Energy Efficiency (BEE)**
 - c) Central Pollution Control Board
 - d) National Productivity Council
2. **Which of the following is a measure included in the Energy Conservation Act 2001?**
 - a) Energy audits
 - b) Energy-saving certificates
 - c) Standards and labelling
 - d) **All of the above**
3. **Calculate the energy consumed by a 200-watt appliance used for 5 hours a day over 30 days.**
 - a) **30 kWh**
 - b) 27000 kCal
 - c) 6500 kJ
 - d) 30 kJ/h
4. **Which of the following is a non-renewable energy source?**
 - a) Solar
 - b) Wind
 - c) Biomass
 - d) **Coal**
5. **How is energy efficiency typically improved in industrial processes?**
 - a) Reducing production rates
 - b) **Optimizing equipment performance**
 - c) Increasing labour
 - d) None of the above
6. **Which of the following is a typical step in an energy audit?**
 - a) Data collection
 - b) Analysis
 - c) Reporting
 - d) **All of the above**

7. **Which tool is commonly used for measuring power factor ?**
a) Thermometer
b) Hygrometer
c) Anemometer
d) None of the above
8. **What is the payback period in energy management?**
a) Time taken to identify savings
b) Time taken to report savings
c) Time taken to recover the investment through savings
d) All of the above
9. **Which of the following is a method for financing energy efficiency projects?**
a) Loans
b) Leasing
c) Performance contracting
d) All of the above
10. **What is the primary financial metric used to evaluate energy projects?**
a) Gross margin
b) Net present value (NPV)
c) Revenue
d) Operating income
11. **Which principle is energy monitoring and targeting based on?**
a) Energy consumption is constant
b) You can't manage what you don't measure
c) Energy consumption is unpredictable
d) Production rate has no effect
12. **Calculate the reduction in CO₂ emissions if energy efficiency measures save 1000 kWh, assuming 0.8 kg CO₂/kWh.**
a) 800 kg
b) 1250 kg
c) 625 kg
d) 1000 kg
13. Which of the following is not true, equivalent to 1 atm pressure?
a) 1 atm = 101.3 kPa
b) 1 atm = 10332 mmWC
c) 1 atm = 14.7 psi
d) 1 atm = 0.98 kg/cm²
14. Redwood Seconds is measure of _____
a) Density
b) Viscosity
c) Specific Gravity
d) Flash Point

15. For calculating plant energy performance which of the following data is not required
- a) Current year production
 - b) Capacity Utilization**
 - c) Reference year production
 - d) Reference year Energy use
16. The internal rate of return is discount rate for which NPV is
- a) Positive
 - b) Zero**
 - c) Negative
 - d) All of the above
17. Transit time method is used in which of the instrument
- a) Lux Meter
 - b) Ultrasonic Flow Meter**
 - c) Pitot Tube
 - d) Fyrite
18. Which of the following GHG has the longest atmospheric life time
- a) Carbon dioxide (CO₂)
 - b) Sulphur Hexafluoride (SF₆)
 - c) Chlorofluorocarbons (CFC)
 - d) Perfluorocarbons (PFC)**
19. What is the heat content of 500 liters of water at 6°C in terms of the basic unit of energy in kilojoules?
- a) 12000
 - b) 3000
 - c) 500
 - d) None of the above**
20. The number of moles of water contained in 72 grams of water is
- a) 2
 - b) 3
 - c) 4**
 - d) 5
21. Which of the following is not objective of Demand Side Management?
- a) Managing Demand by DISCOM to reduce peak demand
 - b) Increasing Load of Generator to meet Peak demand**
 - c) Reducing Capital need for Power Capacity Expansion
 - d) None of the above
22. Which of the following has the lowest energy content in terms of MJ/kg
- a) LPG
 - b) Diesel
 - c) Bagasse**

- d) Furnace Oil
23. Heat transfer in an air-cooled condenser occur predominately by
- a) Conduction
 - b) Convection**
 - c) Radiation
 - d) All of the above
24. The force field analysis in energy action planning considers
- a) Positive forces only
 - b) Negative Forces only
 - c) No forces
 - d) Both Positive and Negative forces**
25. To arrive at the relative humidity at a point we need to know _____ of air
- a) DBT
 - b) WBT
 - c) Dew point
 - d) Both A and B**
26. Which statement is false regarding Critical path
- a) CP is longest duration path
 - b) It identifies minimum time to Complete the project
 - c) Activities lies on it cannot be delay
 - d) It is maximum time required to complete the project**
27. The roto axis is aligned with wind direction in windmill by _____ control?
- a) Yaw**
 - b) Pitch
 - c) Disc Break
 - d) Both A and B
28. For activity in project, Latest start time is 8 weeks and Latest Finish time is 12 Weeks. If the earliest finish time is 9 Weeks, Slack time for the activity is
- a) 1 Week
 - b) 3 Weeks**
 - c) 4 Weeks
 - d) 7 Weeks
29. Which techniques takes care of time value of money in evaluation
- a) Payback Period
 - b) IRR
 - c) NPV
 - d) Both B and C**
30. If asset depreciation is considered, then the net operating cash inflow will be
- a) Lower

- b) Higher**
- c) No effect
- d) None of the above

31. One Silicon cell in PV modules typically produces

- a) 0.5 V**
- b) 1.0 V
- c) 1.5 V
- d) 2.0 V

32. When the evaporation of water from wet substance is zero, the relative humidity of air is likely to be

- a) 0%
- b) 50%
- c) 100%**
- d) Unpredictable

33. The energy conversion efficiency of solar cell does not depend on

- a) Solar Energy Insolation
- b) Inverter**
- c) Area of the Solar Cell
- d) Maximum Power Output

34. Energy Intensity is ratio of

- a) Fuel Consumption/GDP
- b) GDP/Fuel Consumption
- c) GDP/Energy Consumption
- d) Energy Consumption/GDP**

35. In inductive and resistive combination circuit, the resultant power factor under AC supply will be

- a) Less than Unity**
- b) More than Unity
- c) Zero
- d) Unity

36. If wind speed triples, the energy output from wind turbine will be

- a) 3 Times
- b) 6 Times
- c) 9 Times**
- d) None of the above

37. If we heat air without changing absolute humidity, % relative humidity will

- a) Increase
- b) Decrease**
- c) No change
- d) Can't Say

38. Among which of the following fuel the difference between the GCV and NCV is maximum
- a) Coal
 - b) Furnace Oil
 - c) Natural Gas**
 - d) Rice Husk
39. Which among the following factors is most appropriate for adopting EnMS?
- a) To improve their energy efficiency
 - b) To reduce cost
 - c) To increase productivity
 - d) Systematically manage their energy use**
40. The Ozone layer in stratosphere act as an efficient filter for
- a) UV-B Rays**
 - b) UV-C Rays
 - c) X- Ray
 - d) Gamma Rays
41. An induction motor with 30 kW rating and efficiency of 85% in its name plate means
- a) It will draw 35.29 kW at full load**
 - b) it will always draw 30 kW at full load
 - c) it will draw 25.5 kW at full load
 - d) it will draw 28.23 kW at full load
42. Which of the following macro factors is used in the sensitivity analysis of project finance
- a) Change in Tax rate**
 - b) Change in O & M Cost
 - c) Change in Debt : equity Ratio
 - d) Change in forms of Financing
43. An indication of Sensible heat content in air-water vapour mixture is
- a) Wet bulb temperature
 - b) Dry bulb temperature**
 - c) dew point temperature
 - d) density of air
44. Energy content in 2500 kgs of coal with a calorific value of 4000 kcal/ kg in terms of toe would be
- a) 1 toe**
 - b) 10 toe
 - c) 100 toe
 - d) 1000 toe
45. Reserve per production (R/P) is estimated as
- a) Reserves remaining at end of year X production in the year
 - b) Reserves remaining at end of year / production in the year**
 - c) production in year / Reserves remaining at end of the year

d) None of the above

46. In a fuel cell, ___ combines with ___ to generate electricity and ___ comes out as a by-product.

- a) **Hydrogen, Oxygen, water**
- b) Hydrogen, Nitrogen, nitrous oxide
- c) Carbon, hydrogen, methane
- d) Carbon, oxygen, carbon dioxide

47. A manufacturing plant consumes 5 tonnes of coal (CV = 4000 kCal/ kg) to produce 25 tonnes of cement. The Specific Energy Consumption (SEC) of the plant shall be

- a) 100 kcal/ kg of cement
- b) 200 kcal/ kg of cement
- c) 400 kcal/ kg of cement
- d) **800 kcal/ kg of cement**

48. A solution of common salt in water is prepared by adding 25 kg of salt to 100 kg of water. The concentration of salt in this solution as a weight fraction shall be

- a) 10%
- b) 15%
- c) **20%**
- d) 25%

49. An electric iron of power 2000 watts is used for a total of 120 minutes per month. Compute its monthly electricity consumption

- a) 2.0 kWh
- b) 2.4 kWh
- c) **4.0 kWh**
- d) 24.0 kWh

50. The dryness fraction (x) of superheated steam will be

- a) $x = 0.8$
- b) $x = 0.9$
- c) **$x = 1$**
- d) $x = 0$

..... **End of Section I**

Section – II: SHORT DESCRIPTIVE QUESTIONS

Marks: 8 x 5 = 40

- (i) Answer all **Eight** questions
- (ii) Each question carries **Five** marks

- | | |
|----|---|
| S1 | <ul style="list-style-type: none">a) Lower energy intensity of a country need not necessarily mean higher energy efficiency. Explain?b) Why is energy intensity expressed taking into account purchase power parity? |
|----|---|

	<p>Solution:</p> <p>a) Page No 17</p> <p>b) Page No 18</p>
S2	<p>a) Differentiate between commercial and non-commercial energy with an example for each.</p> <p>b) Differentiate between renewable and non-renewable energy with an example for each.</p> <p>Solution:</p> <p>a) Page No 2</p> <p>b) Page No 3</p>
S3	<p>a) Write down the parameters, which can be measured by the following instruments.</p> <ul style="list-style-type: none"> • Stroboscope • Sling Psychrometer • Fyrite • Pitot Tube <p>b) An electric resistive heater consumes 3.6 MJ when connected to a 200 V supply for one hour. Find the rating of the heater and the current drawn from the supply.</p> <p>Solution:</p> <p>a)</p> <p>Stroboscope – Non Contact Speed measurement</p> <p>Sling Psychrometer – Dry and wet bulb temperature</p> <p>Fyrite – To measure O₂ and CO₂</p> <p>Pitot Tube – To measure pressure in gas ducts</p> <p>b)</p> <p>Energy=power x time</p> <p>Power=Energy / time</p> <p>= $3.6 \times 10^6 \text{ J} / (60 \times 60) = 1 \text{ kW}$</p> <p>Current = Power / Voltage = $1000 \text{ W} / 200 \text{ V} = 5 \text{ Ampere}$</p>
S4	<p>A 10 HP rated induction motor, with nameplate details indicating 415V, 12 amps, and a power factor (PF) of 0.9, is being audited. During the audit, the monitoring equipment displays a reactive power of 2 kVAr and a power factor of 0.758. Calculate the percentage loading of the motor at the time of the test.</p> <p>Solution:</p> $\text{PF} = \text{kW} / \text{KVA} \quad (1)$ $(\text{KVA})^2 = (\text{kVAr})^2 + (\text{kW})^2 \quad (2)$ <p>Given kVAr = 2 and PF=0.758</p> <p>Solve for kW in eqn (2) using eqn (1) we get, kW measured = 2.32kW</p>

	<p>Motor rated input kW= $1.732VI\cos \phi = 1.732 \times 0.415 \times 12 \times 0.9 = 7.76 \text{ kW}$</p> <p>Percentage loading of motor= $\text{kW measured /rated input kW} \times 100$</p> <p style="text-align: center;">$= 2.32/7.76 \times 100 = \mathbf{29.88\%}$</p>
S5	<p>A renovation and modernization (R&M) program of a 1 MW coal-fired thermal power plant was carried out to enhance the operating efficiency from 28% to 32%. The specific coal consumption was 0.7 kg/kWh before R&M. For 7000 hours of operation per year and assuming coal quality remains the same, calculate</p> <p>a) The coal saving per year in tonnes b) The expected avoidance of CO₂ into the atmosphere in Tons/year if the emission factor is 1.3 kg CO₂/kg coal.</p> <p>Solution:</p> <p>a) Coal consumption per kWh with 32 % efficiency = $28 \times 0.7 / 32 = 0.61 \text{ kg/kWh}$ Saving in coal = $(7000 \times 1000 \times (0.7 - 0.61)) = 630000 \text{ kg}$</p> <p>b) Expected Avoidance = $63000 \times 1.3 = 819 \text{ Tons/year}$</p>
S6	<p>A drilling machine drawing continuously 5 kW of input power and with an efficiency of 50%, is used in drilling a bore in an aluminum block of 5 kg of mass. A portion of energy imparted to the block is lost to surroundings and the balance is absorbed by the block in its uniform heating. A 45 °C rise in temperature of the block was observed at the end of 100 seconds and the specific heat of aluminum block is 900 J/kgK. What percentage of drilling machine output power is lost to the surroundings?</p> <p>Solution:</p> <p>Power input to the drilling machine = 5kW</p> <p>Power output of drilling machine = $5 \times 0.5 = 2.5 \text{ kW}$</p> <p>Energy used in drilling of bore, Q = $2.5 \times 1000 \times 100 = 250000 \text{ J}$</p> <p>Effective energy absorbed by block, Q' = $m \times c \times p \times (\text{temp rise}) = 5 \times 900 \times 45 = 202500 \text{ J}$</p> <p>Percentage of energy utilized for heating = $202500/250000 = 81\%$</p> <p>Percentage of energy lost to surroundings = $100 - 81 = \mathbf{19\%}$</p>
S7	<p>Calculate the investment of the project having IRR of 16% and having respective annual savings of Rs 15,000, Rs. 18,000 and Rs. 20,000 at the end of the first, second and third year.</p>

	<p>Solution:</p> $\text{NPV} = (15000/1.16) + 18000/(1.16 \times 1.16) + (20000/(1.16 \times 1.16 \times 1.16))$ $= 12931 + 13377 + 12813$ $= 39,121/-$
S8	<p>In a heat exchanger steam is used to heat 5 kL/ hour of furnace oil from 30°C to 90° C. Specific heat of furnace oil is 0.22 kcal/ kg/°C and the specific gravity of furnace oil is 0.95.</p> <p>a) How much steam per hour is required, if steam used is having latent heat of 510 kcal/kg?</p> <p>b) If steam cost is Rs.3.40/kg and electrical energy cost is Rs.6/kWh, which type of heating would be more economical in this particular case?</p> <p>Solution:</p> <p>a) Total heat required = $m C_p \Delta T = (5 \times 1000 \times 0.95) \times 0.22 \times (90 - 30) = 62,700 \text{ kcal/hr}$</p> <p>Latent heat of steam = 510 kcal/kg</p> <p>Amount of steam required = $62700/510 = 123 \text{ kg/hr}$</p> <p>b) Steam cost = $123 \times \text{Rs.}3.40 = \text{Rs.}417.9/\text{hr}$</p> <p>Amount of electricity required = $62700/860 = 72.9 \text{ kWh}$</p> <p>Cost of electricity = $72.9 \times \text{Rs.} 6 = \text{Rs.}437.4/ \text{hr}$</p> <p>Steam heating will be more economical</p>

..... End of Section II

Section – III: LONG DESCRIPTIVE QUESTIONS

Marks: 6 x 10 = 60

- (i) Answer all Six questions
- (ii) Each question carries Ten marks

L1	<p>a) A cement plant is planning for ISO 50001 certification. Write a goal, objective and target for meeting the requirements of energy management system (</p> <p>b) For an energy efficiency project, define (i) net operating cash inflows (ii) Economic life (iii) Salvage value</p> <p>c) Compare between NPV and IRR</p> <p>Solution:</p> <p>a) Book 1, Page 157</p> <p>b) Book 1, Page 173</p>
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L2

a)

You are part of the team responsible for evaluating the total energy consumption of a manufacturing plant. This plant operates around the clock and has substantial heating and cooling needs due to its production processes. It sources energy from electricity purchased from the grid, furnace oil for thermic fluid heaters, coal for steam boilers, High-Speed Diesel for diesel generators, and Liquefied Petroleum Gas for ovens. To determine if the plant qualifies as a designated consumer under EC Act, list down the data required for assessing the MTOe.

(5 Marks)

b) An energy manager in a factory has gathered following data to arrive at the plant energy performance. Reference year (2022) energy use was 20 million kcal and production factor (PF) for the current year (2023) is 0.9. While the current year's energy use is 19 million kcal. What is the plant energy performance of the factory for the year 2023? State the inference.

(5 marks)

Solution:

a)

Energy Source	Description	Unit of Measurement
Electricity	Purchased from grid	kWh
Furnace Oil	Used for thermic fluid heater	Liters
Coal	Used for steam boiler	Metric tons
HSD (High-Speed Diesel)	Used for diesel generators	Liters
LPG (Liquefied Petroleum Gas)	Used for ovens	Kilograms

b)

Given:

Reference year energy use (2022) = 20 million kcal

Production factor (PF) for the current year (2023) = 0.9

Reference year energy equivalent = Reference year energy use × Production factor
 = 20 million kcal × 0.9
 = 18 million kcal

To calculate the plant energy performance for the year 2023:

Plant Energy Performance = $\frac{\text{Reference Year Equivalent} - \text{Current Years Energy use}}{\text{Reference Year Equivalent}} \times 100$

$$= \frac{18 - 19}{18} \times 100 = -5.56\%$$

Inference:

	The plant energy performance has decreased by 5.56% in 2023 compared to the reference year energy use in 2022. This indicates that the factory's energy efficiency has worsened, as it consumed 5.56% more energy than expected based on the production factor.																																	
L3	<div>a) Draw PERT chart for the following task, dependency and duration.</div> <div>b) Find the critical path</div> <div>c) Calculate expected project duration</div> <table><tr><th>Task</th><th>Predecessors Tasks (Dependencies)</th><th>Expected Time as Calculated (Weeks)</th></tr><tr><td>A</td><td>-</td><td>3</td></tr><tr><td>B</td><td>-</td><td>5</td></tr><tr><td>C</td><td>-</td><td>7</td></tr><tr><td>D</td><td>A</td><td>8</td></tr><tr><td>E</td><td>B</td><td>5</td></tr><tr><td>F</td><td>C</td><td>5</td></tr><tr><td>G</td><td>E</td><td>4</td></tr><tr><td>H</td><td>F</td><td>5</td></tr><tr><td>I</td><td>D</td><td>6</td></tr><tr><td>J</td><td>G - H</td><td>4</td></tr></table> <div>Solution:</div> <div>a)</div> <div><pre>graph LR A((A)) -- 3 --> D((D)) A -- 7 --> C((C)) B((B)) -- 5 --> E((E)) C -- 5 --> F((F)) D -- 8 --> I((I)) E -- 4 --> G((G)) F -- 5 --> H((H)) G -- 4 --> J((J)) H -- 5 --> J I -- 6 --> J</pre></div> <div>b) The critical path is through activities C, F, H, J</div> <div>c) The expected project duration is 21 weeks (7+5+5+4)</div>	Task	Predecessors Tasks (Dependencies)	Expected Time as Calculated (Weeks)	A	-	3	B	-	5	C	-	7	D	A	8	E	B	5	F	C	5	G	E	4	H	F	5	I	D	6	J	G - H	4
Task	Predecessors Tasks (Dependencies)	Expected Time as Calculated (Weeks)																																
A	-	3																																
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C	-	7																																
D	A	8																																
E	B	5																																
F	C	5																																
G	E	4																																
H	F	5																																
I	D	6																																
J	G - H	4																																
L4	<div>An evaporator is to be fed with 5000 kg/hr of a solution having 0.5 % solids. The feed is at 38°C, and is to be concentrated to 1% solids. Steam is entering at a total enthalpy of 640 kcal/kg and the condensate leaves at 100 °C. Enthalpies of feed are 38.1 kCal/kg, product solution is 100.8 kCal/kg and that of the vapour is 640 kCal/kg. Find the mass of vapour formed per hour and the mass of steam used per hour.</div> <div>Solution:</div> <div>Mass of vapour</div> <div>Feed= 5000 kg/hr @ 0.5 solids</div>																																	

Solids = $5000 \times 0.5/100 = 25 \text{ kg/hr}$
 $\text{Mass}_{\text{out}} \times 1/100 = 25$
 $\text{Mass}_{\text{out}} = 2500 \text{ kg/hr}$
Vapour formed = $5000 - 2500 = 2500 \text{ kg/hr}$
Thick liquor = 2500 kg/hr

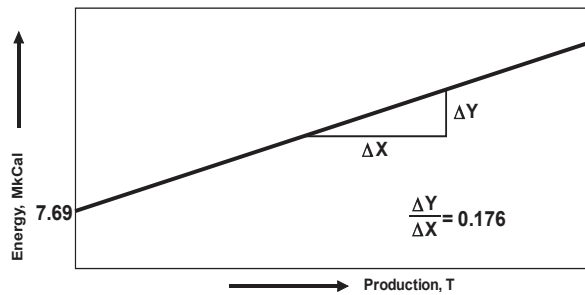
Steam Consumption

Enthalpy of Feed = $5000 \times 38.1 = 190500 \text{ kcal}$
Enthalpy of the thick liquor = $100.8 \times 2500 = 252000 \text{ kcal}$
Enthalpy of vapour = $640 \times 2500 = 16,00,000 \text{ kcal}$

Heat Balance

Heat input by steam + Heat in Feed = Heat out in vapour + Heat out in thick liquor
 $[M \times (640 - 100) + 38.1 \times 5000] = 1600000 + 252000$
 $M \times 540 = 1661500$
 $M = 3076.8 \text{ kg/hr}$

L5 Using the details given below, construct the CUSUM table and calculate the annual savings in MTOE, considering 10,000 kcal/kg of fuel.



Month	Electrical Power in kWh	Production (T)
Apr	90981	493
May	94993	335
Jun	88010	297
Jul	85374	493
Aug	88741	381
Sep	88450	479
Oct	90780	585
Nov	82216	440
Dec	90612	318
Jan	85672	234
Feb	74939	239
Mar	83823	239

Solution:

Year	Cash Flow (Rs. Lakhs)
0	-20
1	6
2	7
3	-1 (4-5)
4	9
5	15 (12+3)

The IRR is the discount rate that makes the Net Present Value (NPV) of these cash flows equal to zero.

$$NPV = -20 + \frac{6}{(1+r)^1} + \frac{7}{(1+r)^2} + \frac{-1}{(1+r)^3} + \frac{9}{(1+r)^4} + \frac{15}{(1+r)^5} = 0$$

Let's start with, say $r=15\%$ or 0.15.

$$\begin{aligned}
 NPV &= -20 + \frac{6}{(1+0.15)^1} + \frac{7}{(1+0.15)^2} + \frac{-1}{(1+0.15)^3} + \frac{9}{(1+0.15)^4} + \frac{15}{(1+0.15)^5} \\
 &= -20 + \frac{6}{1.15} + \frac{7}{1.3225} + \frac{-1}{1.520875} + \frac{9}{1.74900625} + \frac{15}{2.0113571875} \\
 &= -20 + 5.217 + 5.293 + (-0.657) + 5.146 + 7.457 \\
 &= -20 + 22.456 = 2.456
 \end{aligned}$$

Since the NPV is positive, we need a higher rate. Let's try $r = 20\%$ or 0.20.

$$\begin{aligned}
 NPV &= -20 + \frac{6}{(1+0.20)^1} + \frac{7}{(1+0.20)^2} + \frac{-1}{(1+0.20)^3} + \frac{9}{(1+0.20)^4} + \frac{15}{(1+0.20)^5} \\
 &= -20 + \frac{6}{1.20} + \frac{7}{1.44} + \frac{-1}{1.728} + \frac{9}{2.0736} + \frac{15}{2.48832} \\
 &= -20 + 5 + 4.861 + (-0.578) + 4.339 + 6.027 \\
 &= -20 + 19.649 = -0.351
 \end{aligned}$$

Since the NPV is negative, we need a slightly lower rate. Let's try $r = 19\%$ or 0.19.

$$\begin{aligned}
 NPV &= -20 + \frac{6}{(1+0.19)^1} + \frac{7}{(1+0.19)^2} + \frac{-1}{(1+0.19)^3} + \frac{9}{(1+0.19)^4} + \frac{15}{(1+0.19)^5} \\
 &= -20 + \frac{6}{1.19} + \frac{7}{1.4161} + \frac{-1}{1.684319} + \frac{9}{2.0043401} + \frac{15}{2.384163719} \\
 &= -20 + 5.042 + 4.942 + (-0.594) + 4.490 + 6.292 \\
 &= -20 + 20.172 = 0.172
 \end{aligned}$$

Since the NPV is positive, we need a slightly higher rate. Let's try $r = 19.2\%$ or 0.192.

$$\begin{aligned}
 NPV &= -20 + \frac{6}{(1+0.192)^1} + \frac{7}{(1+0.192)^2} + \frac{-1}{(1+0.192)^3} + \frac{9}{(1+0.192)^4} + \frac{15}{(1+0.192)^5} \\
 &= -20 + \frac{6}{1.192} + \frac{7}{1.421664} + \frac{-1}{1.693737088} + \frac{9}{2.01797351296} + \frac{15}{2.40449389128} \\
 &= -20 + 5.035 + 4.924 + (-0.591) + 4.458 + 6.239 \\
 &= -20 + 20.065 = 0.065
 \end{aligned}$$

Since the NPV is positive but close to zero, we continue refining our guess slightly higher until we zero in on the IRR. With iterative refinement, we would zero in on an IRR of approximately 19.32%.

By interpolation Method

NPV at 20% = -0.351

NPV at 19% = 0.172

IRR = Lower rate + $\frac{\text{NPV at lower rate} \times (\text{Higher rate} - \text{lower rate})}{(\text{NPV at lower rate} - \text{NPV at higher rate})}$

$$\text{IRR} = 19 + \frac{0.172 \times (20-19)}{(0.172 - (-0.351))}$$

$$\text{IRR} = 19 + \frac{0.172}{0.523}$$

$$\text{IRR} = 19 + 0.32 = 19.32\%$$