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Class	10th	Chapter	10
Subject	Physics	Board	Federal

Chapter 10 — Heat Capacity and Modes of Heat Transfer

MULTIPLE CHOICE QUESTIONS

QI. Choose the best possible option in the following questions.

1. **Why is water used in radiators of automobile as coolant?**
   - **Options:** A. It is easily available | B. It is low cost or free | C. It has large specific heat | D. It has oxygen
   - **Correct Answer: C. It has large specific heat**
2. **Which of the following situations is the best example of conduction?**
   - **Options:** A. A metal spoon becomes hot when placed in boiling water | B. Warm air rising near a heater | C. Sunlight warming the surface of the Earth | D. A microwave oven heating food
   - **Correct Answer: A. A metal spoon becomes hot when placed in boiling water**
3. **Which combination of heat transfer methods would be dominant when you place your hand near, but not touching, a fire?**
   - **Options:** A. Conduction and radiation | B. Convection and conduction | C. Radiation and convection | D. Conduction and Insulation
   - **Correct Answer: C. Radiation and convection**
4. **What is symbol and what is unit for the heat capacity of an object?**
   - **Options:** A. $\mathrm{J\,C^{-1}}$ | B. $\mathrm{J\,kg^{-1}K^{-1}}$ | C. $\mathrm{J\,kg\,K^{-1}}$ | D. $\mathrm{J\,kg^{-1}K}$
   - **Correct Answer: A.** $\mathrm{J\,C^{-1}}$ *(Note: Standard SI symbol for heat capacity is C with unit* $\mathrm{J\,K^{-1}}$ *or* $\mathrm{J\,^{\circ}C^{-1}}$*)*
5. **If the same amount of heat energy is supplied to equal masses of water and copper, why does the temperature of copper increase faster?**
   - **Options:** A. Copper has a lower specific heat capacity | B. Water is a poor conductor of heat | C. Convection in water dissipates heat energy quickly | D. Radiation from water is stronger
   - **Correct Answer: A. Copper has a lower specific heat capacity**
6. **The transfer of heat that takes place because of density difference in fluids is:**

- **Options:** A. Conduction | B. Radiation | C. Convection | D. Insulation
- **Correct Answer: C. Convection**

7. **Which of the following statements best explains why the Earth experiences more heat from the Sun than the Moon, despite being almost the same distance away?**
   - **Options:** A. Earth is better conductor than the moon | B. The Earth has greenhouse gases | C. The Moon reflects most of the Sun's radiation | D. Moon traps heat effectively
   - **Correct Answer: B. The Earth has greenhouse gases**
8. **Dull black colour on a surface is the best absorber of radiation, which of the followings is the best radiator?**
   - **Options:** A. Dull black surface | B. Shining silver surface | C. Red Coloured Surface | D. White surface
   - **Correct Answer: A. Dull black surface**
9. **How does the enhanced greenhouse effect contribute to global warming?**
   - **Options:** A. It increases the Earth's ability to reflect solar radiation | B. It traps more heat in the Earth's atmosphere, raising global temperatures | C. It blocks ultraviolet rays from entering the atmosphere | D. It increases the Earth's rotation speed, causing heat buildup
   - **Correct Answer: B. It traps more heat in the Earth's atmosphere, raising global temperatures**
10. **What is the primary driving force behind the movement of tectonic plates?**
    - **Options:** A. Gravitational pull of the Moon | B. Solar radiation | C. Mantle convection currents | D. Magnetic field of the Earth
    - **Correct Answer: C. Mantle convection currents**
11. **Which layer of the Earth is composed of partially molten rock that can flow slowly?**
    - **Options:** A. Lithosphere | B. Asthenosphere | C. Mesosphere | D. Outer core
    - **Correct Answer: B. Asthenosphere**
12. **Which of the following extreme weather events is most directly associated with rising sea levels?**
    - **Options:** A. Tornadoes | B. Wildfires | C. Hurricanes | D. Earthquakes
    - **Correct Answer: C. Hurricanes**

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CONSTRUCTED RESPONSE QUESTIONS

QII. 1. AI-generated Image & Global Warming Questions

- **a. How do increased temperatures lead to more frequent heatwaves in cities?**
  - **Answer:** Cities feature vast concrete, asphalt, and dark building materials that absorb solar radiation quickly and retain heat—a phenomenon known as the **Urban Heat Island (UHI) effect**. As global temperatures rise, these surfaces store significantly more thermal energy during the day and release it slowly at night, amplifying local heat intensity and leading to more frequent, severe, and prolonged heatwaves.
- **b. How might the intensity of future hurricanes change if global temperatures continue to rise?**
  - **Answer:** Warm ocean surface waters act as the primary energy source for hurricanes. As global atmospheric temperatures rise, sea surface temperatures increase, leading to higher rates of evaporation and greater thermal moisture in the air. This additional thermal energy accelerates storm winds and atmospheric pressure differences, resulting in higher storm surges and significantly more intense, destructive hurricanes.
- **c. Explain what the glass roof of a greenhouse and carbon dioxide in Earth's atmosphere have in common in terms of heat and temperature.**
  - **Answer:** Both allow short-wavelength, high-energy solar radiation (visible light) to pass through freely. Once this radiation hits surfaces inside and is re-emitted as long-wavelength thermal infrared radiation (heat), both the glass roof and CO_2 molecules prevent these thermal waves from escaping outward. By trapping thermal energy, both raise and maintain internal temperatures higher than the surrounding ambient environment.

QII. 2. Data Table Analysis (10 g Water vs. 10 g Iron in Sunlight)

Time (minutes)	**0**	**15**	**30**	**45**	**60**
Temperature of water (°C)	25	26.2	27.5	28.8	30
Temperature of iron (°C)	25	35	45	55	65

- **a. Line Graph Instructions:**
  - **X-axis:** Time in minutes (scale: 0 to 60, mark every 15 min).
  - **Y-axis:** Temperature in °C (scale: 20 to 70 °C).
  - **Plot Water:** Connect points (0,25), (15,26.2), (30,27.5), (45,28.8), (60,30) with a steady, low-slope line labeled **"Water"**.
  - **Plot Iron:** Connect points (0,25), (15,35), (30,45), (45,55), (60,65) with a steep linear line labeled **"Iron"**.

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- **b. Based on the data in the table, which heats up quickly: water or metal?**
    - **Answer: Metal (Iron)** heats up significantly faster. Over 60 minutes, iron increases by 40 °C (from 25 °C to 65 °C), whereas water increases by only 5 °C (from 25 °C to 30 °C).
- **c. Which do you think will cool more slowly: water or iron? Elaborate your answer.**
    - **Answer: Water** will cool down much more slowly. Water has a very high specific heat capacity (≈ 4200 J/kg ·° C) compared to iron (≈ 450 J/kg ·° C). A higher specific heat capacity means water stores more energy per degree change and must release far more thermal energy per degree drop, slowing down its cooling process.
- **d. When you boil water in an iron pot on the stove, which heats up faster: the iron pot or the water? Provide a reason for your response.**
    - **Answer: The iron pot** heats up faster. Because iron has a much lower specific heat capacity than water, it requires significantly less heat energy to elevate its temperature. Furthermore, iron transfers heat directly via solid-state thermal conduction rapidly, warming the pot before the enclosed water heats up via convection.

SHORT RESPONSE QUESTIONS

QIII. Answer to Short Questions

1. **Why should we wear dark-coloured clothes in winter and white-coloured clothes in summer?**
    - **Answer:** Dark-coloured clothes are good absorbers and poor reflectors of thermal radiation, helping the body absorb heat from sunlight to stay warm in winter. White or light-coloured clothes reflect most solar thermal radiation and absorb very little, keeping the body cool during summer.
2. **In a house, geysers or water heaters are fitted on the ground floor, and still, we get warm water on the top floor without using a pump. How is it possible?**
    - **Answer:** Heating water creates **convective flow** and buoyant pressure differential. Hot water expands, becomes less dense, and naturally rises through upward piping. The denser, colder water at higher elevations continuously flows downward under gravity to replace it, establishing a natural thermal convection loop that pushes warm water to higher floors.
3. **Where will you get more heat from the wood fire, 1 meter above the woods or 1 meter from the front of the woods?**
    - **Answer:** You will receive more heat **1 meter directly above the wood fire**. Above the fire, heat is transferred by both **radiation and strong upward convection currents** (rising hot air). At 1 meter horizontally from the front, heat transfer occurs almost exclusively through radiation.

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4. **Why do crowded city areas feel hotter compared to the outskirts on a hot summer day? State the reasons for this difference.**
    - **Answer:** This is caused by the **Urban Heat Island effect**:
        - Concentrated concrete, bricks, and asphalt absorb and store large amounts of heat.
        - Tall buildings block natural wind channels, reducing radiative cooling and ventilation.
        - High waste heat output from vehicles, air conditioners, and industrial machinery adds direct thermal energy to urban air.
5. **Why is the metallic handle of a door colder than the wood of the same door when touched?**
    - **Answer:** Metal is a good thermal conductor, whereas wood is a thermal insulator. When touched, metal conducts thermal energy away from your skin rapidly, creating a cold sensation. Wood conducts heat away very slowly, so it feels warmer despite being at the exact same room temperature.
6. **How do trees help reduce the effects of climate change, and what could happen if forests are depleted?**
    - **Answer:** Trees act as carbon sinks by absorbing atmospheric carbon dioxide (CO_2) during photosynthesis and providing cooling through evapotranspiration. If forests are depleted (deforestation), excess CO_2 remains in the atmosphere, accelerating the greenhouse effect, raising global temperatures, and disrupting rain cycles.
7. **How does gravity contribute to the Earth's core temperature?**
    - **Answer:** Earth's high internal core temperature is maintained partly by initial **gravitational contraction energy** during Earth's formation (converting potential energy into thermal energy) and ongoing gravitational pressure/friction generated by heavy sinking elements (e.g., iron and nickel) towards the center.
8. **Why do certain gases in the atmosphere trap more heat than others?**
    - **Answer:** Gases such as CO_2, CH_4, and H_2O vapor have asymmetrical polyatomic molecular structures. These molecular bonds resonate and vibrate at frequencies that match infrared radiation wavelengths, causing them to absorb and re-emit heat back to Earth rather than allowing it to pass into space.
9. **What are the potential environmental impacts of extraction of geothermal energy?**
    - **Answer:** Potential impacts include surface land subsidence, localized seismic activity (minor tremors) caused by deep hydraulic fracturing/fluid injection, greenhouse gas emissions (H_2S, CO_2) trapped deep underground, and contamination of local freshwater sources if geothermal fluids leak.
10. **How does the specific heat capacity of different materials affect their use in cookware?**

- **Answer:**
  - Metals (copper, aluminum, iron) have **low specific heat capacities**, allowing them to conduct heat rapidly from the stove to food efficiently.
  - Handles made of bakelite or wooden materials have **high specific heat capacities** (and low conductivity), ensuring they remain safe to hold without transferring heat to the cook's hand.

11. **Water at** $20\,^{\circ}\text{C}$ **is sent deep underground into heated layers, where it turns into a mix of steam and hot water at** $100\,^{\circ}\text{C}$**. As the steam and hot water cool back down to** $20\,^{\circ}\text{C}$**, why does** 1 kg **of steam release more energy than** 1 kg **of hot water?**

- **Answer:** 1 kg of steam at $100\,^{\circ}\text{C}$ contains **latent heat of vaporization** ($L_v \approx 2.26 \times 10^6$ J/kg). Before cooling from $100\,^{\circ}\text{C}$ down to $20\,^{\circ}\text{C}$, steam must first undergo a phase change into water at $100\,^{\circ}\text{C}$, releasing this huge amount of latent heat energy before sensible heat cooling begins.

LONG RESPONSE QUESTIONS

QIV. Comprehensive Detailed Answers

1. Explain the concept of specific heat capacity in matter. Discuss various applications of water based on its high specific heat capacity.

- **Definition:** Specific heat capacity (c) is defined as the amount of heat energy (Q) required to raise the temperature of a unit mass ($m = 1\text{ kg}$) of a substance by 1 Kelvin (1 K) or 1 °C.
- **Formula:**

$$c = \frac{\Delta Q}{m\Delta T}$$

(Unit: $\text{J} \cdot \text{kg}^{-1}\text{K}^{-1}$ *or* $\text{J} \cdot \text{kg}^{-1}{}^{\circ}\text{C}^{-1}$*)*

- **Applications of Water ($c = 4200\text{ J/kg} \cdot \text{K}$):**
  - **Automobile Radiator Coolant:** Water absorbs large quantities of thermal energy generated by engines without experiencing an excessive increase in its own temperature.
  - **Central Heating Systems:** Hot water is circulated through radiators in cold climates because it retains heat for long durations during transport.
  - **Moderate Coastal Climates:** Oceans store solar heat during summer and release it slowly in winter, moderating temperature extremes near coastal regions (land and sea breezes).

2. What is conduction, and how is it explained by the kinetic theory of solids? What makes metals better conductors than other solid substances?

- **Conduction Definition:** The process of thermal energy transfer through a material medium without any net bulk movement of the material's particles, occurring primarily in solids through direct contact.

- **Kinetic Theory Explanation:** When one end of a solid is heated, particles at that end gain kinetic energy and vibrate more vigorously. These vibrating atoms collide with neighboring atoms, passing along vibrational kinetic energy sequentially through the solid lattice.
- **Why Metals Are Superior Conductors:**
    - Metals contain a high concentration of **free (delocalized) electrons**.
    - When heated, these light, mobile electrons gain kinetic energy and move rapidly through the atomic lattice, transferring thermal energy across distances much faster than slow inter-atomic lattice vibrations alone.

3. Analyze how heat is transferred through convection. Provide at least three practical examples of how convection is used in daily life.

- **Mechanism of Convection:** Heat transfer in fluids (liquids and gases) via physical fluid motion driven by density differences:
    1. Fluid near a heat source absorbs thermal energy, expands, and decreases in density.
    2. The lighter, warmer fluid rises upward.
    3. Cooler, denser fluid sinks down to replace it, establishing continuous **convection currents**.
- **3 Practical Examples:**
    1. **Electric Room Heaters:** Air near the floor heats up, expands, rises to the ceiling, cools down, and sinks back down to create a continuous room-warming circulation loop.
    2. **Land and Sea Breezes:** Daytime solar heating warms land faster than water; hot air over land rises, drawing in cooler air from the sea (Sea Breeze).
    3. **Domestic Hot Water Systems:** Water heated at the bottom of a boiler naturally ascends to storage tanks above due to buoyant convection currents.

4. Analyze the process of heat transfer through radiation, explaining why it is the fastest method of heat transfer. What factors influence the rate of heat transfer by radiation?

- **Radiation Definition:** The transfer of heat across space via **electromagnetic waves** (primarily infrared radiation) without requiring any physical intervening material medium.
- **Why Radiation is the Fastest Method:** Radiation travels at the **speed of light** ($c \approx 3 \times 10^8$ m/s) in a vacuum and does not depend on slower particle-to-particle physical collisions (conduction) or fluid circulation mass motion (convection).
- **Factors Influencing Rate of Radiant Heat Transfer:**
    1. **Surface Temperature:** According to Stefan-Boltzmann Law ($E \propto T^4$), higher surface absolute temperatures emit exponentially higher radiation rates.
    2. **Surface Area:** Larger surface areas radiate and absorb heat more rapidly.

3. **Color and Texture:** Dull, black, rough surfaces are optimal emitters/absorbers, whereas smooth, shiny, light-colored surfaces reflect heat energy.

5. Analyze the role of greenhouse gases in global warming. How does global warming contribute to the increased severity of hurricanes, heat waves, flooding, and droughts?

- **Role of Greenhouse Gases:** Gases like carbon dioxide (CO_2), methane (CH_4), and water vapor absorb outgoing terrestrial long-wave infrared radiation reflected from Earth's surface and re-radiate it in all directions, trapping heat in the troposphere.
- **Impact on Extreme Events:**
  - **Hurricanes:** Warm ocean waters supply extra latent heat to tropical storms, boosting maximum wind speeds and rainfall capacity.
  - **Heat Waves:** Elevated base atmospheric temperatures combined with soil moisture depletion exacerbate severe high-temperature weather spells.
  - **Flooding:** A warmer atmosphere holds more moisture ($\sim 7\%$ increase per degree Celsius warming), triggering high-intensity precipitation events.
  - **Droughts:** Accelerated evapotranspiration rates dry out soil rapidly in arid regions, extending drought periods.

6. Why Earth's core has extreme high temperature even after 4 billion years? Explain in detail.

- Earth's core retains an estimated temperature between $5000\,^{\circ}C$ and $6000\,^{\circ}C$ due to three major factors:
  1. **Primordial Heat Retention:** Massive gravitational potential energy converted into heat during Earth's accretion 4.5 billion years ago remains trapped because the rocky silicate mantle acts as a thick, effective thermal insulator.
  2. **Radiogenic Decay:** Continuous decay of long-lived radioactive isotopes (such as Uranium-238, Thorium-232, and Potassium-40) in Earth's deep interior constantly generates new thermal energy.
  3. **Latent Heat of Crystallization:** As Earth slowly cools, liquid iron in the outer core continuously solidifies onto the solid inner core, releasing latent heat energy into the core boundary.

7. How are tectonic plates formed, and what factors cause them to move? Explain these causes in detail and discuss the effects of plate movements.

- **Formation of Tectonic Plates:** Earth's cool, rigid outer shell (the lithosphere) is broken into major and minor fragments called tectonic plates, which float atop the semi-fluid, ductile asthenosphere beneath.
- **Factors Driving Plate Movement:**
  1. **Mantle Convection Currents:** Radioactive heating deep in Earth's interior causes mantle material to warm, expand, and rise, then cool and sink near the crust, dragging overlying plates horizontally.
  2. **Slab Pull:** Cold, dense oceanic lithospheric plates sink into the mantle at subduction zones under gravity, pulling the trailing plate along.

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3. **Ridge Push:** Mid-ocean ridges sit elevated; gravity forces newly formed, warm, buoyant lithosphere outward and downward away from the ridge crest.

- **Effects of Plate Movements:**
    - **Earthquakes:** Rapid release of stress along fault lines when sliding plates catch and slip.
    - **Volcanism:** Magma rises to the surface where plates diverge or subduct.
    - **Mountain Building (Orogeny):** Continental collision zones force continental crust upward to form mountain chains (e.g., the Himalayas).

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NUMERICALS

1. Convert specific heat of water 4180 J kg^{-1} K^{-1} into units of J $\text{g}^{-1}\text{°C}^{-1}$.

Given Data:

- Specific heat of water, $c = 4180$ J kg^{-1} K^{-1}

Conversion Factors:

1. 1 kg $= 1000$ g $\Longrightarrow 1$ $\text{kg}^{-1} = \frac{1}{1000}$ g^{-1}
2. A temperature change of 1 K is equal to a temperature change of 1 °C, so 1 $\text{K}^{-1} =$ 1 °C^{-1}.

Step-by-step Calculation:

$$c = 4180 \times \frac{1 \text{ J}}{(1000 \text{ g}) \cdot (1 \text{ °C})}$$

$$c = \frac{4180}{1000} \text{ J g}^{-1}\text{°C}^{-1}$$

$$c = 4.18 \text{ J g}^{-1}\text{°C}^{-1}$$

Answer:

$$\mathbf{4.18} \text{ J g}^{-1}\text{°C}^{-1}$$

2. Calculate amount of heat given to 25 kg of water to increase its temperature by 50 °C.

Given Data:

- Mass of water, $m = 25$ kg
- Increase in temperature, $\Delta T = 50$ °C $= 50$ K
- Specific heat capacity of water, $c = 4200$ J kg^{-1} K^{-1} *(or using* 4180 J kg^{-1} K^{-1}*)*

Formula:

$$Q = m \cdot c \cdot \Delta T$$

Calculation:

Using standard $c = 4200$ J kg^{-1} K^{-1}:

$$Q = 25 \text{ kg} \times 4200 \text{ J kg}^{-1} \text{ K}^{-1} \times 50 \text{ K}$$

$$Q = 5{,}250{,}000 \text{ J}$$

$$Q = 5.25 \times 10^6 \text{ J} = 5.25 \text{ MJ}$$

Answer:

$$\mathbf{5.25} \text{ MJ}$$

3. A half kg block of an unknown metal is heated from 30 °C to 80 °C, requiring 19 kJ of heat energy.

(a) Calculate the specific heat capacity of the metal. (b) If the same metal block is heated from 80 °C to 125 °C, how much additional heat energy would be needed?

Given Data:

- Mass of metal block, $m = 0.5$ kg
- Initial temperature, $T_1 = 30$ °C
- Intermediate temperature, $T_2 = 80$ °C

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- Heat supplied for first process, $Q_1 = 19\ \text{kJ} = 19{,}000\ \text{J}$
- Final temperature for second process, $T_3 = 125\ ^\circ\text{C}$

Part (a): Specific Heat Capacity (c)

- Temperature change (ΔT_1):

$$\Delta T_1 = T_2 - T_1 = 80\ ^\circ\text{C} - 30\ ^\circ\text{C} = 50\ ^\circ\text{C} = 50\ \text{K}$$

- Formula:

$$Q_1 = m \cdot c \cdot \Delta T_1 \Longrightarrow c = \frac{Q_1}{m \cdot \Delta T_1}$$

- Calculation:

$$c = \frac{19{,}000\ \text{J}}{0.5\ \text{kg} \times 50\ \text{K}} = \frac{19{,}000}{25} = 760\ \text{J kg}^{-1}\ \text{K}^{-1}$$

Part (b): Additional Heat Energy (Q_2)

- Additional temperature change (ΔT_2):

$$\Delta T_2 = T_3 - T_2 = 125\ ^\circ\text{C} - 80\ ^\circ\text{C} = 45\ ^\circ\text{C} = 45\ \text{K}$$

- Formula:

$$Q_2 = m \cdot c \cdot \Delta T_2$$

- Calculation:

$$Q_2 = 0.5\ \text{kg} \times 760\ \text{J kg}^{-1}\ \text{K}^{-1} \times 45\ \text{K}$$
$$Q_2 = 17{,}100\ \text{J} = 17.1\ \text{kJ}$$

Answer:

- **(a) 760** J kg^{-1} K^{-1}
- **(b) 17.1** kJ

4. Calculate the change in temperature of 5 litre of water if it absorbs 8.4 MJ of heat energy? (Use Specific heat of water = 4200 J kg^{-1} K^{-1})

Given Data:

- Volume of water, $V = 5$ liters
- Density of water, $\rho = 1$ kg/L $\Longrightarrow$ Mass of water $m = 5$ kg
- Heat energy absorbed, $Q = 8.4\ \text{MJ} = 8.4 \times 10^6\ \text{J} = 8{,}400{,}000\ \text{J}$
- Specific heat capacity of water, $c = 4200\ \text{J kg}^{-1}\ \text{K}^{-1}$

Formula:

$$Q = m \cdot c \cdot \Delta T \Longrightarrow \Delta T = \frac{Q}{m \cdot c}$$

Calculation:

$$\Delta T = \frac{8{,}400{,}000\ \text{J}}{5\ \text{kg} \times 4200\ \text{J kg}^{-1}\ \text{K}^{-1}}$$
$$\Delta T = \frac{8{,}400{,}000}{21{,}000} = 400\ \text{K} = 400\ ^\circ\text{C}$$

Answer:

400 ˚C

5. In a container, 100 g of water at 80 ˚C is mixed with 200 g of water at 20 ˚C. What will be the final temperature of the mixture, assuming no heat loss to the surroundings (and container)?

Given Data:

- Mass of hot water, $m_1 = 100\ \text{g} = 0.1\ \text{kg}$
- Initial temperature of hot water, $T_1 = 80\ ^\circ\text{C}$
- Mass of cold water, $m_2 = 200\ \text{g} = 0.2\ \text{kg}$
- Initial temperature of cold water, $T_2 = 20\ ^\circ\text{C}$
- Let final temperature of mixture $= T_f$

Principle of Conservation of Energy:

$$\text{Heat Lost by Hot Water} = \text{Heat Gained by Cold Water}$$

$$m_1 \cdot c \cdot (T_1 - T_f) = m_2 \cdot c \cdot (T_f - T_2)$$

Since specific heat c is the same for both samples of water, it cancels out from both sides:

$$m_1(T_1 - T_f) = m_2(T_f - T_2)$$

Calculation:

$$100 \times (80 - T_f) = 200 \times (T_f - 20)$$

Divide both sides by 100:

$$1 \times (80 - T_f) = 2 \times (T_f - 20)$$

$$80 - T_f = 2T_f - 40$$

$$80 + 40 = 2T_f + T_f$$

$$120 = 3T_f$$

$$T_f = \frac{120}{3} = 40\ ^\circ\text{C}$$

Answer:

40 ˚C

6. A 200 g piece of an unknown solid cylinder is heated to 110 ˚C and then placed into a calorimeter containing 200 g of water at 20 ˚C. The calorimeter has a mass of 60 g and specific heat capacity of 0.9 J/g˚C. The final temperature of the system (solid, water, and calorimeter) is 35 ˚C. Assume no heat is lost to the surroundings. Calculate the specific heat capacity of the solid.

Given Data:

- **Solid Cylinder:**
  - Mass, $m_s = 200\ \text{g}$
  - Initial temperature, $T_s = 110\ ^\circ\text{C}$
  - Final temperature, $T_f = 35\ ^\circ\text{C}$
  - Temperature decrease, $\Delta T_s = 110 - 35 = 75\ ^\circ\text{C}$
- **Water:**

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- Mass, $m_w = 200$ g
- Initial temperature, $T_w = 20$ °C
- Specific heat capacity of water, $c_w = 4.2$ J/g°C
- Temperature increase, $\Delta T_w = 35 - 20 = 15$ °C

- **Calorimeter:**
  - Mass, $m_c = 60$ g
  - Initial temperature, $T_c = 20$ °C
  - Specific heat capacity, $c_c = 0.9$ J/g°C
  - Temperature increase, $\Delta T_c = 35 - 20 = 15$ °C

Principle of Conservation of Energy:

Heat Lost by Solid = Heat Gained by Water + Heat Gained by Calorimeter

$$m_s \cdot c_s \cdot \Delta T_s = (m_w \cdot c_w \cdot \Delta T_w) + (m_c \cdot c_c \cdot \Delta T_c)$$

Calculation:

1. **Heat Lost by Solid:**

$$Q_{\text{lost}} = 200 \times c_s \times 75 = 15{,}000 \cdot c_s$$

2. **Heat Gained by Water:**

$$Q_w = 200 \times 4.2 \times 15 = 12{,}600 \text{ J}$$

3. **Heat Gained by Calorimeter:**

$$Q_c = 60 \times 0.9 \times 15 = 810 \text{ J}$$

4. **Equating Heat Lost and Heat Gained:**

$$15{,}000 \cdot c_s = 12{,}600 + 810$$
$$15{,}000 \cdot c_s = 13{,}410$$
$$c_s = \frac{13{,}410}{15{,}000} = 0.894 \text{ J g}^{-1}\text{°C}^{-1} \approx 0.89 \text{ J g}^{-1}\text{°C}^{-1}$$

Converting to J kg^{-1} K^{-1}:

$$c_s = 0.89 \times 1000 = 890 \text{ J kg}^{-1} \text{ K}^{-1}$$

Answer:

$$\mathbf{890} \text{ J kg}^{-1} \text{ K}^{-1} \quad (\text{or } \mathbf{0.89} \text{ J g}^{-1}\text{°C}^{-1})$$

7. (Second #6 in book) A hot steel rod is cooled by plunging it into cold water, as shown in Fig. The steel rod has a mass of 3 kg and is initially at a temperature of 450 °C. It cools to 50 °C when placed in the water. The specific heat capacity of steel is 460 J kg^{-1} C^{-1}. Calculate the thermal energy (heat) lost by the steel rod as it cools to 50 °C.

Given Data:

- Mass of steel rod, $m = 3$ kg
- Initial temperature, $T_1 = 450$ °C
- Final temperature, $T_2 = 50$ °C
- Change in temperature, $\Delta T = T_1 - T_2 = 450$ °C $- 50$ °C $= 400$ °C $= 400$ K
- Specific heat capacity of steel, $c = 460$ J $\text{kg}^{-1}\text{°C}^{-1}$

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Formula:

$$Q = m \cdot c \cdot \Delta T$$

Calculation:

$$Q = 3\ \text{kg} \times 460\ \text{J kg}^{-1}\text{°C}^{-1} \times 400\ \text{°C}$$
$$Q = 3\ \text{kg} \times 460\ \text{J kg}^{-1}\text{°C}^{-1} \times 400\ \text{°C}$$
$$Q = 3 \times 460 \times 400$$
$$Q = 552{,}000\ \text{J}$$

Answer:

552 kJ

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