PHYSICS

BOOKS - S CHAND PHYSICS (ENGLISH)

THERMAL RADIATION

Solved Examples

1. A metal ball of diameter 14 cm and mass 10kg is heated to a temperature of 227°C and suspended in a box whose waals are at a

temperautre of 27° C. What is the maximum rate at which its temperature will fall ? Stefan's constant = $5.67 \times 10^{-8} Wm^{-2} K^{-4}$, specific heat capacity of the metal = $420 Jkg^{-1} K^{-1}$.

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2. What is the heat lost from the body of a person her hour whose body temperature is 37° C and the surrounding temperature is 20° C ? The emissivity of the skin is 0.92 and the

surface area of skin is $1.6m^2$. (Asssume that the person is unclothed.)

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3. Two black bodies at temperautre 400K and 500K are placed in an evacuated enclosure whose wall are at 300K . Find the ratio of their rates of cooling.

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4. The sun radiates energy at the rate of $6.4 \times 10^{7} Wm^{-2}$. Calculate its temperature assuming it to be a black body.

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5. Calculate the black body temperature of the sun from th e following data :- Stefan's constant = $5.7 \times 10^{-8} Wm^{-2} K^{-4}$. Solar constant = $1500 W / M^{2}$. Radius of the sun =

7×10^8m . Distance between sun and earth = $1.5 \times 10^{11} m$.

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6. Calculate the colour temperautre of the sun assuming that the wavelength of maximum energy in the solar spectrum is 0.48 micron and the Wien's constant is 0.228×10^{-2} mK.

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7. A liquid cools from 70°C to 60°C in 5 minutes. If the temperautre of the surrounding is 30°C, what is the time taken by the liquid to cool from 50°C to 40°C ?

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8. Calculate the wavelength at which a hot body radiates maximum energy if its surface temperature is 3200°C. Wien's constant 0.00289 mK.

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9. The wavelength of greatest radiation intensity inside a greenhouse is 9.66×10^{-6} m. Calculate the corresponding temperature. Wien's constant is 0.00289 mK.

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Additional Solved Problems

1. An aluminiumum foil of relative emittance 0.1 is placed in between two concentric spheres at temperatures 300K and 200k respectively. Calculate the temperature of the foil after the steady state is reached . Assume that the spheres are perfect black body radiators. Also calculate the rater of energy transfer between one of the spheres and the foil.

$[\sigma = 5.67 \times 10^{-8}$ S.I. Unit]

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2. A black body initially at 27° C is heated to 327° C. How many times is the total radiation emitted at the higher temperature than that emitted at the lower temperature ? What is the wavelength of the maximum energy radiation at the higher temperature ? Wien's constant = 2.898×10^{-3} mK.

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3. A black body with an initial temperature of 300°C is allowed to cool inside an evacuated enclosure surrounded by melting ice at the rate of 0.35°C per second. If the mass, specific heat and surface area of the body are 32gm, $420 Jkg^{-1}K^{-1}$ and $8cm^{2}$ respectively, calculate the stefan's constant.

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4. The time taken by a liquid to cool from 65°C to 55°C is 5 minutes and cools to 47°C in the next 5 minutes, calculate the room temperature and the temperature of the body after another 5 minutes.

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Conceptual Short Answer Questions With Answers

1. 'The earth without its atmosphere would be inhospitably cold'. Why?

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2. "A solid sphere of copper of radius R and a hollow sphere of the same material of inner radius r and outer radius R are heated to the same temperature and allowed to cool in the same environment. Which of them starts cooling faster ?"

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3. "A body with larger reflectivity is a poor emitter". Why?

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4. What is the difference between radiation and thermal radiation?

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5. "Water pipes are painted with aluiminium paints". Why?

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6. Is it neccesary that all black coloured bodies to be regarded as perfectly black bodies ?

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7. Why do animals curl into ball during winter ?

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8. A car is left in Sunlight on a hot day with all the window closed. After sometime, it is found that she inside of a car is considerably warmer than the air outside. Why?

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9. "Air is a bad conductor of heat, but still we do not feel warm without clothes". Why?

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10. If the temperature of a black body is raised from 300K to 600K by what factor the rate of emission shall increase ?

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Long Answer Questions

1. State Stefan's law. Sketch graphs showing the distribution of energy in the spectrum of

black body radiation at three temperatures, and indicate which curve corresponds to the highest temperature.

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2. What is a black body ? On what factor does the radiation emitted depend ? Will the total radiation from it be more or less as compared to another body maintained at the same temperautre ? How does total energy radiated from it change with temperature? Is it

possible for a black body to radiate white light ?

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3. (a) Describe the principle of (i) a thermopile and (ii) a bolometer and show how these devices are used.

(b) Define the term black body. What is meant by black body radiation ? As the temeprature of a black body rises, what changes take place in (i) the total energy radiated from it and (ii)

the energy distribution amongst the wavelengths radiated ?

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4. State Stefan's law and Wien's displacement law. Draw graphs showing the distribution of energy in the spectrum of a black body. Explain what quantity is plotted against the wavelength . By considering how this energy distribution varies with tempaerature expalin the colour changes which occur when a piece

of iron is heated from cold to near the melting point.

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5. (a) State and explain Kirchhoff's law.

(b) Describe an experiment to verify it.

(c) Give two examples to illustrate Kirochhoff's law.

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6. (a) State Newton's law of cooling.

(b) Derive Newton's law of cooling from Stefan's law,.

(c) What is the limitation of Newton's law ?

(d) Derive the shape of the cooling curve of a hot body using Newton's law of cooling.

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Short Answer Questions

1. What is the difference between radiation and thermal radiation?

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2. Will a black body appear black at any temperature ? If so when ?

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3. Give two reasons why fluorspar prism is preffered over glass prism for the study of black body spectrum.

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4. Why we use a number of antimony-bismuth couple in a thermopile ?

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5. What is the advantage of a linear thermopile ?

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6. Mention four properties of thermal radiation.

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7. "The inside of Ferry's black body is blackened but nickel polished outside." Why?

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8. What is meant by temperature radiation ?

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9. Name the factors on which the thermal radiation emitted by a hot body depend."

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10. Define emissivity.

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11. What is the difference between absorptive power and spectural absorptive power ?

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12. What is the difference between absorptive power and spectural absorptive power ?

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13. What is the ralation connecting absorpative, reflecting and transmitting power of a body ?

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14. What is the significance of Kirchhoff's law ?

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15. Explain the formation of Fraunhofer lines using Kirchhoff's law .

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16. What is Stefan's constant ?

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17. What is the difference between Stefan's law and Newton's law of cooling ?

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18. State Wien's displacement law. Why is it called so ?

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19. Name the law which helps us to explain the distribution of energy in the spectrum of a black body for

(i) short wavelength only (ii) long wavelength only.

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20. Explain Prevost's theory of heat exchanges.

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21. Which body will emit more radiation under the similar condition, a black body or polished body ?

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22. Which star is at a higher temperature, a red star or a blue star ?

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23. Mention a method to measure the temperature of a star.

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24. "The earth is not in thermal equilibrium with the sun." Why ?

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25. Mountaineers caught in a storm sometimes survive by digging a cave in snow. How do they keep warm in the ice cave ?

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Very Short Answer Questions

1. Name the method of heat transfer which does not depends on gravity ?

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2. Does a body at 0°C radiate any heat ?

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3. Name the instrument used to measure temperature using the radiation emitted from the body ?

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4. What is (i) the absorbing power and (ii) the reflecting power of a 'perfect black body' ?

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5. "A hot liquid' remains hot and a cold liquid remains cold in a thermos flask." Explain how ?

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6. "Lamp black and platinum black are used as perfect black body one for absorption of heat radiation." Why ?

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7. At what temperature does a body strip radiating heat ?

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8. "A black dot on as a porcelain cup apppears dark. But when heated to a high temperature it becomes brighter than the rest of the cup." Why ?

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Selected Problems From Stefan S Law

1. Calculate the amount of radiant energy from a black body at a temperature of (i) 27°C (ii)

2727° C. $\sigma = 5.67 \times 10^{-8} Wm^{-2} K^{-4}$.

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2. Calculate the energy radiated per minute by a black body of surface area $200 cm^2$, maintained at 127° C. $\sigma = 5.7 \times 10^{-8} Wm^{-2} K^{-4}$

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3. A black body having an area of $2 \times 10^{-4} m^2$ for its radiating surface radiates energy of 16.42 J in 15 minutes. What is the temperature of the body ?

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4. Calcualte the maximum amount of heat which may be lost per second by radiation from a sphere of 10 cm in diameter and at a temperature of 227°C when placed in an

encloser at a temperature of 27°C. $\sigma = 5.7 \times 10^{-8} Wm^{-2} K^{-4}$.

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5. Calculate the energy radiated per minute from a filament of an incandescent lamp at 3,000 K if the surface area is $10^{-4} m^2$ and its relative emitted is 0.425.

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6. The energy radiated per hour from the surface of a filament 0.5 cm long and of radius 0.32 cm of an incandescent lamp at a certain temperature is 2.625×10^5 J. If the relative emittance of the surface is 0.8 calculate the temperature of the filament.

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7. A thin brass rectangular sheet of sides 10 cm and 5 cm is heated in a furnace to 500° C and

taken out. How much electric power is needed to maintain the sheet at this temperature ? Its emissivity is 0.25.

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8. Calculate the power of an incandescent lamp whose filament has a surface area of $0.19cm^2$ and is at a temperature of 3645K. Emmisivity of the surface is 0.4, $\sigma = 5.7 \times 10^{-8} Wm^{-2} K^{-4}$?

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9. The temperature of an elactric bulb changes from 2000K to 3000K due to a.c. voltage fluctuations. Calculate the percentage rise in electric power consumed ?

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10. A black body of mass .0.10 g is kept in a black enclosure or temperature 27°C. The temperature of the body is 127°C and the area of the emittimg surface in $10^{-3}m^{2}$. If its

specific heat capacity is 420 J $kg^{-1}k^{-1}$ find the rate of cooling of the body . $\sigma = 5.67 \times 10^{-8} Wm^{-2}K^{-4}$.

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11. If each square cm of the sun's surface radiates energy at the rate of $6.42 \times 10^{3} Js^{-1}cm^{-2}$, calculate the temperature of the sun's surface in degree celsius, assuming Stefan's law applies to the

radiation. (Stefan's constant = $5.67 \times 10^{-8} Wm^{-2} K^{-4}$)

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12. Considering the sun as a perfect sphere of radius 6.8×10^{8} m, calculate the energy radiated by it one minute. Take the temperature of sun as 5800 k and $\sigma = 5.7 \times 10^{-8}$ S.I. unit.

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13. A sphere of radius 5 cm at $1027^{\circ}C$ is suspended in a vaccum in an enclosure at $127^{\circ}C$. Assuming the sphere to be a black body calculate the rate of loss of heat.

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Selected Problems From Wien S Displacement Law

1. Calculate the effective temperature of the sun . Given that the wavelength of maximum

energy in the solar spectrum is 475 mm and Wien's constant is 2.898×10^{-3} mK.

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2. Two stars radiate maximum energy at wavelength 3.6×10^{-7} m and 4.8×10^{-7} m respectively. What is the ratio of their temperatures ?

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3. The surface temperature of a hot body is 1227°C. Find the wavelength at which it radiates maximum energy. Given Wien's constant = 0.2892 cm.K.

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4. Calculate the surface temperature of moon. Given that $\lambda_m = 14$ micrometer where λ_m is the wavelenght of the maximmum intensity of emission. Wien's constant = 0.2892cm.K.

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5. The operating temperature of an indirectly heated filament of a vaccum tube is around 1050K. At what wavelength will it radiate maximum ? Given b = 0.288 cm K.

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6. Calculate the temperature at which a body may appear (i) deep red (7900A) and (ii) blue (5000A).

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7. the maximmum temperature reached during an atomic explosion was of the order of 10^7 K. Calculate the wavelength of maximum energy b = 0.293 cm K.

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8. The temperature of a furnace is 2324° C and the intensity is maximum in its radiation

spectrum nearly at 12000A . If the intensity in the spectrum of a star is maximum nearly at 4800A, calculate the surface temperature of the star.

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9. If wavelength of maximum intensity of radiation emitted by sun and moon are 0.5×10^{-6} m and 10^{-4} m respectively. Calculate the ratio of their temperatures

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10. A black body emits radiation of maximum intensity at a wavelength of 5000A when the temperature of the body is 1227°C. If the temperature of the body is increased by 1000° C, calculate the wavelength corresponding to the maximum intensity.

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11. Two black bodies A and B emit radiations with peak intensities at wavelengths 4000 A

and 8000 A respectively. Compare the total energy emitted per unit area per second by the two bodies.

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12. A body cools from 60° C to 50° C in 6 minutes, the temperature of the surroundings being 25° C. What will be its temperature after another 6 minutes ?

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13. A body in a room cools from 85°C to 80° C in 5 minutes. Calculate the time taken to cool from 80° C to 75° C if the surrounding temperature is 30°C.

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14. A body initially at 80°C cools to 64°C in 5 minutes and to 52° C in 10 minutes. What will be the temprature after 15 minutes and what is the temperature of the surroundings ?

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