INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NPTEL
NPTEL ONLINE CERTIFICATION COURSE

Refrigeration and Air-conditioning

Lecture-36
Human Physiology

with
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Hello I welcome you all in this course on refrigeration and air conditioning today we will discuss the human physiology now today's and in today's lecture we will discuss the thermodynamics of human body.

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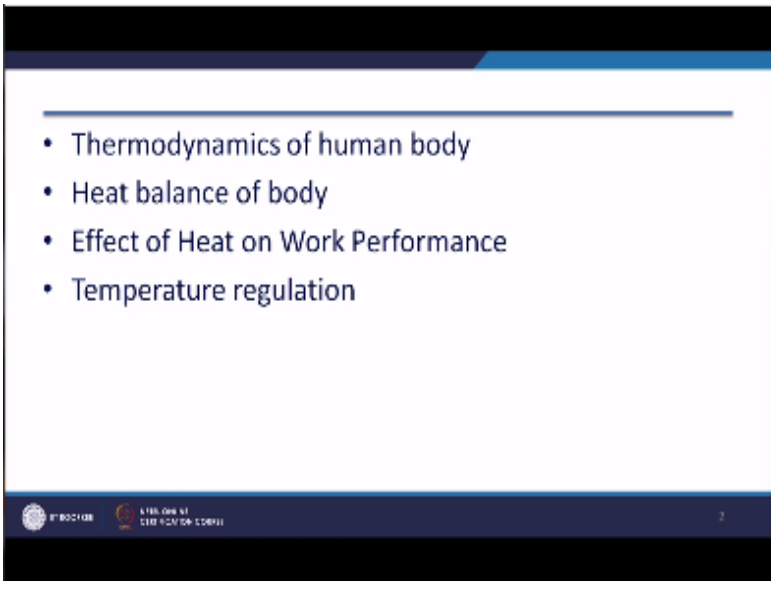

Heat balance of body effect of heat on work performance and human body temperature regulation now we energy we draw to do the work is through metabolic reactions metabolic reaction.

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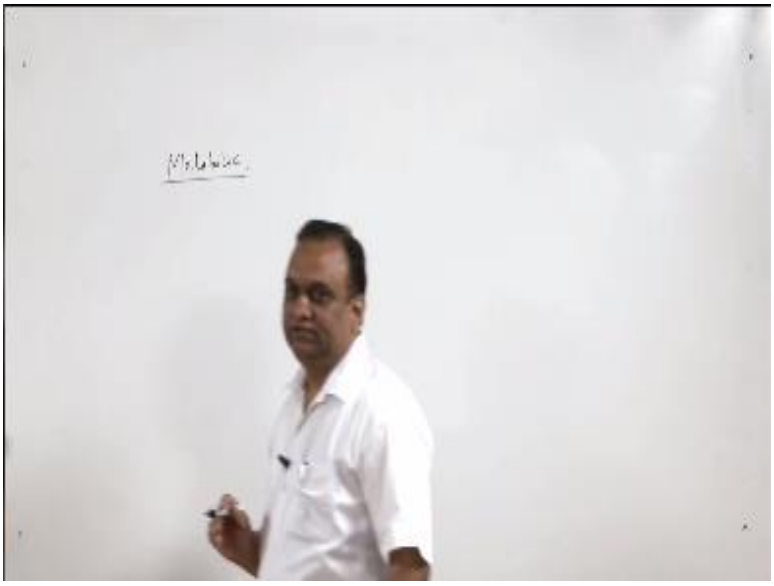

Out of these reactions the energy is involved evolved and approximately 20 % of this energy is used to.

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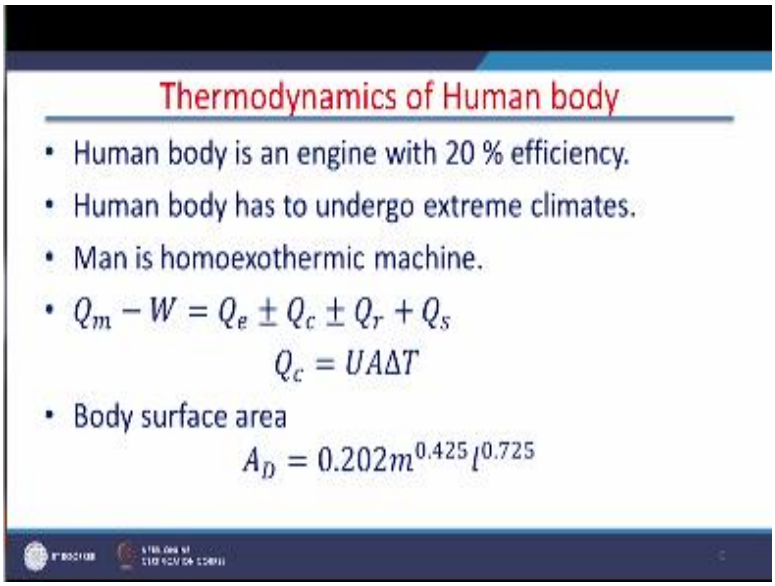

Is used for doing the mechanical work or external work.

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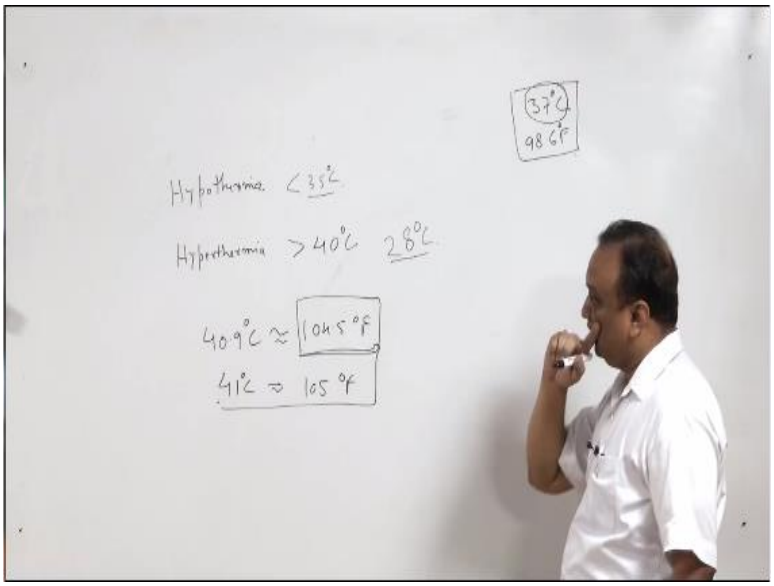

So if we consider our body as an engine the efficiency of our body is 20 % now where does this 80% heat go it cannot be stored in the body because if the heat is stored in a body the temperature of the body will is start rising so this heat has to be dissipated to the surroundings now here the dissipation of heat to the surrounding also depends upon the surrounding condition conditions now in India the climate varies from north to south and east to west east to west and north to south.

We have if you go to the western side of India especially in Rajasthan the climate is maybe 47 degree centigrade temperature and relative humidity this is DBT tribal temperature and relative humidity may be of the order of 10% 10 to 20% this is extremely dry weather if proper hydration of body is not maintained this can be fatal also now another extreme climate we are having like a coastal area coastal area the dry bulb temperature is a typical of coastal climate may be 35 degree centigrade relative humidity me shoot up to 70 or 80% the heat dissipation of human body will differ in this condition in this condition the mode of heat dissipation and heat dissipation from body will differ.

And body temperature has to be maintained constant the body temperature our body temperature is 36.9 earlier it was 98.4 Fahrenheit nowadays it has been corrected to 37 degree centigrade body temperature and 98.6 Fahrenheit our body is a hobo exothermic machine and the body temperature has to be maintained constant under all the circumstances under all the environmental conditions there are two states of body that is hypothermia and another is hyperthermia in hypothermia when the temperature is less than 35 degree centigrade.

And these are very serious situations when temperature is less than 35 degree centigrade or temperature is greater than 40 degree centigrade both are very serious conditions when temperature is let us say 40.9 degree centigrade it is equivalent to 104.5 degree Fahrenheit right so the when the patient enters this body temperature it is assumed that he has entered into a danger zone but at the moment the temperature become 40 degree41 degree centigrade and fresh patient is likely to be unconscious.

On the other hand if the body temperature is 20degree centigrade then there are chances of particles so a constant 37 degree centigrade temperature has to be maintained inside the body so a proper his heat balance of heat emitted from human body is required because metabolic rate is a continuous rate of heat evolution from the body now if you write the heat balance equation that is heat in metabolic.

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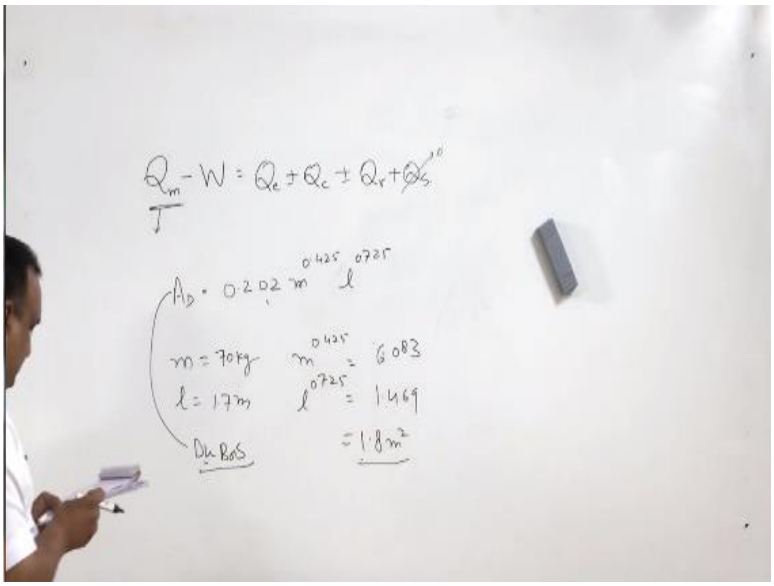

Metabolic minus work done that is energy consumed by doing some work is equal to now one mode of heat transfer from the body can be evaporative cooling so that is Qe another is conduction from the body and connection of the body can be import direction if suppose outside temperature is high heat will be conducted to the body and outside temperature is low heat will be dissipated from the body same is with the radiation heat transfer radiation heat transfer will also takes place will take the may be the temperature difference body temperature difference and outside temperature body temperature and outside temperature difference maybe of 5 degree centigrade but some amount of radiation heat transfer shall also take place +Qs heat stored in the body.

So this has to be zero in ideal condition if the heat body starts storing heat then the temperature of the body will shoot now there is a generalized correlation because when we talk about the heat transfer heat flux is more relevant for engineering practices heat flux appears to be more relevant when we want to do the engineering calculation so in that case you must have the body surface area of an individual right it is very difficult to predict but many samples were taken and a generalized correlation for body surface area that is A_D is equal to 0.202 meter 0.425 and this is height in meters 0.7 25.

Now using this formula you can also find the body surface area for an average European it is found to be 1.8 meter square male and for female it is 1.6 meter square so for yourself also suppose I take a case of let us say mass is 56 kg or 70 kg height is 1.7 m 1 let us see what is the body surface area of a individual that is $70^{0.425}$ $70^{0.5}$ will give us $m^{0.425}$ will give 6.083 and l is 1.7 so $L^{0.725}$ will give this is $1.7^{0.725}$ will give sorry $1.7^{0.7}$ it will give a 1. 469 and if we multiply this and this then we will get body surface area and that is going to be equal to 0.202 x 6.089x 1.469 approximately 1.8 meter square.

So this is how you can find the your body surface area also and this is known as DuBois equation similarly metabolic rate also you can calculate metabolic rate for yourself you can also calculate by using the equation.

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Metabolic rate = 210.23 RQ + 0.7 7 Q_{O2} / A now you have the area right now you have body area now you would have two unknowns that is RQ and Q_{O2} now RQ is the respiration quotient molar ratio of co2 and N oxygen in N and carbon dioxide exhale so this is the molar ratio molar

ratio of carbon dioxide exhale oxygen inhale linear normally inhale and exhale gases are measured in volumes, liters or milliliters.

So if you have this measurement in liters using PV is = mRT you can always find the mass of oxygen inhale and once you know the mass you can always find n you can find from here itself m universal gas constant P divided a molecule rate of oxygen right so bowls of oxygen you can find from this formula itself if you have the volume of the oxygen consumed right similarly you can find the moles of carbon dioxide in exhaled here and ratio these two will give you the respiratory coefficient quotient.

And Q_{o2} are is volume rate of oxygen consumption if you take volumetric rate of oxygen consumption at normal temperature and pressure it means zero degree centigrade temperature and pressure is 101.325kilo Pascal right now having the value of respiration coefficient in an oxygen consumption metabolic rate can be found out so in a human body now we can calculate the area of human body we can find the metabolic rate of the human body and metabolic rate is important so normally for a human body it is assumed that in this reactivity suppose somebody is sitting on this chair and doing nothing.

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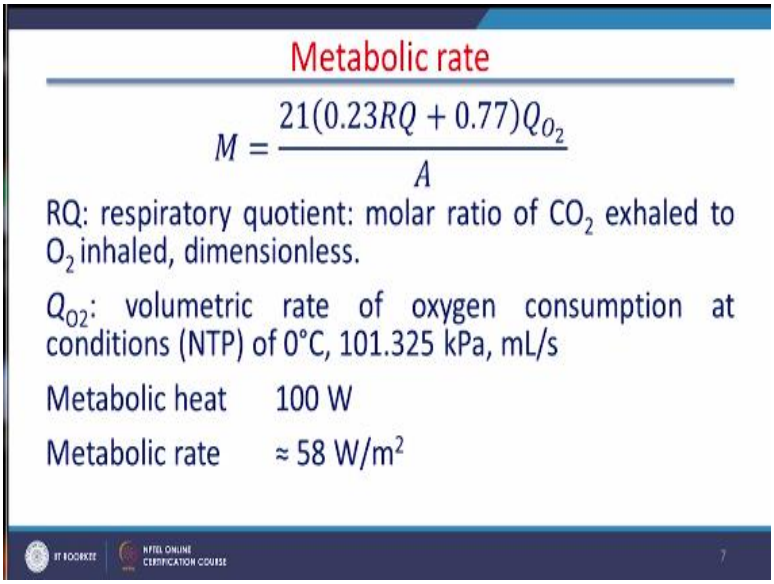

In that case the metabolic heat evolved from the body's 100 watts now if I divide this by surface area I will get the heat flux and that heat flux is approximately 58.1 or approximately 58 watt per meter square and this is known as 1 met.

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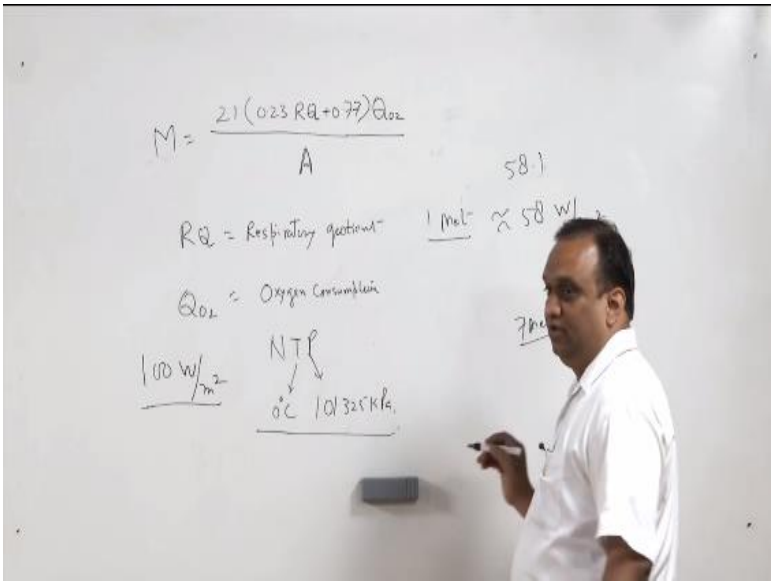

Metabolic rate is not expressed in terms of watts it is expressed in terms of met and one met is approximately 58 point 58 watts per meter square now we can have different metabolic rates for different somebody's doing wrestling for wrestler it goes up to 7 met so the heat rate of heat coming from the body is often expressed in terms of met when effective temperature of work output is effective temperature I have already explained you earlier is increased to 26 degree centigrade.

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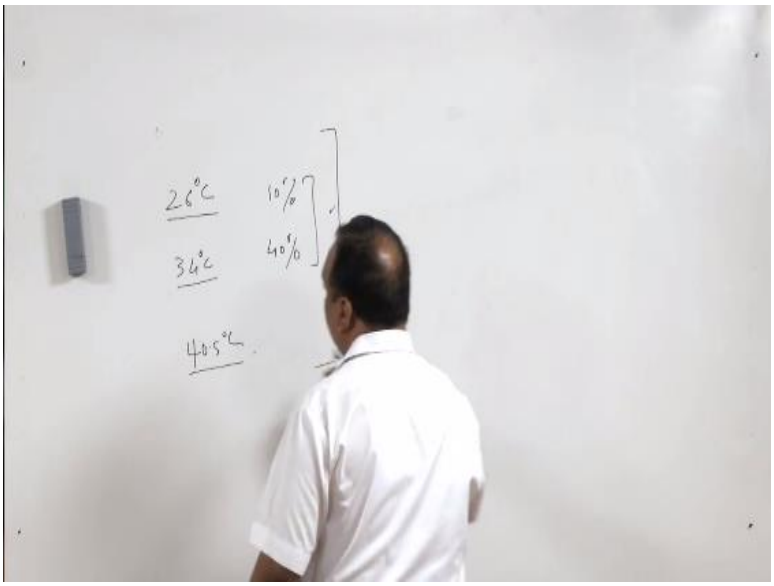

It is their estimate that the work output will reduce my 10% and then it exceeds 34 degree centigrade work output remains only 40 % so temperature is a major governing factor in worker that is why you will find that many of the factory or many of the workplaces were production is important rate of protection affects the performance of the factory the indoor environment is maintained in a comfortable state so air conditioning in fact in those cases air conditioning becomes a profitable investment because the productivity of the worker increases substantially increases in air-conditioned environment you can see a effective temperature is26 it is reduced by 10% for effective temperature 34 degrees centigrade it is reduced to 40%.

Now if the temperature keeps on increasing if temperature keeps on increasing the body temperature above 40.5 degree centigrade the body will experience heatstroke and heat is pro before heat is frog there are certain other state is also I will take them one by one.

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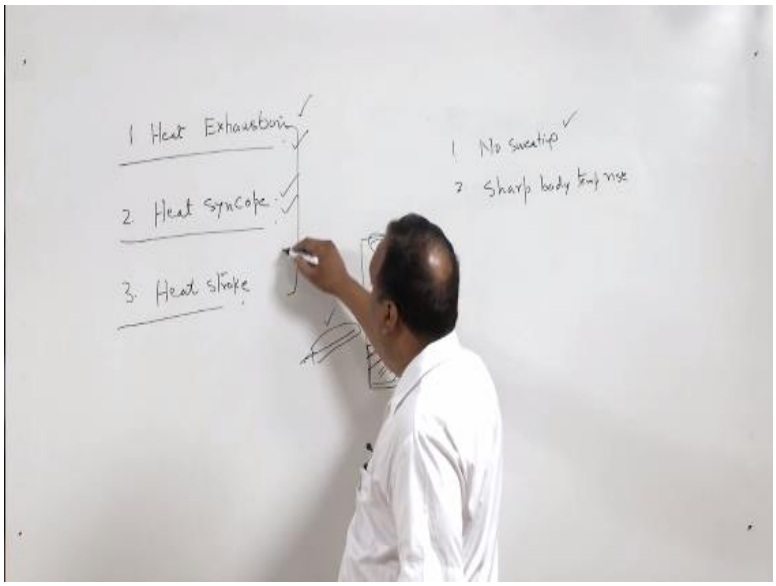

First is heat exhaustion so heat exhaustion around 40 degree centigrade it is due to 2 reasons shortage of water and second is salt and efficiency salt deficiency now in this heat exhaustion the person feel tired, giddy, nauseated and sometimes chilly also but these three symptoms are there when there is a heat exhaustion and the best thing is to give water to the patient if proper supply of water to the patient is made this problem can be avoided in this case the patient also feels shallow breathing and color of the skin also changes to pale.

So they are symptoms and immediately the symptom symptomatic relief will come the moment the water is supplied and water with the salt is supplied so is the case with the salt deficiency his proper salt is provided is supplied to the patient he will recover from this now another case is a second one that is heat syncope now in his heat syncope a in this case what happens due to high temperature above 40 degree centigrade the arteries or in the ways they get dilated when the veins and arteries that get dilated the blood is pulled in the lower half of the body and proper blood circulation is not there for the brain.

And patient becomes immediately unconscious so you must have harder you must have seen people is standing in the in the hot environment out a hot outer environment all of a sudden they

collapse right the reason being there is a shortage of blood supply to the brain and a pool of blood is formed in the bottom half of the body near the legs due to direction of veins so immediately this patient should be laid down in a in the shadow area and his head should be kept below the other parts of the body.

So there will be proper supply of blood to the brain and immediately within 5 and 10 minutes the patient will recover now the third is heat stroke which I was talking to about earlier now in heat stroke there is no sweating and it is a very it can be fatal also in heat stroke there is no sweating in heat stroke there is a sharp body temperature rise no sweating means the cooling mechanism of the body fails right and in this case the patient should be immediately put into the water or water should be pour over the patient immediately he or she should be taken to the hospital.

So these are the effects on the body on of high the surrounding temperatures the body has got its own temperature controlling mechanism these are the extreme cases otherwise body has its own temperature control mechanism and temperature regulatory Center TRC.

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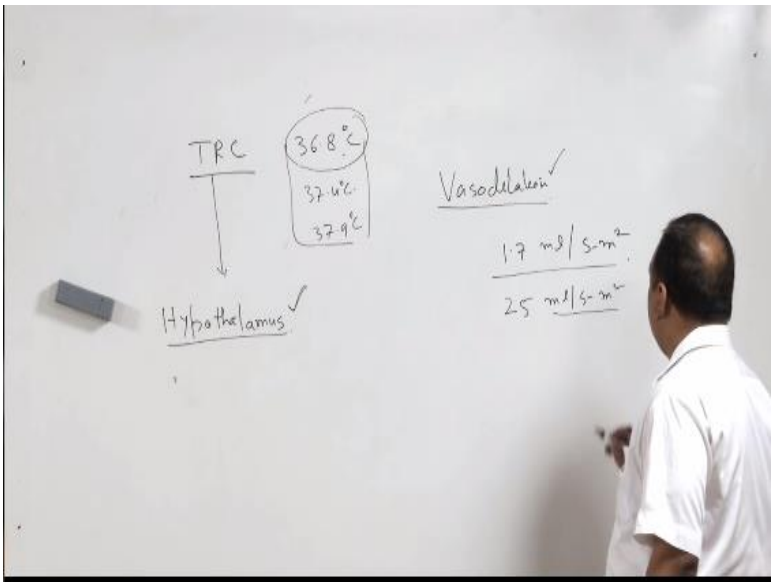

Temperature regulatory center in the body is at 36.8 degree centigrade it is in the brain temperature regulatory center and at this temperature it controls the body temperature itself remains at this temperature if somebody is walking this temperature may rise to37.4 degree centigrade and somebody is jogging this temperature becomes 37.9 degree centigrade right this temperature regulatory center is known as hypothalamus it is placed in the brain hypothalamus controls the body temperature.

Now the blood in the body blood in the body has many functions the function of the blood in the body is not only to circulate oxygen to different parts of the body but blood also helps in cooling the body in a significant manner suppose there is a rise in outside temperature when there is a rise in outside temperature the blood flow near the skin will increase this is known as vasodilatation in vasodilatation in this process the blood circulation to the skin increases when the blood supply to the skin increases the more easily the heat can be dissipated to the surroundings right.

So in vasodilatation process the dilation of ways takes place and for normally the flow density flow rate of blood is ml per second per meter square it is expected this is the normal blood flow rate in a vessel and it can go up to 15 times 25 ml per second per meter square so blood flow can increase 15 times near the skin in order to dissipate heat to the surroundings now why I am writing per second per meter square reason being in many of the fluid mechanics and lasses or two phase flow and let especially two phase flow analysis.

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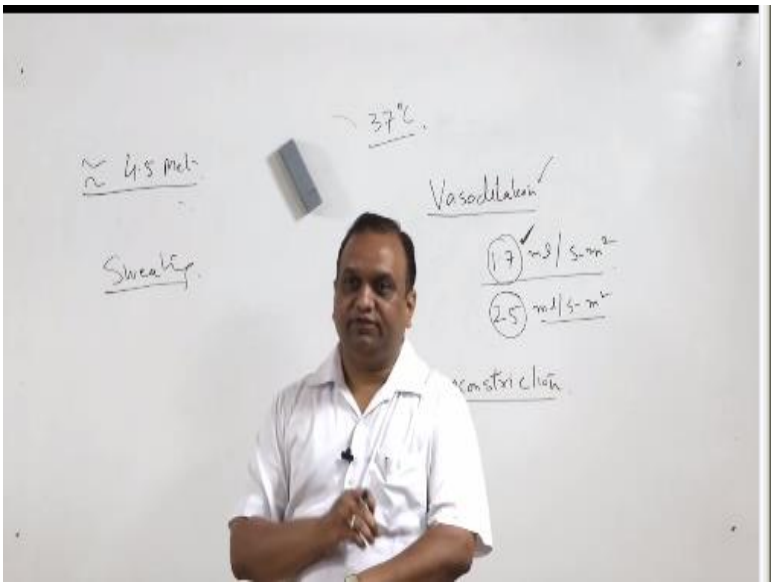

The mass flow rate or mass flux is expressed in kg per centum second per meter square and this becomes important here itself because in engineering practice the passage has a rigid wall I mean if you are realizing flow in a pipe the pipe has a rigid wall right so cross section area of the pipe is constant and we can do fluid mechanic analysis on this pipe but when we are dealing with the arteries and veins they are pipes of flexible wall the moment blood pressure rises the cross section area of the wall also rise cross section area also increases with the pressure they expend

So in order to express the mass flow rate it is always expressed in terms of per unit area so here also you can see starting from 1.7 to 225 ml per second per meter square blood flow can be increased to this level now another is extreme is when the temperature is low vasoconstriction construction takes place or cross section area of the blood of the veins which are take it by taking blood through the veins ways through which the blood is passed is reduced.

So due to this contraction vasoconstriction in winters by controlling this blood flow rate you will get an effect equal into the one sweater suppose you have in a normal atmosphere and all of a sudden there is a drop in temperature outside temperature outside temperature reduces then

immediately vasoconstriction takes place blood flow to the surface of the skin orbit just below the skin will reduce and you will get insulation equal into that of one sweater.

After that if more energy is required then muscles of the body they start increasing tension so they become tense, when the muscle in the body they become tense they liberate energy and that energy to your surprise is approximately 4.5 met up to 4.5 met energy can be liberated by just pushing or just through the attention of the muscles in the body.

So this is how heat body internal heat of the body is liberated just to maintain the body temperature $37^{O}C$ so this is inbuilt mechanism in the body which helps in maintaining this in the body temperature. Another mechanism is sweating evaporation from the surface evaporation of water from your skin that causes cooling effect.

But in some of the cases for example, cloak this coastal climate outside air is humid outside air is already at 80% relative humidity. In that case the sweating of the skin takes place sweating of skin sweating of skin and you start feeling comfortable when 25% more than 25% of skin is wet right, then normally what happens people take bath because this is also a complete with society's hygroscopic.

It helps in retaining sweat on the surface of the skin now what if he starts feeling uncomfortable because due to one reason being the friction between the cloth and the body skin increases that makes you uncomfortable and when you feel uncomfortable get a chance you take a bath when you take a bath the body cools down and the salt on the skin is also removed and you get immediately hypertonic sweat film on the surface.

So you must have realized that even after taking bath you start sweating but you do not feel that uncomfortable as you are feeling earlier.

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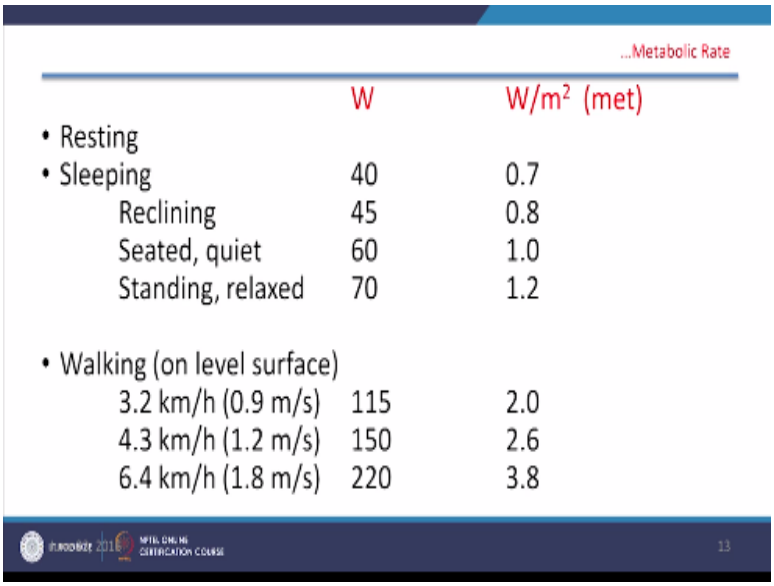

The reason being your, the sweat has become hypertonic means the salt is diluted, the salt is diluted and that gives you the relative comfort feeling.

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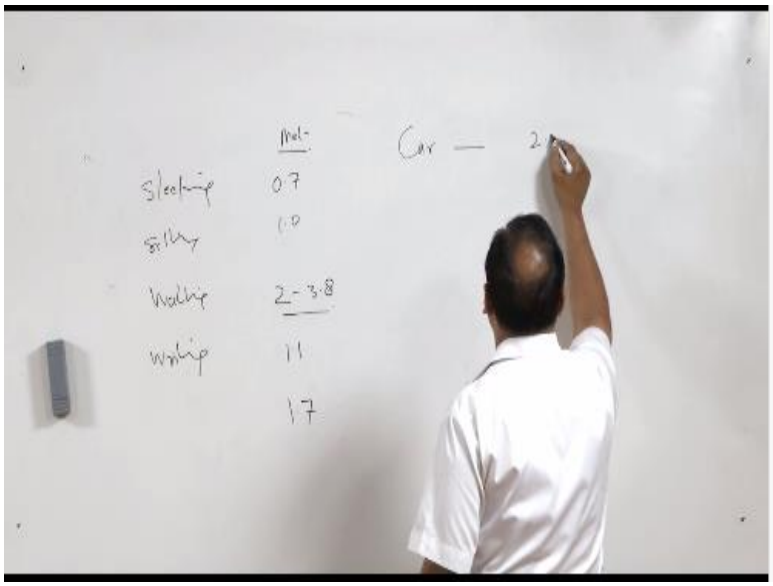

Now activities I will take one by one for example you are sleeping when you are sleepy the activity is 0.7 met you have met just to have an idea I mean as a linear you should have numerical values of numerical values of that gives you the sound idea. Suppose you are sitting, sitting is one sitting and when you are walking it is two met and it can go up to 3.8 met depending upon the speed of the walk.

If you are walking if the brisk walk it can go upto 3.8 or approximately four met. So 4 times energy will be released even if you are walking fast walking okay. If you are tired typing and writing it is approximately 1.1 type writing 1.1 met just walking about in the office just moving around 1.7 met when you are driving a car it can go up to 2 met in your driving. Car driving can go up to two met if you are exerted right.

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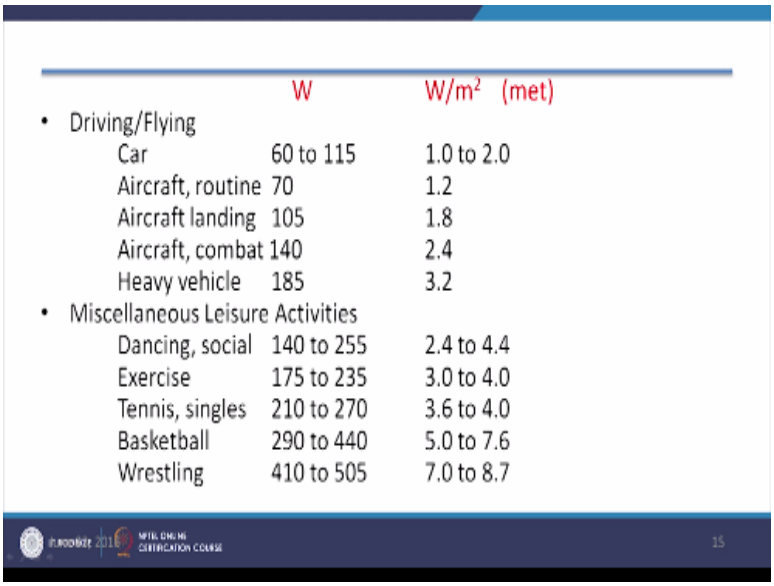

Now heavy vehicle driving can go up to 3.2 met, so truck driving is more energy consuming and energy consumed consumption is approximately two to three times that of driving a car. Even dancing social dancing may be 4.4 met so these are number of wrestling, wrestling is 7 to 8.7 met.

So wrestling is most energy consuming activity it can go upto 8, 7 met in case of wrestling basketball also, basketball is 5 to 7.6 tennis. So for different activities singles tennis can go up to 3.6 24 met so for different activities their energy levels but say wrestling it is very high, but the issue is to what level you can go for up to.

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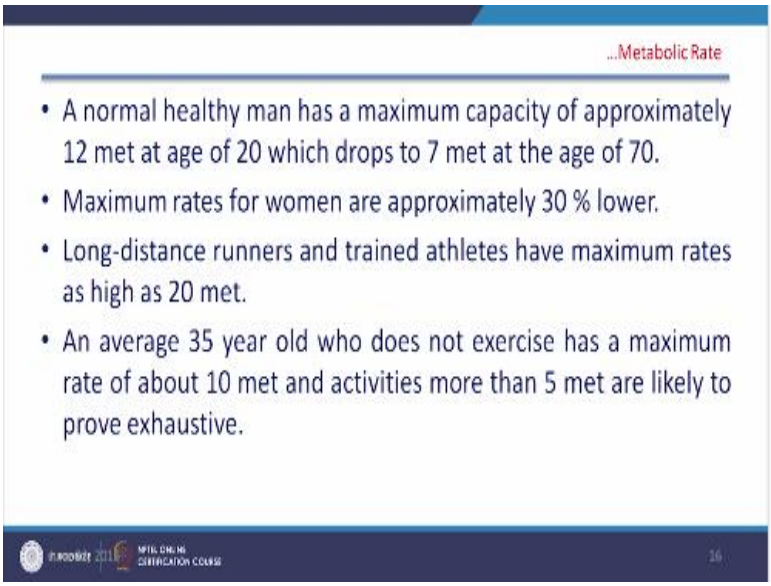

So individual capacities individuals capacity for short duration it can go up to 12 met at the age of 60 that is also related with the age, age of 20 yes and if somebody is of eight of 70 years it can go up to seven met only. This is the energy dissipation from the body of an individual and this also helps us in designing the system.

Suppose I want to do air-conditioning for the wrestler so definitely I must know how much energy is regulated by the Western wrestlers. So these are the different energy levels liberated by the through different activities I think that is all for today. In the next lecture we will take up carbon compound. Thank you, very much.

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Acknowledgement

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