Engineering Thermodynamics
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Lecture 08
Examples on basic concept & energy balance

Welcome back! Myself Parul Katiyar and I am the TA of this course. Today will be discussing few examples related to basic concept and energy balanced.

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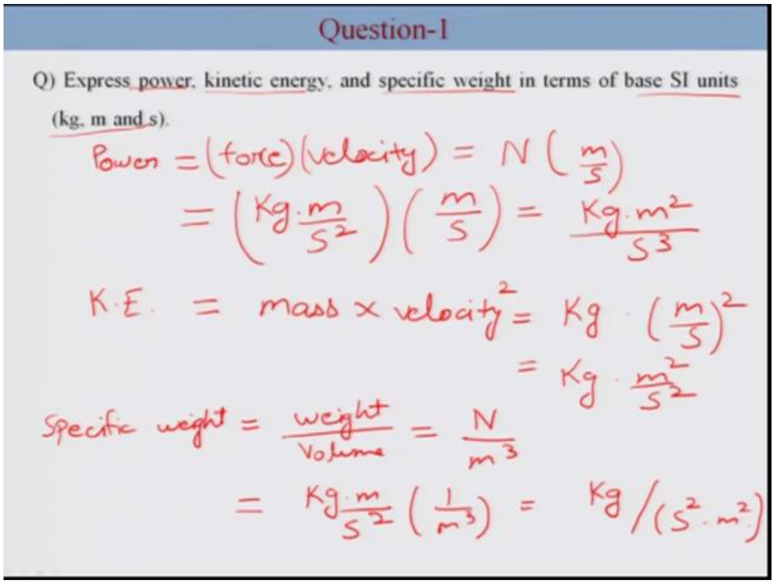

So, the question one begins with SI units. So, here we have to express power, kinetic energy and specific weight in terms of that base SI units, that is kilogram, meter and second. Power can be written as force multiplied by velocity so units of both are same. Power can be expressed as unit of force into velocity.

Unit of force is Newton and velocity is meter per second. Newton can further be written in terms of SI unit as kg meters per seconds square and to simplifying this gives kg meters square per second cube as a unit of power. Further kinetic energy is written as mass multiplied by velocity square, unit of mass is kg and velocity is meter per second and square of that, so this gives kg meter square per second square. So, unit of kinetic energy is kg meter square per second square in terms of SI units.

For specific weight is weight per unit volume, so unit of weight is Newton and volume is meter cube. Newton further writing it in terms of SI units, so it is kg meter per second square and volume is one by meter cube, so this simplifies to kg per Second Square per meter square. So, this unit of specific weight in terms of SI unit is kg per second square per meter square.

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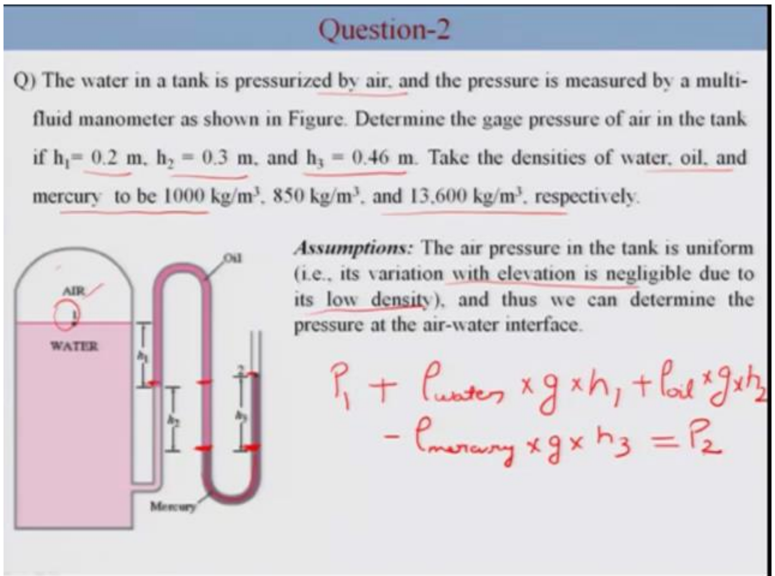

Moving away on to the next question which is related to pressure. So, in this question the water in a tank is pressurized by air. So, here the air is filled and the pressure is measured by a multi fluid manometer as shown in the figure. So, is this shows the figure shows the complete set up determined the gage pressure of air in the tank we have to determine the gage pressure of air in this tank. Gage pressure means difference of pressure and atmospheric pressure and it is given the different height h 1 is given 0.2, h 2 is 0.3, h 3 is 0.46 and the densities of water, oil and mercury are also given in the question.

The assume in this question that air pressure in the tank is uniform it is not varying with the elevation because the density of air is very low. If this start with pressure at point one, so we can write this as P 1, so pressure at point one, the pressure of air is P 1. Now if we move in the downward direction so pressure will increase and this moving in downward direction, so pressure will be multiplication of density, thee height which we are moving downwards and the acceleration due to gravity.

So, it will be density of water as we are moving downward, so density of water multiplied by g acceleration due to gravity and height 1. So, with this we get the pressure at this point. Now this pressure will be same as pressure at this point in the tube, because it is a same fluid so these two pressures are at these two points are same. Now if we move height h 2 downwards, so we can calculate the pressure at this point, now this fluid is oil, so we will add a pressure which is density of oil multiplied by g into h 2.

So, this gives a pressure at this point, now the pressure at this point will be same as this point. Now we know pressure at this point and we are moving in the upward direction. So, we need to subtract the pressure because of height h 3 and this fluid, this is mercury. So, it will be density of mercury multiplied by g into height which is h 3. Now we get the pressure at point two. These gives the pressure at point two, so this is equal to P 2 and this P 2 this tube is open to atmosphere. So, this P 2 pressure is equal to atmospheric pressure.

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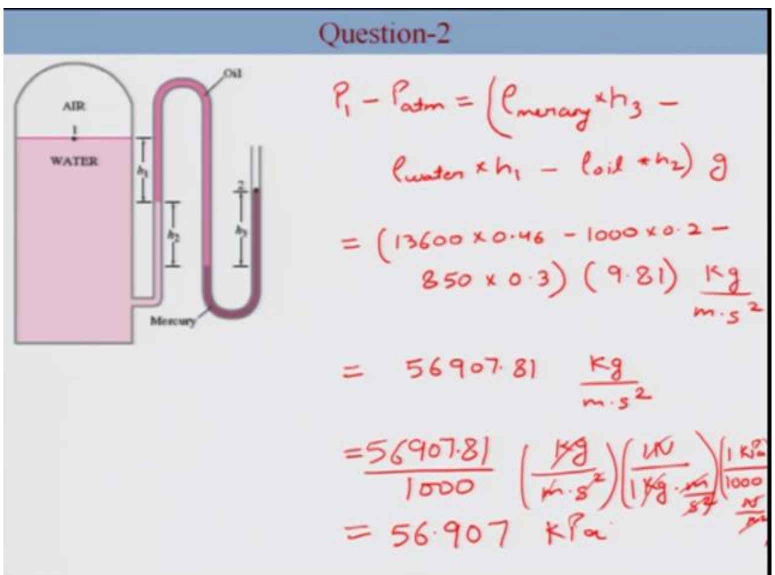

Now we have to tell what is the gage pressure? So gage pressure will be P 1minus P atmosphere. So, this expression simplifies to Rho mercury into h 3 minus density of water into h 1 minus density of oil into h 2 and completely multiplied by g and g is taken commons of. Putting all the values which are given in the question, density of mercury is 13600, h 3 is 0.46 and density of water is 1000 kg per meter cube, h 1 is 0.2 and density of oil is given 850 and h 2 is 0.3 and value of g is 9.81, putting all the units so also, so this will all the unit this will simplify to kg per meter per second square.

So, this simplifies to 56907.81 kg per meter per Second Square. If we convert this into kilopascals then this kg meter per second square, 1 Newton can be written as 1 kg meter per second square and 1kilopascals as 1000 Newton per meter square. This will get cancelled and we will get 1 by 1000 and this is 56.907 kilopascals. So, the gage pressure of air is, has a this value in the tank.

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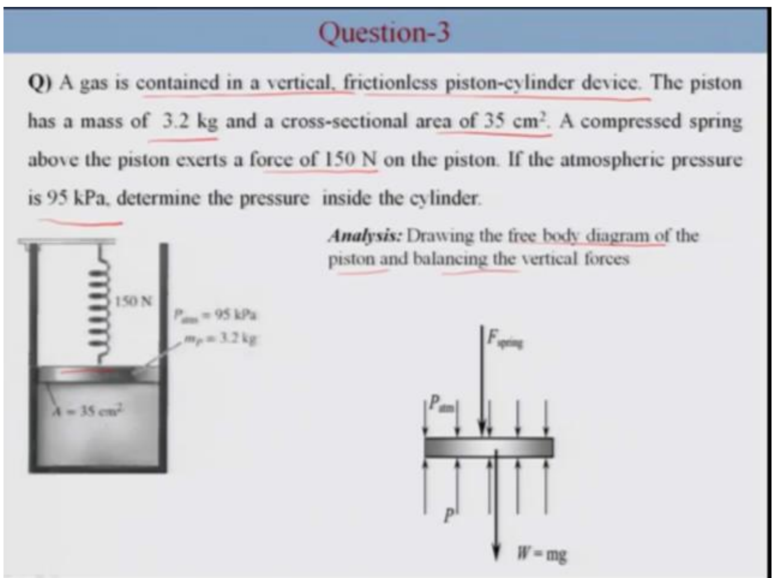

Moving to the next question, in this question the gas is containing a vertical friction less piston cylinder device. The mass of this piston is 3.2 kg and a cross sectional area is 35 centimeter square, a compressed spring above the piston. So, this is the spring which is compressed and exerts a force of 150 Newton of all the piston.

So, this is spring is exerting a force of 150 Newton on the piston. If the atmospheric pressure is 95 kilopascals, determine the pressure inside the cylinder. So, we have to calculate this pressure inside the cylinder. Now if we analyze this problem by drawing a free body diagram of all the forces which are acting on the piston, upward and downward forces.

So, this is the free body diagram because of spring a force is acting in the downward direction on the piston. Weight of the piston is also acting in the downward direction, because of atmospheric pressure a force is acting in the downward direction and because of gas inside this cylinder there is a upward pressure. So, we need to write a forced balanced for all this.

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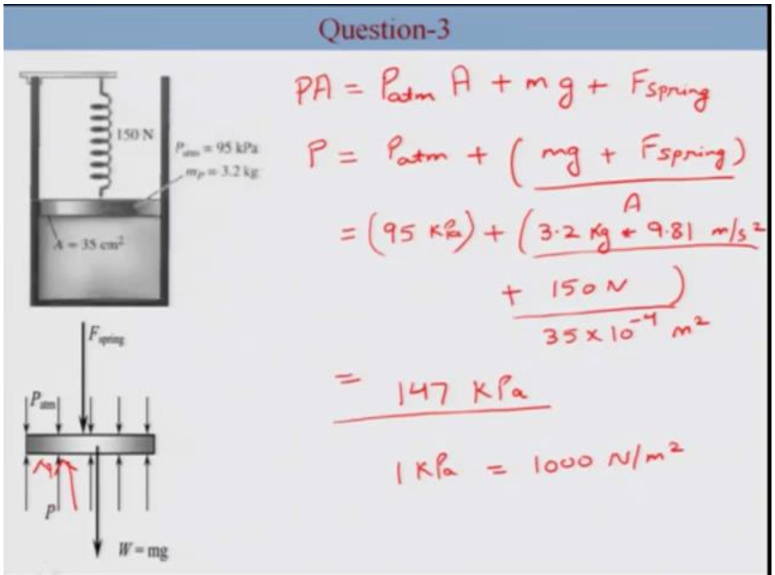

So forced balanced for this is P which is this is an upward pressure. So, P multiplied by area is the force which is acting upward. This is equal to all the forces which are acting downward. So, force due to atmospheric pressure is acting downward, so this is P atmosphere, pressure atmospheric pressure multiplied by area plus, because of the weight so weight is mass multiplied by acceleration due to gravity plus force because of the compressed spring.

The expression for P simplifies to P atmosphere plus mg plus force due to spring divided by area. Value of P atmosphere is given as 95 kilopascals plus mass is mass of piston is 3.2 kilograms, g is 9.81 meter per second square plus the force due to spring is given 150 Newton and if we divide this entire by area. So, area is 35 centimeter square, so in terms of meter it will be 35 into 10 to the power minus 4 meter square.

So, simplifying this we get we convert units of the second term in kilopascal, then we get 147 kilopascal, because 1 kilopascal is equal to 1000 Newton per meter square. So, this will give a pressure inside the cylinder to be 147kilopascal okay.

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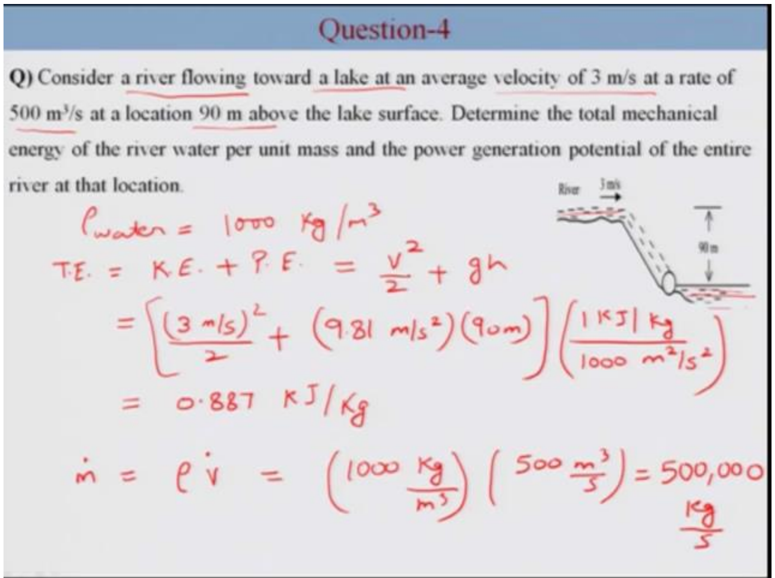

Let us move to the next problem, so next problem is about a river which is flowing toward a lake at an average velocity of 3 meter per second, at a rate of 500 meter cube, at a location of 90 meter above the lake surface. So, this is a lake, so this is a lake, the river is flowing at a velocity of 3 meter per second and the volume flow rate is 500 meter cube per second and the height of the river above the lake is 90 meter.

So, we have to determine the total mechanical energy of the river water per unit mass and the power generation potential of entire river at that location. We also assume that the density of water is 1000 kg per meter cube this question. So, the total energy of the water per unit mass is the sum of total energy is the sum of kinetic energy per unit mass plus potential energy per unit mass.

So, kinetic energy per unit mass can be written as V square by 2 and potential energy as g h, g is the acceleration due to gravity and h is the height. So, velocity is given as 3meter per second, so square of this divided by 2 where the is g is, g is 9.81 meter per Second Square and h is 90 meter. Now for the whole if we convert this 2 kilojoule. So, 1 kilojoule per kg is equivalent to 1000 meter square per Second Square. So, simplifying this it gives a value of 0.887 kilojoule per kg.

This is the total mechanical energy of the wate0,r river water. Now we also we have to determine the power generation potential of the entire river at that location. So, the power generation potential is this energy multiplied by the mass flow rate of the river. So, mass flow rate is density multiplied by the volume flow rate. So, this is 1000 is the density of water multiplied by volume flow rate that is 500 meter cube per second. So, the mass flow rate comes out to be kg per second.

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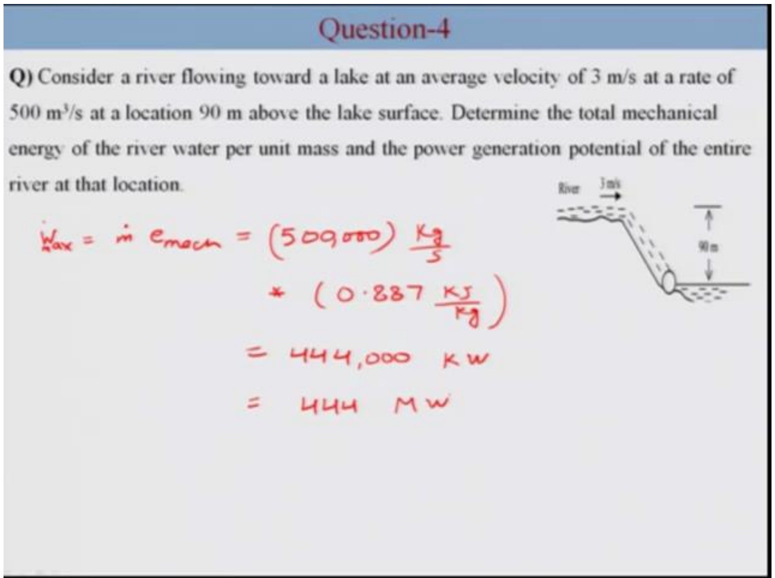

Now the work the maximum work which can be produced or generated by this water flowing in the river, so this is mass multiplied by the mechanical energy of the river. So, mass flow rate is this as calculated multiplied by the mechanical energy per unit mass of water. So, this is kilowatt or we can write it as 444 megawatts. So, this is the potential of the river, if it is recovered completely.

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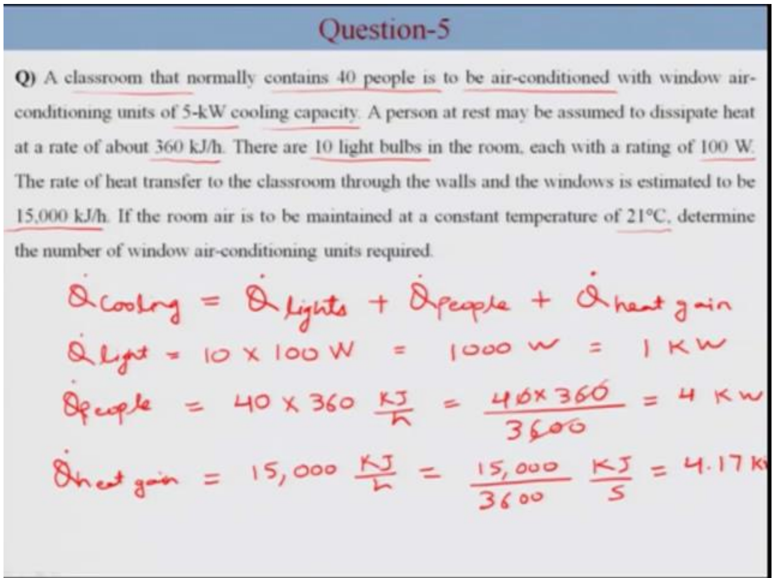

Moving to the next question which is completely based on energy balanced classroom that normally contains 40 people is to be air conditioned with window air conditioning units of 5 kilovolt cooling capacity. So, one air condition has a cooling capacity of 5 kilowatts, a person at rest may be assumed to dissipate heat at a rate of about 360 kilo joule per hour.

So, there are people in the and each person is assumed to dissipate a heat at a rate of 360 kilojoule per hour. And there are 10 light bulbs in the bulbs in the room each with the rating of 100 watt. The rate of the heat transfer to the class room through the walls and the window is estimated to be 1500 kilojoule per hour. If the room is to be maintain at a constant temperature of 21 degree Celsius determine the number of window air conditioning units required.

In this we have to determine the total cooling capacity of the air conditioners. So, the total load because of the bulbs, people and the heat which is coming inside will be same as what the air conditions have to remove. So, total cooling load is because of lights that is bulbs is because of the people which are sitting in the room plus the heat load because of the heat gain from the windows and the walls. So, because of light bulbs there are 10 light bulbs each consumes a power of 100 watts this gives a total of 1000 watt which is equivalent to 1 kilowatt.

Because of the 40 people sitting in the room, the total is 40 multiplied by 360 kilojoule per hour. So, it is 40 into 360 and we can converts r into seconds. So, this is 3600, so this gives 4 kilowatt because of the heat gain from the surrounding. So, it is 1500 kilojoule per hour we can convert it into kilowatt, so it will be 1500 divided by 36, 3600. So, it is kilojoule per second and this is 4.17 kilowatt.

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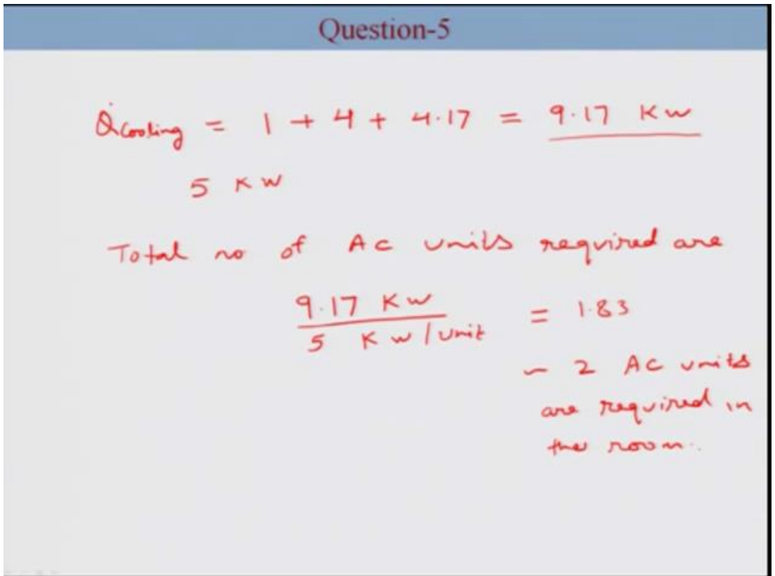

So, total load for air conditioners is 1 because of the light, 4 because of the people and because of the heat gain it is 4.17. So, this sums up to 9.17 kilowatt, so 9.17 kilowatt is to be removed from the room. So, total numbers of AC units required are total cooling load divided by the cooling capacity of one AC or this is equal to 1.83 and so approximately 2 AC units are required in the room.

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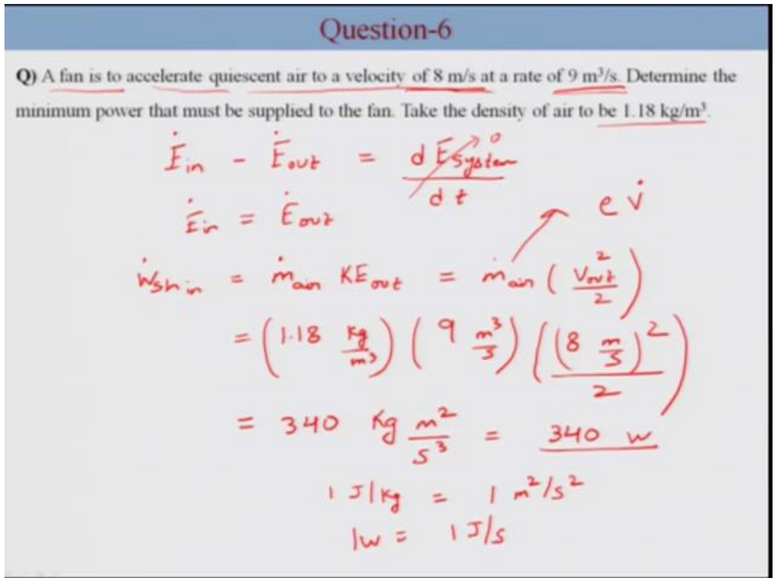

Next question deals with a fan, where it has to accelerate quiescent air to a velocity of 8 meter per second at a rate of 9 meter cube per second. So, we have to determine the minimum power that must be supply to the fan and the density of air is given as 1.18 kg per meter cube.

So, we assume that a fan operates steadily and the mechanical energy which is given to the fan, a shaft of the fan is being transferred to the air in terms of it is mechanical energy. So, applying an energy balanced energy which is entering or rate rate of net energy which is transferred in, because of heat work and mass minus the rate of energy which is going out, because of heat, work and mass is equal to the change in energy of the system.

Now this rate of change in energy of the system is zero, because this is steady flow process. So, here E in is equal to E out, so energy is given as input to the shaft of the fan and it is taken, it is coming out as in terms of the velocity of the air or increase in mechanical energy of the air. So, energy which is given is tops of shaft work which is given to the fan and it is equal to mass of the air multiplied by the kinetic energy of the air which is coming out and this can be written as mass of air into velocity of the air by 2.

So, this is the formula for the kinetic energy. Now we know this mass of the air can be written in terms of density and volume flow rate. So, mass of the air, so this can be written as density of the air into volume flow rate. So, we are directly putting the values, so density of the air is 1.18 as given in the question kg per meter cube and volume flow rate is 9 meter cube per second. The velocity of the air coming out is 8 meter per second, so square of this as it is b square divide by 2.

So, this comes out to be 340 kg meter square per second cube, which is equivalent to 340 watt. As 1 joule per kg is equivalent to 1 meter square per Second Square and 1 watt is 1 joule per second. This is the minimum power required if there are no heat losses. So, let us end this and see you in the next lecture.