Marine Propulsion
Prof. Anirban Bhattacharyya
Department of Ocean Engineering and Naval Architecture
Indian Institute of Technology, Kharagpur

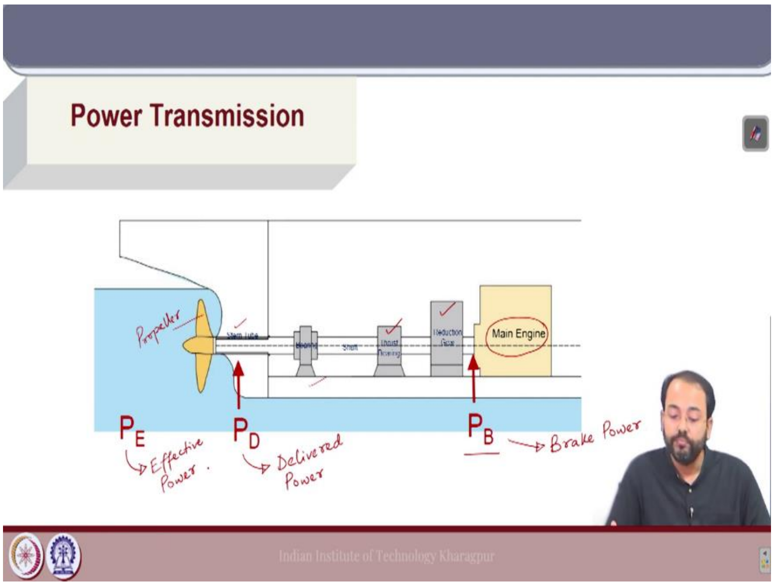
Lecture - 18
Ship Powering and Efficiency Components

Welcome to lecture 18 of the course Marine Propulsion. The topic today is Ship Powering and Efficiency Components.

(Refer Slide Time: 00:37)

So, the key concepts covered in today's lecture will be ship powering, the different power components which are associated with. So, the key components which will be covered in today's lecture are the different power components involved in ship powering analysis and the efficiencies of the ship powering system.

(Refer Slide Time: 01:00)



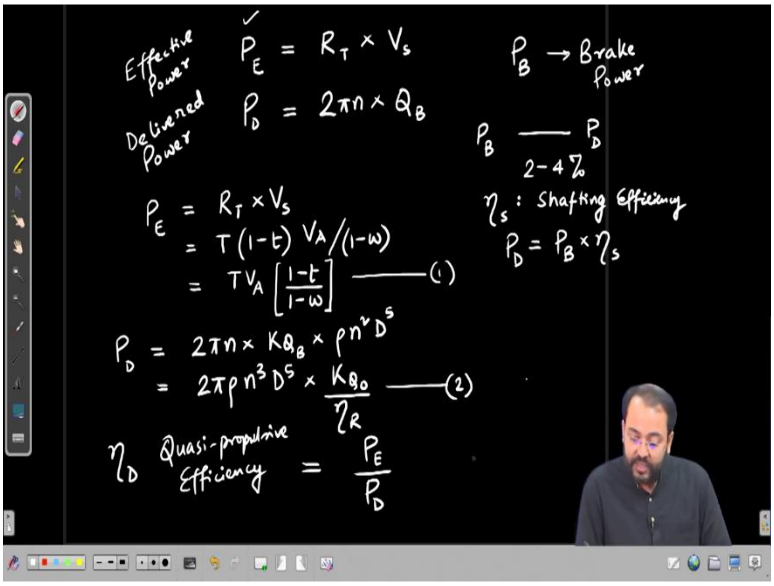
So, if we look at the entire ship propeller system, which involves the power supplied by the main engine to the final power that is being absorbed by the propeller and the power required to move the ship forward. This is the depiction of the stern part of the ship. Here we have the main engine, which provides the power to the propeller finally, the propeller is absorbing this power which is the delivered power and it provides the thrust for the ship to move ahead.

So, P_B is the brake power supplied by the marine engine. Now this marine engine is connected to the propeller here. So, we have the propeller by a shaft and here we have a reduction gear, which is required if the speed of the engine is higher than the propeller rpm then a reduction gear is required. On the other hand if we have slow speed diesel engines we can get rid of this reduction gear component. Then thrust bearing is required which basically transmits the thrust generated by the propeller through the shaft to the ship hull.

So, the propeller generates a thrust, which is taking the ship forward and this thrust force has to be transmitted to the ship hull and this is done using this thrust bearing or sometimes called also thrust box for certain ships and there are other bearings which are involved for this shaft and finally, this shaft passes through the stern tube at the aft end of the ship and connected to the propeller.

P_D is the delivered power that we have calculated before which is given by 2 π n into the torque Q of the propeller absorbed by the propeller and P_E is the effective power of the ship. So, P_E is the final output power which is required by the ship to move forward with a specific velocity.

(Refer Slide Time: 03:51)



Now, let us see how these power components are related to each other. So, the effective power P_E is given by the total resistance of the ship multiplied by the speed of the ship which is the effective power. Next we have the delivered power which is the rotational speed into the torque for the propeller. We say the Q_B which is the torque in the behind condition or we can write it as Q only. And on the other hand we have the brake power of the engine.

Sorry now this brake power of the engine undergoes some losses as it is transmitted via the shaft to the propeller as the delivered power. So, between P_B and P_D there is some loss, which is due to the shafting the gearboxes and the bearings in that case. So, this loss is generally in the range of 2 to 4 percent. So, we have an efficiency term calling shafting efficiency, which is basically relating the delivered power to the brake power.

So, P_D will be P_B multiplied by the shafting efficiency (η_s). Now P_D is the power which is delivered to the propeller and P_E is the effective power which is the resistance multiplied by the velocity which is utilized by the ship to move forward. Now the relation between P_D and P_E is important here because that is where the hydrodynamics of the ship propeller system will come into play.

So, if we write $P_E = R_T \times V_S$. R_T = T (thrust) × (1 – t (thrust deduction)) × V_A (velocity of advance) / (1 - w (wake fraction)). This we have already deduced when we discussed hull propeller interaction. So, this becomes

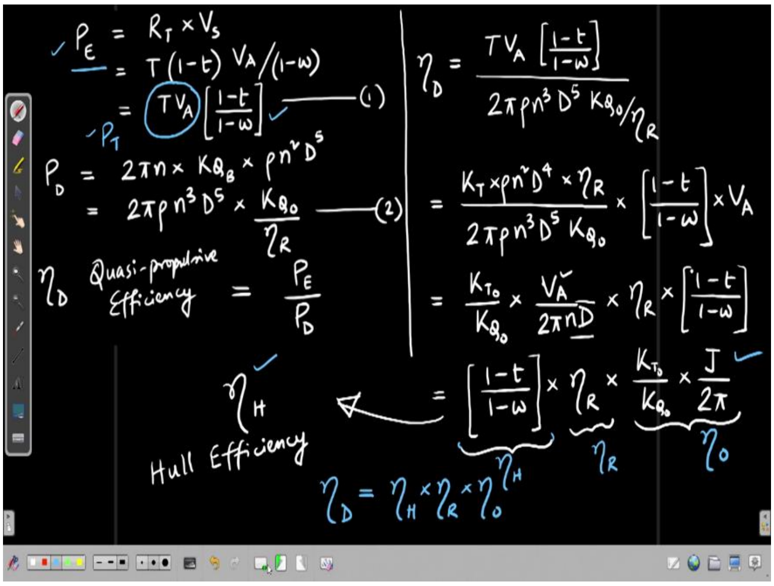
$$P_E = T \times V_A \times (1 - t) / (1 - w \text{ (wake fraction)}) \qquad (1)$$

So, this is the expression for the effective power. On the other hand if we look at delivered power $P_D = 2 \pi n \times Q \times K_{QB} \times \rho n^2 D^5$. Now, what is K_{QB} if we assume thrust identity then K_{QB} can be expressed as a ratio of K_{QO} and η_R this is

$$P_D = 2 \pi \rho n^3 D^5 \times K_{QO} / \eta_R \qquad (2)$$

Now the relation between the effective power and the delivered power is using all these propulsion coefficients. And the efficiency involved here is called the quasi propulsive efficiency. η_D is called the quasi propulsive efficiency given by P_E / P_D. So, this is the ratio of the effective power to the delivered power for a ship.

(Refer Slide Time: 09:02)



Now, using 1 and 2 we can write $\eta_D = (T \times V_A (1 - t) / (1 - w \text{ (wake fraction)})) / (2 \pi \rho n^3 D^5 \times K_{QO}/\eta_R)$. Now what is T? It can be expressed as thrust coefficient multiplied by rho $n^2 D^4$. So, $K_T \times \eta_R$ will go in the numerator. Now certain terms here will cancel out. So, we will have K_T / K_{QO}. Now if we assume thrust identity then the K_T is equal to K_{QO} just like we have written the equation for K_Q as K_{QO}/ η_R because we had already assumed thrust identity.

So, I can write K_T as $K_{TO} \times$ there will be a V_A term here V_A / 2 π. So, we can write this as $(1 - t)/ (1 - w) \times \eta_R \times K_T / K_Q$ in the open condition $\times$ V_A / nD. This V_A / nD is the advance coefficient J / 2 π right. So, here we can think of three terms. The first term is this ratio the second term and the third term here. Now (1 - thrust deduction) / (1 - wake fraction) is denoted as η_H, which is hull efficiency.

Now, this is also not strictly an efficiency term. We call it efficiency because we are expressing the η_D as a function of different components. So, this component is (1 – t) / (1 –w) which basically relates the thrust power of the ship to the effective power. So, if we see here in the equation for $P_E = T \times V_A$ the thrust generated by the propeller multiplied by the advance speed is basically the thrust power this can be mentioned as P_T the thrust power.

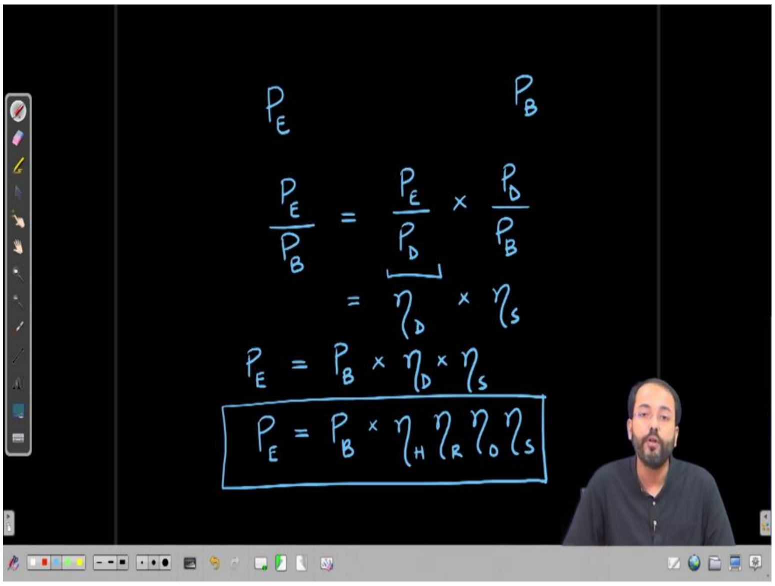
So, this thrust power is related to the effective power P_E with this term (1 – t) / (1 – w) wake fraction where t is the thrust reduction factor. So, the propeller generates a thrust power which is the thrust multiplied by the advanced speed. Now the effective power is the final power which is required to drive the ship forward at a specific speed. So, how is the thrust power related to the effective power that will depend on the configuration of the ship in the stern region; that means, the shape the lines plane of the ship especially towards the stern region and also the propeller design.

So, this is related to both the thrust deduction and the wake fraction. So, the effect of hull propeller interaction is very much expressed using this factor which is the hull efficiency. Again to reiterate this hull efficiency is not an efficiency stern. So, this is just the ratio of (1 - thrust deduction factor) / (1 - wake fraction). Now this hull efficiency can also be greater than 1 and depending on the value of wake fraction and thrust deduction fraction it can be in the range of 0.9 to1.2 it can have values.

So, this hull efficiency value depends on the value of thrust deduction and wake fraction. Later we will see that for single screw and twin screw ships the value of hull efficiency is typically very much different because for single screw ships the wake fraction is very high. So, because of that we have a higher hull efficiency ok.

So, what is the third term here? $K_T / K_Q \times J$ / 2 π in the open water sense. So, K_{TO} / K_{QO} we have. So, this is the open water efficiency η_O. This is the hull efficiency we have just seen and we have η_R here. So, finally, we get the quasi propulsive efficiency η_D can be expressed as $\eta_H \times \eta_R \times \eta_O$ ok.

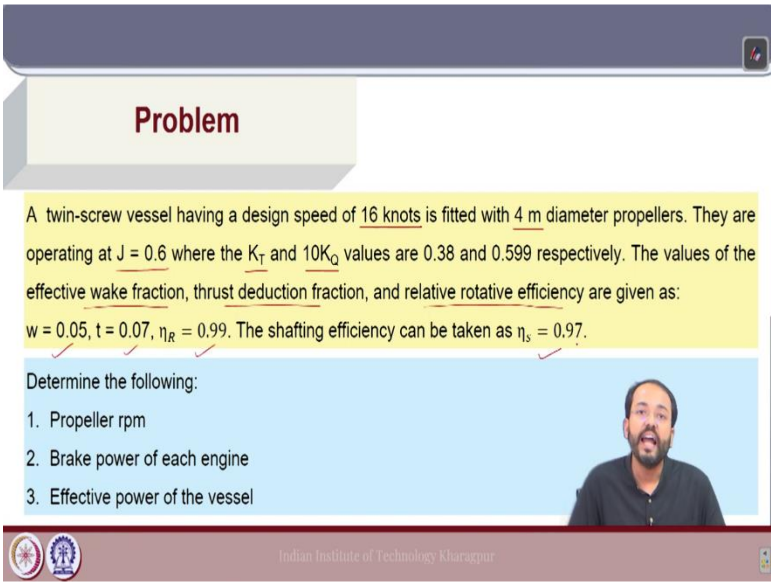
(Refer Slide Time: 15:40)



So, finally, if we want to relate the effective power of the ship to the brake power; that means, the power generated by the engine then we have P_E / P_B will be P_E by the delivered power × P_D / P_B. Now, this first term is the quasi propulsive efficiency depending on the hydrodynamics of the ship and propeller and the second term is basically the shafting efficiency because the delivered power depends on the losses that are incurred in the shaft.

So, P_D / P_B is η_S. So, P_E can be expressed as the brake power of the engine multiplied by $P_D \times \eta_S$ or in total P_E can be written as $P_B \times \eta_H \times \eta_R \times \eta_O \times \eta_S$. So, this expression relates the effective power of the ship to the brake power generated by the engine. Now, let us try to do a simple problem to evaluate these coefficients from the given data for a specific ship.

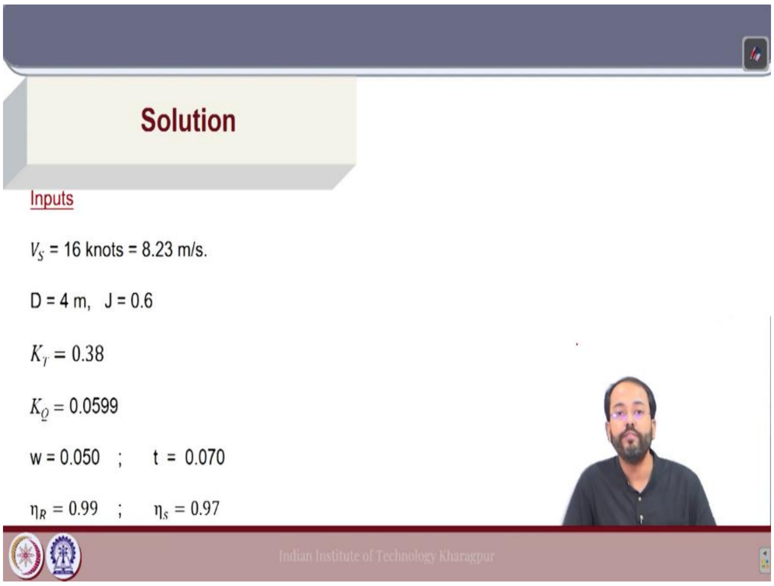
(Refer Slide Time: 17:27)



In this problem a twin screw vessel is given; that means, there are two propellers. The design speed being 6 knots and the propellers are of 4 meter diameter. The operation condition is given with respect to the advance coefficient and the K_T and $10K_Q$ values are given for that specific value of J. So, effective wake fraction thrust deduction fraction and relative rotative efficiency values are also given as inputs.

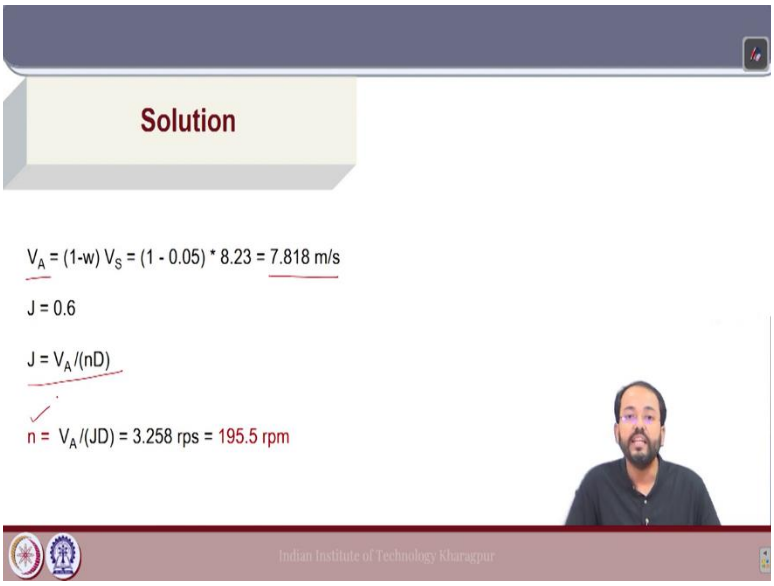
Here the shaft efficiency can be taken as 0.97, which is typically related to around 3 percent losses in the shafting. So, we have to determine the propeller rpm, the brake power of each engine and the effective power of the ship ok. So, the propulsion coefficients are given and certain operation conditions are given based on that we have to calculate the propeller rpm and power.

(Refer Slide Time: 18:39)



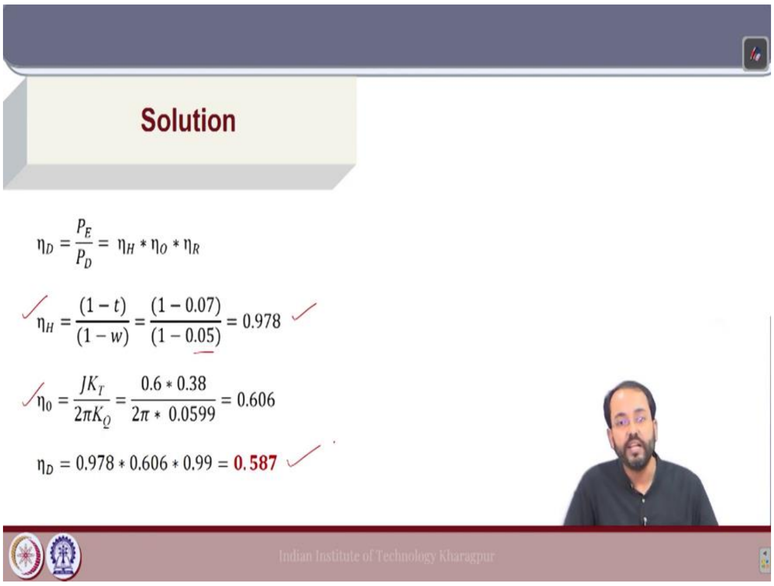
So, first we look at the inputs in this problem the speed of the ship is given in knots again we convert to meter per second the diameter is given and J, K_T, K_Q these are given wake fraction thrust deduction relative rotative efficiency these are given as inputs.

(Refer Slide Time: 19:00)



So, based on the given value of ship speed and the wake fraction we can calculate the advanced velocity. So, V_A can be calculated based on V_S and wake fraction. Next, using the value of J we can use this V_A to get the value of n we have already been given the value of the advanced coefficient. So, if we know the velocity of advance V_A we can use this equation to calculate n ok. So, this gives the propeller rpm the first part of our answer ok. Next we will compute the powers.

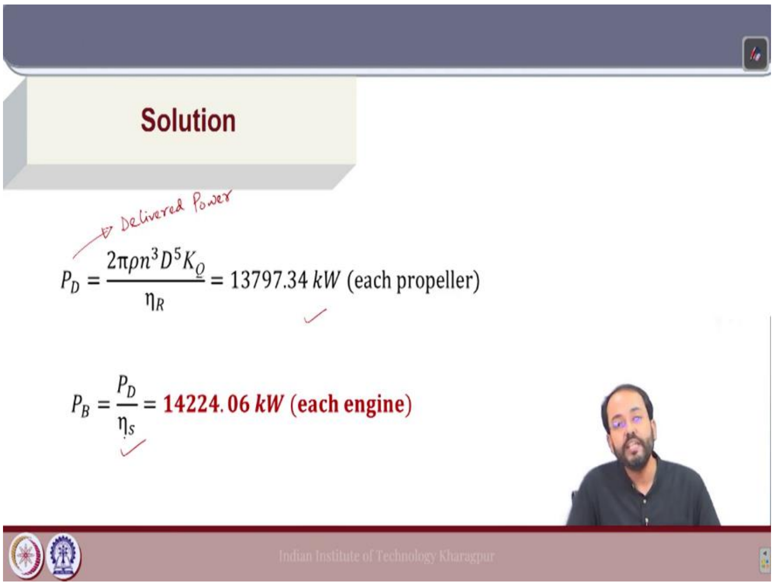
(Refer Slide Time: 19:47)



So, η_D is the quasi propulsive coefficient given as $\eta_H \times \eta_O \times \eta_R$. Now, the hull efficiency η_H can be computed from the given values of thrust deduction and wake fraction. We get this value. Here it is 0.978 slightly less than 1. Here the vessel considered is a twin screw vessel and hence the wake fraction is very low compared to a single screw vessel because for a single screw vessel the blockage effect of the hull will be very much in the propeller plane because it is at the central plane of the ship.

But for the twin screw vessel the two propellers will be at the two sides where the velocities in the wake field will be higher and hence the wake fraction will be low. η_O can be calculated from the given values of K_T and K_Q with the J and finally, we can calculate the value of η_D which is the total quasi propulsive coefficient which comes from the hydrodynamics of ship propeller interaction.

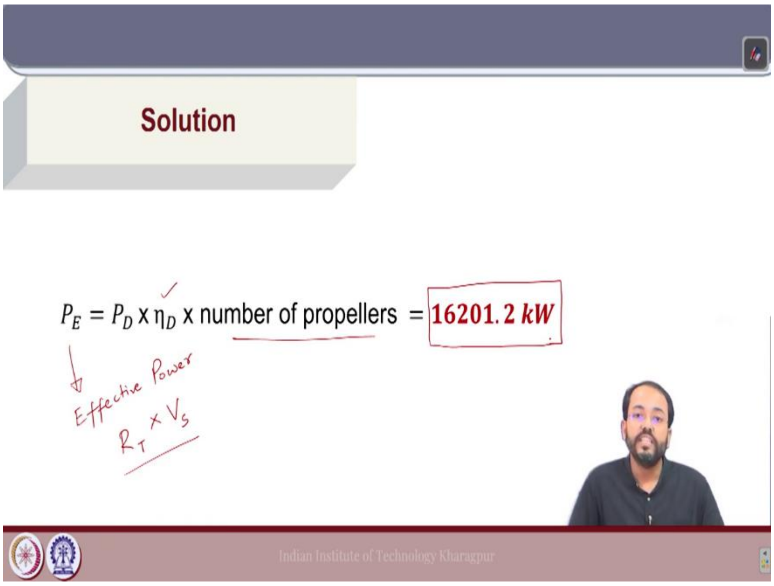
(Refer Slide Time: 20:55)



Now, the delivered power can be calculated for each propeller. So, P_D is the delivered power based on the torque coefficient and relative rotative efficiency. The delivered power to each propeller can be calculated here and based on the shafting efficiency of 0.97, which was given in the problem the brake power of each engine can be computed from the delivered power.

So, P_D / η_S will be the brake power. Now in this case we have two propellers. So, there will be two engines. So, the brake power of each engine will be calculated from the delivered power from each propeller divided by the shafting efficiency.

(Refer Slide Time: 21:47)



And finally, the effective power which is the power required to drive the ship forward which is this is the effective power given as $R_T \times V_S$ right. In this problem we did not know R_T ok. So, we are calculating the effective power from the delivered power side using the quasi propulsive efficiency η_D. Now the delivered power that has been computed is for each propeller, but the effective power is for the entire ship.

So, we have two propellers. So, we have to multiply the delivered power with the number of propellers which is 2 here and also the quasi propulsive efficiency to get the effective power. So, this is the value of the effective power of this ship. So, these simple problems on propulsive coefficients and powering can give some idea on how to evaluate the powering performance of a ship based on some operational conditions. So, this will be all for today's class.

Thank you.