Course Name: Watershed Hydrology

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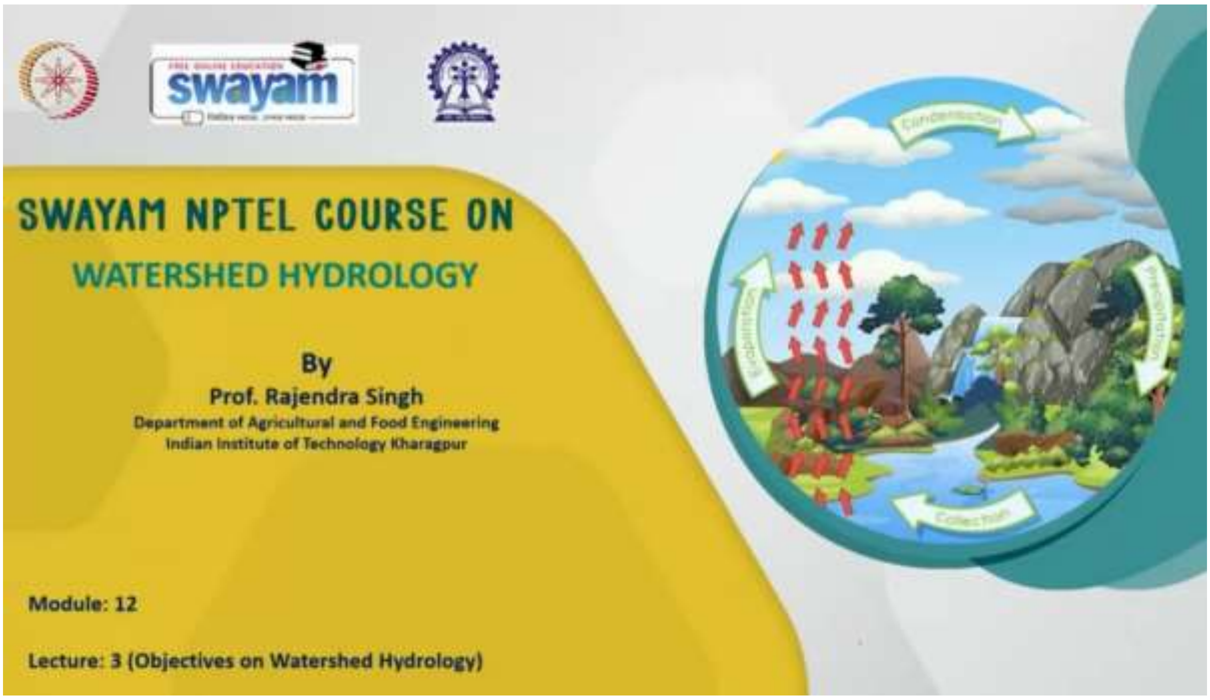
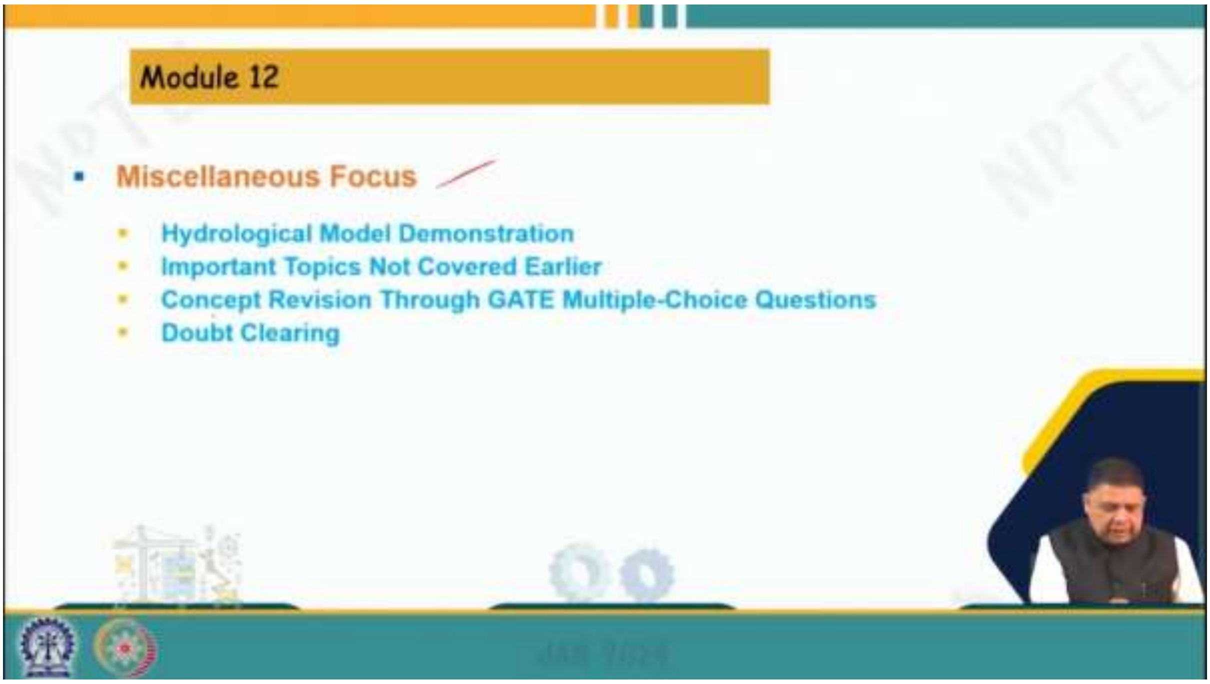
Institute Name: Indian Institute of Technology Kharagpur

Week: 12

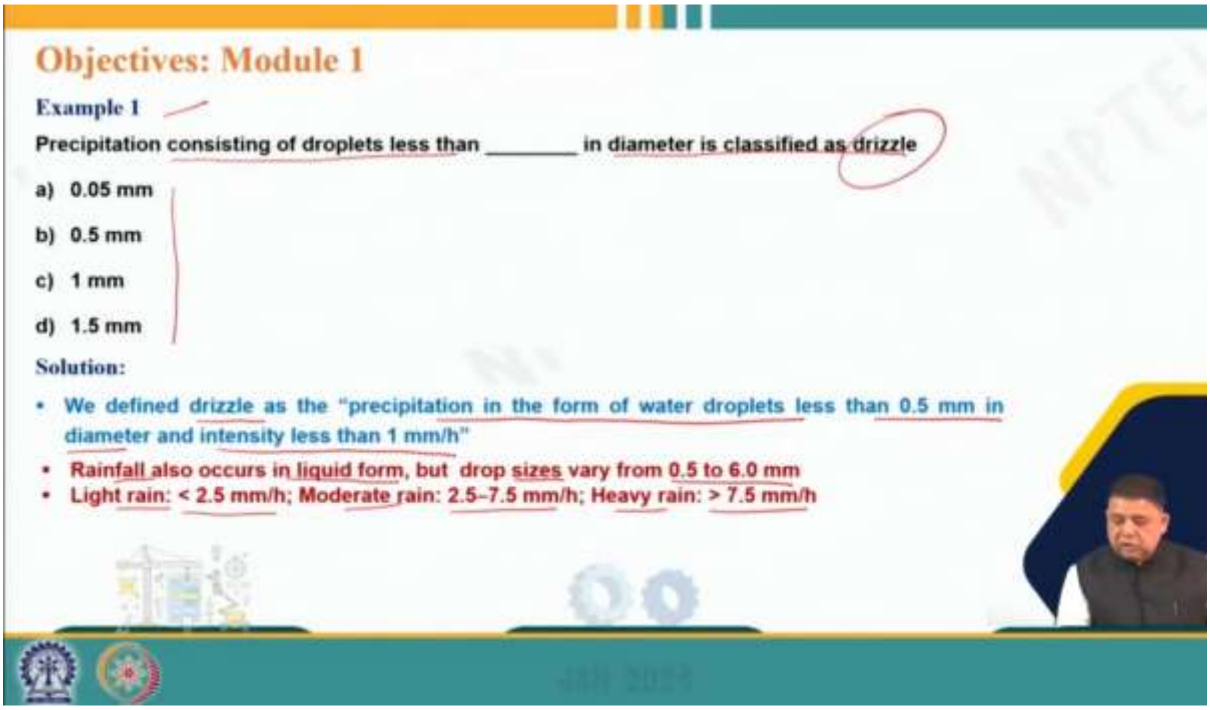
Lecture 58: Objectives on Watershed Hydrology



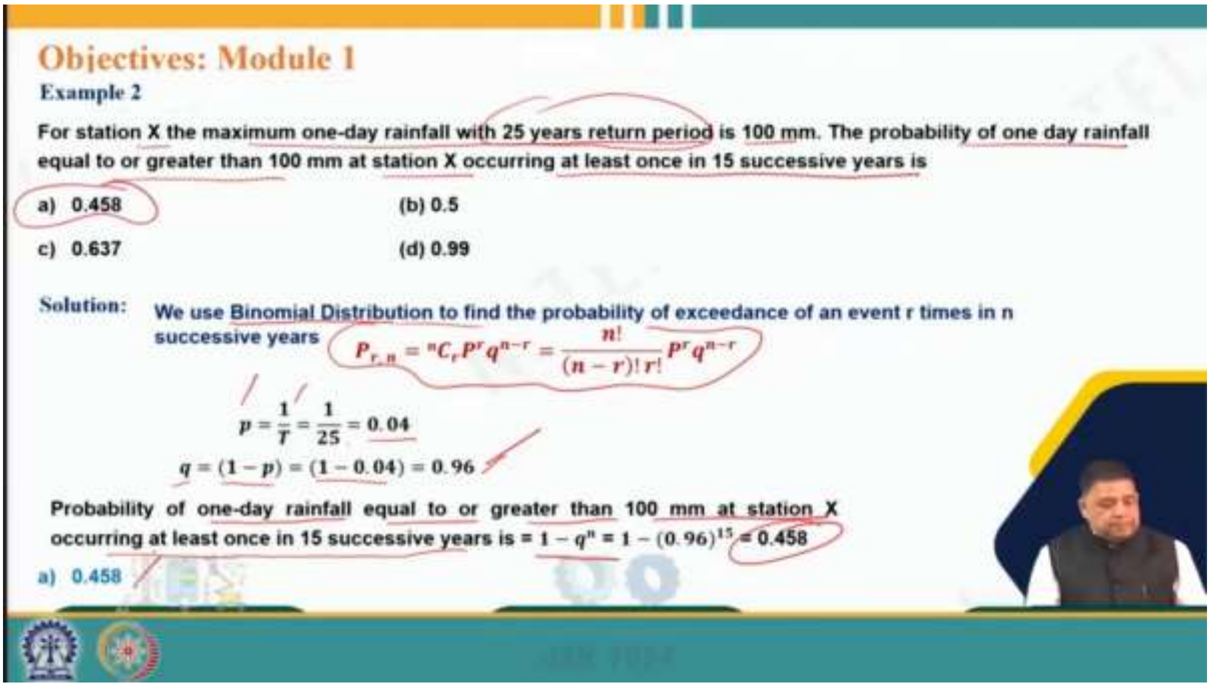
Hello friends, welcome back to this online certification course on Watershed Hydrology. I am Rajendra Singh, a professor in the Department of Agriculture and Food Engineering at the Indian Institute of Technology, Kharagpur. We are in module 12, this is lecture number 3, where we will be focusing on objectives in watershed hydrology.



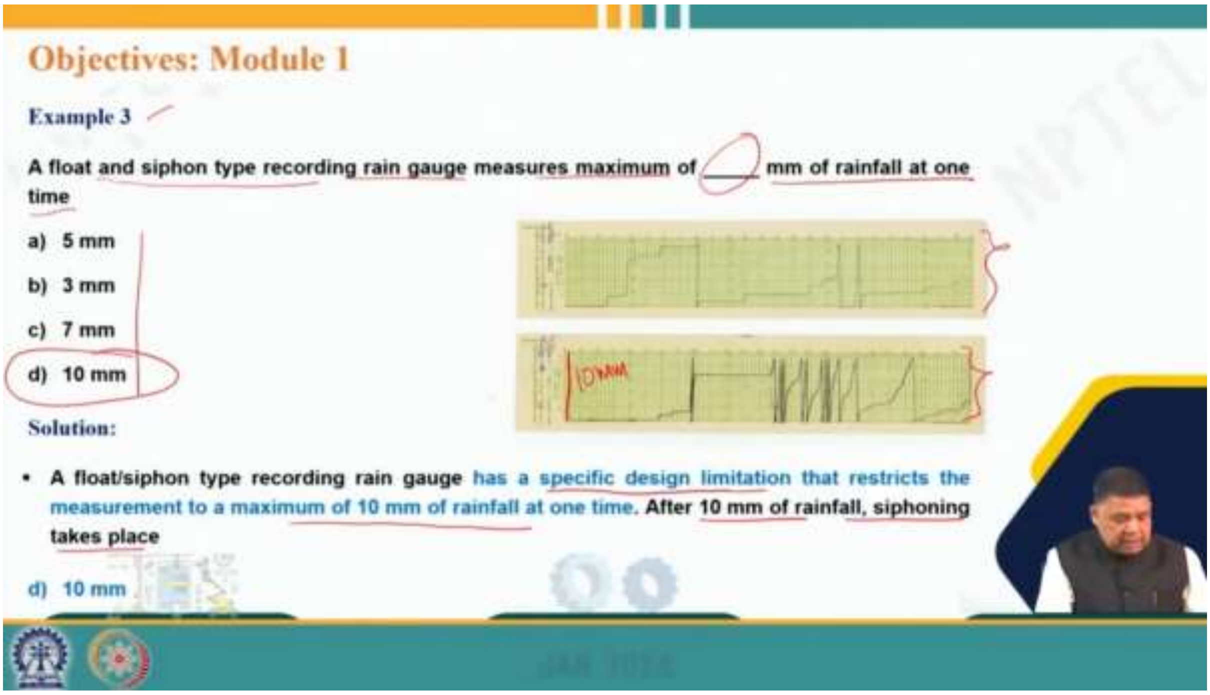
So, basically, at the beginning of module 12, we said that this module will have a miscellaneous focus, and today's lecture will be on concept revision through multiple-choice questions. So, we will take multiple questions and then we will try to revise the concepts based on those questions.



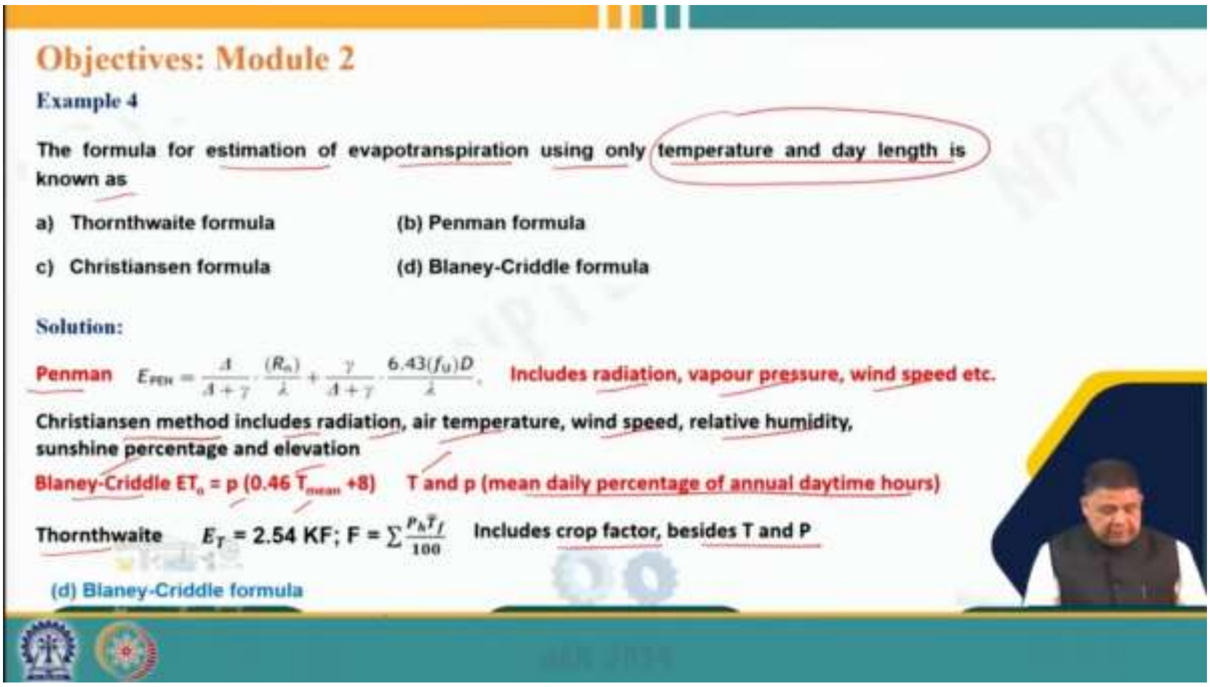
Let us begin with example number 1, which says that precipitation consisting of droplets less than _____in diameter is classified as drizzle, and then we have been given 4 options: 0.05, 0.5, 1, 1.5 mm. Obviously, you must recall when we discussed in the beginning precipitation temperature that we defined drizzle as the precipitation in the form of water droplets less than 0.5 mm in diameter and intensity less than 1 millimetre per hour. We also defined that rainfall also occurs in liquid form, but drop sizes vary from 0.5 to 6 mm, and based on the intensity of rain, we classify rainfall as light rain, less than 2.5 millimeters per hour; moderate rain, 2.5 to 7.5 millimeters per hour; and heavy rain, greater than 7.5 millimeters per hour. So, obviously, because this question refers to drizzle, the diameter has to be less than 0.5 mm. That means option B is the correct answer.



Then we take the next example: for station x, the maximum one-day rainfall with 25 instant periods is 100 mm. The probability of one-day rainfall equal to or greater than 100 mm at station x occurring at least once in 15 successive years. We have been given 3 or 4 options probability options, and we know that for probability of accidents, we use binomial distribution, which is given by this relationship: $P_{r,n}={}^nC_rP^rq^{n-r}$, which can be expanded like this. And we also know that probability is 1 by recurrence interval. So, here we have given 25 years return period. So, 1 by 25 is 0.04, and that is probability of accidents, and probability of non-accidents is 1 minus P, that is, 1 minus 0.04, which is 0.96. And while discussing binomial distribution, we also said that the probability of one-day rainfall equal to or greater than 100 mm at station x occurring at least once in 15 successive years can be given by this relationship: $1-q^n$, and we already calculated q. So, $(1-0.96)^{15}$. So, the answer comes out to be 0.458, which matches option A given here. So, option A is the correct answer to this question.

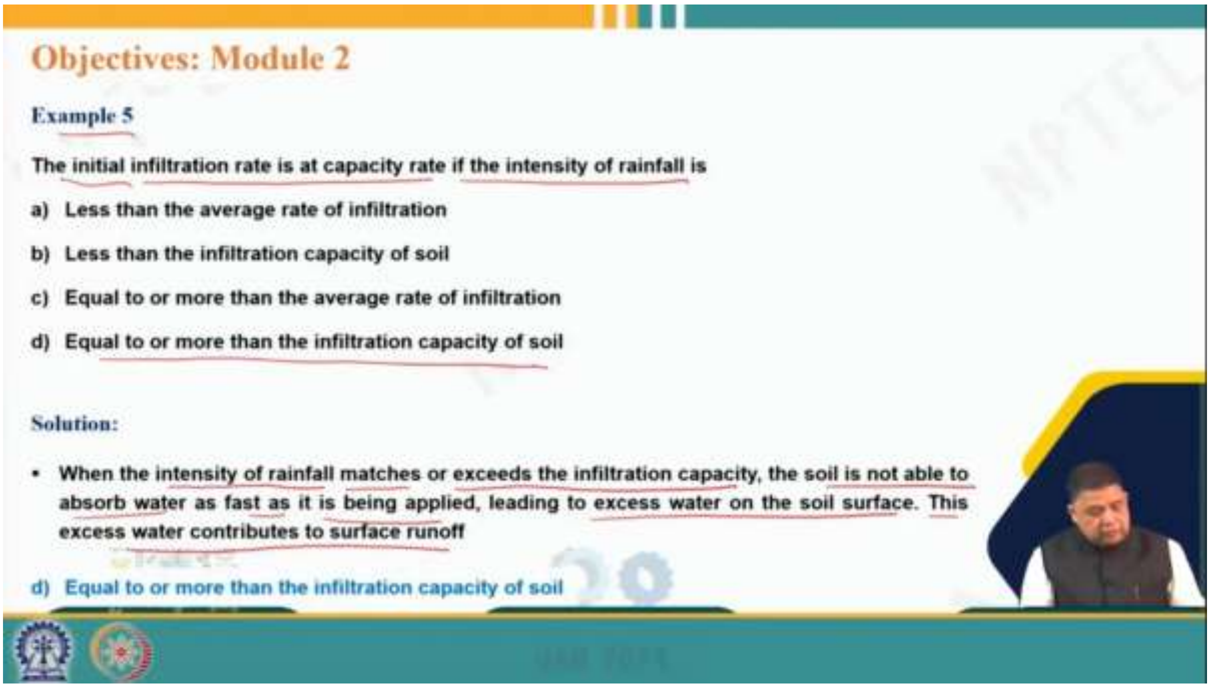


Then we take up the next example, example 3: a float and siphon type rain recording rain gauge measures a maximum of this much millimetre of rainfall at one time. Options are given: 4 options are given. And if you recall, the float or siphon type of rain gauge recording rain gauge, we always say that there is a specific design limitation for each of the gauges. And in the case of float siphon type, if you remember, we showed this typical chart where the depth scale is 10 mm. So, what happens is that when the rainfall reaches 10 mm of depth, then siphoning occurs. So, basically, it has a maximum of 10 mm of rainfall at one time; after 10 mm of rainfall, siphoning takes place. So, that means the correct answer is 10 mm, and that is option D is the correct answer.

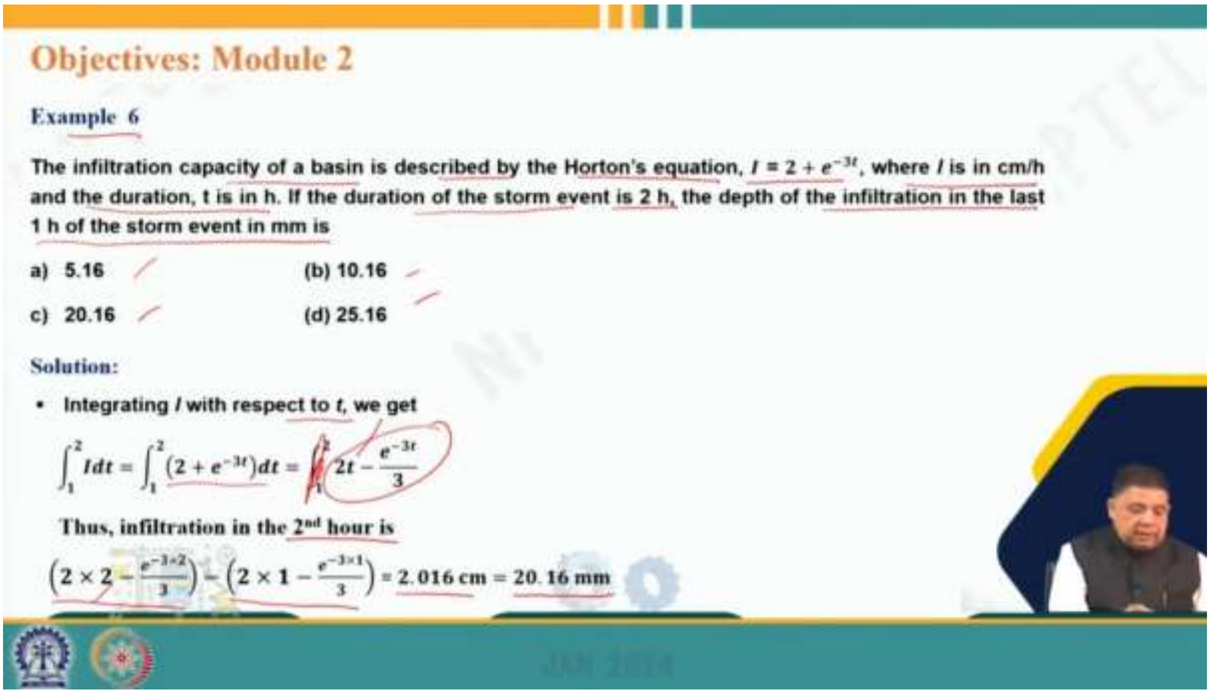


Then we take the next example: the formula for estimation of evapotranspiration using only temperature and day length is known as 4 methods are given: Thornthwaite, Penman, Christiansen, and Blaney Criddle.

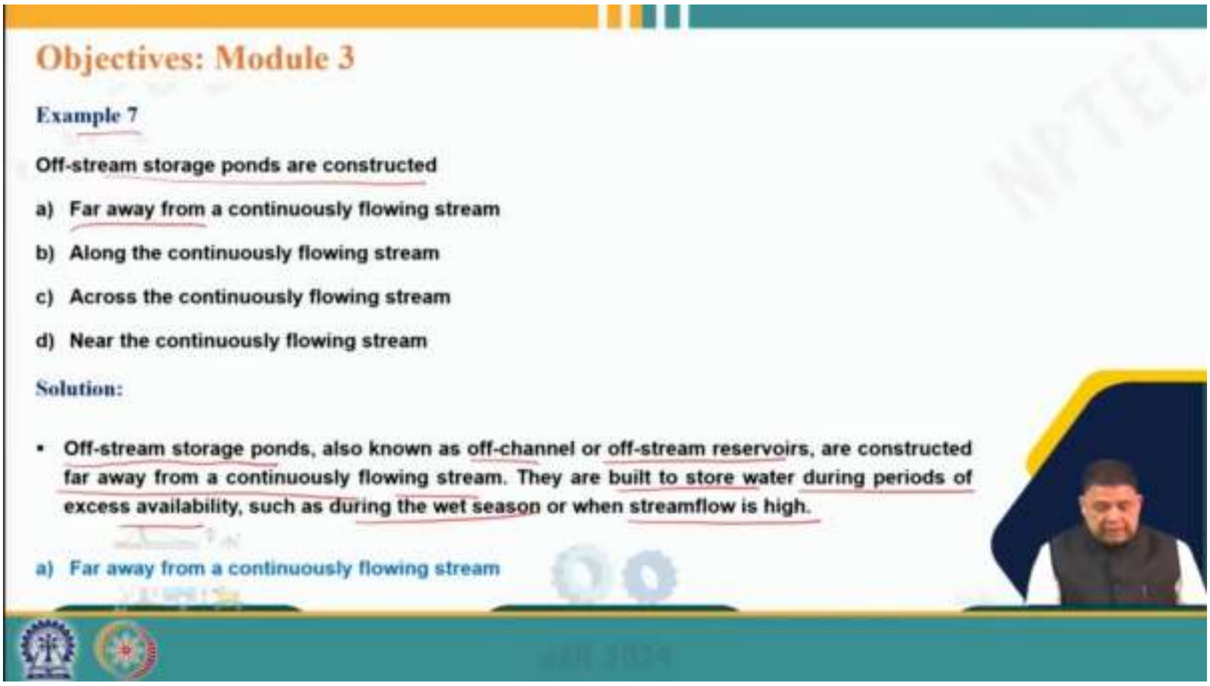
We studied at least 3 of these methods, and we know that the Penman method is the most advanced, which includes radiation, vapor pressure, and wind speed. Another advanced version is the FAO 24 Penman, which is the standard ET equation, but modifications have been made to it. Then, Christiansen's method includes radiation, air temperature, wind speed, relative humidity, sunshine, and elevation. Blaney Criddle, if you take it, uses P and T mean, where T is the temperature and P is the mean daily percentage of annual daytime hours. Thornthwaite uses a crop factor besides T and P. So, from these descriptions, we can see that the Blaney Criddle formula is the one which uses only temperature and day length, thus option D is the correct answer.



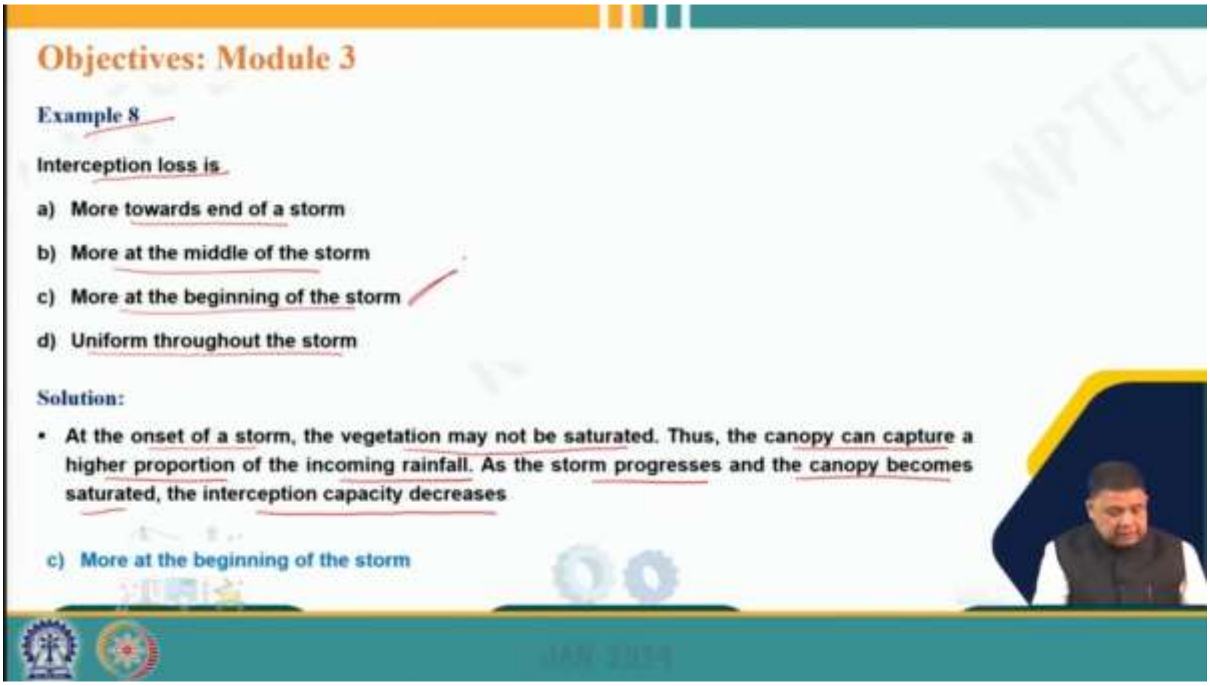
Then we move on to example 5, which talks about the initial infiltration rate. When the intensity of rainfall matches or exceeds the infiltration capacity, the soil is not able to absorb water as fast as it is being applied, leading to excess water on the soil surface. So, obviously, the initial infiltration capacity will be at capacity rate if the intensity of rainfall is equal to or more than the infiltration capacity of the soil. Option D is the correct answer.



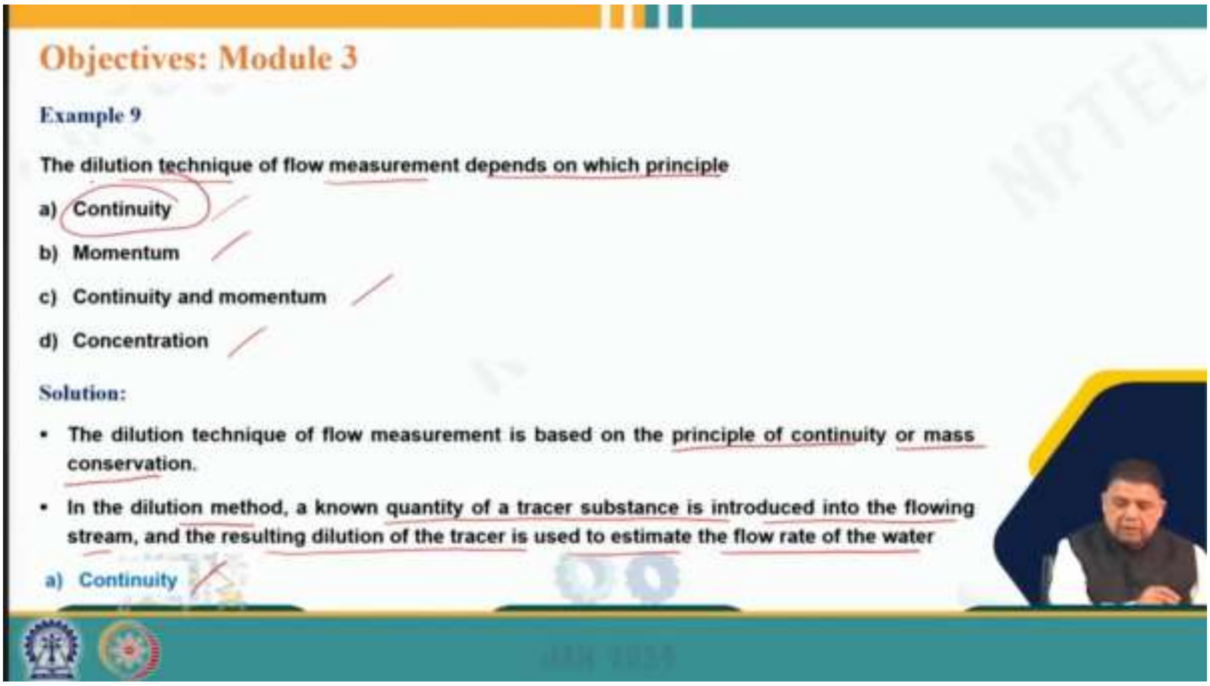
Next, in example 6, we have to find the depth of infiltration in the last 1 hour of a 2-hour storm event, given Horton's equation. Integrating between 1 and 2 hours, we find that the infiltration depth is 2.016 centimeters or 20.16 millimeters, so option C is the correct answer.



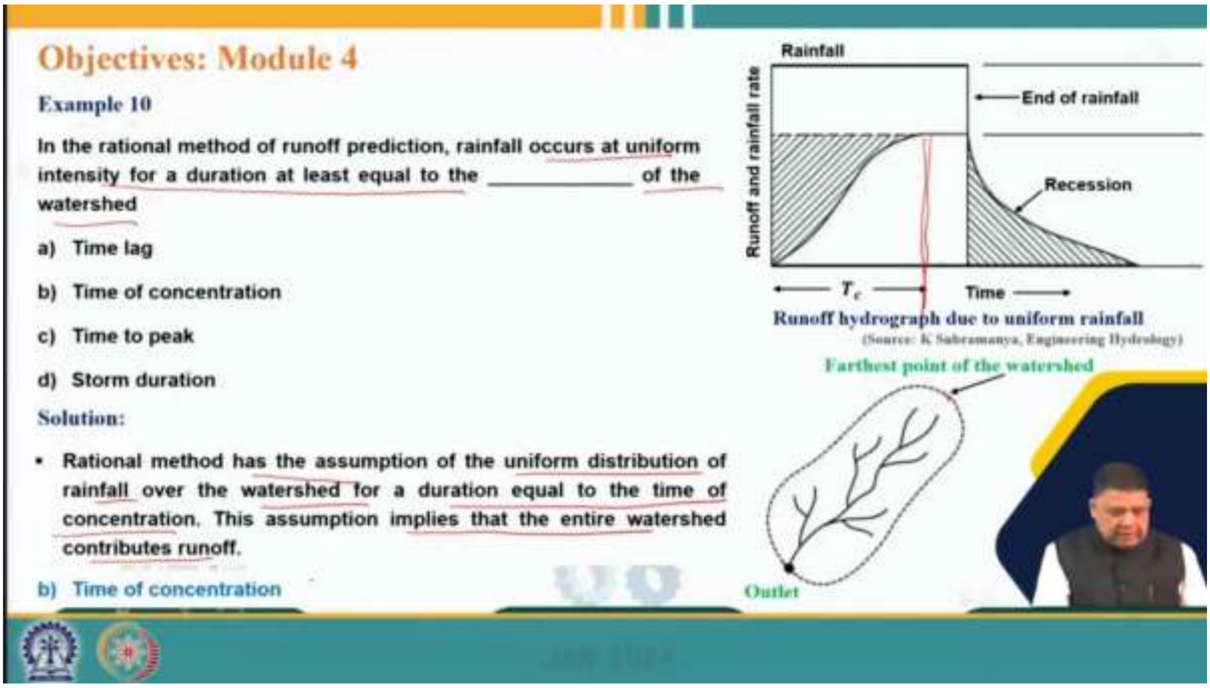
Example 7 is about upstream storage ponds, which are constructed far away from continuously flowing streams. They are built to store water during periods of excessive availability, away from the stream. Therefore, option A is the correct answer.



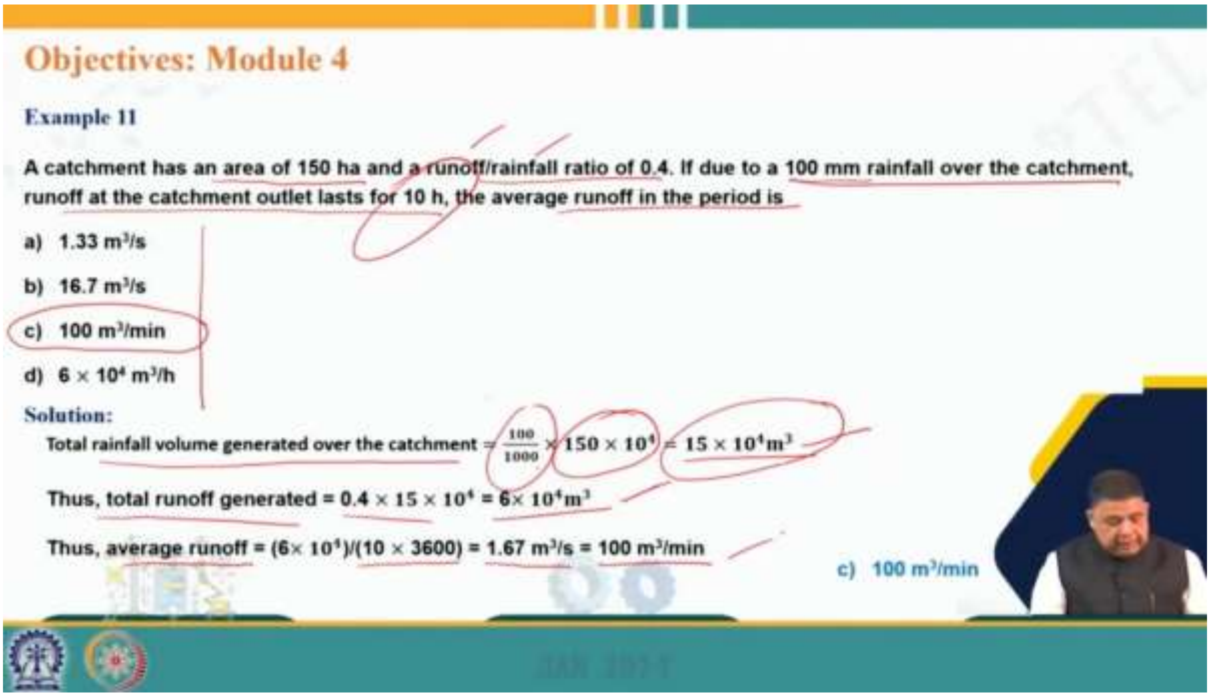
Finally, in example 8, interception losses are highest at the beginning of the storm when the canopy can capture a higher proportion of the incoming rainfall. As the storm progresses and the canopy becomes saturated, the interception capacity decreases. So, the highest value of interception will be at the beginning of the storm.



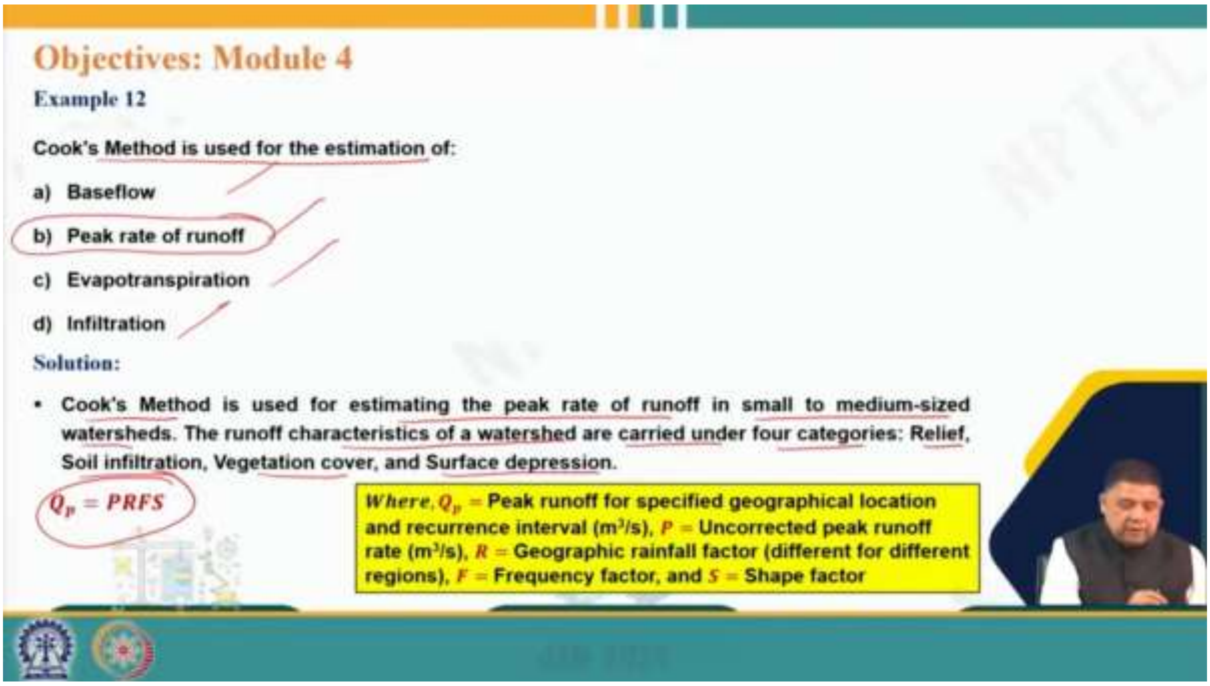
In example 9, the dilution technique of flow measurement depends on which principle? The correct principle is continuity or mass conservation. In the dilution method, a known quantity of tracer substance is introduced into the flowing stream, and the resulting dilution of this tracer is used to estimate the flow rate of the water. Therefore, the correct answer is A, the principle of continuity.



Moving on to example 10, in the rational method of runoff prediction, rainfall occurs at a uniform intensity for a duration at least equal to the dash of the watershed. The correct term here is "time of concentration." The rational method assumes a uniform distribution of rainfall over the watershed for a duration equal to the time of concentration, ensuring that the entire watershed contributes to runoff.

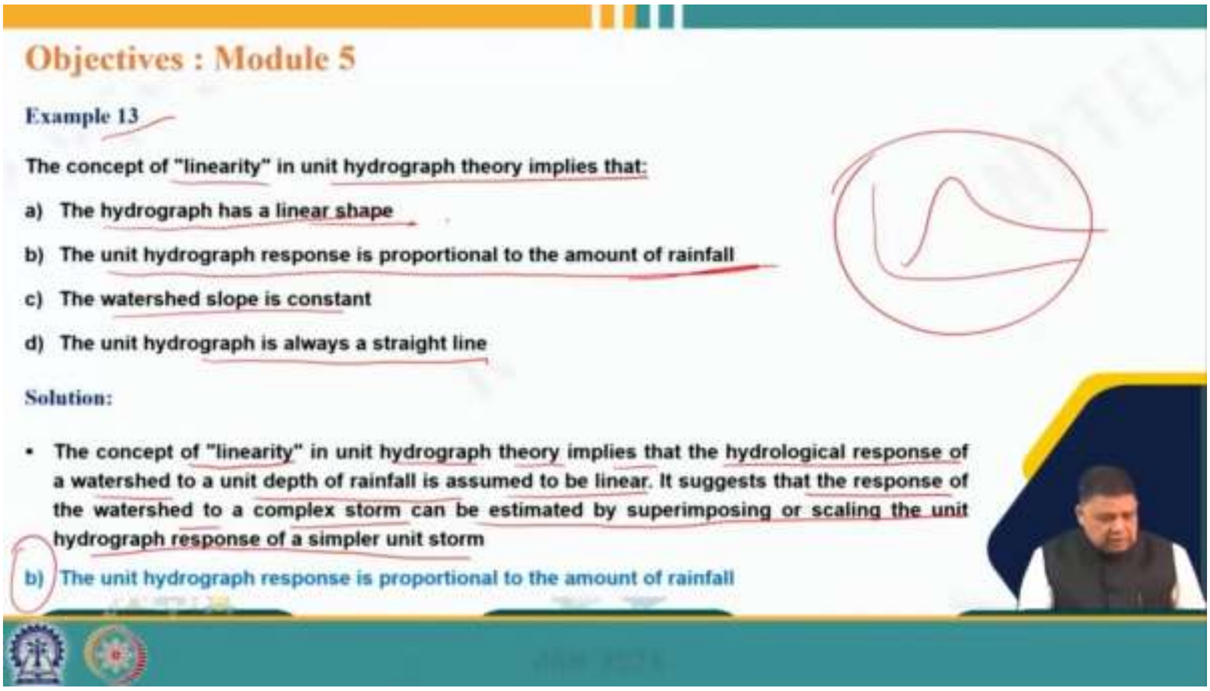


Example 11 involves calculating the average runoff rate given the catchment area, runoff rainfall ratio, and duration of runoff. After converting units appropriately, the average runoff rate is found to be 100 cubic meters per minute, making option C the correct answer.



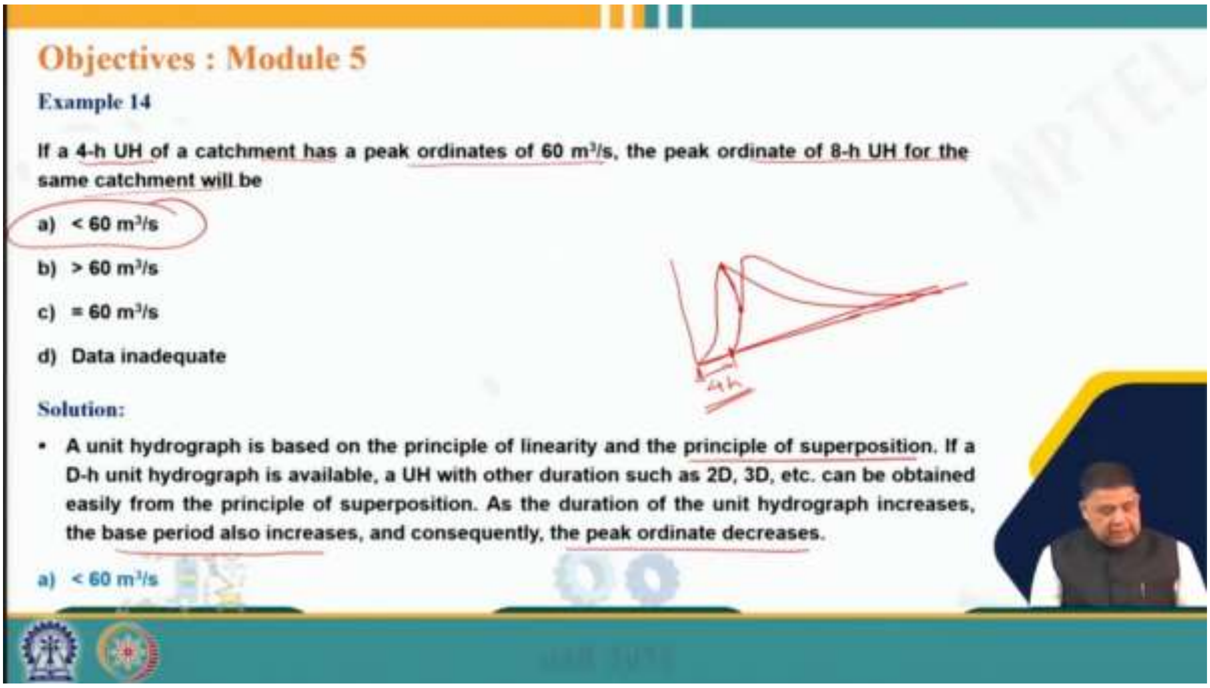
Finally, in example 12, Cook's method is used for the estimation of the peak rate of runoff in small to medium-sized watersheds.

Runoff characteristics of watersheds are analysed under four categories: relief, soil infiltration, vegetation cover, and surface preparation. Then, we use the relationship Q=PRFS for calculating the peak runoff rate. So, basically, the answer is the peak rate of runoff, which is option B.



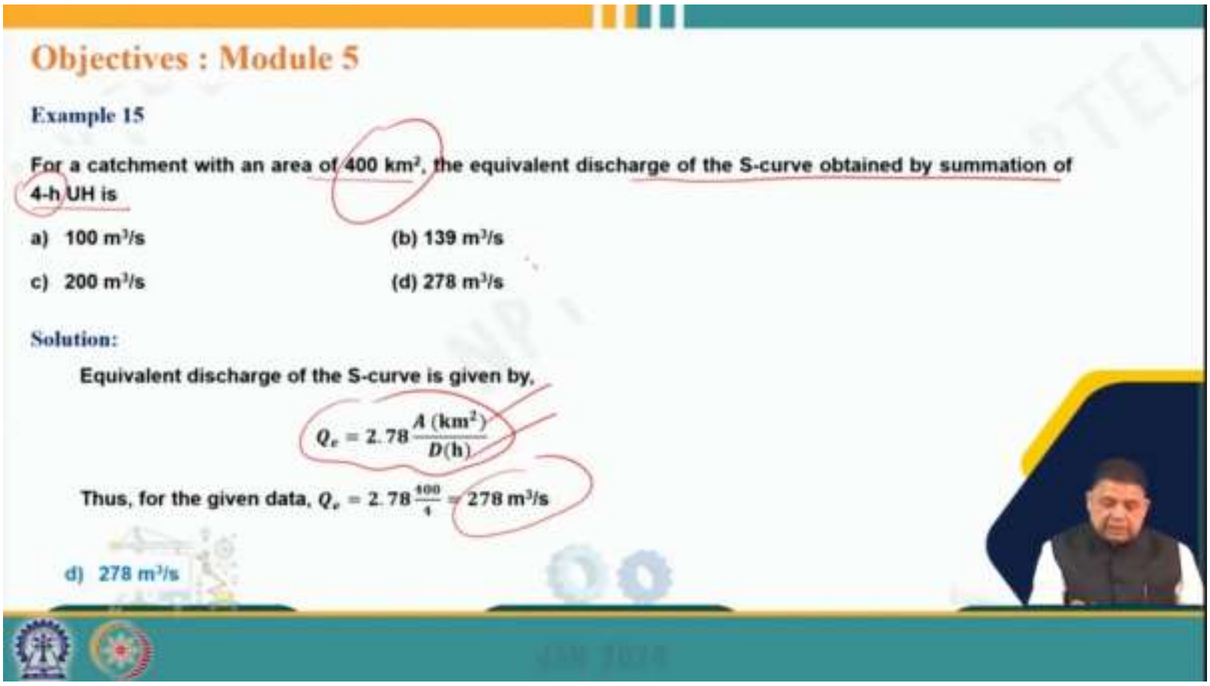
Moving on to example 13, the concept of linearity in unit hydrograph theory implies that the hydrograph has a linear shape. The correct interpretation is that the unit hydrograph responds in proportion to the amount of rainfall. It doesn't necessarily mean that the hydrograph is always a straight line. This can be determined through an elimination process, as hydrographs typically exhibit curvilinear shapes rather than straight lines.

And the watershed slope does not come into the picture as far as the hydrograph is concerned. So, the only possible option is that the unit hydrograph response is proportional to the amount of rainfall. The explanation is that the concept of linearity in unit hydrograph theory implies that the hydrological response of a watershed to a unit depth of rainfall is assumed to be linear. This means that the response of the watershed to a complex storm can be estimated by superimposing or scaling the unit hydrograph response of a simpler unit storm. So, the correct option is option B, as I already mentioned through the process of elimination.

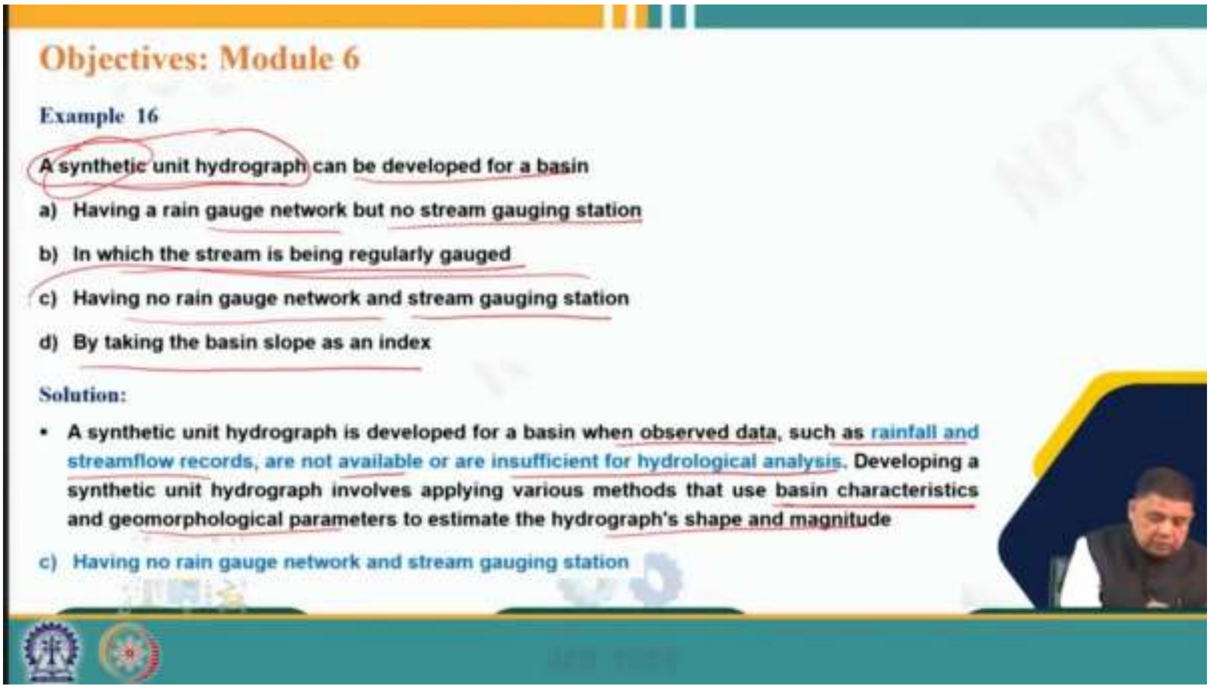


Moving on to example 14, a 4-hour unit hydrograph of a catchment has a peak ordinate of 60 cubic meters per second. The peak ordinate of an 8-hour unit hydrograph for the same catchment will be less than that. There are four options given, and of course, we know that if we are given a 4-hour unit hydrograph, then we can develop the 8-hour unit hydrograph.

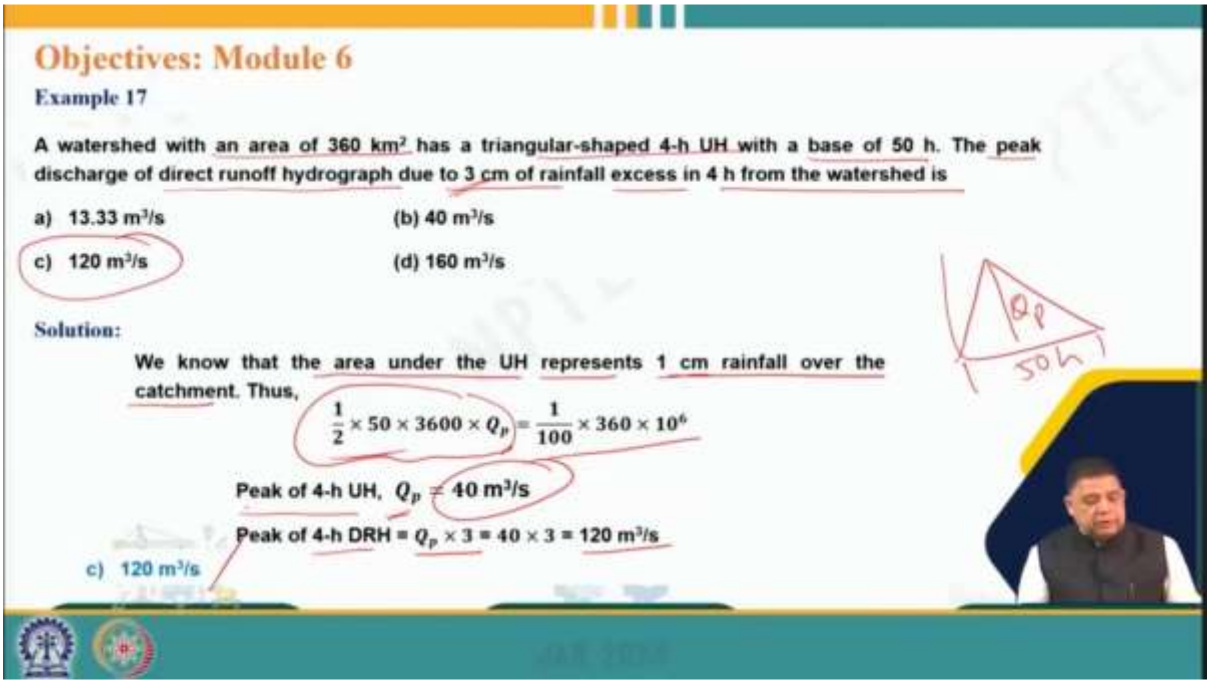
So, if we have a 4-hour unit hydrograph given, then for developing an 8-hour unit hydrograph, we use the principle of superposition. That means, the two 4-hour unit hydrographs, because n=2, will be superimposed, each lagging the previous one by 4 hours. That is the concept we use, or that is the procedure we use. And of course, as you know, with a unit hydrograph, the base increases, and the peak decreases. So, the peak ordinate of an 8-hour unit hydrograph will always be less than 60 cubic meters per second. This means that the base period increases, so the peak ordinate will obviously decrease. Thus, option A, "less than 60 cubic meters per second," is the correct answer.



Next, for a catchment with an area of 1400 square kilometers, the equivalent discharge of the S-curve obtained by summation of the 4-hour unit hydrograph can be calculated using the formula Q_e=2.78×A/D, where A is in square kilometers and D is in hours. With the area given as 400 square kilometers and D given as 4 hours, plugging these values into the equation yields Q_e=278 cubic meters per second, matching option D. So, option D is the correct answer for this question.

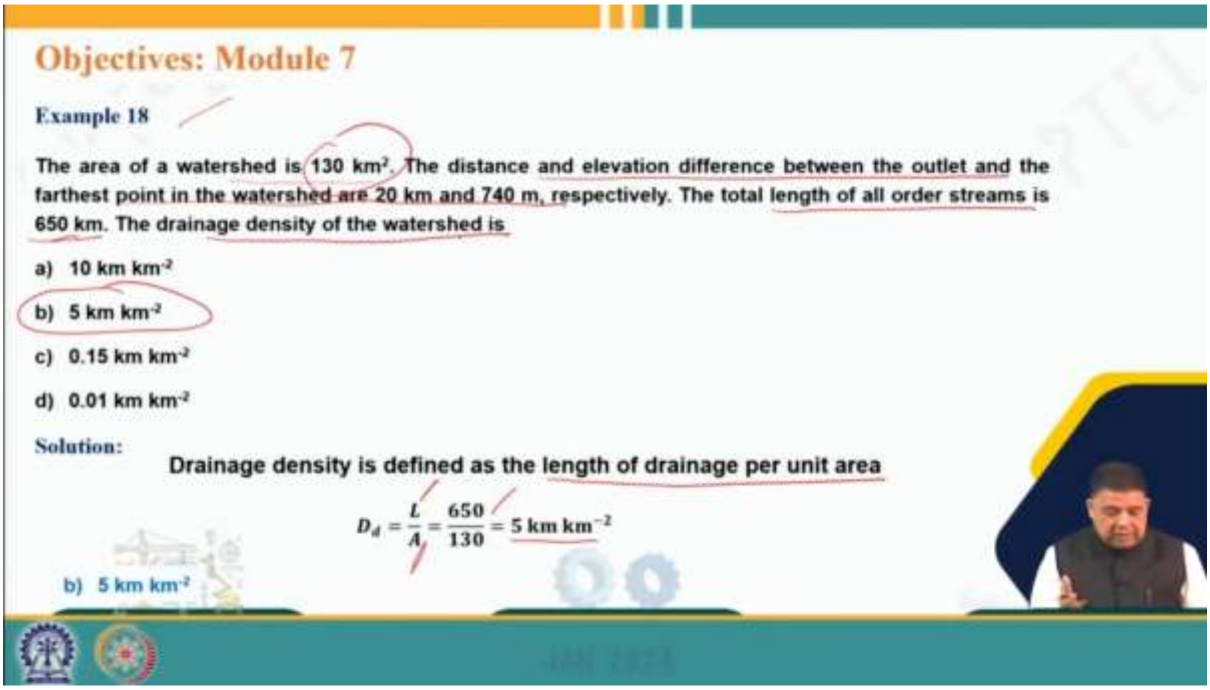


Then, in example 16, a synthetic unit hydrograph can be developed for a basin having a rain gauge network but no stream-gauging station. Conversely, it can also be developed for a basin with no rain gauge network or stream-gauging station, using basin slope as an index. So, we use a synthetic unit hydrograph when observed data such as rainfall and stream flow records are not available or insufficient for hydrological analysis. This means we use different methods that utilize basin characteristics and geomorphological parameters to estimate the hydrograph shapes and magnitudes. Thus, we will go for a synthetic unit hydrograph only when it is an ungauged basin, meaning it has no rain gauge or stream-gauging station. Therefore, option C is the correct answer.

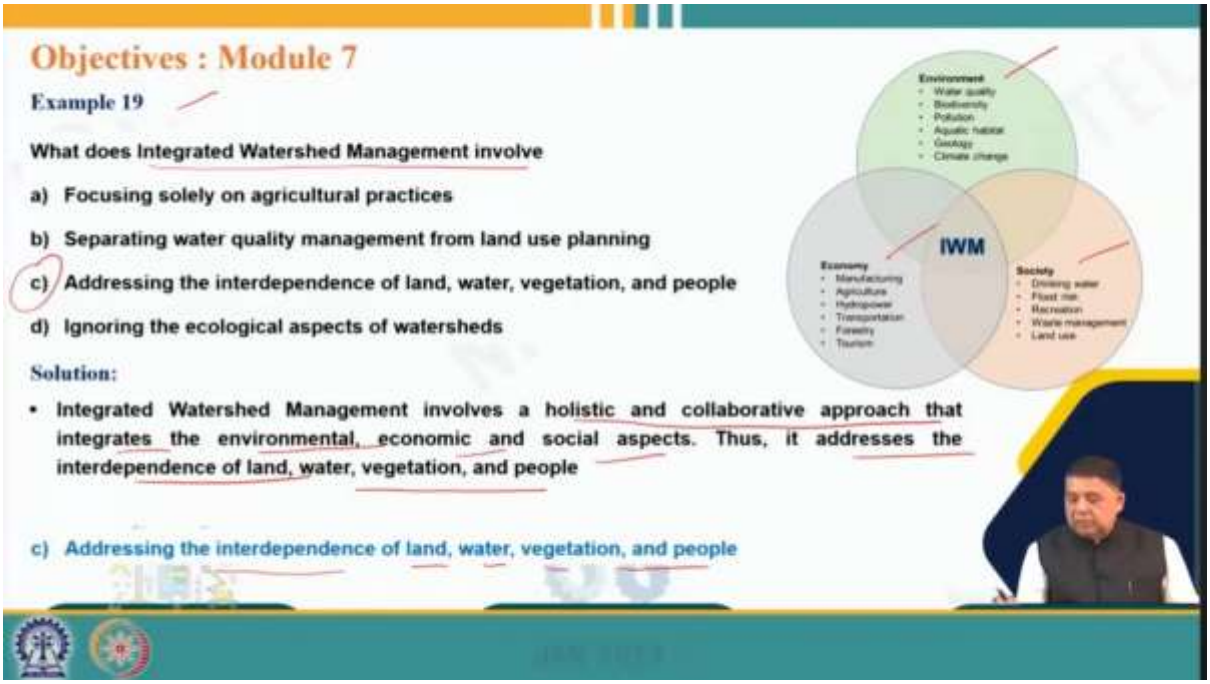


Lastly, in example 17, a watershed with an area of 360 square kilometers has a triangular-shaped 4-hour unit hydrograph with a base of 50 hours.

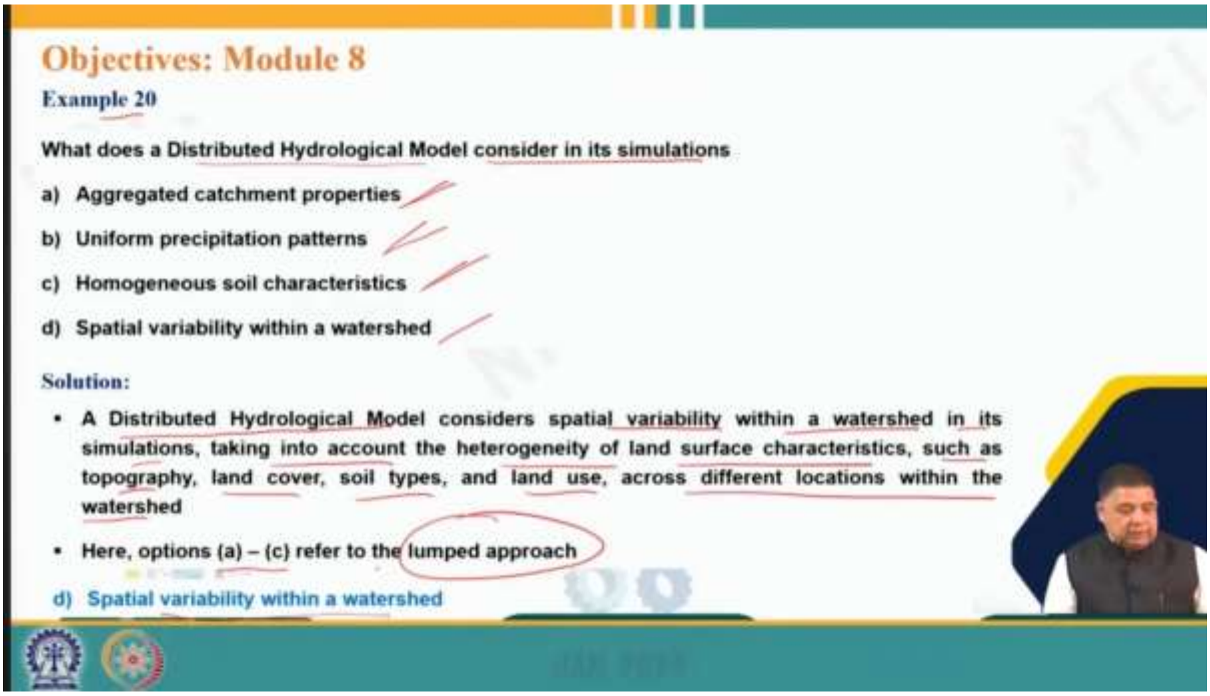
The peak discharge of the direct runoff hydrograph due to 3 centimeters of rainfall exceeds that of the 4-hour watershed. So basically, with the given unit hydrograph (UH), you have to find the peak value of the 3-centimeter direct runoff hydrograph (DRH). We know that the area under the UH represents 1 centimeter of rainfall over the catchment. Therefore, the unit hydrograph area (A) can be calculated using the formula: $A=\frac{1}{2} \times base \times 3600 \times Qp$, where the time base is given as 50 hours. Equating this area to the volume represented by 1 centimeter of rainfall over the entire area, we find Q_P to be 40 cubic meters per second. Now, we need the peak of the 4-hour DRH for 3 centimeters of runoff, which is Q_P times 3 or 120 cubic meters per second, matching option C. So, option C is the correct answer to this question.



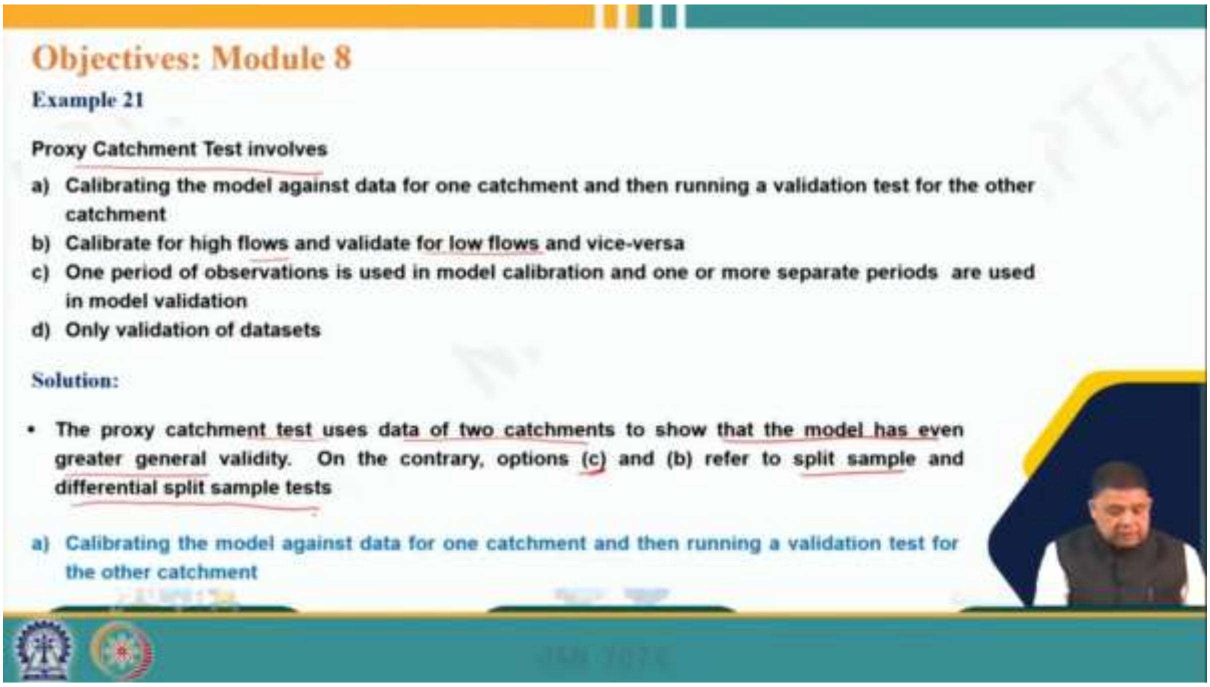
Moving on to example 18, the area of the watershed is 130 square kilometers, and the distance and elevation difference between the outlet and the farthest point in the watershed are given as 20 kilometers and 740 meters, respectively. The total length of all-order streams is 650 kilometers. The drainage density (D_d) of the watershed, calculated as the length of drainage area per unit area, is $\frac{L}{A}$. Although additional data is given, such as elevation difference and distance, these are not needed. The D_d value comes out to be 5 kilometers per square kilometer. So, option B is the correct answer. This is just to demonstrate that additional data might be given to confuse you, testing your conceptual clarity.



Next, in example 19, integrated watershed management involves a holistic and collaborative approach that integrates environmental, economic, and social aspects, addressing the interdependence of land, water, vegetation, and people. Since integrated watershed management focuses on the environment, economy, and societies, option C, addressing the interdependence of land, water, vegetation, and people, is the correct answer.

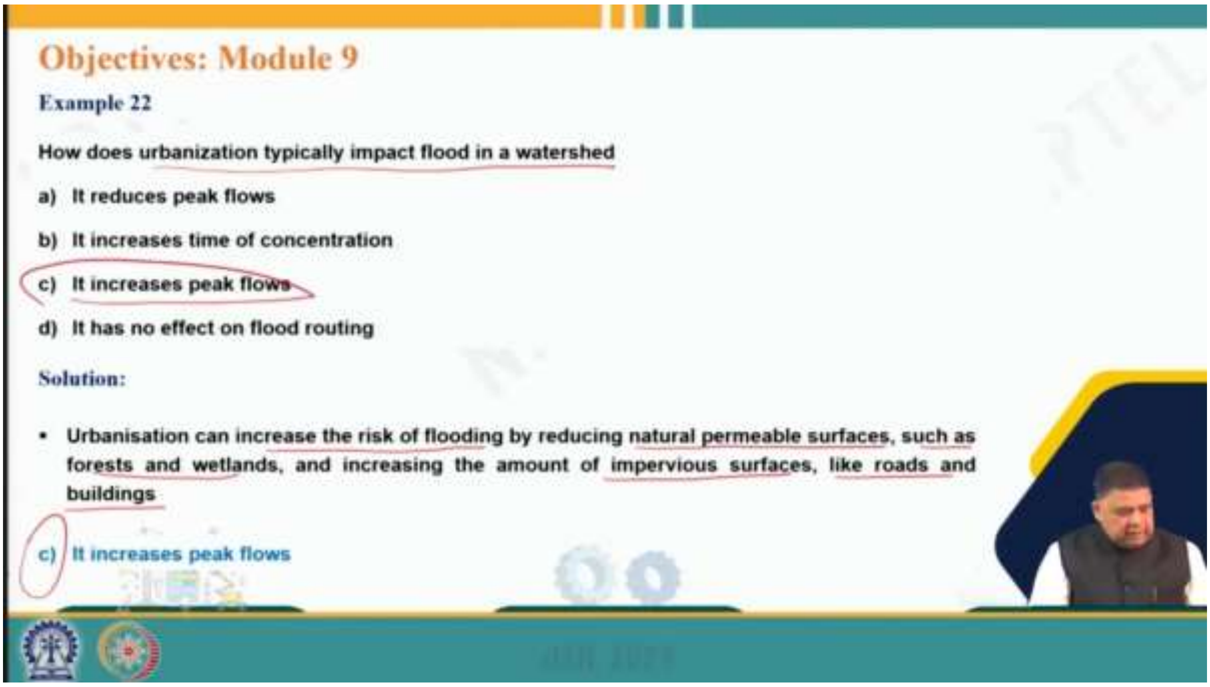


Then, in example 20, a distributed hydrological model considers spatial variability within the watershed in its simulation, taking into account the heterogeneity of land surface characteristics such as topography, land cover, soil types, and land use across different locations within the watershed. Options A to C, which refer to aggregated catchment properties, uniform precipitation patterns, and homogeneous soil characteristics, belong to or refer to the lumped approach. Therefore, the only suitable option for a distributed hydrological model is D, especially variability within the watershed.

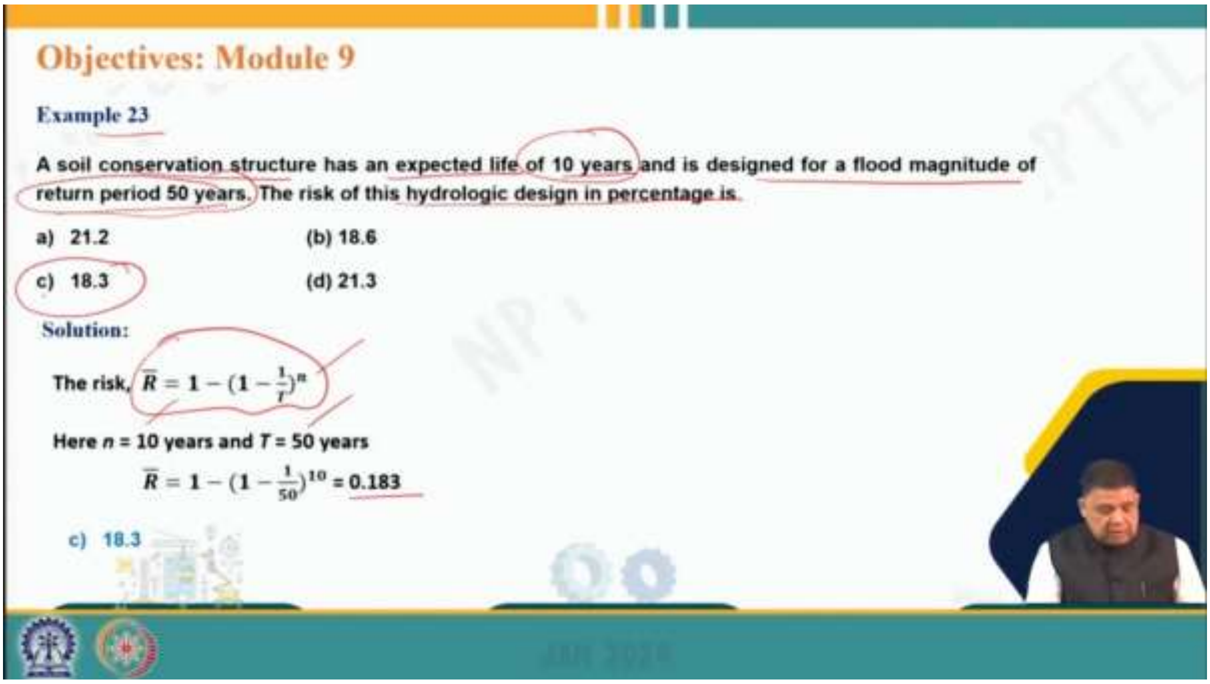


Lastly, in example 21, proxy catchment tests involve...

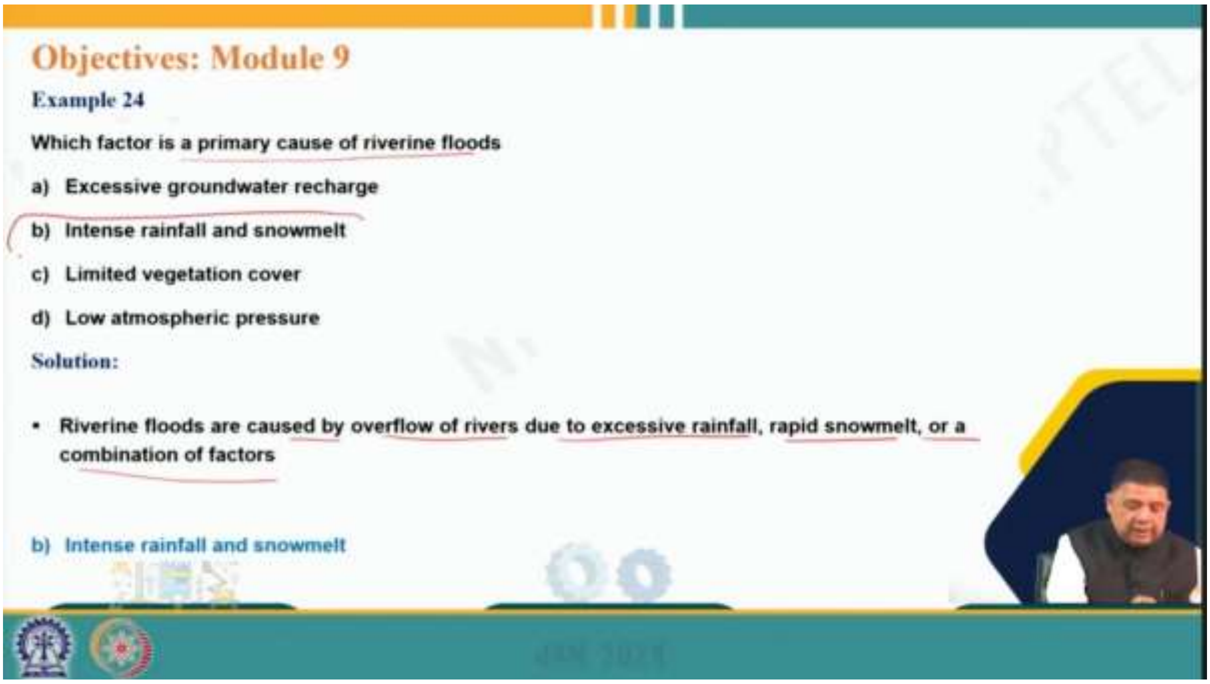
Then, the proxy catchment test uses data from two catchments to show that the model has general validity. On the contrary, option C, which states that one period of observation is used for model calibration and another period for model variation, refers to split-sample testing. Option B, which suggests calibration for high flows and validation for low flows, and vice versa, represents a differential split-sample test. Therefore, in this case, since only validation data is used, it has nothing to do with calibration. Thus, option A, calibrating the model against data for one catchment and then conducting validation tests for the other catchment, is the correct answer to this question.



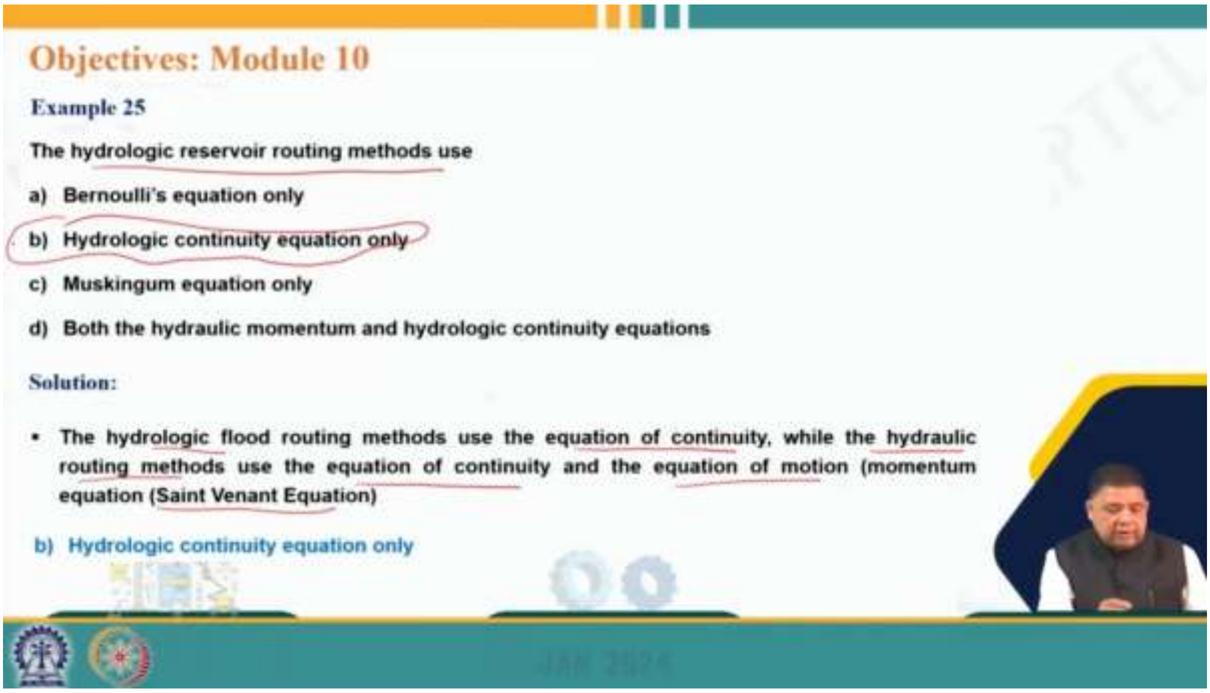
Moving on to example 22, urbanization typically impacts floods in a watershed by increasing the risk of flooding. This is due to the reduction of natural permeable surfaces such as forests and wetlands, leading to an increase in impervious surfaces like roads and buildings. Consequently, infiltration decreases, while flooding increases, resulting in an increase in peak flows. Therefore, option C, increases peak flows, is the correct answer.



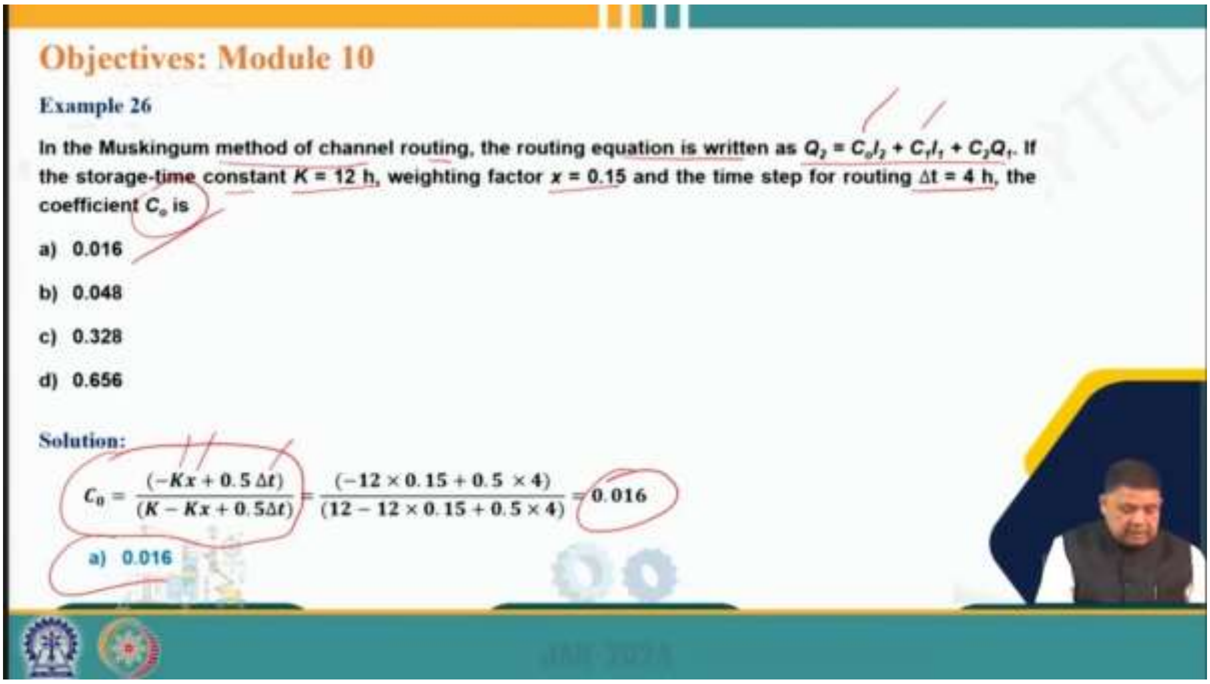
Then, in example 23, a soil conservation structure with an expected life of 10 years is designed for a flood magnitude with a return period of 50 years. The risk of this hydrological design, expressed as a percentage, can be calculated using the formula $1-(1-\frac{1}{T})^n$, where T is the return period (given as 50 years) and n is the expected life of the structure (given as 10 years). Substituting these values, we get a result of 18.3 percent, which matches option C.



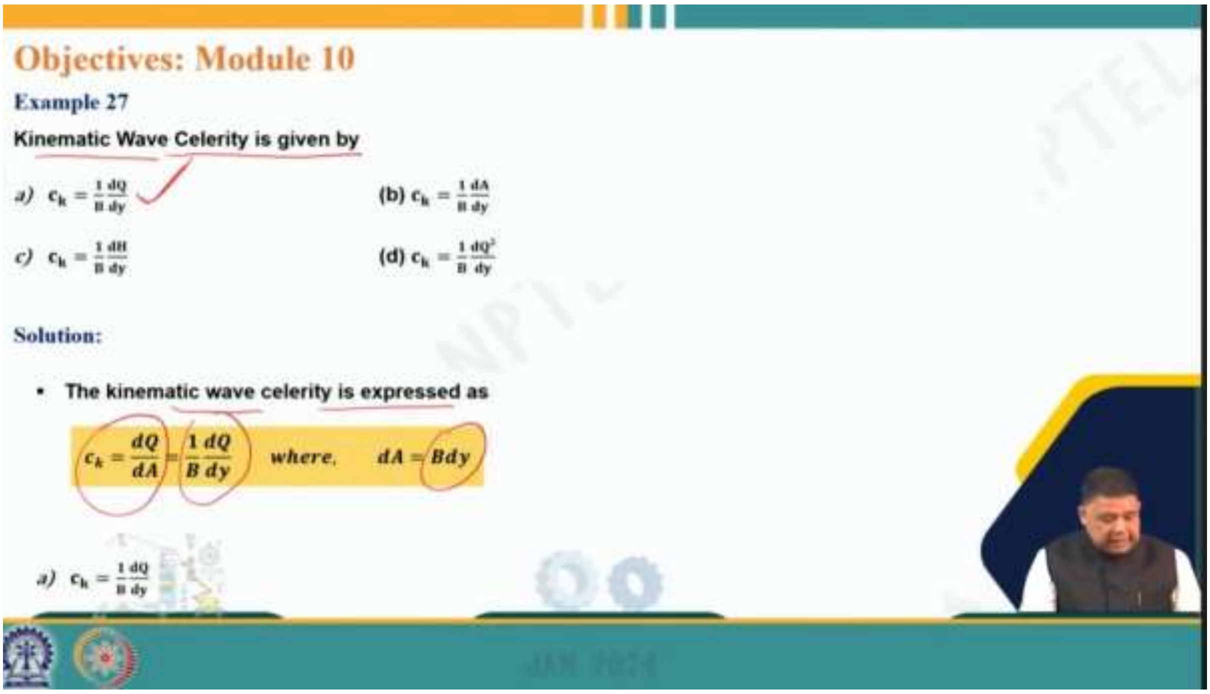
In example 24, the primary cause of riverine floods is intense rainfall and snowmelt, leading to the overflow of rivers. Therefore, option B, intense rainfall, and snowmelt, is the correct choice.



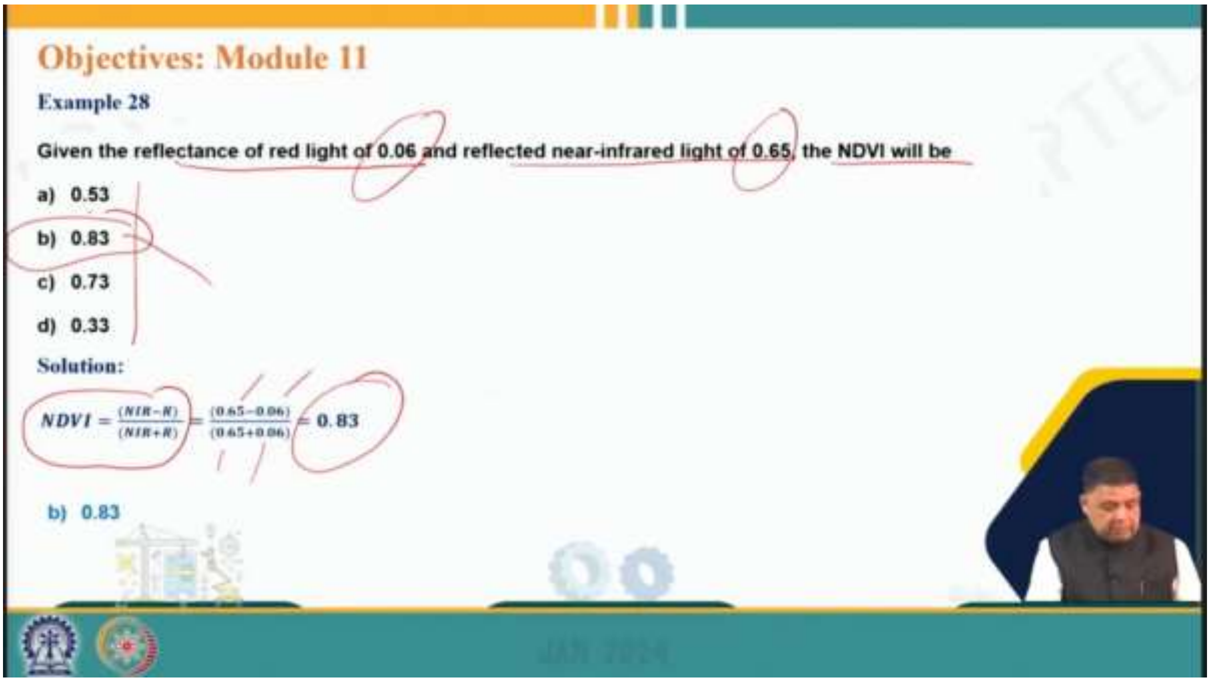
Lastly, in example 25, hydrological reservoir routing methods use the hydrological continuity equation. So, option B, which states that hydrological reservoir routing methods use the hydrological continuity equation, is correct.



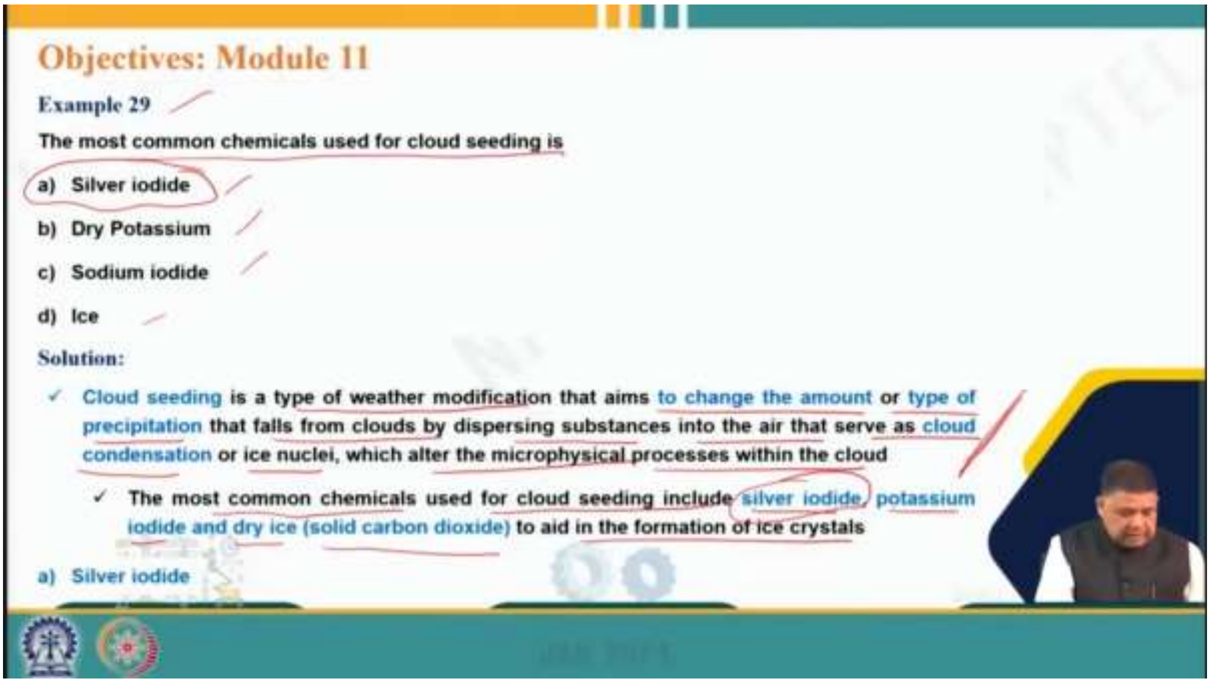
In the Muskingum method of channel routing, the routing equation is written as Q_2, as given in the equation. If the storage time constant K is 12 hours and the weighing factor x is 0.15, the time for routing, Δt, is 4 hours, and the coefficient C_0 is. We have to remember this question and the formulae for C_1, C_0, and C_2. Of course, we only have to calculate C_0, and we know that C_0 is given by this equation: $C_0 = \frac{-kx+0.5\Delta t}{k-kx+0.5\Delta t}$. We have been given Kx and Δt values here. Kx and Δt are already given. So, putting these values, we calculate C_0 to be 0.016. So, that means, option A is the correct answer to this particular question.



Then we go to example number 27, which relates to kinetic wave celerity. Kinetic wave celerity, given by the equation, is provided. This means you have to remember the formula, and you know that we discussed kinetic wave celerity and derived the formula also. C_k is dQ/dA, or if we express it in terms of bed width, then we will get $\frac{1}{B} \times \frac{dQ}{dA}$, and this matches straight away with option A. So, option A is the correct answer to this particular question.



Then we go to example number 28. Given the reflectance of red light of 0.06 and reflected near-infrared light of 0.65, the NDVI value will be. Options are given as 0.53, 0.83, 0.73. Obviously, you have to remember the formulae of NDVI and calculate the value, and we know that NDVI is given by this relationship: $\frac{(NIR-R)}{(NIR+R)}$, where NIR value is given as 0.65 and R value is given as 0.06. Putting the values of NIR and R in the numerator and denominator, we get an NDVI value of 0.83, which matches option B. So, option B is the correct answer to this particular question.



Then we take example 29. The most common chemical used for cloud seeding is silver iodide, dried potassium sodium iodide, ice. Of course, if you remember, you can easily pick the answer, but just to recall the concept, cloud seeding is a type of weather modification that aims to change the amount or types of precipitation that fall from clouds by dispersing substances into the air that serve as cloud condensation or ice nuclei, which alter the microphysical process within the cloud. So, basically, as we discussed, we artificially create hygroscopic materials through so that condensation could take place, and the most common chemicals used for cloud seeding include silver iodide, potassium iodide, and dry ice or solid carbon dioxide to aid in the formation of ice crystals. We also discussed that silver iodide is also naturally available in the atmosphere. So, obviously, the only possible answer to this question is silver iodide. So, option A is the correct answer. With this, we come to the end of this lecture. We have covered 29 different problems that appeared in GATE examinations in different years, and we also reviewed our concepts while solving these questions. Obviously, if you aim to pursue higher studies, you have to write the GATE examination, and of course, then you need to prepare for these questions. If you have any questions or doubts, please read the queries and also provide your feedback. Thank you very much.


THANK YOU