TEAMS
TESTS OF ENGINEERING APTITUDE, MATHEMATICS AND SCIENCE

November Monthly Math Challenge
Middle School Level
Problem & Solution

Instructions: TEAMS coaches submit student answers to the question(s) below using the submission link on the TEAMS website. All submissions must be made during the month of November. Those submissions with correct answers will be entered into a drawing for a $25 Visa gift card, which will be sent to the student in care of the TEAMS coach.

Agricultural Irrigation System Design

A ranch manager was recently permitted to withdraw water from a nearby creek for irrigation supply water. The water will be conveyed from the creek over to the field where irrigation occurs through an existing diversion and rectangular irrigation channel. The channel is 3 ft wide and 1 ft deep and open to the atmosphere. Manning's equation is used to calculate flow in an open channel such as the irrigation channel mentioned here. Manning's equation is an empirically derived equation with the form below used for English units:

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} \sqrt{S}$$

Where

Q = flowrate (ft^3/s)
n = Manning's roughness coefficient
A = cross sectional area of the flow (ft^2)
R = hydraulic radius of flow (ft) = A/P
P = Perimeter of channel (ft)
S = Channel slope (ft/ft)

Question 1:

The existing rectangular channel is lined with grass, which has a Manning's roughness coefficient of 0.022. The channel slopes at a rate of 0.06 inches per foot. What is the maximum water flow the irrigator can expect to convey through the channel?

Solution

Water flow rate = 10.22 ft^3/sec

Determine the area of the rectangular channel

Area = length x width

Area = 3 ft x 1 ft = 3 ft^2

This is the maximum area of flow if the channel is flowing full

Determine the hydraulic radius of the channel

R = A/P

Perimeter (P) = 1 ft + 3 ft + 1 ft = 5 ft

R = 3 ft^2/5ft = 0.6 ft

Determine the flow in the channel using Manning's Equation

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} \sqrt{S}$$

Determine the slope

S = 0.06 in/ft * 1/12 ft/in = 0.005 ft/ft

Where n = 0.022 and S = 0.005 ft/ft

$$Q = \frac{1.49}{0.022} (3)(0.6)^{\frac{2}{3}} \sqrt{(0.005}$$

Q = 10.22 ft^3/sec