

Instructions: i) This is an **OPEN NOTES** examination, ii) Solve **ALL** the problems, iii) Exchange of books/notes or consultation is not permitted; iv) assume any data required suitably.

**Problem 1 (5 marks)**

The joint density function of two random variables  $x$  and  $y$  is

$$f(x,y) = 6xy(2-x-2y) \text{ where } 0 \leq x \leq 1 \text{ and } 0 \leq y \leq 1$$

$$= 0, \text{ other wise}$$

Compute  $\text{Cov}[x,y]$ ,  $\rho(x,y)$

**Problem 2 (6 marks)**

a) Derive an equation for  $GY = \frac{(1+r)^Y - 1}{r}$  and indicate the assumptions on which this equation is obtained. (3)

b) Also estimate the equivalent 18-kip single axle load repetitions (ESAL) for a six-lane pavement (three lanes in each direction) of a rural interstate highway with a truck count of 1000 per day (including 2-axle, 4-tire panel, and pickup trucks), annual growth rate of 5% and a design life of 15 years. (3)

**Problem 3 (8 marks)**

The predicted traffic  $W_{18}$  and serviceability loss due to frost heave  $\Delta\text{PSI}_{\text{FH}}$  as a function of time can be expressed by  $W_{18} = 5 \times 10^6 [(1.04)^Y - 1]$ ;  $\Delta\text{PSI}_{\text{FH}} = 0.08 (Y)^{0.6}$  in which  $Y$  is time in years. Determine the performance period for rigid pavement with the following information:  $R = 90\%$ ;  $S_0 = 0.4$ ,  $D = 8$  in  $\Delta\text{PSI} = 4.5 - 2.5 = 2.0$ ;  $S_c = 600$  psi,  $C_d = 1.05$ ;  $J = 3.2$ ,  $E_c = 5 \times 10^6$ , and  $k = 100$  pci.

**Problem 4 (8 marks)**

Design a JPCP for a National Highway (4-lane divided carriageway) in Bihar as per IRC: 58-2002 with axle load survey data shown in Table 1 below. The total two-way traffic at the end of the construction period is 2800. Other important data, design life = 30 years, Traffic growth rate = 7.5%, CBR = 7%. DLC layer of 150 mm is provided as sub-base. Assume any other data required suitably.

Table 1

Single Axle Loads				Tandem Axle Loads			
Axle Load (tons)	Load (tons)	Percentage of Axle Loads	Expected Repetition	Axle Load (tons)	Percentage of Axle Loads	Percentage of Axle Loads	Expected Repetition
13-15	14	0.8	1,84,984	14-16	15	0.5	1,23,322
11-13	12	4.2	9,86,579				
9-11	10	3.4	8,01,595				
Less than 9	Less than 10	65.6	1,55,38,619	Less than 14	Less than 15	25.5	60,42,796

**Problem 5 (8 marks)**

A bonded PCC overlay is planned for an existing JPCP. The existing slab thickness is 8.2 in. NDT was performed to back calculate the dynamic  $k$ -value and the modulus of concrete.  $E_c$  under a dynamic load of 9000 lb. The deflections measured at distances of 0, 12, 24 and 36 in are 3.68, 3.08, 2.64, 2.23 mils (1 mil =  $1 \times 10^{-3}$  in) respectively. Determine the a)  $E_c$  and the static  $k$ -value b) Determine the  $D_{OL}$  by using the static  $k$ -value obtained from NDT and assuming  $\text{ESAL} = 11 \times 10^6$ ,  $R = 95\%$ ;  $S_0 = 0.35$ ;  $p_1 = 4.5$ ,  $p_2 = 2.5$ ,  $C_d = 1$ ,  $J = 4$ ,  $F_{jc} = 10$   $F_{fat} = 0.95$ , and  $F_{dur} = 1.00$ .