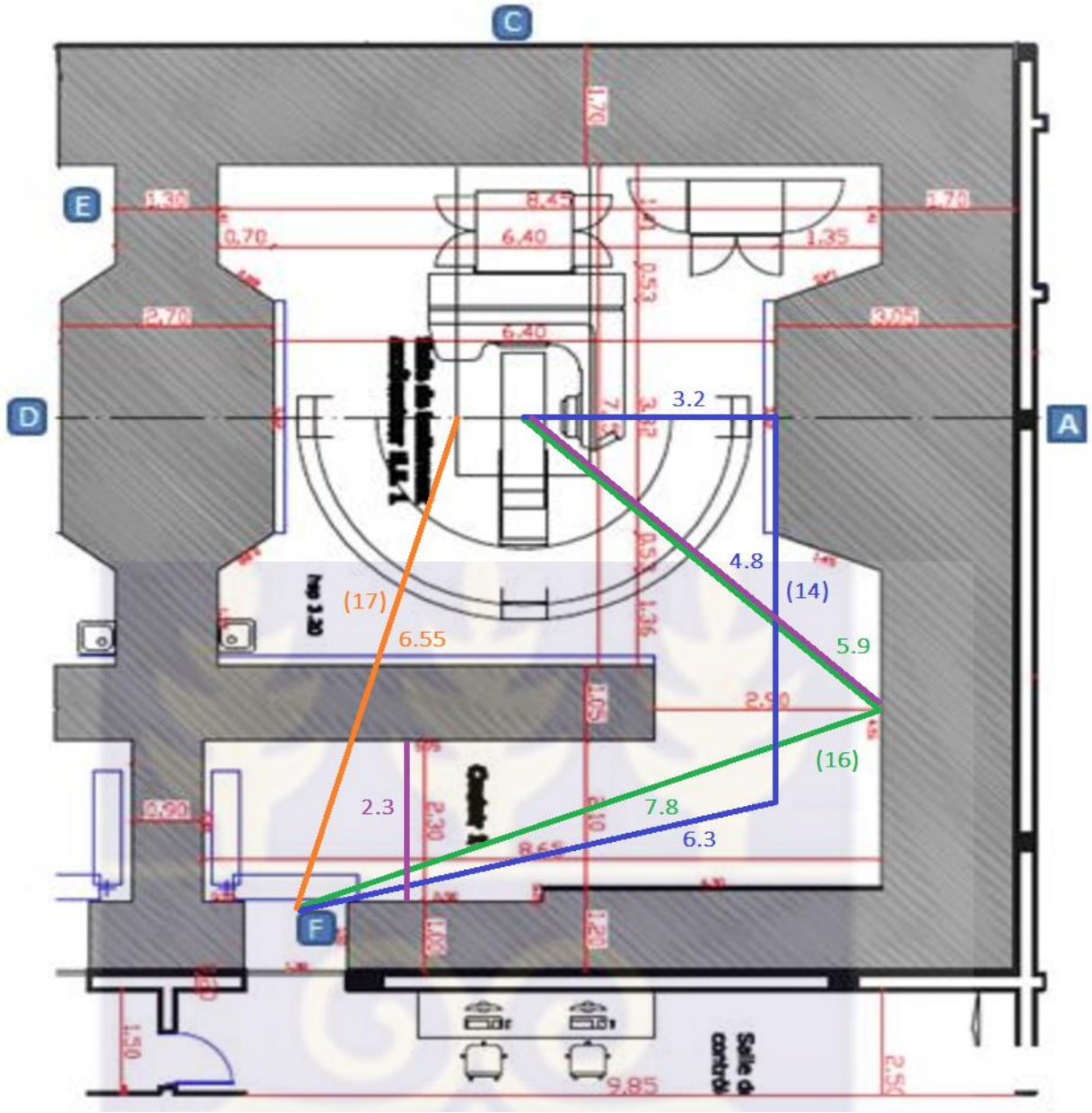
Day 3, Take Home Exercise – Maze Shielding Calculation

Equations: IAEA Report 47, "Radiation Protection in the Design of Radiotherapy Facilities"
Figure : Dine, B.N. "Evaluation of Shielding Design for a Linear Accelerator (LINAC) Facility."



For the facility shown in the diagram, determine the dose at point F using the equations below and assuming the following:

The facility treats an average of 20 patients daily

The average dose per patient is 2Gy at isocenter

The typical QA load is 20Gy per week

Day 3, Take Home Exercise – Maze Shielding Calculation

Equations: IAEA Report 47, "Radiation Protection in the Design of Radiotherapy Facilities"
Figure : Dine, B.N. "Evaluation of Shielding Design for a Linear Accelerator (LINAC) Facility."

Assume just 6MV is used

Assume that all barriers are irradiated equally

Use the diagram for assistance with distances

(11) - Find one value for the worst-case gantry angle, do not integrate through all angles. See table 8 below for f values.

(13) - Use 'a' =1.39x10^{-3} for the scatter primary ratio, F=400. Obtain α values from tables 6 or 7. 'A' can be calculated geometrically assuming a 40x40cm^2 field size at 1m rotated 45 degrees.

(14) - Obtain α values from tables 6 or 7.

(16) - You can conservatively assume L_0 = 10^{-3}

Equations and figures taken from IAEA Report 47

$$D_d = \sum_G D_p + \sum_G f \times D_w + \sum_G D_L + \sum_G D_T \qquad (11)$$

where

$\sum_G$ integrates through all gantry angles;
D_p is the dose arising from patient scatter;
f is the primary radiation transmitted through the patient;
D_w is the primary radiation scattered by the wall into the maze;
D_L is the leakage radiation scattered down the maze;
D_T is the leakage radiation transmitted through the maze wall.

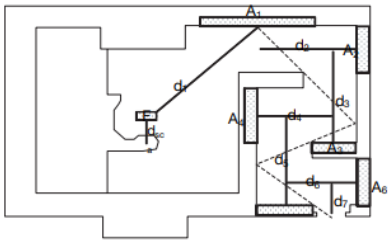


FIG. 3. Schematic diagram to show the scatter paths to the maze entrance.

$$D_p = \frac{WU_0 a(F/400)(\alpha_1 A_1)\cdots(\alpha_{n-1}A_{n-1})}{(d_{sca} \times d_1 \cdots d_n)^2} \qquad (13)$$

where

W is the workload, in Gy·week^{-1};
U_0 is the use factor (usually assumed to be 0.25 for each of the four cardinal beam directions).
a is the scatter primary ratio at the patient (phantom). These values are tabulated per 400 cm^2 incident field area on the patient (Table 5).
α_1, etc., are the wall reflection coefficients for 0.5 MeV X rays (assumed to be the same energy for all subsequent scattering processes) (Tables 6 and 7).
F is the field area incident on the patient, in cm^2.
A_1, etc., are the areas of wall that scattered radiation can strike and be reflected down the maze. Subsequent areas are taken to be the cross-sectional area of the maze.
d_{sca} is the distance of the radiation source from the patient, in metres.
$d_1 \ldots d_n$ are the distances to the next scattering surface, and subsequently the length of each leg of the maze, in m.

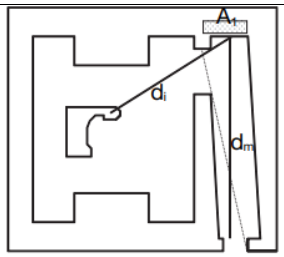


FIG. 6. Schematic diagram showing the path of scattered head leakage to the maze entrance.

$$D_L = \frac{L_0 W \alpha_1 A_1}{(d_i d_m)^2} \qquad (16)$$

where

L_0 is the fraction of the dose due to head leakage at 1.0 m from the radiation source relative to the dose on the beam axis at one metre (this is usually at the isocentre);
W is the workload, in Gy·m^2 per week;
α_1 is the wall reflection coefficient;
A_1 is the area of wall that can be seen from the maze entrance;
d_i is the distance from the radiation source to the maze centreline;
d_m is the centreline distance along the maze.

Day 3, Take Home Exercise – Maze Shielding Calculation

Equations: IAEA Report 47, "Radiation Protection in the Design of Radiotherapy Facilities"

Figure : Dine, B.N. "Evaluation of Shielding Design for a Linear Accelerator (LINAC) Facility."

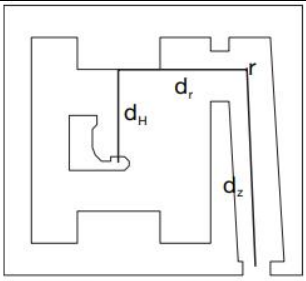


FIG. 4. Schematic diagram showing the scatter path for the primary radiation beam to the maze entrance (gantry rotation axis perpendicular to the maze axis).

$$D_w = \frac{WU_H}{d_H^2} \times \frac{\alpha_H A_H \alpha_r A_r}{d_r^2 \times d_z^2} \quad (14)$$

where

- W is the workload, in Gy·m^2 per week;
- U_H is the use factor for wall H, usually assumed to be 0.25;
- α_H is the reflection coefficient from wall H;
- A_H is the area of the maximum field size projected onto wall H, in m^2;
- α_r is the wall reflection coefficient at r;
- A_r is the cross-sectional area of the inner maze opening, in m^2;
- d_H is the distance from the radiation source to wall H, in m;
- d_r is the distance from where the central axis of the radiation beam strikes wall H to the centre of the maze opening r, in m;
- d_z is the distance from point r to the maze entrance, in m.

TABLE 8. SUGGESTED TRANSMISSION FACTORS (PERCENTAGE DEPTH DOSES FOR A 10 cm × 10 cm FIELD, 100 cm SSD AT A DEPTH OF 30 cm)[21]

Energy	Co-60	6 MV	10 MV	15 MV	18 MV	25 MV
Transmission, f	0.15	0.23	0.28	0.33	0.34	0.38

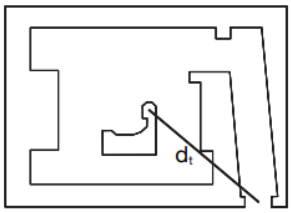


FIG. 7. Schematic diagram showing the path of head leakage radiation transmitted through the maze wall to maze entrance.

$$D_T = \frac{L_0 WB}{(d_t)^2} \quad (17)$$

where

- d_t is the distance from the radiation source to the maze entrance;
- B is the transmission through the maze wall.

TABLE 6. DIFFERENTIAL DOSE ALBEDO (WALL REFLECTION COEFFICIENT) 45° INCIDENT ANGLE, ORDINARY CONCRETE [34]

	Angle of reflection (from normal)			
	75	45	15	0
24 MV	3.37E-03	3.91E-03	3.91E-03	3.74E-03
20 MV	3.75E-03	4.20E-03	4.14E-03	3.95E-03
18 MV	4.01E-03	4.41E-03	4.32E-03	4.11E-03
15 MV	4.48E-03	4.78E-03	4.56E-03	4.34E-03
10 MV	5.75E-03	5.75E-03	5.38E-03	5.10E-03
6 MV	7.69E-03	7.35E-03	6.71E-03	6.35E-03
4 MV	9.36E-03	9.01E-03	8.19E-03	7.77E-03
Co-60	1.26E-02	1.19E-02	1.07E-02	1.02E-02
0.5 MeV	1.70E-02	2.15E-02	2.10E-02	2.03E-02
0.25 MeV	1.82E-02	3.05E-02	3.50E-02	3.39E-02

TABLE 7. DIFFERENTIAL DOSE ALBEDO (WALL REFLECTION COEFFICIENT) NORMAL INCIDENCE, ORDINARY CONCRETE [34]

	Angle of reflection (from normal)				
	75	60	45	30	0
24 MV	1.47E-03	2.30E-03	2.82E-03	3.15E-03	3.20E-03
20 MV	1.57E-03	2.43E-03	2.98E-03	3.31E-03	3.34E-03
18 MV	1.62E-03	2.51E-03	3.07E-03	3.42E-03	3.46E-03
15 MV	1.75E-03	2.69E-03	3.29E-03	3.65E-03	3.66E-03
10 MV	2.06E-03	3.15E-03	3.83E-03	4.24E-03	4.25E-03
6 MV	2.60E-03	3.92E-03	4.76E-03	5.28E-03	5.35E-03
4 MV	3.16E-03	4.77E-03	5.81E-03	6.46E-03	6.62E-03
Co-60	4.06E-03	5.94E-03	7.00E-03	7.65E-03	7.79E-03
0.5 MeV	7.54E-03	1.26E-02	1.58E-02	1.78E-02	1.82E-02