Mathematics

1. If $r \neq r'$, no solution, if $r = r' = n$, unique solution if $r = r' < n$, many solutions. (non-homogeneous)
2. If $r = n$, trivial solution, if $r < n$,then $(n - r)$ linearly independent solutions. (Many solutions) and if $m < n$, then many solutions.
3. $f(x+h) = f(x) + hf'(x) + \frac{h^2}{2!}f''(x) + \frac{h^3}{3!}f'''(x) + \ldots\ldots\ldots\infty$
4. If $rt - s^2 > 0$ and $r < 0$ $f(x,y)$ have maximum, if $rt - s^2 > 0$ and $r > 0$ $f(x,y)$ have minimum at(a,b) and if $rt - s^2 < 0$, then saddle point. If $rt - s^2 = 0$, $further$ investigation is required to decide.
5. $\int_c (\emptyset dx + \psi dy) = \int\int_E \left(\frac{\partial\psi}{\partial x} - \frac{\partial\emptyset}{\partial y}\right) dxdy$ (Green's)
6. $\int_c \boldsymbol{F}.d\mathbb{R} = \int_S curl\boldsymbol{F}.Nds$ (Stokes)
7. $\int_S \boldsymbol{F}.Nds = \int_E div\boldsymbol{F}dv$ (Gauss)
8. $ye^{\int Pdx} = \int Q\, e^{\int Pdx}dx + c$
9. If $M\,dx + N\,dy = 0$ be a homogeneous equation in x and y, then $\frac{1}{M\,x + N\,y}$ is an integrating factor
10. If the equation of the type $f_1(xy)y\,dx + f_2(xy)x\,dy = 0$. If the equation $M\,dx + N\,dy = 0$ be of this type then $\frac{1}{M\,x - N\,y}$ is an integrating factor
11. If $\frac{\frac{\partial M}{\partial y} - \frac{\partial N}{\partial x}}{N}$ be a function of x only = $f(x)$ say then $e^{\int f(x)dx}$ is an integrating factor
12. If $\frac{\frac{\partial N}{\partial x} - \frac{\partial M}{\partial y}}{M}$ be a function of y only = $f(y)$ say then $e^{\int f(y)dy}$ is an integrating factor.
13. $\int_{y=cont} Mdx + \int$ terms of N not containing x dy = c
14. $P.I. = \frac{1}{f(D)}e^{ax} = \frac{1}{f(a)}e^{ax}$, $f(a) \neq 0$, if $f(a) = 0$, $then\ P.I. = x\frac{1}{f'(a)}e^{ax}$, $f'(a) \neq 0$
15. $P.I = \frac{1}{f(D^2)}\sin(ax+b) = \frac{1}{f(-a^2)}$, $f(-a^2) \neq 0$, if $f(-a^2) = 0$,
 then $P.I. = x\frac{1}{f'(-a^2)}\sin(ax+b)$, $f'(-a^2) \neq 0$
16. $P.I. = \frac{1}{f(D)}e^{ax}V = e^{ax}\frac{1}{f(D+a)}V$
17. $P.I = \frac{1}{f(D)}x^m = [f(D)]^{-1}x^m$,
18. $(1+x)^{-1} = 1 - x + x^2 - \cdots$
19. $(1-x)^{-1} = 1 + x + x^2 + \cdots$
20. $x^n\frac{d^ny}{dx^n} + k_1x^{n-1}\frac{d^{n-1}y}{dx^{n-1}} + \cdots k_{n-1}x\frac{dy}{dx} + k_ny = X, x = e^t$,
 $x\frac{dy}{dx} = Dy, x^2\frac{d^2y}{dx^2} = D(D-1)y, x^3\frac{d^3y}{dx^3} = \mathrm{D(D-1)(D-2)}$
21. $\frac{\partial}{\partial x}\left(\int_{f(x)}^{g(x)} h(t,x)dt\right) = \int_{f(x)}^{g(x)}\frac{\partial}{\partial x}h(t,x)dt + \frac{dg}{dx}\,h[g(x),x] - \frac{df}{dx}\,h[f(x),x]$
22. $L\{f(t)\} = \int_0^\infty e^{-st}\ f(t)dt$
23. $L(1) = \frac{1}{s}$
24. $L(t^n) = \frac{n!}{s^{n+1}}$
25. $L(e^{at}) = \frac{1}{s-a}$
26. $L(\sin at) = \frac{a}{s^2+a^2}$
27. $L(\cos at) = \frac{s}{s^2+a^2}$
28. $L(\sinh at) = \frac{a}{s^2-a^2}$
29. $L(\cosh at) = \frac{s}{s^2-a^2}$
30. $L\{e^{at}f(t)\} = \bar{f}(s-a)$
31. $f(t+T) = f(t)$ then $L\{f(t)\} = \frac{\int_0^T e^{-st}f(t)dt}{1-e^{-sT}}$
32. $L\{f'(t)\} = s\bar{f}(s) - f(0)$
33. $L\{f^n(t)\} = s^n\bar{f}(s) - s^{n-1}f(0) - s^{n-2}f'(0) - \cdots\ldots\ldots.f^{n-1}(0)$
34. $L\left\{\int_0^t f(x)dx\right\} = \frac{1}{s}\bar{f}(s)$
35. $L\{t^nf(t)\} = (-1)^n\frac{d^n}{ds^n}.[\bar{f}(s)]$
36. $L\left\{\frac{1}{t}f(t)\right\} = \int_S^\infty \bar{f}(s)\ ds$
37. $f(x) = \frac{a_0}{2} + \sum_{n=1}^\infty a_n\cos nx + \sum_{n=1}^\infty b_n\sin nx$
38. $a_0 = \frac{1}{\pi}\int_\alpha^{\alpha+2\pi}f(x)dx,\ a_n = \frac{1}{\pi}\int_\alpha^{\alpha+2\pi}f(x)\ \cos nx\,dx,\ b_n = \frac{1}{\pi}\int_\alpha^{\alpha+2\pi}f(x)\ \sin nx\,dx$
39. $f(x) = \frac{a_0}{2} + \sum_{n=1}^\infty a_n\cos\frac{n\pi x}{c} + \sum_{n=1}^\infty b_n\sin\frac{n\pi x}{c}$
40. $a_0 = \frac{1}{c}\int_\alpha^{\alpha+2c}f(x)dx, a_n = \frac{1}{c}\int_\alpha^{\alpha+2c}f(x)\ \cos\frac{n\pi x}{c}dx,\ b_n = \frac{1}{c}\int_\alpha^{\alpha+2c}f(x)\ \sin\frac{n\pi x}{c}dx$
41. $f(x) = \sum_{n=1}^\infty b_n\sin\frac{n\pi x}{c}$, where $b_n = \frac{2}{c}\int_0^c f(x)\ \sin\frac{n\pi x}{c}dx$
42. $f(x) = \frac{a_0}{2} + \sum_{n=1}^\infty a_n\cos\frac{n\pi x}{c}$ where, $a_0 = \frac{2}{c}\int_0^c f(x)dx$,
 $a_n = \frac{2}{c}\int_0^c f(x)\ \cos\frac{n\pi x}{c}dx$
43. $\mu = \sum_j\ x_jf(x_j)$ and $\mu = \int_{-\infty}^\infty x\,f(x)dx$
44. $\sigma^2 = \sum_j\ (x_j-\mu)^2f(x_j)$ and $\sigma^2 = \int_{-\infty}^\infty (x-\mu)^2 f(x)dx$
45. $Mean{:}\,np = \mu\ \ Variance{:}\,\sigma^2 = \mu$ (Poisson's distribution)
46. $f(x) = \frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$ (Normal distribution)
47. $y = a + bx$, $\sum y = na + b\sum x$, $\sum xy = a\sum x + b\sum x^2$
48. $y = a + bx + cx^2, \sum y = na + b.\sum x + c.\sum x^2$, $\sum xy = a\sum x + b.\sum x^2 + c\sum x^3$, $\sum x^2y = a\sum x^2 + b.\sum x^3 + c\sum x^4$
49. $y = f(x) = \frac{(x-x_1)(x-x_2)\ldots(x-x_n)}{(x_0-x_1)(x_0-x_2)\ldots(x_0-x_n)}y_0 + \frac{(x-x_0)(x-x_2)\ldots(x-x_n)}{(x_1-x_0)(x_1-x_2)\ldots(x_1-x_n)}y_1 + \cdots + \frac{(x-x_1)(x-x_2)\ldots(x-x_{n-1})}{(x_n-x_0)(x_n-x_1)\ldots(x_n-x_{n-1})}y_n$
50. $\left(\frac{dy}{dx}\right)_{x_0} = \frac{1}{h}\left[\Delta y_0 - \frac{1}{2}\Delta^2y_0 + \frac{1}{3}\Delta^3y_0 - \frac{1}{4}\Delta^4y_0 + \cdots\right]$
51. $\left(\frac{dy}{dx}\right)_{x_n} = \frac{1}{h}\left[\nabla y_n + \frac{1}{2}\nabla^2y_n + \frac{1}{3}\nabla^3y_n + \frac{1}{4}\nabla^4y_n + \cdots\right]$
52. $x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$ (Newton-Raphson)
53. $\int_{x_0}^{x_0+nh}f(x)dx = \frac{h}{2}[y_0 + y_n + 2(y_1 + y_2 + \cdots..+y_{n-1})]$ (Trapezoidal)
54. $\int_{x_0}^{x_0+nh}f(x)dx = \frac{h}{3}[(y_0+y_n) + 4(y_1 + y_3 + \cdots y_{n-1}) + 2(y_2 + y_4 + \cdots y_{n-2})]$ (Simpson's)
55. $Error = -\frac{b-a}{12}h^2\,f''(\xi) = O(h^2)$ (Trapezoidal)
56. $Error = -\frac{b-a}{180}h^4f^{iv}(\xi) = O(h^4)$ (Simpson's)
57. $y_{k+1} = y_k + h.f(t_k, y_k)$ where $\frac{dy}{dx} = f(t,y)$ (Euler's)

Strength of material

1. $\mu = \frac{Lateral\ strain}{Longitudinal\ strain}$
2. $e_x = \frac{f_x}{E} - \mu\frac{f_y}{E} - \mu\frac{f_z}{E}$
3. $e_y = \frac{f_y}{E} - \mu\frac{f_x}{E} - \mu\frac{f_z}{E}$
4. $e_z = \frac{f_z}{E} - \mu\frac{f_x}{E} - \mu\frac{f_y}{E}$
5. $G = \frac{E}{2(1+\mu)}$
6. $K = \frac{E}{3(1-2\mu)}$
7. $\frac{M}{I} = \frac{f}{y} = \frac{E}{R}$
8. $\tau = \frac{VQ}{Ib}$
9. $\frac{T}{J} = \frac{\tau}{r} = \frac{G\theta}{L}$
10. $M_e = \frac{1}{2}\left[M + \sqrt{M^2+T^2}\right]$
11. $T_e = \sqrt{M^2+T^2}$
12. $\sigma = \frac{3wl}{2nbt^2}$ and $\delta = \frac{\sigma l^2}{4Et}$ (Leaf spring)
13. $\delta = \frac{64WR^3n}{Gd^4}$ (Helical spring)
14. $\sigma_n = \frac{\sigma_x+\sigma_y}{2} + \frac{\sigma_x-\sigma_y}{2}\cos 2\theta + \tau\sin 2\theta$
15. $\tau_t = -\left(\frac{\sigma_x-\sigma_y}{2}\right)\sin 2\theta + \tau\cos 2\theta$
16. $\sigma_1 = \frac{\sigma_x+\sigma_y}{2} + \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau^2}$
17. $\sigma_3 = \frac{\sigma_x+\sigma_y}{2} - \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau^2}$
18. $P = \frac{\pi^2 EI}{l^2}$ (hinged and hinged)) , $P = \frac{\pi^2 EI}{4l^2}$ (fixed and free)
19. $P = \frac{4\pi^2 EI}{l^2}$ (Fixed and fixed) , $P = \frac{2\pi^2 EI}{l^2}$
20. $P = \frac{\sigma_c.A}{1+\alpha\left(\frac{l_e}{K}\right)^2}$ where $\alpha = \frac{\sigma_c}{\pi^2 E}$ is Rankine's constant

Structural analysis

1. $\bar{M}_{AB} = -\frac{Pab^2}{l^2}$ and $\bar{M}_{AB} = \frac{Pa^2b}{l^2}$ (Point load)
2. $\bar{M}_{AB} = -\frac{wl^2}{12}$ and $\bar{M}_{AB} = \frac{wl^2}{12}$ (udl)
3. $\bar{M}_{AB} = -\frac{wl^2}{30}$ and $\bar{M}_{AB} = \frac{wl^2}{20}$ (uvl from left to right increase)
4. $\bar{M}_{AB} = \frac{Mb}{l^2}(3a-l)$ and $\bar{M}_{AB} = \frac{Ma}{l^2}(3b-l)$ (clockwise moment)
5. $U = \frac{P^2L}{2AE}$, $U = \int_0^L \frac{M^2}{2EI}\,dx$ and $U = \frac{T^2L}{2GJ}$
6. $U = 1.2\int_0^L \frac{V^2}{2GA}dx$ (rectangular beam)
7. $H = \frac{\int_0^l \frac{M_s y}{EI}dx + \propto tl - \delta}{\int_0^l \frac{y^2dx}{EI}}$ (two hinged arch)
8. H$= \frac{wl^2}{8d}$ (cable with udl) and Length of cable $L = l + \frac{8}{3}\frac{d^2}{l}$
9. $M_{AB} = \bar{M}_{AB} + \frac{2EI}{L}\left(2\theta_A + \theta_B - \frac{3\Delta}{L}\right)$, right support sinks by Δ
10. $M_{BA} = \bar{M}_{BA} + \frac{2EI}{L}\left(2\theta_B + \theta_A - \frac{3\Delta}{L}\right)$, right support sinks by Δ
11. $M_A l_1 + 2M_B(l_1+l_2) + M_C l_2 = -\frac{6a_1x_1}{l_1} - \frac{6a_2x_2}{l_2}$
12. $\delta = \sum\frac{PkL}{AE}$
13. $Q = -\frac{\sum\frac{PkL}{AE}}{\sum\frac{k^2L}{AE}+\frac{L_0}{A_0E_0}}$ and $Q = -\frac{\sum\left(\frac{PL}{AE}+L\alpha t\right)k}{\sum\frac{k^2L}{AE}+\frac{L_0}{A_0E_0}}$
14. $k_{ij} = force\ at\ i\ due\ to\ displacement\ at\ j,$
    $\delta_{ij} = displacement\ at\ i\ due\ to\ force\ at\ j$
15. Far end fixed, Transverse displacement, $\delta = \frac{L^3}{12EI}$ and $k = \frac{12EI}{L^3}$
16. Far end hinged, Transverse displacement, $\delta = \frac{L^3}{3EI}$ and $k = \frac{3EI}{L^3}$

RCC

1. $f_m = f_{ck} + 1.65\,\sigma$
2. $E_c = 5000\sqrt{f_{ck}}$ and $f_{cr} = 0.7\sqrt{f_{ck}}$
3. $\varepsilon_{st} = 0.002 + \frac{0.87\,f_y}{E_s}$
4. $E_s = 2\times 10^5\ MPa$, $m = \frac{280}{3\sigma_{cbc}}$
5. $b_f = \frac{l_0}{6} + b_w + 6D_f$ for T-beams.
6. $b_f = \frac{l_0}{12} + b_w + 3D_f$ for L-beams.
7. $\frac{l_0}{\frac{l_0}{b}+4} + b_w \le b$ for isolated T-beams.
8. $\frac{0.5l_0}{\frac{l_0}{b}+4} + b_w \le b$ for isolated L-beams.
9. $\frac{x_u}{d} = \frac{0.87\,f_y.\,A_{st}}{0.36\,f_{ck}\,bd}$ and $\frac{x_{u,max}}{d} = \frac{0.0035}{0.0055+\frac{0.87\,fy}{E_s}}$
10. $M_u = 0.87\,f_y.A_{st}\ (d - 0.42\,x_u)$ for $x_u \le x_{u,\max}$
11. $M_u = 0.36\,f_{ck}.b.x_{u,max}(d - 0.42\,x_{u,max})$
12. $\frac{x_{u,max}}{d} = \frac{0.87\,f_y}{0.36\,f_{ck}}\left(\frac{P_{t,lim}}{100}\right)$
13. $M_u = 0.87\,f_y\,A_{st}\left(d - \frac{f_y\,A_{st}}{f_{ck}\,b}\right)$
14. $y_f = 0.15\,x_u + 0.65\,D_f$ when $\frac{D_f}{d} > 0.2$
15. $0.87\,f_y\,(A_{st} - A_{st,l}) = (f_{sc} - 0.447\,f_{ck}).A_{sc}$
16. $M_u = M_{u,l} + 0.87\,f_y.(A_{st} - A_{st,l})\,(d - d')$
17. $\frac{A_{st}}{bd} = \frac{0.85}{fy}$ (minimum tension reinforcement)
18. $A_{st,min} = 0.12$ % of A_g for Fe-415 and 0.15 % of A_g for Fe-250. (slabs)
19. $A_{st,max} = 4\%\ of\ A_g$ (Beams) , $A_{sc,max} = 4\%\ of\ A_g$ (Beams)
20. $\left(\frac{l}{d}\right)_{max} = \left(\frac{l}{d}\right)_{basic} k_t\,k_c$
21. $\left(\frac{l}{d}\right)_{basic}$ =7 for cantilever, 20 for SS and 26 for continuous beams. If span is more than 10 m, multiply above values with 10/span for SS and continuous beams.
22. $L_d = \frac{f_s \emptyset}{4\tau_{bd}}$, multiply τ_{bd} value with 1.6 for deformed bars and 1.25 for bars in compression.
23. $\frac{M_u}{V_u} + L_0 \ge L_d$ and $1.3\frac{M_u}{V_u} + L_0 \ge L_d$ (If confinement exists)
24. $\tau_v = \frac{V_u}{bd}$, $V_{u,net} = V_u + \frac{M}{d}\tan\beta$
25. $V_{us} = \frac{0.87\,f_y\,A_{sv}\,d}{s_v}$
26. $\frac{A_{sv}}{b\,s_v} \ge \frac{0.4}{0.87\,f_y}$ (minimum shear reinforcement)
27. $s_v \le 0.75\ d\ and\ 300\ mm$ for vertical stirrups.
28. $V_e = V_u + 1.6\frac{T_u}{b}$ and $M_e = M_u + \frac{T_u}{1.7}\left(1+\frac{D}{b}\right)$
29. $\frac{l}{d} \le 35$ for ss and 40 for continuous slabs for Fe-250. For Fe-415 multiply above values with 0.8
30. $\tau_{c2} = k_s\,0.25\sqrt{f_{ck}}$, $k_s = 0.5 + \beta_c \le 1.0$ and $\beta_c = \frac{b}{D}$
31. $e_{x,min} = \frac{l}{500} + \frac{d}{30}$, $20\ mm$ whichever is greater.
32. $e_{y,min} = \frac{l}{500} + \frac{b}{30}$, $20\ mm$ whichever is greater.
33. $P_u = 0.4\,f_{ck}\,A_c + 0.67\,f_y A_{sc}$
34. $\frac{V_h}{V_c} \ge 0.36\left(\frac{A_g}{A_c} - 1\right)\frac{f_{ck}}{f_y}$, $d_c = d - 2c$ and $d_m = d_c - \emptyset$
35. $C_r = 1.25 - \frac{l_e}{48b}$
36. $f_{br,max} = 0.45\,f_{ck}\sqrt{\frac{A_1}{A_2}}$, $1 < \sqrt{\frac{A_1}{A_2}} \le 2$, A_1 =Largest frustum of a pyramid with side slopes 1 in 2, A_2 =loaded area of column base

Geotechnical Engineering

1. $I_f = \frac{W_1 - w_2}{\log_{10} N_2/N_1}$
2. $I_t = \frac{I_p}{I_f}$
3. $C_u = \frac{D_{60}}{D_{10}}$
4. $C_c = \frac{D_{30}^2}{D_{60} D_{10}}$
5. $I_P = 0.73\,(w_L - 20)$
6. $I_P = w_L - w_P$
7. $I_s = w_P - w_S$
8. $I_L = \frac{w - w_P}{I_P}$
9. $I_c = \frac{w_L - w}{I_P}$
10. $A = \frac{I_p}{F}$ where F is clay fraction (Activity)
11. $R_D = \frac{e_{max} - e}{e_{max} - e_{min}} = \frac{1/\gamma_{d,min} - 1/\gamma_d}{1/\gamma_{d,min} - 1/\gamma_{d,max}}$
12. $\frac{k_1}{k_2} = \frac{\tan\alpha_1}{\tan\alpha_2}$ (non homogeneous)
13. $k = C\frac{\gamma_W}{\mu}\frac{e^3}{1+e}\,d^2$
14. $K = \frac{k\mu}{\gamma_W}$ (absolute permeability)
15. $k = \frac{q}{\pi}\frac{\ln(r_2/r_1)}{z_2^2 - z_1^2}$ (Permeability in unconfined aquifer)
16. $k = \frac{q}{2\pi b}\frac{\ln(r_2/r_1)}{z_2 - z_1}$ (Permeability in confined aquifer)
17. $k_h = \frac{k_1 H_1 + k_2 H_2}{H_1 + H_2}$ (effective horizontal permeability in stratified soils)
18. $k_v = \frac{H_1 + H_2}{\frac{H_1}{k_1} + \frac{H_2}{k_2}}$ (effective vertical permeability in stratified soils)
19. $k_e = \sqrt{k_h k_v}$ (effective permeability)
20. $k = \frac{aL}{At}\ln\frac{h_1}{h_2}$ (falling head permeability test)
21. $k = \frac{qL}{Ah}$ (constant head permeability test)
22. $q = k_e\,h\frac{N_f}{N_d}$ (seepage discharge)
23. $\sigma_z = \frac{3Q}{2\pi}\frac{1}{z^2}\left(\frac{1}{1+\left(\frac{r}{z}\right)^2}\right)^{\frac{5}{2}}$ (Boussinesq's formula)
24. $\sigma_z = \frac{cQ}{2\pi}\frac{1}{z^2}\left(\frac{1}{c^2+\left(\frac{r}{z}\right)^2}\right)^{\frac{3}{2}}$ where $c = \sqrt{\frac{1-2\mu}{2-2\mu}}$ (Wesrwegaard's formula)
25. $\sigma_z = \frac{2q}{\pi z}\left(\frac{1}{1+\left(\frac{x}{z}\right)^2}\right)^2$ (line load)
26. $\sigma_z = \frac{q}{\pi}(2\theta + \sin 2\theta)$ where $\theta = \tan^{-1}\frac{b}{z}$ (stress under centre of strip load of width $2b$)
27. $\sigma_z = \frac{q}{\pi}(2\theta + \sin 2\theta \sin 2\emptyset)$ where $2\theta = \beta_1 - \beta_2$ and $2\emptyset = \beta_1 + \beta_2$ (strip eccentric point)
28. $\sigma_z = q(1 - \cos^3\theta)$ where $\theta = \tan^{-1}\frac{R}{z}$ (stress under centre of circular load)
29. $\sin\emptyset = \frac{\sigma_1 - \sigma_3}{\sigma_1 + \sigma_3}$ (for cohesion less soils)
30. $\sin\emptyset = \frac{(\sigma_1 - \sigma_3)/2}{c\cot\emptyset + (\sigma_1 + \sigma_3)/2}$ (for cohesive soils)
31. $\sigma_1 = 2c\tan\alpha + \sigma_3\tan^2\alpha$ where $\alpha = 45 + \frac{\emptyset}{2}$
32. $\tan\emptyset = \frac{\tau}{\sigma}$ (shear box test for cohesion less soils)
33. $T = c\,\pi D^2\left(\frac{H}{2} + \frac{D}{6}\right)$ (if both top and bottom surfaces contributes)
34. $T = c\,\pi D^2\left(\frac{H}{2} + \frac{D}{12}\right)$ (if only bottom surface contribute)
35. $S_i = q\,B\,\frac{1-\mu^2}{E}\,I_f$ (immediate settlement)
36. $S_f = S_p\left(\frac{B_f}{B_p}\frac{B_p + 0.3}{B_f + 0.3}\right)^2$ (settlement of footing based on plate settlement)
37. $\Delta u = B(\Delta\sigma_c) + AB\,(\Delta\sigma_d)$ (Skempton's pore pressure parameters)
38. $q = mP + k$ is stress path equation where $\emptyset = \tan^{-1} m$ and $c = k/\cos\emptyset$
39. $C_c = \frac{\Delta e}{\log_{10}\frac{\sigma_0 + \Delta\sigma}{\sigma_0}}$
40. $C_c = 0.009\,(w_L - 10)$ (for normally consolidated soil)
41. $C_c = 0.007\,(w_L - 10)$ (for over consolidated soil)
42. $\frac{\Delta e}{1+e_0} = \frac{\Delta H}{H}$
43. $m_v = \frac{\Delta H/H}{\Delta\sigma_0}$
44. $c_v = \frac{k}{\gamma_W m_v}$
45. $T_v = \frac{c_v t}{d^2}$
46. $T_v = \frac{\pi}{4}U^2$ when $U \le 0.6$
47. $T_v = -0.933\,\log_{10}(1 - U) - 0.085$ when $U > 0.6$
48. $S_f = \frac{C_c H}{1+e_0}\log_{10}\frac{\sigma_0 + \Delta\sigma}{\sigma_0}$
49. $S_f = \frac{C_r H}{1+e_0}\log_{10}\frac{\sigma_c}{\sigma_0} + \frac{C_c H}{1+e_0}\log_{10}\frac{\sigma_0 + \Delta\sigma}{\sigma_c}$
50. $A_r = \frac{D_0^2 - D_i^2}{D_i^2}$
51. $S_n = \frac{c_u}{F\gamma H}$
52. $q_u = cN_c + q\,N_q + 0.5\,\gamma\,B\,N_\gamma$ (Terzaghi's strip)
53. $q_u = 1.3\,cN_c + q\,N_q + 0.4\,\gamma\,B\,N_\gamma$ (Terzaghi's square)
54. $q_u = 1.3\,cN_c + q\,N_q + 0.3\,\gamma\,B\,N_\gamma$ (Terzaghi's circle)
55. $q_u = \left(1 + 0.3\frac{B}{L}\right)cN_c + q\,N_q + \left(1 - 0.2\frac{B}{L}\right)0.5\,\gamma\,B\,N_\gamma$ (Terzaghi's rectangle)
56. $q_u = cN_c S_c d_c i_c + q\,N_q S_q d_q i_q + 0.5\,\gamma\,B'\,N_\gamma\,S_\gamma d_\gamma i_\gamma$ (Meyerhof)
    $B' = B - 2e_x$ and $L' = L - 2\,e_y$
57. $q_{nu} = cN_c$ (Skempton)
    $N_c = 5\left(1 + 0.2\frac{D_f}{B}\right)\left(1 + 0.2\frac{B}{L}\right)$
    Limiting value of D_f/B is 2.5
58. $Q_u = \frac{Wh\,\eta_h}{S+C}$ (ENR) where
    $C = 2.54\,cm$ for drop hammer and $0.254\,cm$ for steam hammer
59. $Q_u = \frac{Wh\eta_h\eta_b}{S+\frac{C}{2}}$ (Hiley)
    where $C = C_1 + C_2 + C_3$
    $C_1 = 9.05\frac{R}{A}$ with dolley and $C_1 = 1.77\frac{R}{A}$ without dolley and
    $C_2 = 0.657\frac{RL}{A}$
    $C_3 = 3.55\frac{R}{A}$
    $L = Length\ of\ Pile\ in\ m$
    $R = Pile\ capacity\ in\ tonnes = 0.1Q$
    $A = cross\ section\ area\ of\ pile\ in\ cm^2$
    $\eta_b = \frac{W + e^2 P}{W+P}$ when $W > P$
    $\eta_b = \frac{W + e^2 P}{W+P} - \left(\frac{W - eP}{E+P}\right)^2$ when $W < Pe$
60. $Q_u = \frac{Wh\eta_h}{S+\frac{S_0}{2}}$ (Danish) $S_0 = \sqrt{\frac{2\eta_h WhL}{AE}}$
61. $Q_u = A_p cN_c + A_s\alpha\,c$ (clays)
62. $Q_u = A_p cN_c + A_s\,\lambda(\bar{\sigma} + 2c)$ (clays)
63. $Q_u = A_p\bar{\sigma}\,N_q + A_s\bar{\sigma}\,k\tan\delta$ (sands)
    $\bar{\sigma}$ increase upto $15\,d$ depth
64. $Q_u = N(A_p cN_c + A_s\alpha\,c)$ or $Q_u = (A_{gp} cN_c + A_{gs}\,c)$ (Group)
65. $p_a = k_a\bar{\sigma} - 2c\sqrt{k_a} + u$
66. $p_p = k_p\bar{\sigma} + 2c\sqrt{k_p} + u$
67. $k_a = \frac{1-\sin\emptyset}{1+\sin\emptyset}$ and $k_p = \frac{1+\sin\emptyset}{1-\sin\emptyset}$

68. $H_c = \frac{2c}{\gamma\sqrt{K_a}}$ and unsupported vertical cut $= 2H_c$

69. $k_a = \frac{\sin^2(\beta+\emptyset)}{\sin^2\beta\sin(\beta-\delta)\left(1+\sqrt{\frac{\sin(\emptyset+\delta)\sin(\emptyset-i)}{\sin(\beta-\delta)\sin(\beta+i)}}\right)^2}$

(Coulomb's active)

70. $k_p = \frac{\sin^2(\beta-\emptyset)}{\sin^2\beta\sin(\beta+\delta)\left(1-\sqrt{\frac{\sin(\emptyset+\delta)\sin(\emptyset+i)}{\sin(\beta+\delta)\sin(\beta+i)}}\right)^2}$

(Coulomb's passive)

71. $k_a = \frac{\cos\beta-\sqrt{\cos^2\beta-\cos^2\emptyset}}{\cos\beta+\sqrt{\cos^2\beta-\cos^2\emptyset}}$ and $P_a = \frac{k_a\gamma h^2}{2}\cos\beta$

(Inclined backfill)

72. $k_p = \frac{\cos\beta+\sqrt{\cos^2\beta-\cos^2\emptyset}}{\cos\beta-\sqrt{\cos^2\beta-\cos^2\emptyset}}$ and $P_p = \frac{k_p\gamma h^2}{2}\cos\beta$

(Inclined backfill)

73. $N_c = 15 + \frac{1}{2}(N-15)\ when\ N > 15\ and\ N_c = N\ when\ N \leq$ 15 (dilatancy)

74. $i_c = \frac{G-1}{1+e}$ (Quick sand condition)

Hydrology

1. A tropical cyclone is a zone of low pressure with anticlockwise winds in the northern hemisphere.
2. Anticyclones cause clockwise wind circulations in the northern hemisphere.
3. $N = \left(\frac{C_v}{\varepsilon}\right)^2$, $C_v = \frac{100\times\sigma_{m-1}}{\bar{P}}$ and $\sigma_{m-1} = \sqrt{\frac{\sum_1^m(P_i-\bar{P})^2}{m-1}}$
4. $\frac{P_x}{N_x} = \frac{1}{M}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \cdots + \frac{P_m}{N_m}\right]$ (Normal ratio method)
5. $\bar{P} = \frac{P_1A_1+P_2A_2+\cdots+P_mA_m}{P_1+P_2+\cdots+P_m}$ (Thiessen-mean method)
6. $\bar{P} = \frac{a_1\left(\frac{P_1+P_2}{2}\right)+a_2\left(\frac{P_2+P_3}{2}\right)+\cdots+a_{n-1}\left(\frac{P_{n-1}+P_n}{2}\right)}{A}$ (Isohyetal method)
7. $P_{r,n} = n_{C_r}p^r q^{n-r}$ and $P_1 = 1 - q^n$
8. 75% dependable annual rainfall is annual rainfall with probability $P = 0.75$, i.e. $T = \frac{N+1}{m} = \frac{1}{0.75}$
9. The chemical used as evaporation inhibitor is cetyl alcohol.
10. Evapotranspiration can be measured by Lysimeters.
21. $K_s = \frac{K_0}{A} = \frac{1}{T_r}\ln\frac{H_1}{H_2}$ (recuperation test)
11. $f_p = f_c + (f_0 - f_c)e^{-K_h t}$ (Horton's equation)
12. $\emptyset\ index$: It is the average rainfall above which the rainfall volume is equal to the runoff volume.
13. $W\ index$: $W = \frac{P-R-I_a}{t_e}$
14. $\bar{v} = v_{0.6}$ and $\bar{v} = \frac{v_{0.2}+v_{0.8}}{2}$
15. $Q_tC_1 + QC_0 = (Q+Q_t)C_2$ (Dilution technique)
16. $Q_s = 2.778\frac{A}{D}$, (Equilibrium discharge) A in km^2 and D in h. Q_s in m^3/s
17. $\frac{\sigma_{n-1}}{S_n}(y_{T1} - y_{T2}) = x_{T1} - x_{T2}$ and $y_T = -\left(ln.\ln\frac{T}{T-1}\right)$ (Gumbels)
18. $Risk, R = 1 - q^n = 1-(1-P)^n = 1-\left(1-\frac{1}{T}\right)^n$
19. $Q_2 = C_0I_2 + C_1I_1 + C_2Q_1$, $C_0 = \frac{-kx+0.5\,\Delta t}{k-kx+0.5\,\Delta t}$, $C_1 = \frac{kx+0.5\,\Delta t}{k-kx+0.5\,\Delta t}$ and $C_2 = \frac{k-kx-0.5\,\Delta t}{k-kx+0.5\,\Delta t}$, $C_1 + C_2 + C_3 = 1$
20. $S_y + S_r = \eta$

Fluid mechanics

1. $\tau = \mu . \frac{dv}{dy}$
2. $\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}(\rho v_x) + \frac{\partial}{\partial y}(\rho v_y) + \frac{\partial}{\partial z}(\rho v_z) = 0$ (continuity equation)
3. $\frac{D\rho}{Dt} + \rho \, \nabla . V = 0$ (continuity equation)
4. $F_1 - F_2 = \frac{M_2 - M_1}{t} = \frac{mv_2 - mv_1}{t} = \rho Q(v_2 - v_1)$
5. $F = \rho a(v+u)[(v+u) - u] = \rho a(v+u)v$ (Jet propulsion moving with u velocity)
6. $\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2$
7. $\frac{\partial \tau}{\partial y} = \frac{\partial p}{\partial x}$ and $\mu \frac{\partial^2 v}{\partial y^2} = \frac{\partial p}{\partial x}$
8. $\tau = -\frac{\partial P}{\partial x} . \frac{r}{2}$ and $\tau = \frac{\gamma_w . h_L}{L} . \frac{r}{2}$
9. $v = \frac{1}{4\mu} . \left(-\frac{\partial p}{\partial x}\right) . (R^2 - r^2) = v_{max} . \left[1 - \left(\frac{r}{R}\right)^2\right]$
10. $p_1 - p_2 = \frac{32\mu VL}{D^2} = \frac{128\mu QL}{\pi D^4}$
11. $f = \frac{64\mu}{\rho VD} = \frac{64}{R_e}$
12. $v = v_{max} . \left(1 - \frac{r}{R}\right)^{1/7}$ (Turbulent)
13. $h_L = \frac{fLv^2}{2gD}$
14. $\frac{L}{D^5} = \frac{L_1}{D_1^5} + \frac{L_2}{D_2^5} + \frac{L_3}{D_3^5}$ (Compound pipe)
15. $\frac{p_a}{\gamma} - h = \frac{p_s}{\gamma} + \frac{flv^2}{2gD} + \frac{0.5v^2}{2g} + \frac{v^2}{2g}$ and $H = \frac{fLv^2}{2gD} + \frac{1.5v^2}{2g}$ (Siphon)
16. $\delta^* = \int_0^\infty \left(1 - \frac{v}{V}\right) dy$
17. $\theta = \int_0^\infty \frac{v}{V}\left(1 - \frac{v}{V}\right) dy$
18. $\delta_E = \int_0^\infty \frac{v}{V}\left(1 - \frac{v^2}{V^2}\right) dy$
19. Blassius boundary layer thickness $\frac{\delta}{x} = \frac{5}{\sqrt{R_{ex}}}$
20. Displacement thickness $\frac{\delta^*}{x} = \frac{1.729}{\sqrt{R_{ex}}}$
21. Momentum thickness $\frac{\theta}{x} = \frac{0.664}{\sqrt{R_{ex}}}$
22. $c_{d,x} = \frac{0.664}{\sqrt{R_{ex}}}$ and $\tau_x = c_{d,x} \frac{\rho V^2}{2}$
23. Drag force= $C_d \frac{\rho A V^2}{2}$ and $\frac{F}{A} = \tau_0 = C_d \frac{\rho V^2}{2}$, $C_d = \frac{1.328}{\sqrt{R_e L}}$
24. $\delta' = \frac{11.6\,\vartheta}{\sqrt{\tau_o/\rho}} = \frac{11.6\vartheta}{v_*}$ (Laminar sub layer)
25. $\bar{h} = \bar{x} + \frac{I_G}{A\bar{x}}$ and $\bar{h} = \bar{x} + \frac{I_G}{A\bar{x}} . sin^2\theta$
26. $GM = \frac{I}{V} - BG$
27. Q= $\frac{8}{15} C_d . \sqrt{2g} . \tan\theta/2 \; H^{5/2}$
28. $v = \sqrt{\frac{gx^2}{2y}}$
29. $Q = C_d \frac{a_1 a_2}{\sqrt{a_1{}^2 - a_2{}^2}} . \sqrt{2gh}$ and $h = x\left(\frac{s_m}{s_f} - 1\right)$
30. $Q = \psi_1 - \psi_2$
31. $\frac{\partial \emptyset}{\partial x} = -v_x$ and $\frac{\partial \emptyset}{\partial y} = -v_y$
32. $\frac{\partial \psi}{\partial x} = v_y$ and $\frac{\partial \psi}{\partial y} = -v_x$
33. $(R_e)_r = \frac{\rho_r V_r L_r}{\mu_r} = 1$
34. $(F_r)_r = \frac{v_r}{\sqrt{g_r L_r}}$
35. $a_x = v_x . \frac{\partial v_x}{\partial x} + v_y . \frac{\partial v_x}{\partial y} + v_z . \frac{\partial v_x}{\partial z} + \frac{\partial v_x}{\partial t}$
36. $a_y = v_x . \frac{\partial v_y}{\partial x} + v_y . \frac{\partial v_y}{\partial y} + v_z . \frac{\partial v_y}{\partial z} + \frac{\partial v_y}{\partial t}$
37. $a_z = v_x . \frac{\partial v_z}{\partial x} + v_y . \frac{\partial v_z}{\partial y} + v_z . \frac{\partial v_z}{\partial z} + \frac{\partial v_z}{\partial t}$
38. $\omega = \frac{1}{2} \, curl \, v = \frac{1}{2}(\nabla \times v)$
39. Vorticity $= 2\omega$
40. Circulation $= vorticity \times area$
41. $F = \rho a v^2$
42. $Q_1 = \frac{Q}{2}[1 + \cos\theta]$ and $Q_2 = \frac{Q}{2}[1 - \cos\theta]$ (θ is with plate)
43. $N_s = \frac{N\sqrt{Q}}{H^{3/4}}$, $N_s = \frac{N\sqrt{P}}{H^{5/4}}$
44. $\frac{Q^2}{g} = \frac{A^3}{T}$
45. $F = \frac{v}{\sqrt{g . \frac{A}{T}}}$
46. $y_c^3 = \frac{2y_1^2 y_2^2}{y_1 + y_2}$ and $E = \frac{y_1^2 + y_1 y_2 + y_2^2}{y_1 + y_2}$
47. $\frac{dy}{dx} = \frac{s_o - s_f}{1 - \frac{Q^2 T}{gA^3}}$
48. $P_1 + M_1 = P_2 + M_2$ (specific force=pressure force+momentum per sec)
49. $\frac{y_2}{y_1}\left[1 + \frac{y_2}{y_1}\right] = \frac{2q^2}{gy_1^3}$ (sequent depths for rectangular channel)
50. $E = \frac{(y_2 - y_1)^3}{4y_1 y_2}$ (Energy loss in jump)

Irrigation Engineering

1. $t = \frac{y}{f}\log_e\left(\frac{Q}{Q-fA}\right)$
2. $A_{max} = \frac{Q}{f}$
3. $SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++}+Mg^{++}}{2}}}$
4. $\Delta = 8.64\frac{B}{D}$
5. $A = QD$
6. $\eta_c = \frac{Water\ delivered}{Water\ supplied}$
7. $\eta_a = \frac{Water\ stored\ in\ root\ zone}{Water\ delivered}$
8. $\eta_s = \frac{Water\ stored\ in\ root\ zone}{Water\ needed\ in\ root\ zone}$
9. $\eta_d = 1 - \frac{d}{D}$, $D = mean\ of\ depths$ and
   $d = mean\ of\ absolute\ values\ of\ deviations$
10. $CIR = C_u - Re$
11. $NIR = CIR + water\ lost\ as\ percolation$
12. $C_u = \frac{kp}{40}(1.8t + 32)$
13. $depth\ of\ water\ to\ be\ applied = \frac{\gamma_d}{\gamma_w}\ d(F - OMC)$
14. $\tau_o = \gamma_w RS$
15. $n = \frac{1}{24}d^{\frac{1}{6}}$, d is in meters
16. $v_0 = 0.55\ m\ y^{0.64}$
17. $v = \left[\frac{\frac{1}{n}+\left(23+\frac{0.00155}{S}\right)}{1+\left(23+\frac{0.00155}{S}\right)\frac{n}{\sqrt{R}}}\right]\sqrt{RS}$
18. $v = \left(\frac{Qf^2}{140}\right)^{\frac{1}{6}}$
19. $R = \frac{5}{2}\left(\frac{v^2}{f}\right)$
20. $P = 4.75\sqrt{Q}$
21. $S = \frac{f^{\frac{5}{3}}}{3340Q^{\frac{1}{6}}}$
22. $D_s = 1.35\left(\frac{q^2}{f}\right)^{\frac{1}{3}}$
23. $v = 10.8R^{\frac{2}{3}}S^{\frac{1}{3}}$
24. $A = y^2(\theta + \cot\theta), P = 2y(\theta + \cot\theta)$ for Lined Triangular section.
25. $A = By + y^2(\theta + \cot\theta), P = B + 2y(\theta + \cot\theta)$ for Lined Trapezoidal section.
26. Launching apron scour depth,
    $D = xR - water\ depth\ above\ bed, R = 0.47\left(\frac{Q}{f}\right)^{\frac{1}{3}}$
27. Length of launching apron $= \sqrt{5}\ D$
28. $t = \frac{h'}{G}$, where
    $h' = ordinate\ of\ HGL\ above\ bottom\ of\ the\ floor$
29. $t = \frac{h}{G-1}$, where
    $h = ordinate\ of\ HGL\ above\ the\ top\ of\ the\ floor$
30. $C = 19\sqrt{\frac{D}{b'}}\left[\frac{d+D}{b}\right]$, $d = depth\ of\ pile\ and\ D = Depth\ of\ neighbouring\ pile\ below\ the\ point.$
31. $G_E = \frac{H}{d}\frac{1}{\pi\sqrt{\lambda}}$, $\lambda = \frac{1+\sqrt{1+\alpha^2}}{2}$ and $\alpha = \frac{b}{d}$
32. $\emptyset_D = \frac{1}{\pi}\cos^{-1}\left(\frac{\lambda-2}{\lambda}\right)$ and $\emptyset_E = \frac{1}{\pi}\cos^{-1}\left(\frac{\lambda-1}{\lambda}\right)$
33. $\emptyset_C = \frac{1}{\pi}\cos^{-1}\left(\frac{\lambda_2+1}{\lambda_1}\right), \emptyset_D = \frac{1}{\pi}\cos^{-1}\left(\frac{\lambda_2}{\lambda_1}\right)$ and $\emptyset_E = \frac{1}{\pi}\cos^{-1}\left(\frac{\lambda_2-1}{\lambda_1}\right)$, $\lambda_1 = \frac{\sqrt{1+\alpha_1^2}+\sqrt{1+\alpha_2^2}}{2}$ and $\lambda_2 = \frac{\sqrt{1+\alpha_1^2}-\sqrt{1+\alpha_2^2}}{2}$, $\alpha_1 = \frac{b_1}{d}\ and\ \alpha_2 = \frac{b_2}{d}$
34. Non-modular modules: Drowned pipe outlet, masonry sluice and wooden shoots.
35. Semi modules or flexible modules: Pipe outlet, venturi flume or Kennedy', open flume and orifice semi module.
36. Rigid modules: Gibb's module, Kanna's rigid module and foote module.
37. Flexibility $F = \frac{dq/q}{dQ/Q} = \frac{m}{n}.\frac{y}{H}$, $q =$discharge in outlet and $Q =$ discharge in channel, $m =$outlet index and $n =$channel index. $H =$working head of outlet and $y =$ depth of water in channel.
38. Proportionality: $F = 1\ and\ \frac{m}{n} = \frac{H}{y}$
39. Setting $= \frac{H}{y}$
40. $\frac{m}{n} > \frac{H}{y}$, hyper proportional outlet.
41. $\frac{m}{n} < \frac{H}{y}$, sub proportional outlet.
42. Sensitivity, $S = \frac{dq/q}{dy/y} = n\frac{dq/q}{dQ/Q} = n\ F$
43. Aqueduct: Canal over drainage with clear gap.
44. Syphon Aqueduct: Canal over drainage with syphonic action.
45. Super passage: Drain over canal with clear gap.
46. Canal Syphon: Drain over canal with syphonic action.
47. Principal stress in dam
    $\sigma = p_v\sec^2\alpha - p'\tan^2\alpha$
    where $p_v = maximum\ vertical\ stress$ and $p' =$ water pressure of tail water and
    $\alpha = angle\ of\ dam\ face\ with\ vertical$
48. $B = \frac{H}{\sqrt{S_c - C}}$
49. $H = \frac{f}{\gamma_w(S_c - C + 1)}$ and $H_{max} = \frac{f}{\gamma_w(S_c+1)}$
50. $x^{1.85} = 2\ H_d^{0.85}y$

Environmental Engineering

1. $P_n = P_0 + n\bar{x}$, where $\bar{x}$ =average of population increase (Arithmetic increase method)
2. $P_n = P_0\left(1+\frac{r}{100}\right)^n$, where $r = (r_1 r_2 \dots r_t)^{\frac{1}{t}}$ (Geometric increase method)
3. $P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2}\,\bar{y}$, where $\bar{y}$ =average of incremental increase
4. Carbonate hardness=Total hardness or Alkalinity whichever is lesser.
5. Non-carbonate hardness = Total hardness – carbonate hardness
6. Total hardness $= Ca^{++}$ in mg/l $\times \frac{50}{20} + Mg^{++}$ in mg/l $\times \frac{50}{12} + Al^{3+}$ in mg/l $\times \frac{50}{9}$
7. Akalinity $= CO_3^{--}$ in mg/l $\times \frac{50}{30} + HCO_3^{-}$ in mg/l $\times \frac{50}{61} + OH^{-}$ in mg/l $\times \frac{50}{17}$
8. Ammonia nitrogen and organic nitrogen is called Kjedahl nitrogen.
9. Colour: 5 Hazen units (max), PH: 6.5-8.5, Turbidity: 1 NTU (max), TDS: 500 mg/l (max), Chloride: 250 mg/l (max), Sulphate: 200 mg/l (max), Nitrate: 45 mg/l (max), fluoride : 1mg/l (max), Total alkalinity: 200 mg/l (max), Total hardness: 200 mg/l (max), Magnesium: 30 mg/l (max), Calcium: 75 mg/l (max), Zinc: 5 mg/l (max), Iron: 0.3 mg/l (max), Free residual chlorine: 0.2 mg/l (min).
10. Toxic substances: Cadmium, Cyanide, lead, Mercury, Nickel, Arsenic, chromium.
11. E-coli shall not be detectable in any 100 ml sample of drinking water.
12. Standard sample of MPN: 10ml, 1 ml and 0.1 ml
13. MPN/100 ml, by Thomas $= \frac{100\times \textit{Number of Positive tubes}}{\sqrt{\textit{Volume of sample in negative tubes} \times \textit{total volume of sample}}}$
14. $v_s = \frac{g}{18}(G-1)\frac{d^2}{\vartheta}$
15. Percentage particle removal: $\frac{v_s}{v_0} \times 100$ (If $v_s < v_0$)
16. Chemical used in coagulation: Alum (Aluminium sulphate), Copperas (Ferrous sulphate), Chlorinated copperas, Sodium aluminates.
17. $Al_2(SO_4)_3\,18H_2O + 3\,Ca(HCO_3)_2 \rightarrow 3CaSO_4 + 2Al(OH)_3 + 6CO_2 + 18H_2O$
18. Alkalinity requirement $= \frac{300}{666}\ mg/l$ as $CaCO_3$ per $1 mg/l$ of Alum
19. Permanent hardness due to alum $= \frac{408}{666}\ mg/l$ as $CaCO_3$ per $1mg/l$ of Alum
20. Sludge production $= \frac{156}{666} mg/l$ as $CaCO_3$ per $1mg/l$ of Alum
21. CO_2 release $= \frac{264}{666}\frac{mg}{l}$ as $CaCO_3$ per $1mg/l$ of Alum
22. $G' = \left(\frac{P}{\mu V}\right)^{\frac{1}{2}}$ where P is in Watts
23. PH range for alum: 6.5 to 8.3.
24. $HOCl$ is most destructive disinfectant.
25. Quick lime required in softening =Carbonate hardness in mg/l as $CaCO_3 \times 56/100 + Mg^{++} \times \frac{56}{24} + CO_2 \times \frac{56}{44}$
26. Soda required in softening =Non-carbonate hardness in mg/l as $CaCO_3 \times 106/100$
27. $Y_t = L(1-10^{-k_D t})$
28. $k_{D,T} = k_{D,20} \times (1.047)^{T-20}$
29. $S = 1-(0.794)^{t_{20}}$ and $S = 1-(0.630)^{t_{37}}$
30. $\eta\% = \frac{100}{1+0.0044\sqrt{u}}$
    where u =organic loading kg/ha-m/day
31. $\eta\% = \frac{100}{1+0.0044\sqrt{u/F}}$ where $F = \frac{1+R/I}{(1+0.1R/I)^2}$
32. HRT $= \frac{V}{Q} = \frac{\text{volume of Aeration tank}}{\text{Rate of sewage flow.}}$
33. Volumetric BOD loading = organic loading = $\frac{\text{Mass of BOD applied per day to Aeration tank}}{\text{volume of aeration tank.}} = \frac{QY_0}{V}$
34. $\frac{F}{M} = \frac{Q\ Y_0}{V\ X_t}$
35. $MCRT = \frac{V.X_t}{Q_w.X_R+(Q-Q_w)X_E.} = \frac{\textit{Biomass in the system}}{\textit{Bio mass leaving per day}}$
36. Sludge volume index (SVI) $= \frac{\textit{Volume of sludge settled in 30 min in ml}}{\textit{mass of dry sludge solids in gm}}$
37. $\frac{Q_R}{Q} = \frac{X_t}{X_R - X_t} = \frac{X_t}{\frac{10^6}{SVI} - X_t}$
38. $C = \frac{V_s Q_s + V_R Q_R}{Q_s + Q_R}$
39. $\left(\frac{L_0}{D_c f}\right)^{f-1} = \left\{1-(f-1)\frac{D_0}{L_0}\right\} f$
40. $t_c = \frac{1}{k_r - k_d}.\,log\left[\left\{1-(f-1)\frac{D_0}{L_0}\right\} f\right]$
41. $D_t = \frac{L_0}{f-1}(10^{-k_D t} - 10^{-k_R t}) + D_0 10^{-k_R t}$
42. Primary pollutants: CO, SO_2, No_x, hydrocarbons and particulate matter are primary air pollutants.
43. Secondary pollutants: Ozone, PAN (Peroxy acetyl nitrate), photochemical Smog, Aerosols and mists.
44. $ELR < ALR$: Sub adiabatic and stable.
45. $ELR > ALR$: Super adiabatic and unstable
46. L_p =20 $\log_{10}\frac{P_{rms}}{P_o}$ where $P_o = 20\ \mu Pa$
47. L_{eq}=10log $\sum_{i=1}^{n} 10^{\frac{L_i}{10}} \times t_i$
48. Addition of sound levels:
    $L_p = 10\ \log_{10}\left[10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}} + \dots + 10^{\frac{L_n}{10}}\right]$
49. Averaging of Sound Pressure Levels:
    $\overline{L_p} = 20\ \log_{10}\left\{\frac{1}{n}\left(10^{\frac{L_1}{20}} + 10^{\frac{L_2}{20}} + \dots + 10^{\frac{L_n}{20}}\right)\right\}$
50. $L_2 = L_1 - 20\ log_{10}\left(\frac{r_2}{r_1}\right)$

Transportation Engineering

1. $y = \frac{2x^2}{nW}$ (parabolic camber)
2. $SSD = vt + \frac{v^2}{2g(f \pm n)}$, $ISD = 2 \times SSD$
3. $OSD = d_1 + d_2 + d_3$, $d_1 = v_b\, t$, $d_2 = 2s + v_b T$, $d_3 = vT$, $T = \sqrt{4s/a}$
4. $\frac{v^2}{Rg} = e + f$, $W_e = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}}$
5. $L_s = \frac{v^3}{CR}$ (comfort condition)
6. $L_s = eN(W + W_e)$ (rotated about inner edge)
7. $L_s = 2.7\frac{V^2}{R}$ for plain and rolling terrain, $L_s = \frac{V^2}{R}$ for steep and mountainous terrain.
8. IRC recommends Spiral as transition curve.
9. $S = \frac{L_s^2}{24R}$
10. $m = R\left(1 - \cos\frac{\theta}{2}\right)$, $\theta = S/R$ (single lane, $L > S$)
11. $m = R\left(1 - \cos\frac{\theta}{2}\right) + \frac{S-L}{2}\sin\frac{\theta}{2}$, $\theta = \frac{L}{R}$ (Single lane, $L < S$)
12. Curve resistance $= T(1 - \cos\alpha)$
13. Grade compensation $= \frac{30+R}{R}$ or $\frac{75}{R}$ whichever is less
14. $L = \frac{Ns^2}{(\sqrt{2h}+\sqrt{2H})^2}$ when $L > s$ (Summit curve for SSD), $h = 0.15\ and\ H = 1.2$
15. $L = 2s - \frac{(\sqrt{2h}+\sqrt{2H})^2}{N}$ when $L < s$ (Summit curve for SSD), $h = 0.15\ and\ H = 1.2$
16. $L = \frac{Ns^2}{(\sqrt{2H}+\sqrt{2H})^2}$ when $L > s$ (Summit curve for OSD), $H = 1.2$
17. $L = 2s - \frac{(\sqrt{2H}+\sqrt{2H})^2}{N}$, $L < s$ (Summit curve for OSD), $H = 1.2$
18. $L = \frac{Ns^2}{2h + 2s\tan\alpha}$ when $L > s$ (valley curve), $h = 0.75\ and\ \alpha = 1°$
19. $L = 2s - \frac{2h+2s\tan\alpha}{N}$, $L < s$ (valley curve), $h = 0.75\ and\ \alpha = 1°$
20. $L = 2\left(\frac{Nv^3}{C}\right)^{\frac{1}{2}}$ (valley curve comfort condition)
21. $C = \frac{80}{75+V}$
22. $Flakiness\ Index = \frac{weight\ of\ flaky\ particles\ which\ are\ thinner\ than\ 0.6\ d_m}{total\ weight} \times 100$
23. $Elongation\ Index = \frac{weight\ of\ flaky\ particles\ which\ are\ longer\ than\ 1.8\ d_m}{total\ weight} \times 100$
24. Angularity number= $67 - \frac{100\left(\frac{W}{G}\right)}{C}$, C is weight water in the cylinder, W is weight of aggregate packed in the cylinder.
25. Penetration test unit is 1/10th mm. Weight used 100 grams. Temperature 25℃.
26. $G_a = \frac{W_1+W_2+W_3}{\frac{W_1}{G_1}+\frac{W_2}{G_2}+\frac{W_3}{G_3}}$ and $G_t = \frac{W_a+W_b}{\frac{W_a}{G_a}+\frac{W_b}{G_b}}$
27. $G_m = \frac{weight\ of\ mould}{Volume\ of\ mould}$
28. $v_a = \frac{G_t - G_m}{G_t}$, $v_b = \frac{W_b}{W_m} \times \frac{G_m}{G_b}$ and $VMA = v_a + v_b$
29. $VFB = \frac{v_b}{VMA}$
30. Flow value units 1/4th mm
31. $N = 365A\left[\frac{(1+r)^n - 1}{n}\right] VDF \times LDF$ and $A = P(1+r)^x$
32. $LDF = 0.75\ for\ two\ lanes\ and\ 0.4\ for\ four\ lane$ (single carriageway)
33. LDF=0.75 for two lanes and 0.60 for three lane and 0.45 for four lane (dual carriageway)
34. $VDF = \left(\frac{P}{80}\right)^4$, where P is in kN
35. $CBR\ at\ 2.5\ mm = \frac{pressure\ in\ kg/cm^2}{70} = \frac{load\ in\ kg}{1370}$
36. $CBR\ at\ 5\ mm = \frac{pressure\ in\ kg/cm^2}{105} = \frac{load\ in\ kg}{2055}$
37. $ESWL$: interpolate load for depth from line joining $\left(logP, \log\frac{z}{2}\right)$ and $(log2P, \log 2s)$.
38. Radius of relative stiffness $l = \left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{\frac{1}{4}}$
39. $k = \frac{p\left(\frac{kg}{cm^2}\right)}{0.125\ cm}$ (modulus of subgrade reaction)
40. $k = \frac{E}{1.18\ a}$ (a is rigid plate radius)
41. $k = \frac{E}{1.5\ a}$ (a is flexible plate radius)
42. $k_1 a_1 = k_2 a_2$
43. $Rigidity\ factor = \frac{contact\ pressure}{tyre\ pressure}$ (below 7 kg/cm^2 contact pressure is more)
44. $L\alpha t = \frac{\delta}{2}$ (expansion joint)
45. $\frac{L_c}{2} bh\gamma_c f = S_c\ bh$
46. $bh\gamma_c f = A_{st}\ S_s$ (tie bar area of steel per meter)
47. $\frac{L}{2}\pi\emptyset\tau_{bd} = \frac{\pi\emptyset^2}{4} S_s$ (length of tie bar)
48. $P(x) = \frac{(\lambda t)^x e^{-\lambda t}}{x!}$ (Poisson distribution)
49. $P(h \geq t) = e^{-\lambda t}$
50. $k = k_j\left(1 - \frac{v}{v_f}\right)$ and $v = v_f\left(1 - \frac{k}{k_j}\right)$
51. $q = kv$ and $k = \frac{1000}{spacing}$
52. $PHF = \frac{peak\ hour\ flow}{4 \times peak\ 15\ min\ flow}$ or $PHF = \frac{30th\ hourly\ volume}{AADT}$
53. $Time\ mean\ speed = \frac{v_1+v_2+\cdots+v_n}{n}$
54. $Space\ mean\ speed = \frac{d}{\frac{t_1+t_2+\cdots+t_n}{n}}$
55. $q = \frac{n_a+n_y}{t_a+t_w}$, $\bar{t} = t_w - \frac{n_y}{q}$
56. Safe speed limit is 85th percentile speed
57. Geometric design is based on 98th percentile speed.
58. Road side facilities are based on 30th highest hourly volume.
59. $C_0 = \frac{1.5L+5}{1-Y_0}$
60. $Q = 280w\ \frac{\left(1+\frac{e}{w}\right)\left(1-\frac{p}{3}\right)}{\left(1+\frac{w}{l}\right)}$
61. $T_r = T_a + \frac{T_m - T_a}{3}$
62. $Elevation\ correction = 7\ \%\ for\ 300\ m$
63. $Standard\ temperature\ of\ airport, T_s = 15 - \frac{6.5}{1000}h$
64. Temperature correction $= 1\%\ per\ 1℃\ rise\ of\ T_r\ above\ T_s$
65. Gradient correction $= 20\%\ per\ 1\%\ effective\ gradient.$
66. $Turning\ radius\ R = \frac{V^2}{125f}$
67. $Turning\ radius\ R = \frac{0.388W^2}{\frac{T}{2} - S}$ where $s = 6 + \frac{tread}{2}$
68. Turning radius for subsonic aircraft is 120 m and for supersonic it is 180 m
69. Grade compensation for BG is 0.04%, for MG is 0.03% and for NG is 0.02% per degree of curve.
70. $D = \frac{1720}{R}$
71. $Versine\ of\ curve = \frac{c^2}{8R}$
72. $Equilibrium\ cant = \frac{V^2}{127R} \times G$
73. Theoretical cant $= Equilibrium\ cant + cant\ deficiency$
74. Widening of gauge in cm, $d = \frac{13(B+L)^2}{R}$ where B is wheel base in m, lap of flange in m, $L = 0.02\sqrt{h^2 + Dh}$, h is depth of wheel flange below rail top level, D dia of wheel in cm.
75. $L_s = 3.28\frac{v^3}{R}$ (Transition curve)
76. $y = \frac{x^3}{6LR}$ (Transition curve)
77. Usually adopted transition curve for railways is cubic parabola.