Chapter 1:

1.2) Based entirely on the information given and not making any "realistic" assumptions:
$200,000,000 divided by 100,000 simultaneous calls (think of each call as a "line") gives:
$200/line. The line can take 20 three minute calls/hour so 480 calls/day so
480x360x15 =2592000 calls per lifetime of the satellite. So each call costs: $200/2592000 or .0077 cents.
(note this naively assumes that each line will be used continuously)

1.3) The illumination at 40000km for a 30W source will be
$30/[4*\pi*(40000)^2] = 1.492\times10^{-9}$ W/km^2=1.492×10^{-15} W/m^2

a) So a 1 m^2 antenna will receive 1.492×10^{-15} W
b) If the Tx antenna has a linear gain of 1000, then the received signal will be 1.492×10^{-12} W

1.4) 1000W x 100,000 antenna gain gives an EIRP of 100,000,000 W = 80 dBW
In linear: 40000km=40,000,000m so the received power will be
$100,000,000* (1//[4*\pi*(40000000)^2]* (.5)= 2.4868\times10^{-9}$W = – 86 dBW
In dB: illumination= 80 -20log(40000)-71=–83dbW/m^2 . –83 + 10log(.5) = –86 dBW

1.5) 1000W & an antenna gain of 1000 at 1000km =1,000,000m will have an illumination of
$1000*1000/[4*\pi*(1,000,000)^2]= 7.9577\times10^{-8}$ W/m^2 .

a) Thinking of the balloon as a 30m diameter circle means it will reflect: 7.9577×10^{-8} W/m^2 $*\pi*(30/2)^2$ m^2 = .00005625 W
b) Now .00005625 W radiating isotropically will illuminate the ground 1000km =1000000m away at $.00005625/[4*\pi*(1,000,000)^2]= 4.476\times10^{-18}$ W/m^2 . For a 10 m^2 antenna, you will get 4.476×10^{-17} W

1.6) FSL = $(4*\pi*40,000,000/0.05)^2 = 1.01*10^{20}$ This is what you would need to divide by. As a multiplier you get $9.89*10^{-21}$. NOTE: you must covert the distance to meters since the wavelength is in meters.

1.7) A 1.5m dish collects 10^{-10} W. The dish area is $(0.75)^2* \pi = 1.767$m^2. The efficiency is 0.55, so the effective area = 1.767*0.55=0.97185m^2 So the illumination must have been 10^{-10} W / 0.97185m^2 = 1.029×10^{-10} W/m^2

Chapter 2:

2.12) 10= 10dB, 12.5= 10.97dB, 15=11.76dB, 16=12.04dB Total= 44.77 dB = 29991.6 factor ≈ 30000

2.13)

TX	100W	20 dBW
Waveguide	½	-3 dB
Antenna	2000	33 db (dbi)
EIRP	100,000W	50 dBW

2.14)
This problem can be done in dB or in linear. I will do linear since it seems easier (to me…)
23dBi antenna is a factor of 200. So EIRP is 700*200=140000W. The power captured by the satellite will be the illumination times the antenna area, that is:
$[140000/(4*\pi*[40,000,000]^2)] * [3.5]=2.437*10^{-11}$ W = -106.`13dBW

Maybe it would have been easier in dB….
2.15) Reverse link budget! Pt +Gt – FSL + Gr = Pr so Pt = Pr – Gt + FSL – Gr
Pr = -100 dBW
Gt = 20 dBi
FSL = 20log(40000) + 20log(f) +92.45 = 184.49 + 20log(f) dB (we don't know f, but that's ok….)
For Gr we need the diameter D = 2* sqrt (1.5/π)= 1.382m
Gr = 20log(1.382) + 20log(f) +10log(.60) + 20.4= 20.99 +20log(f) dB
So:
Pr= -100 – 20 + 184.49 +20log(f) – 20.99 -20log(f) = 43.5 dBW = 22387W

2.16) G = 20log(7.5) + 20log(6) +10log(.55) + 20.4 = 50.868 dBi

2.18) Pr = EIRP –FSL + Gr
EIRP = 40 dBW, Gr=40 dBi
FSL = 20log(40000) + 20log(10) + 92.45=204.49 dB
Pr = 40 – 204.49 + 40 = -124.49 dBW

2.19) a) W = EIRP -20log(S) -71 = 30dBW – 20log(40000) -71 = -133.04 dBW/m^2
b) Ae = (.55)* π*$(3)^2$/4 = 3.8878m^2
c) Converting eqn 2.25 to db gives: Pr = W + 10log(Ae) = -133.04 + 5.9 = -127.14 dBW

2.20) G/T = 25 – 10log(125) = 4.03 dB/K

2.21) C/T = EIRP – PL + Gr/T
Gr/T = 40 – 10log(100)= 20
C/T = 30 – 200 + 20 = – 150 dBW/K

2.22) C/N = C/T + 228.6 – 10log(BW) =-178.6 + 228.6 – 30 = 20 dB

2.23) C/N = EIRP – PL + Gr/T +228.6 – 10log(BW)
15 = 40 – 204 + Gr/T + 228.6 – 73 = Gr/T – 8.4
Gr/T = 23.4 dBi/K

2.24) Gt = 20log(12) + 20log(18) +10log(.55) +20.4 = 64.49 dBi
FSL = 20log(40000) + 20log(18) +92.45 = 209.60

Tx	100 W	20dBW
Gt	12m ant η=.55, 18GHz	64.49 dBi
EIRP		84.49 dBW
FSL	40000km 18GHz	–209.6 dB
RSL (before antenna)		–125.11 dBW
Gr/T	9.5 dBi/K	9.5 dBi/K
C/T		–115.61 dBW/K
1/k	228.6 dBHzK/W	228.6 dBHzK/W
C/kT		112.99 dBHz (118)

2.25) FSL = 20log(40000) + 20log(3.9) + 92.45 = 196.31 dB

Sat EIRP	23 dBW	23 dBW
FSL	–196.31	–196.31 dB
RSL		–173.31 dBW
Gr/T	29 dBi/K	29 dBi/K
C/T		-144.31 dBW/K
1/k	228.6 dBHzK/W	228.6 dBHzK/W
C/KT= C/N_0		84.29 dBHz
BW	40 MHz	–76.02 dBHz
C/N		8.27 dB

2.30)

	Value	Unit	Value (dB)	Unit (dB)
Satellite EIRP	1000	Watts	30	dBW
Path loss	10^{-20}	Ratio	200	dB
Antenna Gain Gr	200	Ratio	23	dBi
RSL C	$2x10^{-15}$	Watts	-147	dBW
Noise Temp T	100	K	20	dBK
F.O.M G/T	2	1/K	3	dBi/K
C/T	$2x10^{-17}$	W/K	-167	dBW/K
Boltzmann's k	$1.3806x10^{-23}$	W/HzK	-228.6	dBW/HzK
C/N_0	1531393	Hz	61.7	dBHz
Bandwidth	1000000	Hz	60	dBHz
C/N	1.531	Ratio	1.7	dB

Chapter 3:

3.1) Assuming the satellite velocity is 0 when it is at 30E, it will drift further East (accelerating) passing 75E (45 degrees away) and continue (decelerating, another 45 degrees) to 120E at which point it will be at 0 velocity again and start drifting west. NB. The period of oscillation is 3 years (see page 75) so the satellite has enough time to reach 120E and return to 30E. Ans: 120E

3.3)
a) GEO
b) geosync
c) GEO
d) neither?

3.5) 27.3 days = 2352277.2 seconds. $P=2\pi r^{3/2}\mu^{1/2}$ so $r = \mu^{1/3}(P/2\pi)^{2/3}$=382283km

3.6)
a) 60 km altitude means 1800km radius. $P=2\pi r^{3/2}/\mu^{1/2} = 2\pi(1800)^{3/2}/(4902.78)^{1/2} = 6852.8$ seconds
b) As in 3.5 above, $r = \mu^{1/3}(P/2\pi)^{2/3} = (4902.78)^{1/3}(2352277/2\pi)^{2/3} = 88244$ km. NB I used a sidereal day here. An argument could be made for using a 24 hr day.

3.8) We model the orbital slot as a rectangular prism (i.e. a box). The difference between apogee and perigee gives one dimension: 30km. The north-south dimension is 2*74=148 km. For east-west, the distance is 2*0.1 degrees = 0.2 degrees. At GEO orbit r=42164, so 0.2 degrees => (0.2/360)*(2π*42164)=147.2 km.
a) volume = 147.2*30*148 =653479.8 km^3
b) Each satellite occupies $14m^3$ = .000000014km^3 which is 2.14×10^{-14} part of the volume or 2.14×10^{-12} percent.
NB: The probability of collision is clearly ridiculously small (your chance of winning $100M in the Powerball lottery is 1000 times better!) The actual probability of collision is a little tricky to compute. If we assume the satellites are spherical and that a collision occurs whenever one satellite is "tangent" to the other (or closer) then the centers of the two satellites would need to be separated by < twice the satellite radius. Doubling the radius increases the volume by a factor of 8. Thus the probability of a collision would be the probability that the center of one satellite fell within 8 times the proportion of the area occupied by the other satellite, or 1.7×10^{-13} …. Still ridiculously small.

3.9)We note that to solve this problem we must know the radius of the satellite orbit. In this case (and as is often the case) we are talking about geostationary orbit (otherwise you would not be able to solve part a) with table 3.4 ….)
b) we have S=38000 and r=42164 so we can use eqn 3.10 to find
$\beta_0=\arccos[\ (42164^2 + 6378^2 - 38000^2)/(2*(42164)(6378))\ ] = \arccos(0.6962647) = 45.8719$ degrees
c)We are going along earth's surface by 45.8719 degrees: distance = 2π(6378)(45.8719/360) =5106.33km

3.13) Using eqns in fig 3.9: 40W = 320E, so Δλ = 320 -0 = 320. $\cos(\beta_0) = \cos(50)\cos(320) = 0.4924038765$
tan(h) = (0.4924038765 – 0.15126648)/.870366832 = .39194668, so h=21.40253146

3.14)

sat long	320									
ES lat N	ES long E	Δλ	beta0	tan(h)	h	tan(A)	sgn	A (atan)	Correct A	A (atan2)
12	260	60	60.72028	0.387286	21.171	-8.3307	-1	-83.1551	96.84491	96.84491
40	15	305	63.93535	0.320738	17.783	2.2218	-1	65.76822	245.7682	-114.232
-40	260	60	67.47899	0.250889	14.084	2.69459	1	69.63943	69.63943	69.63943
0	320	0	0	infinity	90	undef 0/	0	0	0	0

NOTE: the last case, the ES is at the subsatellite point and the satellite is directly overhead. Thus: h=90 and A is irrelevant/undefined (any azimuth will get you to the same place).

3.15) 120W= 240E. ES is at 39N, 283E, so $\Delta\lambda = 240 - 283 = -43$, $\cos(\beta_0) = \cos(39)\cos(-43) = 0.5\,683685756$
$\tan(h) = (0.5\,683685756 - 0.15126648)/.822774065 = .50694608645$, so h=26.88255
$\tan(A) = \sin(-43)/(-\sin(39)\cos(-43)) = -0.68199836 / -0.42919547 = 1.589015729$ so using arctan we get A= 57.8169559 degrees. BUT THIS DOESN'T MAKE SENSE (think about it). Since the denominator was negative we must add 180 degrees so the correct A =237.8169559 = –122.1830444 which does make sense.

3.16) 57W = 303E. So $\Delta\lambda = 303 - 283 = 20$, $\cos(\beta_0) = \cos(39)\cos(-20) = 0.730278325$,
a) $\beta_0 = 43.09026788$
b)I'm not sure what the hint is about, but eqn 3.7 gives:
$S = (42164^2 + 6378^2 - 2*(6378)(42164)(0.730278325))^{1/2} = 37758.5219$ km
d)$\tan(h) = (0.730278325 - 0.15126648)/.68314974 = .847562124$, so h=40.2833475
$\tan(A) = \sin(20)/(-\sin(39)\cos(20)) = 0.34202014 / -0.59136773 = -.57835442716$.
arctan gives -30.04313174 but the denominator above is negative so we add 180 and get A= 149.956868

3.17)

				$\cos\beta_0=\cos(\phi)\cos(\Delta\lambda)$			$\tan(h)=(\cos\beta_0 - Re/r)/\sin(\beta_0)$		
ES lat N	ES long E	geo lat N	geo long E	$\Delta\lambda$	geo r	$\cos\beta_0$	β_0	tan(h)	h
0	300	0	300	0	42164	1	0	inf	90
30	300	0	300	0	42164	0.866025	30	1.429992	55.03473
60	300	0	300	0	42164	0.5	60	0.402957	21.9473
85	300	0	300	0	42164	0.087156	85	-0.06412	-3.66864
			$\cos\beta_0=\sin\phi\sin(\delta) + \cos(\delta)\cos(\phi)\cos(\Delta\lambda)$				$\tan(h)=(\cos\beta_0 - Re/r)/\sin(\beta_0)$		
ES lat N	ES long E	mol lat N	mol long E	$\Delta\lambda$	mol r	$\cos\beta_0$	β_0	tan(h)	h
0	300	62.9	300	0	45778	0.455545	62.9	0.355464	19.56848
30	300	62.9	300	0	45778	0.83962	32.9	1.289666	52.2102
60	300	62.9	300	0	45778	0.998719	2.9	16.99077	86.63172
85	300	62.9	300	0	45778	0.926529	22.1	2.09296	64.4619

I added a column for 85N, 60W ES to illustrate that the earthstation can communicate with the Molniya but not the GEO

3.19(my favorite problem…):
100W = 260E. We need to find $\Delta\lambda$ (to get the ES longitude). We also need ES latitude, Ø. We do know: r=42164, h=50, and A=229.59

We can get β_0 from eqn 3.3: β_0 = arccos[(6378/42164)cos(50)]– 50 = 34.4201884
Now: $\cos(\beta_0)$= 34.4201884 =cos($\Delta\lambda$)cos(Ø) We also have:
tan(A) = 1.17458961447 = sin($\Delta\lambda$)/ (–sin(Ø)cos($\Delta\lambda$))

This is essentially 2 equations with 2 unknowns. We can solve…
cos(Ø) = $\cos(\beta_0)/\cos(\Delta\lambda)$, so sin(Ø) = $(1 - \cos^2(\beta_0)/\cos^2(\Delta\lambda))^{1/2}$, Also: $\sin(\Delta\lambda)= (1 - \cos^2(\Delta\lambda))^{1/2}$

Thus, squaring the expression for tan(A) above we get:
$\tan^2(A) = (1 - \cos^2(\Delta\lambda))/[(1 - \cos^2(\beta_0)/\cos^2(\Delta\lambda)) *\cos^2(\Delta\lambda) = (1 - \cos^2(\Delta\lambda))/ (\cos^2(\Delta\lambda) - \cos^2(\beta_0))$
So
$\tan^2(A)* \cos^2(\Delta\lambda) - \tan^2(A)* \cos^2(\beta_0) = 1 - \cos^2(\Delta\lambda)$
So
$1 + \tan^2(A)* \cos^2(\beta_0)= \tan^2(A)* \cos^2(\Delta\lambda) + \cos^2(\Delta\lambda)$
So
$\cos^2(\Delta\lambda)= [1 + \tan^2(A)* \cos^2(\beta_0)]/(\tan^2(A) +1)$= .814754596 so $\Delta\lambda$= 25.4930395 or – 25.4930395
Which one? Since A is pointing southwest (229 > 180) the earthstation must be further east than the satellite. So $\Delta\lambda$ must be negative: $\Delta\lambda$= – 25.4930395, so ES longitude is 285.493E=74.5069605W
cos(Ø) = $\cos(\beta_0)/\cos(\Delta\lambda)$ = 0.913893238 so Ø = 23.950962N
Consulting Google maps reveals you are on San Salvador Island, in the Bahamas. This is (supposedly) the first island Columbus landed on when he discovered the New World.

3.21: There is an error in this problem: 100W is not equal to 280E. Assuming it is really 100W, the satellite will oscillate from 100W to 116W. It will go there and back in 3 years. So in 1 year it should go (approximately 2/3 the way to 116 which would be approximately 110.6W.
In 10 (or 100) years, it will get to 116W.

3.22)
a) range variation ΔS = +/- e*r = .0000537*42164 = 2.2642km
b) range rate dS/dt = +/- e*r*n= .0000537*42164*72.92115*10^{-6} = .0001651 km/s
c) range variation = ΔS = +/- i*(π/180)(Re)*sin(Ø) = (0.0291)* (π/180)*(6378.14)*sin(39)=2.03862 km
d) range rate dS/dt =+/- i*(π/180)(Re)*sin(Ø)n = 2.03862*72.92115*10^{-6} = .000148659 km/s
e) we need $\Delta\lambda$ to compute eqn 3.40. λ_{es} is given as 283E but we need to look at problem 3.20 to get λ_{sat}=335.51E. Thus $\Delta\lambda$=52.51 and range rate dS/dt = D*(π/180)(Re)*cos(Ø)*sin($\Delta\lambda$) = (-.006)* (π/180)*(6378.14)*cos(39)sin(52.51)= . -0.4118604 km/day =-.0000047669031 km/sec. Note that here “km/day” usually refers to a solar day: 24hours=86400sec not a sidereal day.

3.24)They do not specify if it’s 1 way to the satellite, or one way Es through sat to Es
One way: a) 0.1333 b) .01 c) 1.282633 seconds
Two way: a) 0.2667 b) .02 c) 2.565267 seconds

Chapter 6

6.1b) G = 20*log(5) + 20*log(4) + 10*log(.55) +20.4 = 13.979 + 12.041 -2.596 +20.4 = 43.824 dBi
6.2b) G = 20*log(3) + 20*log(6) + 10*log(.55) +20.4 = 9.542 +15.563 – 2.596 +20.4 = 42.909 dBi

6.6) The half beam with is 0.5 degrees so θ_3= 1.0 = 21/(6*D), so D= 21/6 = 3.5m

Chapter 7

7.1) 100W = 20 dBW. EIRP = P_t – L + G_t = 20 – 0 + 24 = 44 dBW

7.4) 1000W = 30 dBW. Input to antenna = P_t – L =30 -.5 = 29.5 dBW.
EIRP = P_t – L + G_t = 30 – 0.5 + 52 = 81.5 dBW

7.6)

P (W)	P (dBW)	Loss	Ant Gain	Ant. Input	EIRP	
750	28.75061	0.2	52.1	28.550613	80.65061	
400	26.0206	0.4	49.5	25.6206	75.1206	
1250	30.9691	0.3	58.7	30.6691	89.3691	
700	28.45098	0.5	47.8	27.95098	75.75098	

7.7)

P (W)	P (dBW)	Backoff	Line loss	Ant Gain	Ant. Input	EIRP
10	10	7	1	30	2	32
20	13.0103	5	2	28	6.0103	34.0103
40	16.0206	4	1	35	11.0206	46.0206
20	13.0103	4	1.5	40	7.5103	47.5103

7.8) W = EIRP – 20*log(S) – 71 = 40 – 20*log(40000) -71 = 40 – 46 – 71 = – 77 dBW/m^2

7.11) We assume the satellites are GEO (otherwise we can't solve the problem!):
Separation angle α = 359 – 325.5= 33.5°
S = 2* r_g* sin(α/2) = 2*42164*sin(16.75) = 24303 km
W = EIRP – 20*log(S) -71 = 20 – 20*log(24303) – 71 = – 138.7 dBW/ m^2 or if you like:
W = EIRP – 20*log(sin(α/2)) – 169,5 = 20 + 10.8 – 169.5 = – 138.7 dBW/ m^2

7.12) Assuming no other losses, EIRP = 10*log(30) +20 = 34.77 dBW
W = EIRP – 20*log(sin(α/2)) – 169,5 = 34.77 + 10*log(sin(60)) – 169.5 =
34.77 + 1.25 – 169.5 = – 133.48 dBW/ m^2

Chapter 8

8.1) Since we are not given enough info to compute based on rain rate, we must use figure 8.5:
Reading the D2 line at 0.01% gives ~ 12 dB of loss

8.4) From fig 8.4b 50mm/hr in region D2 gives an outage % of ~0.01%. \
From fig 8.5 0.01% in region D2 gives ~11 dB of loss.

8.5) From fig 8.4a 25mm/hr in region C gives and outage % of ~0.015%.
From fig 8.5, 0.015% in region C gives ~5 dB of loss

8.6) From fig 8.4b 50mm/hr in region D2 gives an outage of ~0.01%. There are 24*365=8760 hrs/year

.0001*8760=.876hrs = 52.56 minutes. The availability is 100 – .01 = 99.99%

8.8)At 4.2Ghz, 40>25=b so the ITU limit is – 142 dBW/m^2

8.9) At 11.2 GHz, a=5 < 15 < 25=b so ITU limit is given by
– 150 + (h – 5)/2 = – 150 + (15 – 5)/2 = – 145 dBW/m^2

8.10) We assume this is a GEO satellite (or we can't solve the problem….)
a) for clear sky, we take L=0 dB so illumination at edge of coverage is given by
W = EIRP – L – 163.4 = 40 – 163.4 = – 123.4 dBW/m^2
b) for 99.99% reliability, outage will be 0.01%. "Temperate Maritime" = region C.
From figure 8.5, 0.01% at 12GHz gives ~ 7dB of loss. So illumination at edge is given by
W = EIRP – L – 163.4 = 40 – 7 – 163.4 = – 130.4 dBW/m^2

8.11) Bandwidth is B=50MHz, and B_{CCIR}=4000Hz so 10*log(50,000,000/4000)= 40.97 dB
a) For clear sky: PFD = W – 10*log(B/ B_{CCIR}) = – 123.4 – 40.97 = – 164.37 dBW/m^2 in 4KHz Bw
b) For rain : PFD = W – 10*log(B/ B_{CCIR}) = – 130.4 – 40.97 = – 171.37 dBW/m^2 in 4KHz Bw

Chapter 9

9.1) Short answer: In the free space loss term, 20*log(2*f) = 20*log(f) + 6, so doubling frequency increases free space loss by 6 dB.
Longer answer: In addition to FSL increase above, this will also increase the losses due to rain (for the uplink and downlink). See figure 8.1: at 9GHz rain is insignificant. At 18GHz, rain is very significant.
It will also increase sky noise due to rain in the downlink: at 9GHz the sky noise will not substantially increase in heavy rain (since the attenuator will be small for 9GHz rain) but at 18GHz, sky noise could increase substantially

9.2) from 9.1 above, doubling frequency adds 6 dB. To get from 6GHz to 24GHz we need to double the frequency twice. Thus we add 12 dB to 200dB and get 212 dB

9.4) At 35788, FSL = 20*log(35788) + 20*log(10) + 92.45 = 91.07 +112.45 = 203.51 dB
At 41679, FSL= 20*log(41679) + 20*log(10) +92.45 = 92.40 + 112.45 = 204.85
Difference is 1.34 dB. Since 35788 is the altitude of a GEO (and, hence the shortest distance from earth to the satellite), AND 41679 is the edge of coverage distance (and, hence the longest distance from earth to the satellite), We have that the path loss cannot vary by more than 1.34 dB regardless of where the earth station is (as long as it is visible to the satellite and we are in clear sky conditions).
NOTE NOTE NOTE: This difference is the same REGARDLESS of frequency: you will get the same answer if you change the 10 GHz to any other value.

9.6)This problem is not solvable as stated: they don't give specs for the satellite Rx antenna and the earthstation antenna info is not needed since the EIRP is given. So… let's assume the antenna described is on the satellite. Then
C = EIRP –L –FSL +G
EIRP = 94 dBW and L = 1 dB
C-band means they are using the 6GHz band for uplink and the 4GHz band for downlink. We approximate by using 6GHz as the uplink frequency (the true value is between 5.7 and 6.3 GHz roughly)
FSL = 20*log(35788) + 20*log(6) +92.45 = 199.09

$G = 20*\log(30) + 20*\log(6) + 10*\log(0.55) + 20.4 = 29.54 + 15.56 – 2.60 + 20.4 = 62.91$
Thus $C = 94 – 1 – 199.9 + 62.91 = – 43.18$ dBW

NOTE: you should get the same answer if you assume that we are computing the power received at the earthstation if it is using the 30m antenna described and the satellite is transmitting at an EIRP of 94dBW. Note however that you would need to use 4GHz as the frequency in both the FSL and Gain equations but the differences would cancel out…

9.7) You can use eqn 9.9…. or you could derive the value:
$S = 2*r_g*\sin(\alpha/2)$
$L = 20*\log(f) + 20*\log(2*r_g*\sin(\alpha/2)) + 92.45 = 20*\log(f) + 20*\log(2*42164) + 20*\log(\sin(\alpha/2)) + 92.45 =$
$20*\log(23) + 20*\log(\sin(0.01/2)) + 190.97 = 27.23 – 81.18 + 190.97 = 137.02$ dB

9.10) in linear: $G_{linear} = 4\pi A\eta/\lambda^2 = A\eta * G_{1m}{}^2{}_{linear}$ so the ratio will be $A\eta$ in linear.
$A\eta = \pi\,(15/2)^2(.55) = 97.19 = 19.88$ dB

9.11) $W = EIRP – 20*\log(S) - 71 = 40 – 20*\log(40000) – 71 = – 123.04$ dBW/m^2. The Rx antenna information (diameter and efficiency) is superfluous.

9.12) From eqn 9.9 (or the derivation above in exercise 9.7) $L = 20*\log(f) + 20*\log(\sin(\alpha/2) + 190.97$
$= 20*\log(20) + 20*\log(\sin(60/2)) + 190.97 = 210.97$

9.13) In linear N=kBT. So in db:
$N = – 228.6 + 10*\log(B) + 10*\log(T)$
For 10 kHz: $N = – 228.6 + 40 + 20 = –168.6$ dBW
For 10 MHz: $N = – 228.6 + 70 + 20 = – 138.6$ dBW. There is a 30 dB difference.

9.14)
NF = 1.5 dB means the linear noise figure $F = 1.4125 = 1 + T_{RX}/T_R$
So $T_{RX} = 290 * (.4125) = 119.6$K. so the LNA with the 100K noise temperature is better.

9.17) For each G/T, we look at each LNA and compute the required antenna area. From there we get the cost of the antenna and LNA combination. We are given the frequency f=4GHz and we assume the efficiency is 0.55. We compute as follows:
For a given G/T and a given LNA, compute the required antenna gain to get that G/T: $G = G/T – 10*\log T$.
Next compute the required diameter of the antenna: $20*\log(D) = G – 20*\log(f) – 10*\log(.55) – 20.4$
Next compute the area as $A = \pi*D^2/4$. We get the total cost as A*$100 + cost of LNA:

G/T	20		freq	4		efficiency	0.55
	Cost	Temp	Required G	20log(D)	D	Area	Total Cost
LNA 1	$200	30	34.77121255	4.926386	1.763272	2.441903	$444.19
LNA 2	$100	35	35.44068044	5.595854	1.904551	2.848887	$384.89
LNA 3	$50	60	37.7815125	7.936686	2.493643	4.883807	$538.38

G/T	35						
	Cost	Temp	Required G	20log(D)	D	Area	Total Cost
LNA 1	$200	30	49.77121255	19.92639	9.915607	77.21976	$7,921.98
LNA 2	$100	35	50.44068044	20.59585	10.71008	90.08972	$9,108.97

LNA 3	$50	60	52.7815125	22.93669	14.02279	154.4395	$15,493.95

Note the best choice for G/T=20 dB is the 35K LNA but the best choice for G/T=35 is the 30K LNA
For fun: can you find a G/T for which the 60K LNA will be the best choice?

9.18) This problem is similar to 9.17 however we can't know the skynoise value before we solve the problem. Thus we must solve it with both values of skynoise and then choose the one that applies. The calculations will be the same as 9.17 except now to compute the required gain we take
G = G/T + 10*log(T + skynoise)

G/T	25		freq	10		eff	0.7
sky noise	30						
	Cost	Temp T	Required G	20log(D)	D	Area	Total Cost
LNA 1	$100	100	46.139434	7.288453	2.314	4.2066	$520.66
LNA 2	$75	150	47.552725	8.701745	2.723	5.8246	$657.46
LNA 3	$30	170	48.0103	9.15932	2.871	6.4718	$677.18
sky noise	50						
LNA 1	$100	100	46.760913	7.909932	2.486	4.8538	$585.38
LNA 2	$75	150	48.0103	9.15932	2.871	6.4718	$722.18
LNA 3	$30	170	48.424227	9.573246	3.011	7.1189	$741.89

Since all the antenna diameters are >1m the sky noise will be 30K. The best case is the 100K LNA.

9.19) The noise temperature of the receiver affects all the beams, so G/T = 50 dBi – 30 dBK = 20dBi/K.

Chapter 10

10.1) C/N for UL = 28 dB = 631 in linear. C/N for the DL = 15 dB = 31.6 in linear.
C/N total = 1/(1/631 + 1/31.6) = 30.11 = 14.78 dB (answer c). NB if you are clever, you could have guessed c correctly by noticing that a and d are bigger than the DL C/N hence ridiculous, and then noticing that 28 is 13 dB better than 15, hence the UL will only degrade the value below the DL by about 5% in linear… not much :-)

10.3) Lets compute the orbital parameters first, then deal with the RF. We need the elevation angle (because it's requested) AND the distance S (to get the FSL requested). Sat longitude = 330E
ES longitude = 12 E. Δλ = 330 – 12 = 318 degrees. ES longitude = 59N. So
$\cos(\beta_0) = \cos(318)*\cos(59) = 0.387247$, so $\beta_0 = 67.496$ degrees. So $h = \text{atan}((\cos(\beta_0) – R_e/r)/\sin(\beta_0)) = \text{atan}(0.25056) = 14.066$ degrees. $S = (R_e^2 + r^2 – 2*R_e*r* \cos(\beta_0))^{1/2} = 40157.479$ km

Now:
5000W = 37 dBW is the power output of the Tx. The gain of the Tx antenna is
G = 20*log(6) + 20*log(18) + 10*log(.6) + 20.4 = 58.85 dBi So:
EIRP = 37 – 2 + 58.85= 93.85 dBW. NB they are careful to distinguish between waveguide losses (that count toward the EIRP) and path losses (that do not affect EIRP but will decrease C/T).
FSL = 20*log(6) + 20*log(40157.479) +92.45 = 200.09 dB
So RSL before the receive antenna = EIRP – FSL –L = 58.85 – 200.09 – 3 = – 144.24 dBW
So C/T = – 144.24 – 8.6 = – 152.84 dBW/K

The antenna beamwidth is give as 21/(fD) = 21/(18*6) =0.194 degrees
10.5) As with 10.3 above we do the orbital mechanics first and the RF second.
Sat long = 330E, ES long = 12E, ES lat = 32N. So $\Delta\lambda$ = 330 – 12 = 318 degrees.
So $\cos(\beta_0)$= cos(318)*cos(32) = 0.387247, so β_0= 50.933 degrees. So h = atan($(\cos(\beta_0) - R_e/r)/\sin(\beta_0)$) = atan(0.61688) = 31.66968 degrees. S = $(R_e^2 + r^2 - 2*R_e*r*\cos(\beta_0))^{1/2}$ =38464.534 km

Now FSL = 20*log(4) + 20*log(38464.534) + 92.45= 196.19 dB
Actual EIRP = 31 – 8 = 23 dBW So
C/T = EIRP – FSL – L + G/T = 23 – 196.19 – 3 – 8.6 = – 184.79 dBW/K
C/N_0 = – 184.79 + 228.6 = 43.81 dBHz

10.6) W at edge of coverage will be given by W= EIRP – L – 20*log(42164) – 71 which doesn't change with frequency. So:

frequency	edge S	FSL edge	W edge	sub sat	FSL subsat
6	41679	200.41137	-80.3983	35786	199.08729
14	41679	207.77091	-80.3983	35786	206.44682

10.7) This is a little tricky since 325.5E – 60E = 265.5 degrees. But this is silly since we want to go the other way around the earth. So 325.5E = – 34.5E. Now 60 – (– 34.5) = 94.5 degrees which makes more sense. Now from table 10.3:
FSL = 20*log(sin(α/2)) + 20*log(f) + 190.97 = 20*log(sin(47.25)) + 20*log(30) +190.97 = 217.86
W = EIRP – L_{add} – 20*log(sin(α/2)) – 169.52 = 25 – 20*log(sin(47.25) – 169.52 = – 141.84

10.8) C/N = 20 dB = 100 linear. C/I = 15 dB = 31.62 linear.
C/(N+I) = 1/ (0.01 + 1/31.62) = 1/(.04162) = 24.0253 linear = 13.81 dB

10.9)Intermod C/T values add like additional interference so the combined C/T value is given by
C/T = 10*log (1/ ($10^{14.52}+10^{15.62}+10^{14.81}$))= – 157.71 dBW/K

10.10) In each case the UL C/T is at least 10 dB higher than the DL C/T (more than 20 dB in the first 3 columns). This means the comparatively there is very little noise in the UL so the total noise is dominated by the DL noise. Consider : if C/Td = X and C/Tu = 10 + C/Td = X+ 10 then,
10*log(1/($10^{-x} + 10^{-x-10}$)) = 10*log(1/(1.1*10^{-x}))=X – 10*log(1.1) = X – 0.4 dB which is not much of a change… (If there's a 20 dB difference between UL and DL, there will be only .04 dB in total C/T)

10.11)
a) C/N = 10*log(1/ ($10^{-3.21}+10^{-3}$)) = 10*log(1/(0.001616595))= 10*log(618.584)=27.914 dB
b) – 160.0 = 10*log(1/($10^{15.4}$+ 10^{-X})) So: 10^{-16} =1/($10^{15.4}$+ 10^{-X}) So: $10^{16} = 10^{15.4}+10^{-X}$
So: $10^{-X} = 10^{16} - 10^{15.4}$ = 7.48811x 10^{15} so X = – 158.74 = $(C/T)_d$
c)C/N_0 = C/T + 228.6 = 228.6 – 160 = 68.6 From Eqn 9.38: $E_b/N_0 = C/N_0$ – 10*log(R) = 68.6 – 50 = 18.6
d)P = (1/2) exp(-18.6) = 4.18x10^{-9}

10.12) For this problem we run the link budget backwards:
$C/N_0 = E_b/N_0 + 10*\log(R) = 5 + 10*\log(125000) = 55.969$ dBHz
$C/T = C/N_0 – 228.6 = -172.63$
FSL at max distance = 20*log(3.8) + 20*log(41679) + 92.45 = 196.44
EIRP = C/T + FSL – G/T = – 172.63 + 196.44 – 22 = 1.814 dBW
Assuming an efficiency of 0.55, the gain of the transmitting antenna is
G= 20*log(3.8) + 20*log(.1) + 20*log(.55) +20.4 = 9.4 dBi   So the transmitter power is
PTx = 1.814 -9.4 = – 7.585 dBW

10.13) Saying the satellite beam pattern is the same across the earth means that, effectively, every place on earth will see the same EIRP. At edge of coverage we have:
W = EIRP – 20*log(41679) – 71.0 = – 143.0 dBW/m^2 Thus:
EIRP = 20.4 dBW. Now at the subsatellite point:
W= 20.4 – 20*log(35786) – 71.0 = – 141.7 dBW/m^2 which is $6.76x10^{-15}$ W/m^2
So there is a difference of 1.3 dB between the illumination at the subsatellite point and at the edge of coverage. Therefore, I can use a lower gain antenna at the subsatellite point to get the same C/N
The gain of the antenna at the subsatellite point can be 1.3 dB less than at the edge of coverage.
G= 20*log(D) + 20*log(f) + 10*log(.6) +20.4
But assuming the antenna has the same efficiency and is operating at the same frequency, the only thing I'm changing is D. At the edge of coverage:
20*log(D) = 20*log(2) = 6
So at the subsatellite point I only need:
20*log(D) = 4.7
Thus: D = 1.718 m

10.16) If you use the narrowband transponders you can transmit at the saturated EIRP. If you use the broadband (72MHz) transponder, you will need to back off the power to avoid intermodulation between to two carriers. Thus the best solution is the 2 narrowband transponders

10.17) This is a 2 part problem: first you must see if you have enough bandwidth. Then you must see if you have enough power.
For bandwidth, you are currently consuming: 2x10 + 3x2 + 10x0.08 = 26.8 MHz out of 36 so you have 9.4 MHz left which is enough room for 4 additional 2MHz carriers.
For power: your available power is 37 – 7 = 30 dBW = 1000 W
The two 10MHz channels consume 15 dBW = 31.6 W each
The three 2MHz channels consume 20 dBW = 100 W each
The 10 80KHz channels consume 12 dBW = 15.8 W each
So the total is 2x31.6 + 3x100 + 10x15.8 = 521.2 W total so you have 478.8 W left
Which means you can power up to 4 additional 2MHz carriers.

NB: you have more than enough bandwidth to accommodate 100 more 80KHz channels, but only enough power for ~ 30 or so. Also you have enough power to accommodate ~ 15 of the 10MHz channels but not enough bandwidth for even one more!