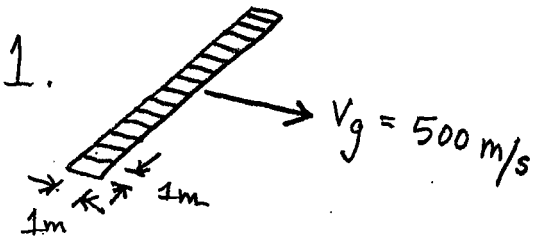
GRAD 590 F Spring 2008 EXAM 1

Time: 75 minutes

1 page of notes allowed (both sides)

Name _____

1. 


The sweep rate of the ground footprint of a linear pushbroom array is shown. The ground dimensions of a single pixel are 1m x 1m. (a) what is the line rate? (b) what is the exposure time/integration time to control image smear?

2. The radiometric design equation is $Q = QE \cdot K \cdot L \cdot \pi \cdot R_a^2 \cdot Te \cdot S^2/H^2$

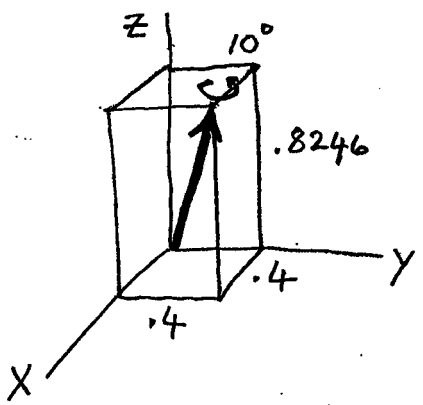
For a focal length of $f = 10$m, and for $R_a = 0.5$m ($D = 2R_a$), the "f-number" is defined as $f/_D = 10$.

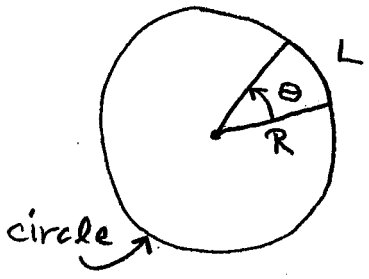
If you wish to change the aperture to <u>double</u> the energy on the detector (a) what is the new aperture?, (b) what is the new f-number?

3. The resolving power of an optical system is $\beta = \frac{1.22\lambda}{D}$.

For green light ($\lambda = 550$ nm) what is the aperture diameter needed to resolve features of 1 cm at altitude of 600 km? (Assume diffraction limited)

4. For a rotation of $\Theta = 10°$ about an axis with components as shown, show its representation as a quaternion:

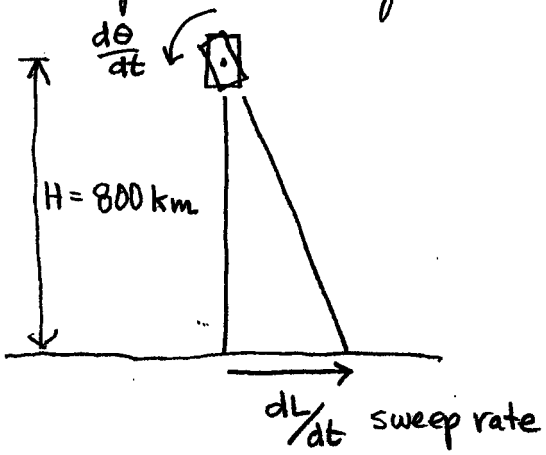


5. 


(a) write L in terms of R and θ

(b) What is $dL/dt$ for constant R ?

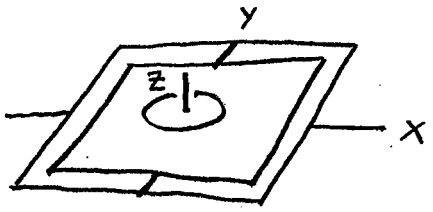
Using the above results, and assuming a Stationary satellite camera, what is the angle rate needed to produce a ground sweep rate of 500 m/s




6. (a) Cross track resolution (GSD) for a pushbroom camera is determined by _____

(b) Along track resolution (GSD) for a pushbroom camera is determined by _____

(c) Which of the kepler elements $\Omega, \omega, i, a, e, f$ become(s) indeterminate for a circular, 2-body orbit ?

(d) 


For the shown mechanical gimbal, what rotation causes two other axes to become collinear, yielding gimbal lock ?

(e) Why do we get polar motion parameters from a web-site rather than a formula ? _____

# GRAD590F Spring 2008 Exam 1
## SOLUTION

1. sweep rate = 500 m/s, 1m pixel

(a) line rate = 500 lines/sec or 500 Hz

(b) $T_l = \frac{1}{500} = 0.002$ sec, $T_e = \frac{1}{2}(0.002) = \underline{0.001}$

also $t < \frac{s}{2V_g}$, $\frac{1}{2 \cdot 500} = 0.001$

2. $Q = QE \cdot K \cdot L \cdot \pi \cdot R_a^2 \cdot T_e \cdot s^2/H^2$ (note: "L" missing from stated equation, but result same)

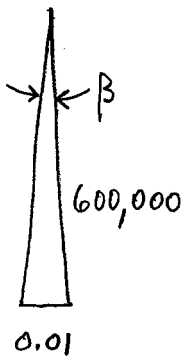
$f = 10m$, $R_a = 0.5m$, $D = 1.0m$, $f/D = 10$

want new $R_a'$ such that $(R_a')^2 = 2(R_a)^2$

That will double Q, if others are constant

$R_a' = \sqrt{2} R_a$, $R_a' = 1.414 \times 0.5 = \underline{0.707}$

$D' = 0.704 \times 2 = 1.414$, $f/D' = \underline{7.1}$

3. 


$\beta = \frac{1.22\lambda}{D}$, $\lambda = 550nm$, solve for unknown D

$\beta = \frac{0.01}{600,000} = \frac{1.22 \cdot 550 \times 10^{-9}}{D}$

$D = \frac{1.22 \cdot 550 \times 10^{-9}}{1.667 \times 10^{-8}} = \underline{40.25}$ m

4. $\Theta = 10^\circ$

$\alpha = .4$

$\beta = .4$

$\gamma = .8246$

$\alpha^2 + \beta^2 + \gamma^2 \approx 1$

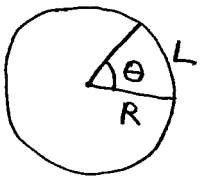
So these are <u>direction Cosines</u>

$q_s = \cos \Theta/2 = 0.99619$

$$\begin{bmatrix} q_i \\ q_j \\ q_k \end{bmatrix} = \sin \Theta/2 \begin{bmatrix} \alpha \\ \beta \\ \gamma \end{bmatrix}$$

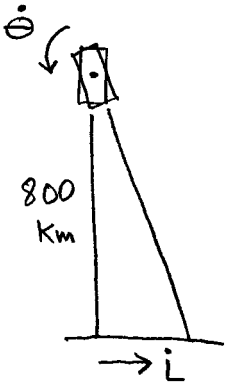
$$\begin{bmatrix} q_s \\ q_i \\ q_j \\ q_k \end{bmatrix} = \begin{bmatrix} 0.99619 \\ 0.03486 \\ 0.03486 \\ 0.07187 \end{bmatrix}$$

length $\approx 1$

5. 


$L$: arc length, $\frac{L}{R} = \theta$ (radians), $L = R\theta$

$$\frac{dL}{dt} = R\frac{d\theta}{dt}, \quad \dot{L} = R\dot{\theta}$$

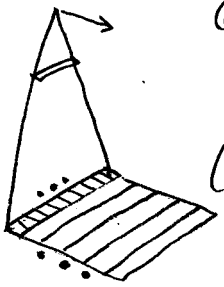



$\dot{L} = R\dot{\theta}$, $500\ m/s = 800{,}000\ m \cdot \dot{\theta}$

$$\dot{\theta} = \frac{500\ m/s}{800{,}000\ m} = 0.000625\ Rad/sec$$

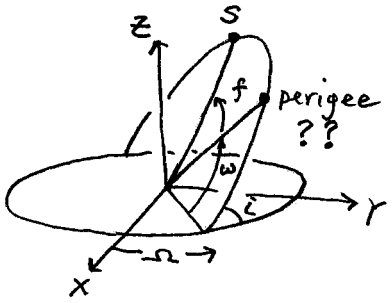
$$= 0.0358\ deg/sec$$

$$= 128\ arcsec/sec$$

6. 

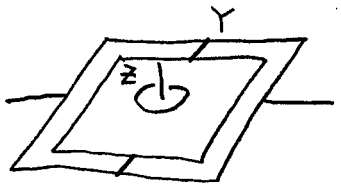
(a) cross track GSD determined by: optics, H, f, detector size

(b) along track GSD determined by: ground sweep rate and line rate (clock, sampling), sweep rate from velocity, slew rate, and H

(c) 


ω and f become <u>indeterminate</u>

e becomes zero, that is not indeterminate

(d) 


+/- 90° on Y-axis causes X and Z axes to become coincident = gimbal lock

(e) polar motion has <u>significant</u> <u>irregular</u> <u>components</u>, in addition to regular ones, therefore cannot be completely modeled.