1. Briefly explain the difference between true north and magnetic north (5%).

2. The included angles given below are recorded at stations forming a closed traverse survey around the perimeter of a field. Determine the amount of angular error in the survey and adjust the values of the included angles. If the azimuth of the line BC is 45° calculate the azimuths of the traverse lines and the corresponding values in the centesimal system (15%).

Station	Included angle (degree-minute-second)
A	122-42-20
B	87-16-40
C	133-08-20
D	125-55-20
E	92-47-40
F	158-06-40

3. In a geodetic survey the mean angles in the following table were observed in one triangle, each having been observed the same number of times under similar conditions. Side AB was known to be 37,269.280m long. Estimate the corrected values of the three angles. Take the radium of the earth to be 6383.393 km (15%).

Station	Mean value (degree-minute-second)
A	62-24-18.4
B	64-56-09.9
C	52-39-34.4

4. GPS phase observations are used for precise kinematic and static positioning.
   (a) How double-differenced phases can eliminate (remove) satellite clock error and receiver clock error? Use equations to assist your answer. (10%)
   (b) How triple-differenced phases eliminate (remove) integer ambiguities? (10%)

5. Let I_n, $_nP_n$, $_nA_m$ be matrices and the subscripts denote the numbers of rows and columns). Show that the following matrix is idempotent: (15%)

$$I - PA(A^T PA)^{-1} A^T$$

6. The 2D projective transformation (i.e. Equation 1) describes the geometrical transformation between two coordinate systems using 8 parameters. The coordinates of control points P_1 to P_n are $[(u_1,v_1), (x_1,y_1)]$, $[(u_2,v_2), (x_2,y_2)]$, ... $[(u_n,v_n), (x_n,y_n)]$. Please answer the following questions :

$$u = \frac{a+bx+cy}{1+gx+hy} \; ; \; v = \frac{d+ex+fy}{1+gx+hy} \tag{1}$$

   (a) Please provide all the **details** of calculating these 8 parameters (i.e. $a \sim h$) using least squares adjustment. (20%)
   (b) How to assign the initial values (i.e. $a_0 \sim h_0$)? (10%)

Physical Geodesy

1. 地球的重力位通常以球面諧和函數級數展開的方式表示，但球面諧和函數是一個定義在緯度 0 到 180 度完整球面的函數。若我們只在台灣這樣 3°X3°的區域內蒐集重力觀測數據，實務上我們要如何建立這樣一個區域的重力位模型？請用球諧級數表示的概念說明。(25%)

2. 在建立大地起伏模型時，我們為何要將重力異常資料進行諸如質量移除，自由空間移動這樣的改正？請解釋何謂間接效應(indirect effect)？請就布格重力異常(Bouguer anomaly)，自由空間異常(free air anomaly)兩種重力異常討論其間接效應的影響。(25%)

3. 台灣的高程基準以基隆潮位站 18.6 年平均海水面當作高程起算面，這樣的定義在與全球或離島高程基準連結時會有甚麼問題？該如何解決這些不同基準系統連結的問題？又若我們將新竹海邊南寮的潮位站也當作起算基準，會有甚麼潛在的問題?(25%)

4. 衛星測高資料可計算海水面的橢球高(ellipsoidal height)，請說明用衛星測高資料計算重力異常的原理，並討論測高資料空間取樣率，平均海水面，與計算重力異常的潛在系統誤差。又若我們欲將測高資料計算的重力異常與陸地上的重力資料整合，會遇到甚麼潛在的問題？該如何克服? (25%)

Satellite geodesy

Time: 60 minutes

Open book

1. Explain the relationships between the following time systems: LAST, GAST, LMST and GMST. (20%)

2. Use the expression of the rotational velocity of right ascension due to the earth's flattening)

$$\frac{d\Omega}{dt} = C_{20} \frac{3na_e^2}{2a^2 (1-e^2)^2} \cos i$$

to explain how the altitude of a sun-synchronous orbit is determined for a given inclination angle (*i*). You need to show all the parameters in this expression. (20%)

3. DORIS is a French positioning system widely used in satellites launched by the European Union. Compare DORIS and GPS. (20%)

4. Use the following figure to explain how waveform retracking in satellite altimetry works. (20%)
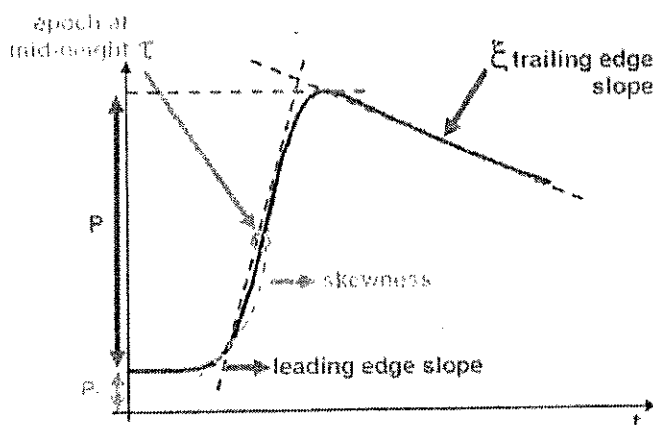
5. Use a diagram to explain the following terms about InSAR. (20%)
   (a) Interferometry
   (b) LOS range change
   (c) Perpendicular baseline
   (d) Parallel baseline