UNIVERSITY OF PETROLEUM & ENERGY STUDIES

End Semester Examination – December, 2017

Program/course: B.Tech GSE/GIE **Semester : VII**

Subject: Geophysical Data Acquisition, Processing & Interpretation **Max. Marks : 100**
Code : GSEG-402 **Duration : 3 Hrs**
No. of page/s: 05

SECTION A: Answer all the questions. **[4*5=20 marks]**

1. The gravity measured at the base of a 10m tall building is 40 mGal. What will be the value at the top of the building ignoring the mass of the building?
2. Compute the maximum value of gravity anomaly in μGal over a buried sphere from the following data:
   Radius of a sphere = 5 m   Depth to centre of sphere =11 m
   Density contrast = 0.1 gm/cc   G = 6.673×10^{-8} dyne-cm^2/gm^2
3. What are the values of Bouguer correction and free air correction at a point from which datum has an elevation of 200 m and a density contrast of 0.2g/cc?
4. What type of 3-layer master curve will form for a subsurface having dry soil on the top followed by a saline water aquifer and igneous rock as a basement?

SECTION B: Answer all the questions. **[4*10=40 marks]**

5. a.A small scale seismic reflection survey was conducted with a shot point located at the middle of a 500 m long geophone spread. The NMO-corrected travel times at the end of the spread were found to be 1.227 s and 1.255 s. If the average seismic wave velocity above the reflector is 2500 m/s, what is the dip of the reflector?
   b. The following table shows a series of measurements made with Wenner configuration over a layered Earth. [06 marks]

a (m)	5	10	20	30	40	60	80	100	150
Rho(ohm-m)	1.0	1.0	0.6	0.2	0.2	0.5	0.7	0.8	0.8

i. Does the data represent electrical sounding or profiling?
ii. Which type of 3 layer curve do the data represents?

6. a. Prove that the sensitivity of a gravimeter is proportional to the square of the time period of oscillation. [03 marks]
   b. Derive an expression for gravity anomaly due to a spherical body. A spherical body with its center located at a depth of 1040 m gives a symmetric residual gravity anomaly high with Δg_{max} = 5.2 mGal. If the same anomaly were to be obtained over a 2-D horizontal cylinder, what will be the depth to the centre of the horizontal cylinder (in m)? [03+04 marks]
7. Using Ohm's law derive an expression for the apparent resistivity for the 4 electrode configuration with constant electrode spacing between two consecutive electrodes
8. What do you understand by DHIs? Briefly explain any three types of seismic DHIs with proper illustration.

<u>SECTION C:</u> Answer all the questions. **[5*08= 40 marks]**

9. **<u>Full-Wave Spectrum: P and S Waves</u>**

Conventional seismic surveys use compressional or pressure (P) waves to penetrate the earth and sea and reflect back data on the strata and structures these energy waves' encounters. When these waves become disturbances propagating through the body of a medium, they either remain compressional waves (P waves) or are converted into shear waves (S waves).

Compressional waves occur when a liquid, solid or gas is sharply compressed. The compression sets off small particle vibrations in the same direction that the compressional waves are traveling. Shear waves, on the other hand, are waves of shearing action and occur only in solids. In shear waves, the small rock particle motion is perpendicular to the direction of wave propagation. They may be generated by a seismic source in contact with a rock formation or by the non-normal incidence of P waves on rock. The generation of S waves from a reflected P wave is called mode conversion. It is slight for small incident angles and becomes more pronounced as the offset increases.

The velocity at which these waves travel is controlled by the mechanical properties of the rock, its density and elastic dynamic constants. In fluid- saturated rocks, these properties depend on the amount and type of fluid present, the composition of the rock grains and the degree of inter grain cementation, formation pressure and temperature. Soft, loosely consolidated rocks are generally less rigid and more compressible than hard, tightly consolidated rocks. As a result, P and S waves travel slower in soft rock than in hard. Extremely unconsolidated rocks support only weak shear- wave propagation

P waves and S waves propagate through rock and reflect differently at interfaces. A P wave reflecting as a P wave, called a P-P reflection, is symmetric about the point of reflection at the common midpoint (CMP) halfway between the source and receiver. A P-S reflection is asymmetric at the point of reflection, called the common conversion point (CCP), which is different from the CMP. The difference in reflection points must be taken into account through processing.

The combination of P- and S-wave data rather than P-wave alone can yield previously unavailable information about fluids in the pore spaces and improve the potential for identifying the prospect lithology. Because gas in a formation causes the compressional velocity to slow but has little effect on shear waves, the combination of compressional and shear measurements helps in identifying gas-related amplitude anomalies. In addition, S-wave data are also able, in some cases, to image structures that P waves cannot adequately portray, such as reservoirs with gas clouds in porous rocks above the reservoir.

Until recently, P and S waves could be acquired simultaneously only onshore, but with the advent of ocean-bottom cable (OBC), both can be obtained. Although the marine seismic source continues to generate only P waves, once those waves have reflected off deep strata, they may be converted and propagate upward as S waves. The new 4Cseabed cable system is in contact with the ocean floor and can record both waveforms.

Explorers don't select a drill-site based on intuition and the whim of the party boss any more. Nor are today's seismic shoots simple exercises in geometry; considerable geological and geophysical input goes into the planning of a modern survey. The information obtained in a full wave spectrum survey (recording of both P wave and S-wave) survey complements that from P waves in eight ways. First, because S waves are relatively unaffected by pore fluids, including gas, they can be used to obtain structural and stratigraphic information in areas where the presence of such fluids precludes coherent images from P waves only. Targets below gas chimneys and gas clouds are notoriously difficult to image with P waves, and S waves have been highly successful in this application.

Second, S waves yield independent information about rock properties, allowing more complete prediction of both fluid type and rock lithology. When only P waves are recorded in a seismic section, it is frequently difficult to discern whether a detected direct hydrocarbon indicator event is due to the presence of hydrocarbons or is simply due to lithologic changes. Shear-wave data lessen this difficulty considerably when acquired simultaneously with P-wave data. In areas where P-wave data produce amplitude anomalies and the S-wave data do not, the presence of hydrocarbons is likely. If the anomaly is observed in both S-wave and P-wave data, it is most likely either a diagenetic or lithological phenomenon. The ratio of P-wave to S-wave velocities, VP/VS, is often used to predict lithology, and the P-wave amplitude to the S-wave amplitude ratio may turn out to help predict fluid- saturation differences.

Third, in deepwater acquisitions, the triple- sensor nature of the geophone data provides a unique opportunity for demultiple processing. Shear waves contribute another velocity function to use in distinguishing between multiples. Since shear waves produce multiples themselves that are similar to those produced by P waves, this helps the interpreter sort the principal reflections from the multiples to image more accurately.

Fourth, by acquiring both P and S waves, explorationists expect to illuminate shadow zones beneath high-velocity salt structures. Because the ray-paths bend at a boundary of two different velocities, and salt bodies often have irregular boundaries, shadow zones, areas with no reflections, are created. By using both P and S waves, some of the shadow zones of one are illuminated by the other. Therefore, better structural and stratigraphic images can be achieved beneath salt.

Fifth, variations in seismic velocities, both P-wave and S-wave, may help identify different lithologies. The use of interval travel- time ratios, Ts/Tp—related to but easier to measure than interval Vp/Vs—over a relatively small time window in the seismic data, may indicate lateral or vertical changes in lithology and pore fluid type. Further, the use of these ratios, in conjunction with seismic facies interpreted from reflection patterns, provides a relatively powerful way to begin inferring lithologic information at a scale more detailed than most seismic velocity models. Sixth, experience with a few situations in the North Sea has shown that some reservoirs have low P-wave reflectivity while having relatively high P-to-S mode-conversion capabilities. Therefore, these reservoirs, which cannot be seen at all on P-wave data, become visible using the mode-converted shear waves. An extension of this idea leads to the conclusion also that by acquiring both P and S waves, seismic information and log and core data can be correlated more convincingly, and perhaps explains why correlation has been difficult in some areas.

Seventh, a stationary acquisition system like the Nessie 4C MultiWave Array permits true 3D acquisition, meaning complete offset and azimuth distributions within the data. Towed 3D surveys, while providing coverage of a 3D volume, do so with a series of essentially 2D traverses, as the source is in line with the receiver cable. By acquiring P and S waves propagating in all azimuths, velocity anisotropy (the variation of a property with direction) of P and S waves may be determined. Velocity anisotropy can be especially pronounced in S waves, and depending on the type and amount, can be used to help discriminate rock types, detect source rocks and identify principal fracture directions. For example, shales are often highly anisotropic, displaying transverse isotropy wherein the vertical velocity is different from the horizontal velocity. Sometimes this can be observed in 4C seismic data, and could indicate a shale, suggesting the existence of what is a common sealing formation for many stratigraphic traps. Velocity anisotropy is also an important consideration when processing surface seismic data for stratigraphic interpretation, as small errors in velocity can impact the resolution of the final seismic image.

An eighth benefit of acquisition with the Nessie 4C MultiWave Array is it allows for the calibration of AVO (amplitude variation with offset) analysis derived from streamer survey data. An AVO effect occurs when the reflection coefficient at an interface changes as a function of distance between source and receiver. When P-wave energy strikes a particular interface, some of it will be transmitted as P waves and some will be reflected as P waves, while some of the energy will reflect as S waves and be transmitted as S waves. Some lithology-fluid combinations generate dramatic AVO effects, and the observed AVO signatures, or anomalies, can be diagnostic of hydrocarbons. But these effects are not seen in conventionally processed seismic data, because the processing step of stacking averages amplitudes from traces at different offsets.

If an AVO effect is suspected, the seismic data can be processed to preserve and high- light rather than average amplitude variations. The data can also be visualized in 3D cubes in the same way stacked data are visualized. But in this case there would be multiple cubes: one for near-offset data, one for medium offsets and one for far offsets. A multitude of 3D cubes can be produced, limited only by how much offset information is captured in the analysis. Geco-Prakla scientists have created as many as 23 different offset ranges for a survey. Once an AVO anomaly has been detected, it needs to be interpreted to identify the rocks and fluids that created it. This is done by generating models and comparing observed AVO effects to the modeled ones. Most models contain information from P waves alone, and the shear-wave velocities required for the model are extrapolated from distant well logs or inferred from empirical transforms relating P to S velocities. Shear-wave velocities extracted from Nessie 4C MultiWave Array data provide crucial input for construction of the models and allow for more reliable interpretation of lithology and fluids in the trap.

Answer the followings questions based on above case study:

a. “In areas where P-wave data produce amplitude anomalies and the S-wave data do not, the presence of hydrocarbons is likely.”- Justify the statement.
b. “The P-wave amplitude to the S-wave amplitude ratio may turn out to help predict fluid-saturation differences”- Explain how this amplitude ratio can be linked with the hydrocarbon saturation and fluid type?
c. What do you understand by mode conversion? Why mode conversion is more pronounced as the offset increases?
d. What do you understand by stacking of seismic data? Explain the effect of stacking on the AVO anomalies.
e. What is Poisson’s ratio? How it can be determined from the velocity of P and S-wave? What happens to the value of Poisson’s ratio with the presence of gas in the reservoir zone?

SET-2 Roll No: --------------------------

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SECTION A: Answer all the questions. **[5*4=20 marks]**

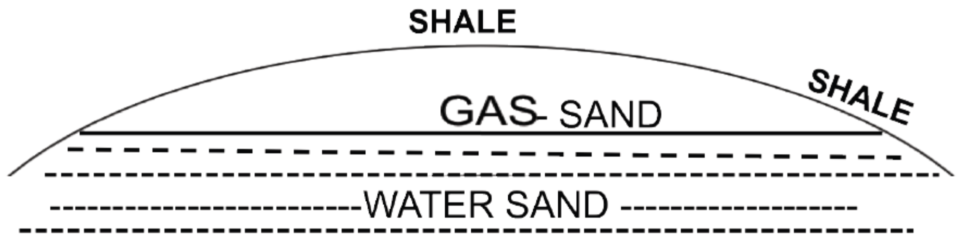
1. Briefly explain what causes pull up in the seismic section? Can a pull up be used as a DHI?
2. Which type of 4 layer master curve will form for the given sequence also give the relationship between the resistivities

Dry Soil
Wet soil
Hard rock
Saline water aquifer

3. The gravity observations taken from the base and the roof of a building by suspending the gravimeter in free air are 0.825 mGal and 0.805 mGal. What is the height of the building?
4. What do you mean by seismic attribute? Give an example of seismic attribute and its utility.

SECTION B: Answer all the questions. **[4*10=40 marks]**

5. What do you mean by free air correction and derive an expression for it? Calcuate the thickness of the granite (2650 kg/m^3) required to give an Bouguer anomaly of 10 mGal assuming country rock density as 2750 kg/m^3
6. Derive an expression for acceleration due to gravity for a spherical body. A spherical cavity of radius 8 m has its centre 15 m below the surface. If the cavity is full of sediments of density 1.5×10^3 kg/m3 and is in a rock body of density 2.4×10^3 kg/m3. What is the maximum value of its gravity anomaly in mGal?.
7. What are DHIs? For the model given below sketch a stack seismic response showing appropriate DHI's.



8. What is a difference between electrical sounding and profiling? Briefly explain how sounding can be done in the field using 4-electrodes in Wenner configuration.

SECTION C: Answer all the questions. **[20*2= 40 marks]**

10. A gravity survey is conducted over a highly compacted ore deposit (spherical shape). Bouguer anomaly values reduced along a profile are given below.
    a. What is the depth to the center of ore deposit?
    b. What is excess mass in metric tons by the deposit?

Distance (m)	Gravity anomaly (mGal)	Distance (m)	Gravity anomaly (mGal)
0	0.75	2400	35.0
200	1.01	2600	16.80
400	1.41	2800	8.85
600	2.05	3000	5.07
800	3.13	3200	3.13
1000	5.07	3400	2.05
1200	8.85	3600	1.41
1400	16.80	3800	1.01
1600	35.00	4000	0.75
1800	70.80		
2000	99.0		
2200	70.8		

9. a. Draw the all four types of 3-layer master curve for electrical sounding? [04 marks]
   b. Derive an expression for apparent resistivity using 4-electrode configuration for Wenner configuration. [10 marks]
   c. The following table shows a series of measurements made with Wenner configuration over a layered Earth. [06 marks]

a (m)	5	10	20	30	40	60	80	100	150
Rho(ohm-m)	1.0	1.0	1.2	1.6	1.6	1.2	1.1	1.1	1.1

i. Does the data represent electrical sounding or profiling?
ii. Which type of curve do the data represents?

OR

a. Derive an expression for apparent resistivity using 4-electrode configuration for Schlumberger configuration. [10 marks]
b. What type of 3-layer master curve will form for a subsurface having dry soil on the top followed by a saline water aquifer and igneous rock as a basement? [05 marks]
c. In Wenner configuration a current of 50mA is passed through a current electrodes and a voltage of 10V is measured across the potential electrodes. What is the apparent resistivity if the spacing between the current electrodes is 90 m. [05 marks]