Name: _____

Student Number:_____

YORK UNIVERSITY
FACULTY OF SCIENCE AND ENGINEERING

SC/EATS 1010 3.0

THE DYNAMIC EARTH AND SPACE GEODESY

FINAL EXAM - December 15, 2011
Duration: 2 Hours

[Total Marks = 150]

PART A: Multiple Choice (50 marks)

Circle the letter beside the **most correct** answer. Each answer is worth 1 mark.

1. The radius of the Earth is :
   a. 700 km
   b. 3,000 km
   c. 3,500 km
   d. 6,400 km
   e. 2,900 km.

2. Examples of strike-slip faults are:
   a. normal and reverse faults
   b. transform faults
   c. normal and transform faults
   d. transcurrent and reverse faults
   e. all of the above

3. The "Ring of Fire" about the Pacific Ocean results from:
   a. the San Andreas Fault
   b. subduction zones
   c. east Pacific M.O.R.
   d. aboriginal campfires at the summer solstice.
   e. none of the above.

4. An earthquake with a Richter magnitude of 8.3 has more energy than an earthquake with a magnitude of 6.7 by a factor of :
   a. 12
   b. 15
   c. 32
   d. 125
   e. 251

5. The lava erupting at diverging plate boundaries is:
    a. Basalt
    b. Andesite
    c. Granite
    d. Olivine.
    e. Pyrolite

6. The height of mid-ocean ridges is due to:
    a. the build up of basaltic volcanism
    b. thermal contraction of cooling lithosphere
    c. unknown forces
    d. pressure release melting at the ridge crest.
    e. plate tectonics

7. 3500 km is the thickness of:
    a. the combined continental and oceanic crust.
    b. the mantle
    c. the outer core
    d. the combined inner and outer core.
    e. the lower mantle

8. GIS data input is usually in the form of:
    a. raster input for linear features like roads and rivers
    b. vector input for linear features like roads and rivers
    c. raster input for digital elevation
    d vector input for digital elevation
    e. both b and c.

9. 1200 km is the thickness of:
    a. the combined continental and oceanic crust.
    b. the mantle
    c. the outer core
    d. the combined inner and outer core
    e. none of the above

10. The temperature at the core-mantle boundary is approximately:
    a. 580 C
    b. 1,300 C
    c. 3,000 C
    d. 5,000 C.

11. The highest resolution satellite imagery available commercially is from the satellite:
    a. IKONS
    b. Quickbird-1
    c. Quickbird-2
    d. Google Earth-Sat 1
    e. Landsat 2

12. A Benioff zone is:
    a. another term for a subduction zone
    b. any linear zone of seismicity
    c. the zone of maximum bending in a sinking plate
    d. another term for a shearing fault zone.
    e. none of the above

13. The age of the planets of the Solar System is approximately:
    a. 4.6 million years
    b. 0.6 billion years
    c. 200 million years
    d. cannot be estimated
    e. None of the above.

14. GPS satellites transmit the following signals:
    a. navigation signals, time signals and ground control updates
    b. navigation signals, time signals and amplitude modulated carrier signals
    c. time corrections for the ground control stations, navigation signals and distance from GPS receivers
    d. distance from the GPS receiver, orbit information and demodulated carrier signals
    e. navigation signals, time signals and frequency modulated carrier signals.

15. A viscous material:
    a. deforms slowly when a force is applied but will later return to its original shape
    b. experiences no net displacement of internal particles when a deforming force is applied
    c. deforms when a force is applied and remains fractured after the force is removed
    d. experiences no displacement of internal particles within broken fragments
    e. deforms no matter how small the applied force is.

16. A brittle material:
    a. behaves viscously on long time scales but elastically on short time scales
    b. experiences no net displacement of internal particles once a stretching force is removed
    c. experiences no net displacement of internal particles when a deforming force is applied
    d. experiences no displacement of internal particles within broken fragments.
    e. does not respond to applied forces.

17. The lava erupting at converging plate boundaries is:
    a. Basalt
    b. Andesite
    c. Granite
    d. Olivine.
    e. Pyrolite

18. The number of fully operational GPS satellites currently in orbit is:
    a. 24
    b. 28
    c. 32
    d. 38
    e. 44.

19. In photogrammetry, relief displacement on a photograph is:
    a. a correction for orientation of the aircraft
    b. required to rectify a digital aerial photograph
    c. required to produce an orthophotograph
    d. made using the x-parallax from a pair of overlapping photgraphs
    e. a correction for scale variations resulting from surface topography.

20. Which of the following is not normally located at a converging plate boundary:
    a. mid-ocean ridge
    b. ocean trench
    c. island Arc
    d. deep earthquakes
    e. all of the above.

21. Continents stand higher than ocean basins because:
    a. continental crust is thicker than oceanic crust
    b. continental crust has a lower density than oceanic crust
    c. continental crust is thicker and has a higher density than ocean crust
    d. continental crust is thicker and has a lower density than oceanic crust
    e. none of the above.

22. The study of ancient magnetic fields is known as:
    a. Geomagnetism
    b. Electromagnetism
    c. Hydromagnetism
    d. Paleomagnetism
    e. Polar Wandering.

23. High quality satellite imagery:
    a. has a resolution of 60 cm/pixel
    b. is taken from heights of 22,000 km
    c. is a secondary use for GPS satellites
    d. is taken from geostationary satellites over strategic Earth locations
    e. is incorporated into a GIS in vector format

24. Rheological boundaries within Earth are:
    a. at the base of the lithosphere and between the inner and outer core
    b. at the base of the crust and at the core-mantle boundary
    c. at the base of the mantle
    d. at the base of the lithosphere
    e. between the upper and lower mantle and between the inner and outer core.

25. The basic formula for the baseline measurement, b, using the VLBI technique, in terms of the speed of light, c, the orientation of the radio telescope antennae, θ, and time delay, Δt, is:
    a. $b = c\,\Delta t\,\cos\theta$
    b. $b = c\,\Delta t / \cos\theta$
    c. $b = c\,\cos\theta\,/\Delta t$
    d. $b = \Delta t\,\cos\theta\,/c$
    e. $b = \cos\theta\,/c\Delta t$.

26. The mass of the Sun is greater than the mass of Earth by a factor of:
    a. 10,000
    b. 33,000
    c. 100,000
    d. 330,000
    e. 1,000,000.

27. The distance from the Sun to its nearest neighbouring star, Proxima Centauri, is:
    a. 4.27 light years
    b. 7,000 AU
    c. 1.30 light years
    d. 10 billion km
    e. 1.3 million light years.

28. At Earth's surface the geomagnetic field looks like a magnetic dipole:
    a. aligned precisely with the Earth's rotation axis
    b. reversed from a normal orientation due to periodic reversals
    c. whose north pole coincides with the geographic south pole
    d. which is tilted relative to the rotation axis by 11 degrees
    e. whose south pole lies at a latitude of 89^0 S.

29. The accuracy of VLBI baseline measurements depends critically on precision timing. Clock accuracy required to obtain baseline measurements accurate to within 3 mm is:
    a. 3 ns(nanoseconds)
    b. 3 μs (microseconds)
    c. 0.1 ms (milliseconds)
    d. 1.0 ps (picoseconds)
    e. 5 ps (picoseconds).

30. The rheology of the mantle is temperature dependent such that:
    a. a small increase in temperature causes a small increase in viscosity
    b. a small decrease in temperature causes a large increase in viscosity
    c. a small decrease in temperature causes a large decrease in viscosity
    d. a small increase in temperature causes a large increase in viscosity
    e. a small decrease in temperature causes a small decrease in viscosity.

31. Earth's magnetic field looks as if it were being produced by a giant bar magnet at the centre of the Earth. We know this cannot be true because:
    a. variations in dip and declination angles rule out permanent magnetization of Earth's core
    b. there are no magnetic minerals in the Earth's core
    c. temperatures in the Earth's core exceed the Curie temperature
    d. temperatures in Earth's core are less than the Curie temperature
    e. we cannot imagine how it could have been placed there.

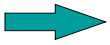
32. The Carbon-14 age dating method:
    a. is good for measuring ages from 500 - 70,000 years
    b. cannot date igneous rocks
    c. involves dating the time of death of organic material
    d. has a half life of 5,730 years
    e. all of the above

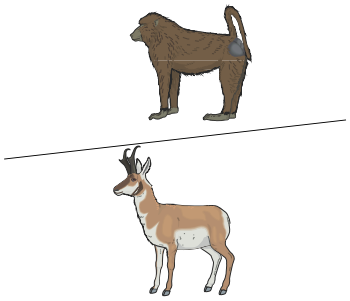
33. Internal circulation within the Earth involves:
    a. rising cool dense material
    b. sinking hot light material
    c. rising hot light material
    d. sinking hot dense material
    e. rising cool light material.

34. There are only a few signs of impact craters on Earth because:
    a. Earth escaped early bombardment from space
    b. the Moon acted as a shield for Earth
    c. plate tectonic recycling of the surface subducted all ancient craters
    d. geological activity has erased almost all evidence on continents
    e. all of the above.

35. The Rubidium atomic clock has an accuracy of 1 part in 10^{12}. Thus it will lose one second of time after:
    a. 30 years
    b. 300 years
    c. 3,000 years
    d. 10^{12} seconds
    e. 1 light year.

36. Historical variations of Earth's magnetic field:
    a. indicate that the inclination and declination of the magnetic field at any point on the Earth's surface have varied by tens of degrees in historical times
    b. indicate that the inclination and declination of the magnetic field at any point on the Earth's surface have varied by tens of degrees in pre-historic times
    c. are the cause of apparent wandering of the magnetic poles
    d. refer to periodic reversals of the north and south poles
    e. all of the above.

37. Consider the strike-slip fault shown here: 
    If this is a Left Lateral Fault,
    a. the baboon and antelope must both move to the left
    b. the baboon moves to the left and the antelope moves to the right
    c. the baboon moves to the right and the antelope moves to the left
    d. the baboon is confused by the antelope moving to the right.
    e. the antelope moves to the left but the baboon thinks the antelope is moving to the right.



38. Although transform faults occur at many locations along mid-ocean ridges, strike-slip motion at each location only occurs:
    a. parallel to the ridge crests
    b. as the spreading sea floor approaches a trench
    c. when the boundaries are convergent
    d. when there are deep focus earthquakes
    e. between the ridge segments.

39. An earthquake is:
    a. a classic example of brittle fracture with no elastic deformation
    b. a randomly occurring fracture of the Earth's lithosphere
    c. unlikely to occur in the same location more than once, since all the stored energy has been released
    d. an instantaneous release of stored elastic energy
    e. a classic example of elastic deformation.

40. Since earthquakes are usually a consequence of plate motion, we expect that after one earthquake occurs in a given location, any future earthquake in the same location:
    a. is unlikely
    b. is likely to be much weaker
    c. will cause ground motion in the same direction
    d. will be predicted accurately so that citizens can be evacuated
    e. will have no effect on local communities since earthquake resistant technology is now used for construction in these areas.

41. The epicentre of an earthquake is:
    a. the point where there is greatest damage to buildings
    b. the point on the surface immediately above the earthquake focus
    c. the point where there is the greatest loss of life
    d. the emergency centre set up after a local earth quake
    e. the point where the first break across the fault plane occurs.

42. Seismic S-waves:
    a. cause the most damage from earthquakes
    b. are the last to arrive at a seismograph
    c. resemble water waves
    d. originate at the earthquake epicentre
    e. cause vibrations perpendicular to their direction of propagation.

43. Earthquakes occur:
    a. frequently in the middle of tectonic plates
    b. at all plate boundaries
    c. only at diverging plate boundaries
    d. at diverging and converging boundaries but not at shearing boundaries
    e. at all depths less then 970 km.

44. The theory explaining the occurrence of, and ground motion during, earthquakes is known as:
    a. elastic rebound
    b. glacial rebound
    c. isostatic rebound
    d. fracture theory
    e. the principle of uniformity.

45. Magnetic stripes on the seafloor are:
    a. symmetric about M.O.R. s
    b. due to reversals of Earth's geomagnetic field
    c. produced at M.O.R.s
    d. all of the above
    c. none of the above.

46. GPS satellites have their navigation and timing information updated by:
    a. 4 ground control stations and one master control station
    b. 4 ground control stations of which one is the master control station
    c. Houston ground control center
    d. neighbouring GPS satellites
    e. navigation timing and ranging satellites.

47. Examples of dip-slip faults are:
    a. normal and reverse faults
    b. transform faults
    c. normal and transform faults
    d. transcurrent faults
    e. all of the above

48. Atomic clocks onboard all GPS satellites allow precisely synchronized signals to be generated. The accuracy of the Cesium atomic clock is:
    a. 1 part in 10^{9}
    b. 1 part in 10^{12}
    c. 1 part in 10^{13}
    d. 1 part in 10^{14}
    e. 1 part in 10^{15}.

49. The two carrier frequencies transmitted by GPS satellites are:
    a. Pseudo Random Number sequences
    b. AM and FM
    c. 1575 MHz and 1228 MHz
    d. 1528 MHz and 1275 MHz
    e. 1645 MHz and 1445 MHZ.

50. An inertial, or fixed, reference frame for measurements of motions in space is provided by:
    a. NAVSTAR GPS
    b. Transit
    c. VLBI
    d. Quasars
    e. LLR.

PART B: True or False (40 Marks) - Circle T for True or F for False

FOR PART B USE (a) FOR TRUE AND (b) FOR FALSE on the scantron forms

51. Deep seismicity at subduction zones reveals earthquakes at all depths down to the core-mantle boundary. T F

52. Geospatial data can be in the form of qualitative attributes. T F

53. Geographic coordinates are stored for each pixel of raster data in a GIS. T F

54. The VLBI baseline measurement technique depends on maximizing the cross-correlation of radio signals from two widely separated optical telescopes. T F

55. The lithosphere includes both the crust and the outermost cold mantle material. T F

56. Andesite volcanism results from pressure release melting in subduction zones. T F

57. Complex craters occur with larger diameters on larger planets. T F

58. The global surface distribution of Earthquakes may be characterized as long narrow bands of seismic activity surrounding large seismically inactive regions. T F

59. After a viscous substance is deformed, it will slowly dry out and become brittle if left alone long enough. T F

60. The average density of planet Earth is about 5.5 times the density of water. T F

61. Impact cratering was the most common type of geological activity during the first two and a half billion years of Earth's history. T F

62. The Earth's surface is divided into about a dozen large viscous plates in relative motion. T F

63. Rocks on the Moon are in general older than rocks on Earth. T F

64. Jovian planets are spaced twice as far apart as Terrestrial planets. T F

65. Permanent magnetization in magnetic minerals such as magnetite results from the alignment of all the atomic dipoles in the same direction. T F

66. At subduction zones the subduction angle determines the distance between an ocean trench and island arc. T F

67. Mars is the fifth planet from the Sun. T F

68. Sediments with buried fossils, minerals and organisms occur in the worlds oceans in the amounts predicted by sedimentologists. T F

69. The most accurate method of measuring plate motions is using GPS satellites. T F

70. The most expensive Space Geodesy technique is Lunar laser ranging. T F

71. Fold mountains are only produced by continent-continent collisions. T F

72. The percentage error of the baseline measurement using VLBI decreases with increasing baseline, b. T F

73. In GPS, the Pseudo-range is the distance, or range, to one GPS satellite. T F

74. The goal of Geomatics is to determine the spatial distribution of surface features on,

or below, the Earth's surface. T F

75. The instrument used to detect seismic waves is a 3-component wave-recorder. T F

76. All areas of Geomatics involve the processing of attribute data. T F

77. A travel-time curve plots seismic-wave velocities against distance. T F

78. An instrument used to measure the strength of Earth's magnetic field is called a magnetometer. T F

79. A positive magnetic anomaly is a magnetic field measurement higher than normal. T F

80. A magnetic reversal is a negative anomaly where the field is less than normal. T F

81. LiDAR and Radar Altimetry are examples of passive remote sensing. T F

82. Isostacy refers to the floating of ice blocks on top of water. T F

83. The primary evidence for the Earth's core comes from seismic waves. T F

84. Plate velocities determined by VLBI in general agree with geophysical estimates. T F

85. The Mohovoricic discontinuity refers to the base of the Crust. T F

86. Radioactive daughter material spontaneously decays to form new parent material. T F

87. An alpha particle is identical to the nucleus of a Helium atom. T F

88. Carbon- 4 age dating measures the time since the death of an organism. T F

89. An island arc is a linear string of mostly extinct volcanoes. T F

90. Evidence for widespread impact cratering early in the Earth's history comes from the preserved faces of Mars and Venus. T F

NOW, TRANSCRIBE ALL YOUR ANSWERS FOR *PARTS A AND B* ONTO THE SCANTRON FORMS.

FOR PART B USE (a) FOR TRUE AND (b) FOR FALSE.

REMEMBER TO ENTER YOUR **STUDENT NUMBER** ON THE SCANTRON FORM BY **FILLING IN BOXES** AS WELL AS IN WRITING. THE COMPUTER DOES NOT READ YOUR WRITING.

YOU WILL HAND IN YOUR QUESTION SHEET AS WELL AS THE SCANTRON FORM

NOW, PROCEED TO PART C ...=>

PART C: Short Answers. (60 Marks) [Answer in the spaces provided below.]

1. (a) List the three types of spontaneous radioactive decay. (3 marks)

(i)_____ (ii)_____

(iii)_____

(b) What is the effect of each type of decay on the structure of the nucleus. (6 marks)
(i)

(ii)

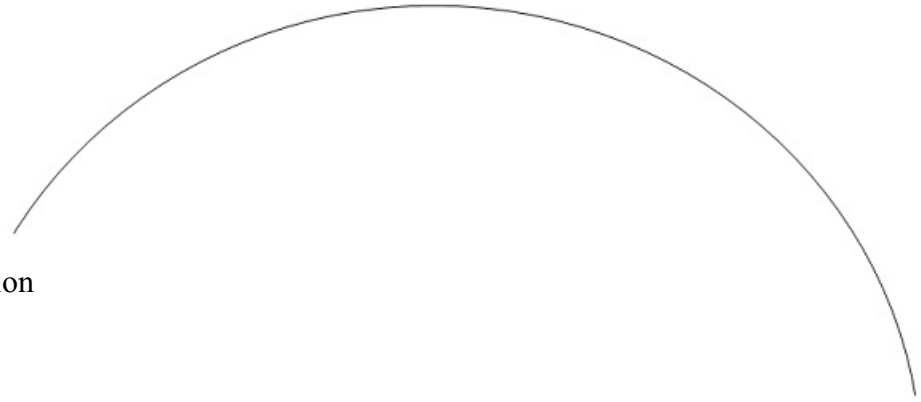
(iii)

(c) Which decay scheme converts K^{40} atoms into Ar^{40}? (1 mark)

2. (a) Sketch on the cross section of the Earth provided the paths of body waves and surface waves from the source region of an earthquake to a point on Earth's surface about 90 degrees away from the epicentre where a seismograph records the incoming wave energy. Label the epicentrre, hypocentre, focus, surface waves, P-waves and S-waves. (b) Sketch the seismogram recorded at the seismograph showing the arrivals of the P, S and surface waves. (c) Which of these wave arrivals causes the most damage to buildings?
(8 marks)

(a)

Cross-section



(b)
Seismogram

(c) Most damaging: _____

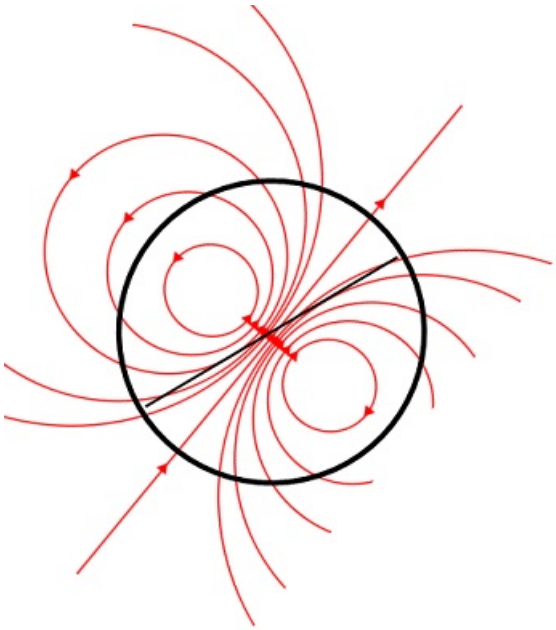
3. Name the four Jovian Planets in order of decreasing size. Which of these has the lowest density?
(5 marks)

1._____ 2. _____

3. _____ 4. _____

Lowest density:_____

4. From the point of view of an approaching space-craft, which is equipped to detect magnetic field lines in space, the Earth and its magnetic field might look as shown in the diagram below. Label the North and South poles of the magnetic dipole field, the geographic North and South poles, and the Magnetic North Pole. (5 marks)



5. (a) Name the layers inside Earth that are separated by major chemical boundaries. (2 marks)

(b) Name the layers inside Earth that are separated by phase boundaries. (2 marks)

(c) Name the layers inside Earth that are separated by a rheological boundary. (1 mark)

6. Compute the height of the small Space Pod observation deck on the CN tower based on the following information:

Two digital photographs were taken of the CN tower and Skydome vicinity from a small fixed wing aircraft flying at an altitude of H = 750 m.
The plane was flying east at a speed of 300 km/hr.
Photograph #1 was taken at 9:21:07 am, and photograph #2 was taken at 9:21:12 am.
The camera had a focal length of 28 mm.
The top of the Space Pod was located on Photograph #1 at x = 20.1 mm (i.e., at a point 20.1 mm to the right of the centre line of the photograph).
The same point was located on Photograph #2 at x' = -18.3 mm (i.e., at a point 18.3 mm left of the centre line of the photograph).
(5 marks)

7. (a) List the three stages of crater formation. (3 marks)

1._____ 2._____

3._____

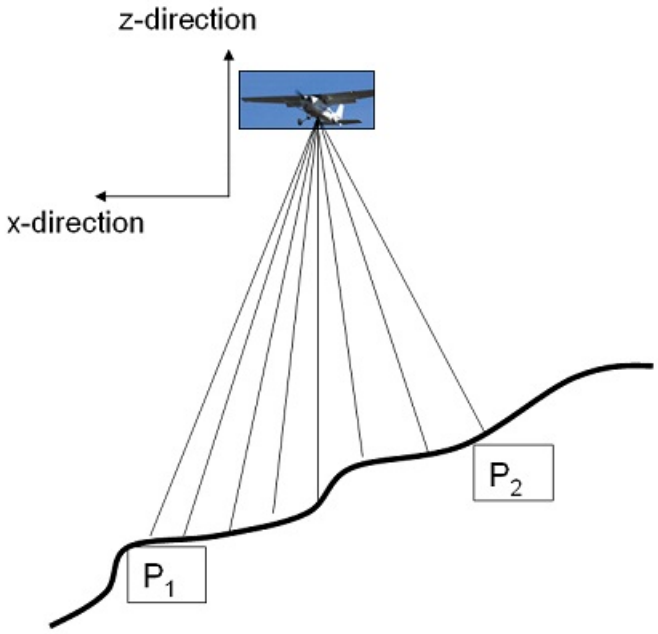
(b) During which stage are the following geological features produced? (2 marks)

1. Rays: _____

2. Central Peaks: _____

8. **(a)** The basic idea in using LiDAR to generate Digital Terrain Models is to measure the distance, d, from an aircraft to a point on the ground. Explain briefly how such a distance measurement is made and show the mathematical formula for the distance, d. (3 marks)

(b) In the sketch below an aircraft carrying LiDAR DTM equipment is flying northwards (along the y-coordinate) at a speed of 200 km/hr. The aircraft has coordinates $(x, y, z)_{plane} = (0, 0, 1500\ m)$. The Lidar emits laser pulses at a rate of 40 kHz, sweeping out a fan in the ± x-directions of $\pm 20^0$, at a rate of 20 sweeps per second. At the instant shown in the sketch below, the first laser pulse of a new sweep hits the ground surface at the point P_1. Using the information provided below, determine the coordinates (x_1, y_1, z_1) of the point P_1 and the coordinates (x_2, y_2, z_2) of the point P_2 at the end of the sweep. How wide is the swath, or path of sampled elevations, and what is the difference in elevation of the two points at the start and end of this sweep? Show your calculations. Take the value of the speed of light to be 3×10^8 m/s. The round-trip travel time for the laser pulse hitting P_1 is $\Delta t_1 = 8.000 \times 10^{-6}$ seconds. When the LiDAR points at P_2, it records a travel time for a laser pulse as $\Delta t_2 = 5.500 \times 10^{-6}$ seconds. (7 marks)



Use space on next page...

9. What is the meaning of the following Space-Geodesy based acronyms? (7 marks)

VLBI:_____

GPS:_____

NAVSTAR:_____

LLR:_____

SLR:_____

DTM:_____

DEM:_____

LiDAR:_____