PREPARING FOR THE PLS EXAM - 2012

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(1) **WHAT'S NEW?** - The 2012 CA PLS Exam will use computer based testing (CBT). The national (PS) exam will still use the conventional paper and pencil format.

(A) Friday - April 13 - The PS exam contains 100 multiple-choice questions. It lasts 6 hours and is split into a 4-hour morning session (67 questions) and a 2-hour afternoon session (33 questions). The PS exam uses USCS measurements.

(B) The PS exam is open-book. You can bring bound reference materials to the exam. They must remain bound during the exam. Place any loose papers in 3-ring binders, brads, plastic snap binders, spiral-bound notebooks, and screw posts. Staples are not allowed. Any sticky notes or flags must be attached to book pages.

(C) Monday - April 23 - An all multiple choice answer format for the 4-hour CA PLS exam.

(2) **WHAT YOU SHOULD DO IN CLASS**

(A) NOTE the instructor's name and phone number in case you want to call with a follow up question afterwards.

(B) TAKE notes, keeping them brief and clear. Write down all formulas given (and know how to use them!) Get the main points and enhance the notes later when you're away from class. Be sure to do this before you forget what was discussed.

(C) DON'T get behind the class pace by trying to understand everything; take the notes but **keep up**.

(D) KEEP your notes in order; organization is important and it will pay off later.

(D) Make note of any questions which you may want to ask the instructor. *The only dumb question is the one that didn't get asked.*

(3) **DON'T** think that you're going to "know it all" when you take the exam... nobody does. If you've worked hard and studied a lot, you'll be ready for it.

(4) **COMMIT TO STUDYING A LOT IN THE COMING DAYS**

(A) ATTENDING this class will not make you pass the exam if all you do is attend.

(B) YOU must be willing to work hard... be really dedicated to studying land surveying for the next three weeks.

(C) DO as many of the old exam questions as possible.

(D) TALK to the other surveyors you know if you have a question. Tap all of your information sources. Try not to get hung up on deep conversations; you're just trying to work problems. Don't waste any time!

(E) DISCUSS the importance of your endeavor with your family including your need for their support; they are your partners in this effort. Let them know their support will be a big help and during your studying and during the exam.

(F) Be sure to review the test plan for the CA PLS exam and the NCEES PS exam.

(5) **METHODS OF ORGANIZING YOUR REFERENCE MATERIALS**

(A) DECIDE what materials you will take with you to the exam, and **use these materials** to get thoroughly familiar with them; items such as calculators, reference books and notes, etc. Keep all material together in the same way you will carry it into the exam. You should put everything in a box or crate as you study.

(B) KEEP each subject separate from others. Put all of your class notes, previous exam questions and notes from other sources (which are all on the same topic) in one binder. Don't over-fill your binders so you can turn the pages easily.

(C) LABEL your binders on the front and end with the subjects they contain.

(D) IF you've worked questions from old exams, file your work with the question in your binder. This organization will pay off.

(E) REMEMBER that all of your materials must be in a bound book or three-ring binder. Don't put loose papers in or you may loose them to the proctor.

(F) GET tab markers from office supply store. You may go through several packages; use as many as you think you need. You can also use the sticky post-it notes.

(G) PUT tabs in your books where you think you need to. As you're reading or skimming, and you think something is worth marking, think about putting a tab there. As you work the problems and you find yourself looking something up, mark that too. If it was worth looking up, it's worth marking. **Fill in the label with whatever makes sense to you, you're the one that has to use it.** Quick reference is the key. Also keep in mind that too many tabs would make you search through a sea of markers before finding what you want; since quick reference is the key, don't overdo it with too many.

(H) USE a high lighter throughout your reference material as you see necessary. If you looked up something to answer a previous exam question, mark it with your high lighter. Mark the topic and main points or key words only, not the whole paragraph. Also, if you looked something up and highlighted it, consider marking the page with a tab. At the same time, remember not to overdo it or your highlighting won't serve its purpose. Don't be afraid to mark in your books; they're *your* books!

(I) PUT all of your references and materials in a box or crate, or whatever works good for you. Only one box per person will be allowed into the exam, so spend a little time deciding the most important things to take.

Be Sure to take a wrist watch since your cell phone cannot be taken into the exams, and don't forget to take extra batteries for your calculators. Even borrow a friend's calculator as an extra, but only if you know how to use it!

TAKING THE LAND SURVEYORS EXAMINATION

(A) YOU should go to the exam area the day before the exam. Find out where to park, and where the building is. Consider getting a room close to the exam site and bringing a packed lunch for additional convenience.

(B) BE sure to bring your driver's license or other picture ID. You will be given paper and pencils to draw sketches you need while taking the exam, we're told. You will also be given a formula page to use during the national NCEES exam. Also, don't forget that calculator.

(C) DRESS comfortably, in layers. You can adjust how much you're wearing, depending on the room temperature. Most likely, it will be a bit cool.

(D) ARRIVE at the exam location at least 30 minutes early. This allows for you to find your seat, get set up, and locate and use the restroom. Don't drink too many liquids before going to the exam; your time is too crucial to spend it in the restroom.

(E) SET your box of references up on the floor, looking down at the binding edge. This allows for quick access to everything.

(F) PAY close attention to the proctor's instructions and follow them completely. You've worked too hard to lose out at this point for not following instructions!

(G) THE PS exam is broken into two parts, the morning and afternoon sessions, being four hours and two hours, respectively. The ending time is exactly four hours or exactly two hours after the session begins. Your wrist watch will help you know the remaining time. The CA PLS exam is a single four-hour session.

(H) As the PS exam is multiple choice, it's reasonable to answer as many questions as you can when just reading thru it the first time. Save the more difficult questions for a second run-thru and even a third. Check your watch after each pass thru the exam to gauge the when to start guessing. Don't turn in your answer sheet with unanswered questions; there is a point where you have to guess at an answer!

(I) The CA PLS exam is a four-hour open-book test. The place you go to take the exam may differ from the location of NCEES PS exam. Currently there are test centers numbering in the mid-twenties for the CBT. The exam is open-book like the PS exam. It is also a multiple choice exam, at least for now.

(J) BE careful to thoroughly read the question. You must understand exactly what is required and answer what is requested. Too much speed here could hurt you. If you intend to highlight key points of questions, be sure this is okay with the proctor as the he/she may not want you writing in the exam booklet.

(K) IF you take two calculators, use them both. You can have a program going in one and use the other for quick calcs or another program. This really speeds you up, so borrow a calculator if you can, but be familiar with it.

(L) THE questions are not intended to be complicated, tricky or confusing. They are looking for an understanding of a professional concept or procedure. Try to recognize this at the beginning of each question. Don't read more into the question than what is stated.

(M) THIS is a professional examination and not a party chief's job application. The exam is determining which of you are qualified to recognize and solve land surveying situations that require **specific** experience and knowledge. You are not expected to be an expert land surveyor. You are expected to know procedures, laws, techniques and land surveying principles that are substantially more detailed than what is required of a party chief.

(N) WHEN you have finished all questions for the session, **don't** get up and leave! Instead, go back through your work and verify your answers. Make sure to check any mathematical calculations, as this is where it's easy to make a mistake.

(O) DON'T discuss the questions from the morning session with the other candidates during the lunch break. You will probably get no benefit from it and may only serve to confuse yourself about a topic that you might otherwise be confident in. Save your confidence for the afternoon session, and save your discussions of the exam until it is all over.

(P) EAT a light lunch and take a walk or just rest, which ever would work best for you. If you stay to yourself, you will probably hold your concentration better. Remember to go to the restroom before returning to the exam, and again, don't consume too many liquids. You don't want to spend test time in the restroom.

(Q) If you've studied hard, prepared good notes and have your reference material indexed, you're nervous but ready. Don't allow distractions to reduce your sharp edge. Good Luck!!

Useful Web Links

CLSA State Web Site

http://californiasurveyors.org/

California Laws & Regulations

http://www.dca.ca.gov/pels/laws.htm

California Law Codes

http://www.leginfo.ca.gov/calaw.html

BPELSG

http://www.dca.ca.gov/pels/

California State Exam Info

http://www.dca.ca.gov/pels/e_exam.htm

PLS License Lookup

http://www2.dca.ca.gov/pls/wllpub/wllqryna$lcev2.startup?p_qte_code=LND&p_qte_pgm_code=7500

ALTA/ACSM Standards

http://www.acsm.net/alta.html

California Land Law (Court Case Links)

http://members.aol.com/e52berg/pubpage.htm#R

CALTRANS Geometronics Info

http://www.dot.ca.gov/hq/esc/geometronics/

National Geodetic Survey

http://www.ngs.noaa.gov/

Professional Publications, Inc.

http://ppi2pass.com/catalog/servlet/MyPpi

Paul Cuomo Press

http://www.pcpressinc.com/index.html

NCEES

http://www.ncees.org/

NGS Online Publications

http://www.ngs.noaa.gov/PUBS_LIB/pub_index.html

California Spatial Reference Center

http://csrc.ucsd.edu/

USGS

http://www.usgs.gov/

National Atlas (Maps Of The U.S.)

http://www-atlas.usgs.gov/index.html

BLM

http://www.blm.gov/nhp/index.htm

Recommended References

(Bring only references you are familiar with. You do not want to be searching thru material you are not familiar with looking for something you may never find!)

1973 / 2009 Manual of Surveying Instructions (BLM)

Boundary Control & Legal Principles - Brown

Restoration of Lost and Obliterated Corners & Subdivisions of Sections

Writing Legal Descriptions - Gurdon H. Wattles

A Basic Survey Text Book - Moffitt & Bossler or other

Black's Law Dictionary

Definitions of Surveying & Associated Terms - ACSM

1001 Solved Surveying Fundamentals Problems - John Van Sickle

Projection Tables CCS NAD 83 - Ira & Robert Alexander

Construction Surveying and Layout - Wesley G. Crawford

Elements of Photogrammetry - Paul Wolf

Ethics for the Professional Land Surveyor - Dennis Mouland

GPS for Land Surveyors - John Van Sicle

Global Positioning System and GIS - An Introduction - Michael Kennedy

Land Surveying Law - John Keen

Water Boundaries - Latest Edition - George Cole

HP Calculator Help Websites

http://www.softwarebydzign.com/

http://www.hp33ssurveyor.com/

http://homepage.mac.com/nwjh/

Don't forget your extra Batteries

Things to Do When Preparing for the 2012 Examinations

Here are some tips for examinees on what to do (and not do) for and what to bring to the upcoming examinations.

- **THINGS TO DO - AND NOT DO**

- **READ THE EXAMINEE INSTRUCTIONS BEFORE GOING TO THE EXAM SITE**
  NOTE: It is the applicant's responsibility to read, understand, and comply with all of the instructions contained in the Examinee Instructions. If you fail to comply with the Examinee Instructions, you will be ejected from the exam, your exams will be voided, and you will forfeit your application fee. Candidates who are taking multi-part exams (such as the Civil Engineer or the Professional Land Surveyor exams) may not be allowed to take the remaining exam(s) and may have all of their exams voided if they are ejected from the exam.

- **ARRIVE EARLY**
  You are required to be at the appropriate building at the "doors open" time indicated on your admission notice. So you need to arrive at the exam site in time to find the appropriate building before the "doors open" time listed on the admission notice. Varied site conditions, large candidate volume, parking, and other events at the site prevent us from providing firm start/stop times for the exams. The "doors open" time for the afternoon portion will be announced and posted at the end of the morning session. Each exam, several candidates are turned away in both the morning and afternoon because they arrive late. So give yourself ample time to allow for delays on the freeways, to locate the exam site and correct parking lot, to pay for parking, and to walk to and locate the the correct building that your exam will be offered in.

- **DO NOT BRING ANY UNAUTHORIZED ITEMS INTO THE SECURED EXAM AREA**
  Do **NOT** bring any unauthorized items into the secured exam area. If you are caught with unauthorized items such as calculators, unbound materials, cell phones, or unauthorized writing instruments after the exam begins, the items will be confiscated, you may be ejected from the exam, your exams may be voided, and you may forfeit your application fee. Candidates who are taking multi-part exams (such as the Civil Engineer or the Professional Land Surveyor exams) may not be allowed to take the remaining exam(s) and may have all of their exams voided if they are ejected from the exam. More information about unauthorized devices and unauthorized materials is included in the Examinee Instructions.

- **APPROVED CALCULATORS**
  It is your responsibility to make sure that you bring only approved calculators with you to the exam.

· If you are taking an NCEES exam and **your calculator is not included on this list**, do **NOT** bring it with you -- NO EXCEPTIONS. If it is not on the approved list, and you are discovered with it in your possession after the exam begins, you will be removed from the exam - even if you are not using it.

  If you are taking a State-specific exam, and your calculator does not meet the requirements described in the **Board's Calculator Policy**, do **NOT** bring it with you -- NO EXCEPTIONS.

If you are found to be in possession of an unauthorized calculator during the exam (even if you are not using it), the calculator will be confiscated, you will be ejected from the exam, your exam will be voided, and you will forfeit your application fee. Candidates who are taking multi-part exams (such as the Civil Engineer or the Professional Land Surveyor exams) may not be allowed to take the remaining exam(s) and may have all of their exams voided if they are ejected from the exam.

Every exam administration, candidates are ejected from the exam because they have brought an unauthorized calculator with them. Their excuses range from "It's just a $10 WalMart calculator" to "It doesn't have any memory capability" to "I wasn't even using it." None of this matters. All that matters is that the calculator is not on the approved list. READ THE LIST AND MAKE SURE THE CALCULATORS YOU BRING ARE ON IT. Don't take the chance of being ejected from the exam because you didn't check your calculators before you went to the exam site.

- **CELL PHONES ARE NOT PERMITTED IN THE SECURED EXAM AREA**
  If you are discovered with a cell phone in your possession while you are in the exam room, you will be ejected from the exam - even if the cell phone is turned off and is in your backpack. Every exam cycle, candidates are ejected and their cell phones are confiscated because it is discovered that they are in possession of cell phones in the secured exam area. DON'T MAKE THIS MISTAKE. DO NOT BRING YOUR CELL PHONE INTO THE SECURED EXAM AREA.

- **WRITING INSTRUMENTS AND ERASERS**
  Do **NOT** bring your own writing instruments (pens, pencils, highlighters) or erasers. You will be given pencils with lead and erasers at the exam. You are **not** allowed to use any other writing instruments or erasers other than the ones given to you at the exam. It is your responsibility, not the proctors', to make sure you use the supplied writing instrument.

  If you are found to be in possession of an unauthorized writing instrument or eraser during the exam (even if you are not using it), it will be confiscated, and your exam may not be scored.

- **KEEP YOUR EYES ON YOUR OWN PAPERS**
  Make sure you keep your eyes on your own papers and that you keep your answer sheet and exam book covered during the exam. NCEES performs an analysis of exam results using five separate methods for detecting potential copying/collusion (cheating). The exam results of the candidates flagged as a result of the analysis must be withheld until the Board completes its investigation to determine if any exam subversion (cheating) occurred. Candidates determined to have copied or to have aided another candidate will have their results voided and may be prohibited from taking future exams.

- **MANAGE YOUR TIME WISELY**
  Bring a time-keeping device such as a watch or a clock and allot the appropriate time for each question. Each exam, several candidates have had their exams voided because they were writing or erasing after time was called. Wristwatches are allowed only if worn on the wrist or placed on the floor. Clocks must be placed on the floor. A cell phone is ***not*** an acceptable time-keeping device.

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- **THINGS TO BRING**

- Government-issued Photo ID -

- **PHOTO ID:**
  In order to gain entrance into the examination, a photo ID is required and you will not be admitted without one. Identification will **NOT BE ACCEPTED UNLESS IT MEETS ALL** of the following criteria:

  (1) Issued by a state or federal governmental agency (including other U.S. states and foreign countries). [Student identification cards or employee identification cards will NOT be accepted]

  . (2) Contains your photograph

  . (3) Contains your visible signature

  . (4) Contains your printed (typed) name

  If you do not have identification which meets ALL of the above criteria, you will NOT be allowed to sit for the examination. **THERE WILL BE NO EXCEPTIONS.**
  More information is available in the Examinee Instructions. Government-issued ID's that do not contain a photo or a visible signature are ***not*** acceptable.

. Exam Authorization Notice

. Approved calculator(s) and spare batteries - See the Approved Calculator item above for more information

. Lunch

. Money for parking

. Sweatshirt, sweater, jacket, etc. - Hats with brims or bills are **NOT** allowed

. Reference materials IF allowed - More information is available in the Examinee Instructions. **NOTE:** FE Examinees: Writing in the supplied reference handbook is **NOT** allowed.

2012 calculator policy

To protect the integrity of its exams, NCEES limits the types of calculators you may bring to the exam room. The only calculator models acceptable for use during the exam are as follows.

Casio: All fx-115 models. Any Casio calculator must contain fx-115 in its model name. Examples of acceptable Casio fx-115 models include (but are not limited to)

- fx-115 MS
- fx-115 MS Plus
- fx-115 MS SR
- fx-115 ES

Hewlett Packard: The HP 33s and HP 35s models, but no others.

Texas Instruments: All TI-30X and TI-36X models. Any Texas Instruments calculator must contain either TI-30X or TI-36X in its model name. Examples of acceptable TI-30X and TI-36X models include (but are not limited to)

- TI-30Xa
- TI-30Xa SOLAR
- TI-30Xa SE
- TI-30XS Multiview
- TI-30X IIB
- TI-30X IIS
- TI-36X II
- TI-36X SOLAR
- TI-36X Pro

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Registration Status

Registration for October 2012 is now closed. Registration for April 2013 will begin on December 17.

Select a state for specific registration details and deadlines.

Change State:
Select a State or Country

General Definition of California Professional Land Surveying Practices:

The practice of land surveying in the State of California consists of determining, establishing, reporting and mapping the positions, contours and/or geospatial configuration of points, physical features, property interests, boundary and/or property lines by applying the principles of surveying, mathematics, measurement and law to meet the distinctive requirements of the State of California to protect the health, safety and welfare of the public.

I. Project Management (13%)

Project Management includes assessing needs of clients, gathering and analyzing data from public and private sources to define project scope of services, negotiating and preparing the final contract, supervising resources necessary to meet contractual obligations, and exercising independent control and direction of land surveying work.

Job Tasks

01 Communicate survey practice to the public and potential clients

02 Negotiate and secure a written contract with client

03 Offer land surveying services

04 Procure land surveying services

05 Direct personnel for office and field survey tasks

06 Coordinate projects with third parties (e.g., agencies, consultants)

07 Identify project standards (e.g., mapping, accuracy requirements, client needs, methodology, quality assurance)

08 Develop project standards (e.g., mapping, accuracy requirements, client needs, methodology, quality assurance)

09 Prepare proposals (e.g., scope, schedule, budget)

10 Preserve monuments in accordance with State law

11 Manage a land surveying business, organization or department

12 Establish and maintain GPS real-time network

13 Make survey records available to the public

14 Maintain an index for survey records available to the public

15 Utilize the Subdivision Map Act

16 Utilize the Professional Land Surveyors Act

17 Assess project needs (e.g., legal requirements, client needs, local ordinance requirements)

Knowledge Areas

Knowledge of:

K01 Professional Land Surveyors' (PLS) Act

K02 Subdivision Map Act (SMA)

K03 impact of local ordinances

K04 project requirements

I. Project Management (Continued)

K05 laws and ordinances pertaining to setting of monuments (e.g., PLS Act § 8771-8772, SMA § 66495-66498, local ordinances)

K06 right of entry laws, rules and regulations

K07 capabilities and limitations of current technologies (e.g., GPS, laser scanning, levels, total stations)

K08 interpretation of elements in construction plans and specifications pertaining to staking

K09 elements required for an aerial flight plan (e.g., photogrammetric, LiDAR)

K10 procedures for preparation for aerial mapping and contouring

K11 procedures for preparation for terrestrial mapping and contouring (e.g., total station, GPS, LiDAR)

K12 National Standard for Spatial Data Accuracy (NSSDA)

K13 when records of survey are required

K14 when corner records are required

K15 when parcel maps are required

K16 when final maps are required

K17 when tentative maps are required

K18 map waivers (e.g., SMA § 66428)

K19 exceptions to SMA (e.g., § 66412)

K20 state and local agency processing requirements for maps and related documents (e.g., submittal, review, filing)

K21 methods to identify mapping requirements and criteria

K22 project location, objectives and constraints

K23 appropriate types of data required

K24 contractual agreements (e.g., cost estimates, scope of services, limitations)

K25 appropriate communication methods (e.g., verbal and written)

K26 project constraints and objectives (e.g., location, physical, regulatory, environmental, legal, political)

II. Research, Pre and Post Field Analysis (25%)

Research, Pre and Post Field Analysis includes determining, evaluating, analyzing, reducing and adjusting field collection data in accordance with accepted standards of practice and in compliance with all applicable statutes, rules and regulations and to meet accuracy standards for design of improvements.

Job Tasks

18 Ensure use of proper control datums and epochs (e.g., plane coordinates, NAVD88 / NGVD29, epoch 1991.35 / 2007.00)

19 Analyze project data (e.g., recorded maps, deeds, control data, title data, land planning requirements)

20 Identify conflicts within the drawing set

21 Conduct project research

22 Prepare construction staking layout and drawings

23 Perform surveying calculations (e.g., boundary, construction staking, control, topographic)

24 Analyze field evidence together with recorded and unrecorded documentation to determine boundaries, easements, and possible encroachments

25 Identify conflicts between project drawings and existing field conditions (e.g., construction plans, condo plans)

26 Determine accuracies of maps and measured survey data

27 Evaluate relevance and spatial relationships of maps and measured survey data

28 Identify boundary conflicts

29 Compile and provide geographic information system (GIS) data

Knowledge Areas

Knowledge of:

K08 interpretation of elements in construction plans and specifications pertaining to staking.

K09 elements required for an aerial flight plan (e.g., photogrammetric, LiDAR)

K10 procedures for preparation for aerial mapping and contouring

K11 procedures for preparation for terrestrial mapping and contouring (e.g., total station, GPS, LiDAR)

K13 when records of survey are required

K14 when corner records are required

K27 public lands survey system

K28 sequential conveyances (e.g., senior, junior rights)

K29 simultaneous conveyances

II. Research, Pre and Post Field Analysis (Continued)

K30 water boundaries

K31 hierarchy of evidence (e.g., CCP 2077)

K32 relationship of land grants between private, state and federal (e.g., Rancho)

K33 effects of unwritten rights on boundaries

K34 boundary resolution

K35 evaluation of field evidence

K36 methods of establishing boundaries

K37 types and components of title documents (e.g., title report, chain of title, lot and block report)

K38 types of conveyances and their effects of ownership on property (e.g., fee vs. easement, grant deed, quitclaim deed)

K39 effect of riparian and littoral rights on boundaries

K40 effect of cloud on title

K41 methods for calculating and adjusting boundary surveys

K42 error analysis

K43 monument recovery and re-establishment procedures

K44 effect of ground movement on boundaries (e.g., earthquakes, subsidence, slides)

K45 procedures, standards and requirements for ALTA/ACSM surveys

K46 easements, rights-of-way and other encumbrances

K47 effects of leases

K48 methods and procedures for retracement and re-establishment of railroads rights-of-way

K49 criteria for acceptance or rejection of monuments

K50 tidal cycles and datums

K51 physical evidence that may indicate unwritten rights (e.g., adverse possession, prescriptive rights)

K52 controlling elements of legal descriptions

K53 types of legal descriptions (e.g., strip, metes and bounds, lot and block, aliquot)

K54 exceptions and reservations of legal descriptions

K55 horizontal and vertical control

K56 projections, datums and epoch dates

K57 transformation between epoch dates

K58 transformation between datums and projections

II. Research, Pre and Post Field Analysis (Continued)

K59 geoid, ellipsoid and orthometric heights

K60 conversion between grid and ground distances

K61 error sources (e.g., multipath, data input, instrument calibration)

K62 calculating and analyzing errors

K63 California Coordinate Systems

K64 real-time-networks (e.g., processes, redundancy, accessibility, accuracy)

K65 methods and procedures to produce control networks within accuracy standards (e.g. Public Resources Code, NGS Standards, FGCS Standards)

K66 procedures for analysis, reduction, and adjustment of raw data to obtain coordinate values

K67 requirements for aerial survey data collection

K68 methods to obtain bearings or azimuths related to geodetic, magnetic, grid or astronomic north

K69 survey calculations (e.g., horizontal and vertical alignments, volumes, grade)

K70 mathematics (e.g., algebra, trigonometry, geometry)

K71 accuracy required for construction staking

K72 field notes and staking reports

K73 basis of control values and their relation to maps and construction plans (e.g., basis of bearing, benchmark)

K74 methods to produce digital terrain models

K75 sources of research data (e.g., public, quasi-public, private)

K76 GIS metadata

K77 methods for identifying and resolving errors in research data (e.g., map or deed misclosure)

K78 source, type and accuracy of digital data (e.g., metadata, GIS)

K79 researching relevant case law (e.g., boundary issues, liability)

III. Field Work (20%)

Field work includes the process of performing field observations by collecting field data in accordance with accepted standards of practice and in compliance with all applicable status, rules and regulations.

Job Tasks

30 Perform topographic surveys

31 Perform control surveys

32 Perform boundary surveys

33 Perform as-built surveys

34 Perform PLSS surveys

35 Perform monitoring surveys

36 Perform cadastral surveys

37 Recognize and locate field features relevant to the survey (e.g., boundary evidence, topographic features)

38 Perform construction staking

39 Set, replace or remove monuments

40 Verify character and position of given horizontal and vertical control points

41 Perform hydrographic survey (e.g., bathymetric, tidal datum, riparian boundary)

42 Communicate with clients and contractors while in the field

43 Communicate with the general public while in the field

Knowledge Areas

Knowledge of:

K06 right of entry laws, rules and regulations

K07 capabilities and limitations of current technologies (e.g., GPS, laser scanning, levels, total stations)

K08 interpretation of elements in construction plans and specifications pertaining to staking

K25 appropriate communication methods (e.g., verbal and written)

K27 public lands survey system

K43 monument recovery and re-establishment procedures

K45 procedures, standards and requirements for ALTA/ACSM surveys

K48 methods and procedures for retracement and re-establishment of railroads rights-of-way.

III. Field Work (Continued)

K51 physical evidence that may indicate unwritten rights (e.g., adverse possession, prescriptive rights)

K55 horizontal and vertical control

K61 error sources (e.g., multipath, data input, instrument calibration)

K63 California Coordinate Systems

K64 real-time-networks (e.g., processes, redundancy, accessibility, accuracy)

K65 methods and procedures to produce control networks within accuracy standards (e.g. Public Resources Code, NGS Standards, FGCS Standards)

K68 methods to obtain bearings or azimuths related to geodetic, magnetic, grid or astronomic north

K69 survey calculations (e.g., horizontal and vertical alignments, volumes, grade)

K70 mathematics (e.g., algebra, trigonometry, geometry)

K71 accuracy required for construction staking

K72 field notes and staking reports

K73 basis of control values and their relation to maps and construction plans (e.g., basis of bearing, benchmark)

K80 types, uses, capabilities of survey equipment

K81 parol evidence (e.g., use, methods to document, and effects of)

K82 procedures to recover and perpetuate control monuments

K83 methods and requirements for collecting field positions and attributes

K84 methods and requirements for performing as-built surveys

K85 field procedures for photogrammetric control layout

K86 field survey methods, procedures and standards

K87 field practices and procedures for construction staking.

K88 methods to maintain and calibrate equipment

IV. Mapping and Document Preparation (28%)

Mapping includes meeting specified accuracy standards and collecting, analyzing, interpreting developing, reducing , and adjusting data (e.g., Control, Geodetic, Topographic, Photogrammetric, California Coordinate System, horizontal and vertical datums) for the purpose of preparing graphic and/or mathematic representations of existing physical features, terrain, monuments, and geospatial positions. Document Preparation includes preparing necessary documents, legal descriptions, maps and exhibits based on clients' needs and contractual obligations and providing documentation of surveys based on all applicable statutes, rules and regulations.

Job Tasks

44 Perform FEMA flood certification

45 Prepare legal descriptions (e.g., easements, lot line adjustments, other interests in real property)

46 Ensure survey documents comply with State law, local ordinance and the appropriate standard of care prior to execution

47 Prepare ALTA/ACSM surveys

48 Create digital terrain model (DTM)

49 Create topographic map from various sources (e.g., photogrammetric, field survey, LiDAR, GIS)

50 Create control maps or reports

51 Create boundary maps

52 Create exhibit maps (e.g., court, easement, aerial)

53 Prepare maps, plats, exhibits and documents for filing and/or recordation (e.g., records of survey, corner records, lot line adjustment, subdivision map, condo documents)

54 Prepare staking reports (e.g., cut-sheets, plots)

55 Compile and provide geographic information system (GIS) data

56 Establish and maintain a geographic information system (GIS) land cadastre

57 Provide geodetic control (e.g., GIS, preliminary, design)

58 Provide mapping services (e.g., GIS, topographic, hydrographic, photogrammetric)

Knowledge Areas

Knowledge of:

K01 Professional Land Surveyors' (PLS) Act

K03 impact of local ordinances

K12 National Standard for Spatial Data Accuracy (NSSDA)

K21 methods to identify mapping requirements and criteria

IV. Mapping and Document Preparation (Continued)

K27 public lands survey system

K45 procedures, standards and requirements for ALTA/ACSM surveys

K53 types of legal descriptions (e.g., strip, metes and bounds, lot and block, aliquot)

K54 exceptions and reservations of legal descriptions

K56 projections, datums and epoch dates

K63 California Coordinate Systems

K65 methods and procedures to produce control networks within accuracy standards (e.g. Public Resources Code, NGS Standards, FGCS Standards)

K72 field notes and staking reports

K74 methods to produce digital terrain models

K76 GIS metadata

K81 parol evidence (e.g., use, methods to document, and effects of)

K89 Code of Regulations (Board Rules)

K90 Streets and Highway Code (survey relevant sections)

K91 signing and sealing requirements

K92 preparation of legal descriptions

K93 components of a legal description (e.g., preamble, body)

K94 elements of topographic maps (e.g., contours, features, symbols, legend, metadata)

K95 elements of corner records (legal content required)

K96 elements of records of survey (legal content required)

K97 methods and procedures for preparing corner records and records of survey

K98 elements of parcel maps (legal content required)

K99 elements of final maps (legal content required)

K100 elements of tentative maps (legal content required)

K101 requirements for signatures (e.g., trustee, owner, beneficiaries)

K102 graphical methods to represent land boundaries and related information

K103 depicting physical evidence that may indicate unwritten rights

K104 GIS software

K105 methods of disclosing and depicting encroachments

K106 reports, documents and exhibits creation

K107 evidence documentation

V. Consultation and Legal (14%)

Consultation and legal pertains to professional consultation expertise provided to the public as the practice of land surveying relates to legal and contractual obligations.

Job Tasks

59 Administer an oath for boundary evidence

60 Communicate accuracies of maps or survey data

61 Represent clients (e.g., depositions, public hearings)

62 Provide expert witness testimony

63 Provide professional surveying consultation

64 Provide litigation support (e.g., land boundary matters, datums, engineering projects)

65 Provide land planning services (e.g., prepare tentative maps)

66 Provide references for Land Surveyor candidates

67 Provide recommendations in accordance with the Subdivision Map Act and Professional Land Surveyors Act

Knowledge Areas

Knowledge of:

K01 Professional Land Surveyors' (PLS) Act

K02 Subdivision Map Act (SMA)

K03 impact of local ordinances

K20 state and local agency processing requirements for maps and related documents (e.g., submittal, review, filing)

K25 appropriate communication methods (e.g., verbal and written)

K33 effects of unwritten rights on boundaries

K39 effect of riparian and littoral rights on boundaries

K40 effect of cloud on title

K44 effect of ground movement on boundaries (e.g., earthquakes, subsidence, slides)

K47 effects of leases

K51 physical evidence that may indicate unwritten rights (e.g., adverse possession, prescriptive rights).

K79 researching relevant case law (e.g., boundary issues, liability)

K89 Code of Regulations (Board Rules)

K90 Streets and Highway Code (survey relevant sections)

K105 methods of disclosing and depicting encroachments

K107 evidence documentation.

V. Consultation and Legal (Continued)

K108 Public Resources Code (survey relevant sections)
K109 Civil Code (survey relevant sections)
K110 Code of Civil Procedure (survey relevant sections)
K111 Penal Code (survey relevant sections)
K112 Government Code (survey relevant sections)
K113 Health and Safety Code (survey relevant sections)
K114 Public Contract Code (survey relevant sections)
K115 Evidence Code (survey relevant sections)
K116 court decorum
K117 public meeting procedures

Surveying Reference Formulas

October 11, 2010

The morning and afternoon FS exam books will include reference material similar to the material shown here. Basic theories, conversions, formulas, and definitions that examinees are expected to know have not been included. When appropriate, NCEES will provide special material in the question statement itself to assist you in solving the problem.

CONVERSIONS AND OTHER USEFUL RELATIONSHIPS

* 1 U.S. survey foot = $\frac{12}{39.37}$ m
* 1 international foot = 0.3048 m
* 1 in. = 25.4 mm (international)

1 mile = 1.60935 km

* 1 acre = 43,560 ft^2 = 10 square chains
* 1 ha = 10,000 m^2 = 2.47104 acres
* 1 rad = $\frac{180^\circ}{\pi}$

1 kg = 2.2046 lb

1 L = 0.2624 gal

1 ft^3 = 7.481 gal

1 gal of water weighs 8.34 lb

1 ft^3 of water weighs 62.4 lb

1 atm = 29.92 in. Hg = 14.696 psi

Gravity acceleration (g) = 9.807 m/s^2 = 32.174 ft/sec^2

Speed of light in a vacuum (c) = 299,792,458 m/s = 186,282 miles/sec

°C = (°F – 32)/1.8

1 min of latitude (ϕ) ≅ 1 nautical mile

1 nautical mile = 6,076 ft

Mean radius of the earth ≅ 20,906,000 ft ≅ 6,372,000 m

* Denotes exact value. All others correct to figures shown.

METRIC PREFIXES		
Multiple	Prefix	Symbol
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	**micro**	**μ**
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d

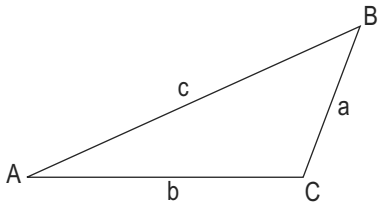
METRIC PREFIXES		
Multiple	Prefix	Symbol
10^{1}	deka	da
10^{2}	**hecto**	**h**
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	**peta**	**P**
10^{18}	exa	E

QUADRATIC EQUATION

$ax^2 + bx + c = 0$

$$\text{Roots} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

OBLIQUE TRIANGLES



Law of sines

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

Law of cosines

$$a^2 = b^2 + c^2 - 2bc\cos A$$

or

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc}$$

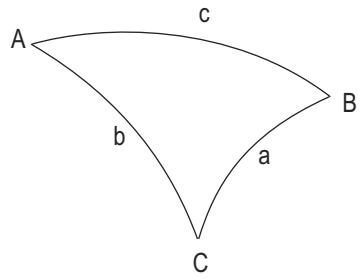
$$\text{Area} = \frac{ab\sin C}{2}$$

$$\text{Area} = \frac{a^2 \sin B \sin C}{2\sin A}$$

$$\text{Area} = \sqrt{s(s-a)(s-b)(s-c)}$$

where s = (a + b + c)/2

SPHERICAL TRIANGLES



Law of sines

$$\frac{\sin a}{\sin A} = \frac{\sin b}{\sin B} = \frac{\sin c}{\sin C}$$

Law of cosines

$$\cos a = \cos b \cos c + \sin b \sin c \cos A$$

$$\text{Area of sphere} = 4\pi R^2$$

$$\text{Volume of sphere} = \frac{4}{3}\pi R^3$$

$$\text{Spherical excess in sec} = \frac{bc\sin A}{9.7\times10^{-6}R^2}$$

where R = mean radius of the earth

PROBABILITY AND STATISTICS

$$\sigma = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}} = \sqrt{\frac{\sum v^2}{n-1}}$$

where:

σ = standard deviation (sometimes referred to as standard error)

$\sum v^2$ = sum of the squares of the residuals (deviation from the mean)

n = number of observations

$\bar{x}$ = mean of the observations (individual measurements x_i)

$$\sigma_{sum} = \sqrt{\sigma_1^2 + \sigma_2^2 + \ldots + \sigma_n^2}$$

$$\sigma_{series} = \sigma\sqrt{n}$$

$$\sigma_{mean} = \frac{\sigma}{\sqrt{n}}$$

$$\sigma_{product} = \sqrt{A^2\sigma_b^2 + B^2\sigma_a^2}$$

$$\Sigma = \begin{bmatrix} \sigma_x^2 & \sigma_{xy} \\ \sigma_{xy} & \sigma_y^2 \end{bmatrix}$$

$$\tan 2\theta = \frac{2\sigma_{xy}}{\sigma_x^2 - \sigma_y^2}$$ where θ = the counterclockwise angle from the x axis

Relative weights are inversely proportional to variances, or:

$$W_a \propto \frac{1}{\sigma_a^2}$$

Weighted mean:

$$\bar{M}_w = \frac{\sum WM}{\sum W}$$

where:

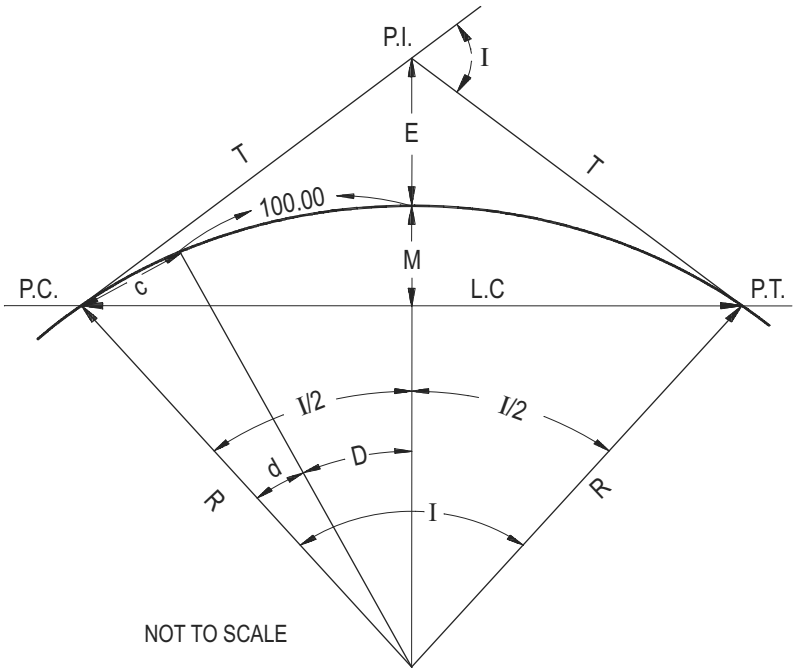
$\bar{M}_w$ = weighted mean

$\sum WM$ = sum of individual weights times their measurements

$\sum W$ = sum of the weights

HORIZONTAL CIRCULAR CURVES

D = Degree of curve, arc definition
L = Length of curve from P.C. to P.T.
c = Length of sub-chord
ℓ = Length of arc for sub-chord
d = Central angle for sub-chord



$$D = \frac{5,729.58}{R}$$

$$T = R \tan\left(I/2\right)$$

$$L = RI\frac{\pi}{180} = \frac{I}{D}(100)$$

$$LC = 2R \sin\left(I/2\right)$$

$$c = 2R \sin\left(d/2\right)$$

$$d = \ell D/100$$

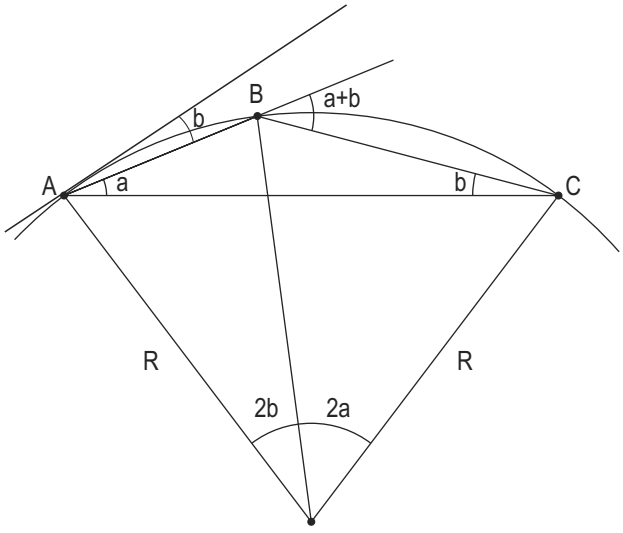
$$M = R\left[1 - \cos\left(I/2\right)\right]$$

$$E = R\left[\frac{1}{\cos(I/2)} - 1\right]$$

$$\text{Area of sector} = \frac{R\,L}{2} = \frac{\pi R^2 I}{360}$$

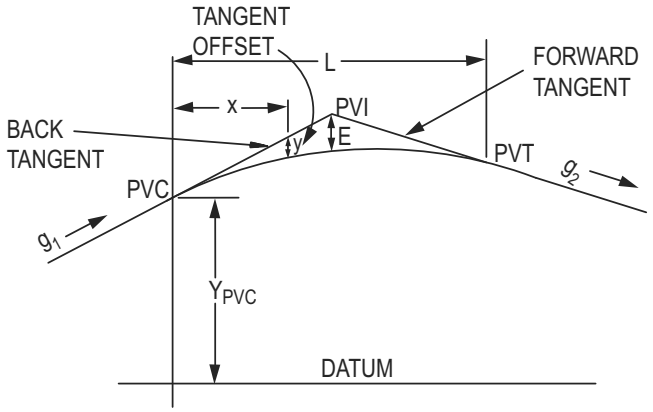
$$\text{Area of segment} = \frac{\pi R^2 I}{360} - \frac{R^2 \sin I}{2}$$

$$\text{Area between curve and tangents} = R\left(T - L/2\right)$$



$$R = \frac{AC}{2 \sin\left(a + b\right)}$$

VERTICAL CURVE FORMULAS



VERTICAL CURVE FORMULAS
NOT TO SCALE

L = Length of curve (horizontal)
PVC = Point of vertical curvature
PVI = Point of vertical intersection
PVT = Point of vertical tangency
g_1 = Grade of back tangent
g_2 = Grade of forward tangent
x = Horizontal distance from PVC (or point of tangency) to point on curve
a = Parabola constant
y = Tangent offset
E = Tangent offset at PVI
r = Rate of change of grade

Tangent elevation = $Y_{PVC} + g_1 x$
and = $Y_{PVI} + g_2 (x - L/2)$

Curve elevation $= Y_{PVC} + g_1 x + ax^2$
$= Y_{PVC} + g_1 x + [(g_2 - g_1)/(2L)]x^2$

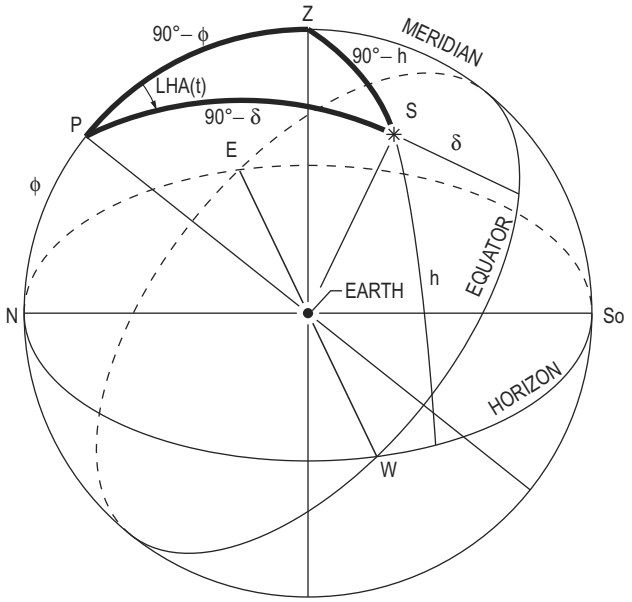
$$y = ax^2; \qquad a = \frac{g_2 - g_1}{2L};$$

$$E = a\left(\frac{L}{2}\right)^2; \quad r = \frac{g_2 - g_1}{L}$$

Horizontal distance to min/max elevation on curve,

$$x_m = -\frac{g_1}{2a} = \frac{g_1 L}{g_1 - g_2}$$

ASTRONOMY



Cos (Az) = (sin δ – sin ϕ sinh) / (cos ϕ cos h)
(altitude method)

Tan (Az) = – sin(LHA) / (cos ϕ tan δ – sin ϕ cos (LHA)
(hour angle method)

Sin h = sin ϕ sin δ + cos ϕ cos δ cos LHA

t = LHA or 360° – LHA

Horizontal circle correction for sun's semi-diameter = SD/cos h

Equations accurate for Polaris only:

h = ϕ + p cos LHA
Az = – (p sin LHA)/cos h

where:

Az = Azimuth (from north) to sun/star
δ = Declination
ϕ = Latitude
h = Altitude of sun/star
LHA = Local hour angle (sometimes referred to as "t" or "hour angle")
SD = Arc length of sun's semi-diameter
p = Polar distance of Polaris

PHOTOGRAMMETRY

$$\text{Scale} = \frac{ab}{AB} = \frac{f}{H-h} \quad (\text{vertical photograph})$$

$$\text{Relief displacement} = \frac{rh}{H} \quad (\text{vertical photograph})$$

Parallax equations:

$$p = x - x'$$

$$X = \frac{xB}{p}$$

$$Y = \frac{yB}{p}$$

$$h = H - \frac{fB}{p}$$

$$h_2 = h_1 + \frac{(p_2 - p_1)}{p_2}(H - h_1)$$

where:

f = Focal length
h = Height above datum
H = Flying height above datum
r = Radial distance from principal point
p = Parallax measured on stereo pair
B = Airbase of stereo pair
x, y = Coordinates measured on left photo
x′ = Coordinate measured on right photo
X, Y = Ground coordinates

PHYSICS

Lens equation:

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

where:

o = Object distance
i = Image distance
f = Focal length

Snell laws:

$$n \sin \phi = n' \sin \phi'$$

where:

n = Refractive index
ϕ = Angle of incidence

Curvature and refraction:

$$(c + r) = 0.0206M^2$$

where:

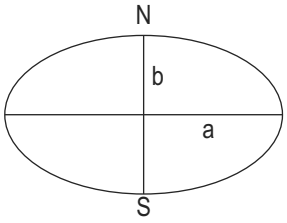
(c + r) = Combined effect of curvature and refraction in feet
M = Distance in thousands of feet

$$s = \frac{1}{2}at^2$$

where:

s = Distance traveled starting from zero velocity
a = Constant acceleration
t = Time of travel

GEODESY



Ellipsoid

a = semimajor axis
b = semiminor axis

$$\text{Flattening, } f = \frac{a-b}{a} \quad (\text{usually published as } 1/f)$$

$$\text{Eccentricity, } e^2 = \frac{a^2 - b^2}{a^2}$$

$$\text{Radius in meridian, } M = \frac{a(1-e^2)}{(1 - e^2 \sin\phi)^{3/2}}$$

$$\text{Radius in prime vertical, } N = \frac{a}{(1 - e^2 \sin^2\phi)^{1/2}}$$

Angular convergence of meridians

$$\theta_{rad} = \frac{d \tan\phi (1 - e^2 \sin^2\phi)^{1/2}}{a}$$

Linear convergence of meridians

$$= \frac{\ell d \tan (1 - e^2 \sin^2\phi)^{1/2}}{a}$$

where:

ϕ = Latitude
d = Distance along parallel at latitude ϕ
ℓ = Length along meridians separated by d

Ellipsoid definitions:

GRS80:	a	= 6,378,137.0 m
	1/f	= 298.25722101
Clark 1866:	a	= 6,378,206.4 m
	1/f	= 294.97869821

Orthometric correction:

Correction = $-0.005288 \sin 2\phi h \Delta\phi \text{arc} 1'$

where:

ϕ = latitude at starting point
h = datum elevation in meters or feet at starting point
$\Delta\phi$ = change in latitude in minutes between the two points (+ in the direction of increasing latitude or towards the pole)

STATE PLANE COORDINATES

Scale factor = Grid distance/geodetic (ellipsoidal) distance

Elevation factor = R/(R + H +N)

where:

R = Ellipsoid radius
H = Orthometric height
N = Geoid height

For precision less than 1/200,000:

R = 20,906,000 ft
H = Elevation above sea level
N = 0

ELECTRONIC DISTANCE MEASUREMENT

$V = c/n$

$\lambda = V/f$

$$D = \left(\frac{m\lambda + d}{2} \right)$$

where:

V = Velocity of light through the atmosphere (m/s)
c = Velocity of light in a vacuum
n = Index of refraction
λ = Wave length (m)
f = Modulated frequency in hertz (cycles/sec)
D = Distance measured
m = Integer number of full wavelengths
d = Fractional part of the wavelength

ATMOSPHERIC CORRECTION

A 10°C temperature change or a pressure difference of 1 in. of mercury produces a distance correction of approximately 10 parts per million (ppm).

AREA FORMULAS

Area by coordinates where i is point order in a closed polygon.

$$\text{Area} = \frac{1}{2}\left[\sum_{i=1}^{n} X_i Y_{i+1} - \sum_{i=1}^{n} X_i Y_{i-1} \right]$$

Trapezoidal Rule

$$\text{Area} = w\left(\frac{h_1 + h_n}{2} + h_2 + h_3 + h_4 + \ldots + h_{n-1} \right)$$

Simpson's 1/3 Rule

$$\text{Area} = w\left[h_1 + 2\left(\sum h_{odds}\right) + 4\left(\sum h_{evens}\right) + h_n \right] / 3$$

EARTHWORK FORMULAS

Average end area formula

Volume = $L(A_1 + A_2)/2$

Prismoidal formula

Volume = $L(A_1 + 4A_m + A_2)/6$

Pyramid or cone

Volume = h(Area of Base)/3

TAPE CORRECTION FORMULAS

Correction for temperature

$C_t = 6.5 \times 10^{-6} (T - T_s)L$

Correction for tension

$C_p = (P - P_s)L/(AE)$

Correction for sag

$C_s = (w^2 \ell^3) / (24P^2)$

where:

T = Temperature of tape during measurement, °F
T_s = Temperature of tape during calibration, °F
L = Distance measured, ft
P = Pull applied during measurement, lb
P_s = Pull applied during calibration, lb
A = Cross-sectional area of tape, in^2
E = Modulus of elasticity of tape, psi
w = Weight of tape, lb/ft
ℓ = Length of unsupported span, ft

STADIA

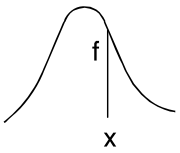
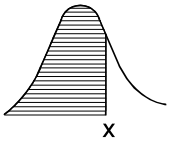
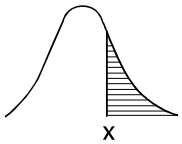
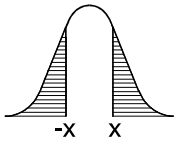
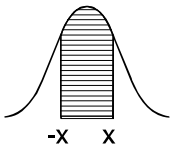
Horizontal distance = $KS \cos^2 \alpha$

Vertical distance = $KS \sin \alpha \cos \alpha$

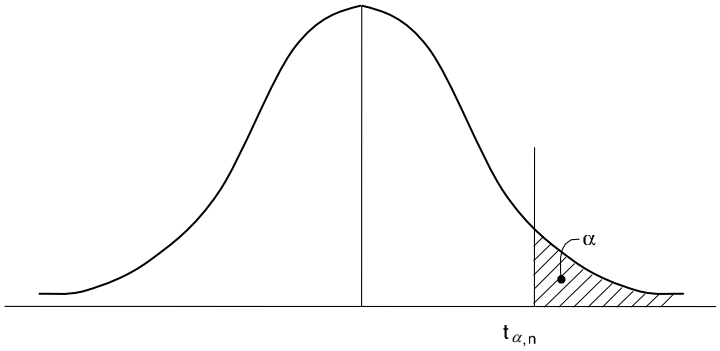
where:

K = Stadia interval factor (usually 100)
S = Rod intercept
α = Slope angle measured from horizontal

UNIT NORMAL DISTRIBUTION TABLE

					
x	**f(x)**	**F(x)**	**R(x)**	**2R(x)**	**W(x)**
0.0	0.3989	0.5000	0.5000	1.0000	0.0000
0.1	0.3970	0.5398	0.4602	0.9203	0.0797
0.2	0.3910	0.5793	0.4207	0.8415	0.1585
0.3	0.3814	0.6179	0.3821	0.7642	0.2358
0.4	0.3683	0.6554	0.3446	0.6892	0.3108
0.5	0.3521	0.6915	0.3085	0.6171	0.3829
0.6	0.3332	0.7257	0.2743	0.5485	0.4515
0.7	0.3123	0.7580	0.2420	0.4839	0.5161
0.8	0.2897	0.7881	0.2119	0.4237	0.5763
0.9	0.2661	0.8159	0.1841	0.3681	0.6319
1.0	0.2420	0.8413	0.1587	0.3173	0.6827
1.1	0.2179	0.8643	0.1357	0.2713	0.7287
1.2	0.1942	0.8849	0.1151	0.2301	0.7699
1.3	0.1714	0.9032	0.0968	0.1936	0.8064
1.4	0.1497	0.9192	0.0808	0.1615	0.8385
1.5	0.1295	0.9332	0.0668	0.1336	0.8664
1.6	0.1109	0.9452	0.0548	0.1096	0.8904
1.7	0.0940	0.9554	0.0446	0.0891	0.9109
1.8	0.0790	0.9641	0.0359	0.0719	0.9281
1.9	0.0656	0.9713	0.0287	0.0574	0.9426
2.0	0.0540	0.9772	0.0228	0.0455	0.9545
2.1	0.0440	0.9821	0.0179	0.0357	0.9643
2.2	0.0355	0.9861	0.0139	0.0278	0.9722
2.3	0.0283	0.9893	0.0107	0.0214	0.9786
2.4	0.0224	0.9918	0.0082	0.0164	0.9836
2.5	0.0175	0.9938	0.0062	0.0124	0.9876
2.6	0.0136	0.9953	0.0047	0.0093	0.9907
2.7	0.0104	0.9965	0.0035	0.0069	0.9931
2.8	0.0079	0.9974	0.0026	0.0051	0.9949
2.9	0.0060	0.9981	0.0019	0.0037	0.9963
3.0	0.0044	0.9987	0.0013	0.0027	0.9973
Fractiles					
1.2816	0.1755	0.9000	0.1000	0.2000	0.8000
1.6449	0.1031	0.9500	0.0500	0.1000	0.9000
1.9600	0.0584	0.9750	0.0250	0.0500	0.9500
2.0537	0.0484	0.9800	0.0200	0.0400	0.9600
2.3263	0.0267	0.9900	0.0100	0.0200	0.9800
2.5758	0.0145	0.9950	0.0050	0.0100	0.9900

t-DISTRIBUTION TABLE

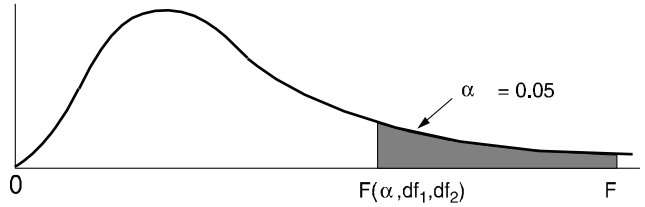


VALUES OF $t_{\alpha,n}$

n	$\alpha = 0.10$	$\alpha = 0.05$	$\alpha = 0.025$	$\alpha = 0.01$	$\alpha = 0.005$	n
1	3.078	6.314	12.706	31.821	63.657	1
2	1.886	2.920	4.303	6.965	9.925	2
3	1.638	2.353	3.182	4.541	5.841	3
4	1.533	2.132	2.776	3.747	4.604	4
5	1.476	2.015	2.571	3.365	4.032	5
6	1.440	1.943	2.447	3.143	3.707	6
7	1.415	1.895	2.365	2.998	3.499	7
8	1.397	1.860	2.306	2.896	3.355	8
9	1.383	1.833	2.262	2.821	3.250	9
10	1.372	1.812	2.228	2.764	3.169	10
11	1.363	1.796	2.201	2.718	3.106	11
12	1.356	1.782	2.179	2.681	3.055	12
13	1.350	1.771	2.160	2.650	3.012	13
14	1.345	1.761	2.145	2.624	2.977	14
15	1.341	1.753	2.131	2.602	2.947	15
16	1.337	1.746	2.120	2.583	2.921	16
17	1.333	1.740	2.110	2.567	2.898	17
18	1.330	1.734	2.101	2.552	2.878	18
19	1.328	1.729	2.093	2.539	2.861	19
20	1.325	1.725	2.086	2.528	2.845	20
21	1.323	1.721	2.080	2.518	2.831	21
22	1.321	1.717	2.074	2.508	2.819	22
23	1.319	1.714	2.069	2.500	2.807	23
24	1.318	1.711	2.064	2.492	2.797	24
25	1.316	1.708	2.060	2.485	2.787	25
26	1.315	1.706	2.056	2.479	2.779	26
27	1.314	1.703	2.052	2.473	2.771	27
28	1.313	1.701	2.048	2.467	2.763	28
29	1.311	1.699	2.045	2.462	2.756	29
∞	1.282	1.645	1.960	2.326	2.576	∞

CRITICAL VALUES OF THE *F* DISTRIBUTION – TABLE

For a particular combination of numerator and denominator degrees of freedom, entry represents the critical values of *F* corresponding to a specified upper tail area (α).



Denominator	Numerator df_1																		
df_2	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**15**	**20**	**24**	**30**	**40**	**60**	**120**	**∞**
1	161.4	199.5	215.7	224.6	230.2	234.0	236.8	238.9	240.5	241.9	243.9	245.9	248.0	249.1	250.1	251.1	252.2	253.3	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38	19.40	19.41	19.43	19.45	19.45	19.46	19.47	19.48	19.49	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.74	8.70	8.66	8.64	8.62	8.59	8.57	8.55	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.91	5.86	5.80	5.77	5.75	5.72	5.69	5.66	5.63
5	**6.61**	**5.79**	**5.41**	**5.19**	**5.05**	**4.95**	**4.88**	**4.82**	**4.77**	**4.74**	**4.68**	**4.62**	**4.56**	**4.53**	**4.50**	**4.46**	**4.43**	**4.40**	**4.36**
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.00	3.94	3.87	3.84	3.81	3.77	3.74	3.70	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.57	3.51	3.44	3.41	3.38	3.34	3.30	3.27	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.28	3.22	3.15	3.12	3.08	3.04	3.01	2.97	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.07	3.01	2.94	2.90	2.86	2.83	2.79	2.75	2.71
10	**4.96**	**4.10**	**3.71**	**3.48**	**3.33**	**3.22**	**3.14**	**3.07**	**3.02**	**2.98**	**2.91**	**2.85**	**2.77**	**2.74**	**2.70**	**2.66**	**2.62**	**2.58**	**2.54**
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.79	2.72	2.65	2.61	2.57	2.53	2.49	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.69	2.62	2.54	2.51	2.47	2.43	2.38	2.34	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.60	2.53	2.46	2.42	2.38	2.34	2.30	2.25	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.53	2.46	2.39	2.35	2.31	2.27	2.22	2.18	2.13
15	**4.54**	**3.68**	**3.29**	**3.06**	**2.90**	**2.79**	**2.71**	**2.64**	**2.59**	**2.54**	**2.48**	**2.40**	**2.33**	**2.29**	**2.25**	**2.20**	**2.16**	**2.11**	**2.07**
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49	2.42	2.35	2.28	2.24	2.19	2.15	2.11	2.06	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45	2.38	2.31	2.23	2.19	2.15	2.10	2.06	2.01	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41	2.34	2.27	2.19	2.15	2.11	2.06	2.02	1.97	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38	2.31	2.23	2.16	2.11	2.07	2.03	1.98	1.93	1.88
20	**4.35**	**3.49**	**3.10**	**2.87**	**2.71**	**2.60**	**2.51**	**2.45**	**2.39**	**2.35**	**2.28**	**2.20**	**2.12**	**2.08**	**2.04**	**1.99**	**1.95**	**1.90**	**1.84**
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32	2.25	2.18	2.10	2.05	2.01	1.96	1.92	1.87	1.81
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30	2.23	2.15	2.07	2.03	1.98	1.94	1.89	1.84	1.78
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27	2.20	2.13	2.05	2.01	1.96	1.91	1.86	1.81	1.76
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25	2.18	2.11	2.03	1.98	1.94	1.89	1.84	1.79	1.73
25	**4.24**	**3.39**	**2.99**	**2.76**	**2.60**	**2.49**	**2.40**	**2.34**	**2.28**	**2.24**	**2.16**	**2.09**	**2.01**	**1.96**	**1.92**	**1.87**	**1.82**	**1.77**	**1.71**
26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22	2.15	2.07	1.99	1.95	1.90	1.85	1.80	1.75	1.69
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25	2.20	2.13	2.06	1.97	1.93	1.88	1.84	1.79	1.73	1.67
28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24	2.19	2.12	2.04	1.96	1.91	1.87	1.82	1.77	1.71	1.65
29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22	2.18	2.10	2.03	1.94	1.90	1.85	1.81	1.75	1.70	1.64
30	**4.17**	**3.32**	**2.92**	**2.69**	**2.53**	**2.42**	**2.33**	**2.27**	**2.21**	**2.16**	**2.09**	**2.01**	**1.93**	**1.89**	**1.84**	**1.79**	**1.74**	**1.68**	**1.62**
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.08	2.00	1.92	1.84	1.79	1.74	1.69	1.64	1.58	1.51
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04	1.99	1.92	1.84	1.75	1.70	1.65	1.59	1.53	1.47	1.39
120	3.92	3.07	2.68	2.45	2.29	2.17	2.09	2.02	1.96	1.91	1.83	1.75	1.66	1.61	1.55	1.50	1.43	1.35	1.25
∞	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88	1.83	1.75	1.67	1.57	1.52	1.46	1.39	1.32	1.22	1.00

ECONOMICS

Factor Name	Converts	Symbol	Formula
Single Payment Compound Amount	to F given P	$(F/P, i\%, n)$	$(1 + i)^n$
Single Payment Present Worth	to P given F	$(P/F, i\%, n)$	$(1 + i)^{-n}$
Uniform Series Sinking Fund	to A given F	$(A/F, i\%, n)$	$\frac{i}{(1+i)^n - 1}$
Capital Recovery	to A given P	$(A/P, i\%, n)$	$\frac{i(1+i)^n}{(1+i)^n - 1}$
Uniform Series Compound Amount	to F given A	$(F/A, i\%, n)$	$\frac{(1+i)^n - 1}{i}$
Uniform Series Present Worth	to P given A	$(P/A, i\%, n)$	$\frac{(1+i)^n - 1}{i(1+i)^n}$
Uniform Gradient Present Worth	to P given G	$(P/G, i\%, n)$	$\frac{(1+i)^n - 1}{i^2(1+i)^n} - \frac{n}{i(1+i)^n}$
Uniform Gradient † Future Worth	to F given G	$(F/G, i\%, n)$	$\frac{(1+i)^n - 1}{i^2} - \frac{n}{i}$
Uniform Gradient Uniform Series	to A given G	$(A/G, i\%, n)$	$\frac{1}{i} - \frac{n}{(1+i)^n - 1}$

Nomenclature and Definitions

A	Uniform amount per interest period
B	Benefit
BV	Book Value
C	Cost
d	Combined interest rate per interest period
D_j	Depreciation in year j
F	Future worth, value, or amount
f	General inflation rate per interest period
G	Uniform gradient amount per interest period
i	Interest rate per interest period
i_e	Annual effective interest rate
m	Number of compounding periods per year
n	Number of compounding periods; or the expected life of an asset
P	Present worth, value, or amount
r	Nominal annual interest rate
S_n	Expected salvage value in year n

Subscripts

j	at time j
n	at time n
†	$F/G = (F/A - n)/i = (F/A) \times (A/G)$

Nonannual Compounding

$$i_e = \left(1 + \frac{r}{m}\right)^m - 1$$

Book Value

BV = Initial cost – $\Sigma\, D_j$

Depreciation

Straight line $D_j = \dfrac{C - S_n}{n}$

Accelerated Cost Recovery System (ACRS)

D_j = (factor from table below) C

MODIFIED ACRS FACTORS				
Year	**Recovery Period (Years)**			
	3	**5**	**7**	**10**
	Recovery Rate (%)			
1	33.3	20.0	14.3	10.0
2	44.5	32.0	24.5	18.0
3	14.8	19.2	17.5	14.4
4	7.4	11.5	12.5	11.5
5		**11.5**	**8.9**	**9.2**
6		5.8	8.9	7.4
7			8.9	6.6
8			4.5	6.6
9				6.5
10				**6.5**
11				3.3

Capitalized Costs

Capitalized costs are present worth values using an assumed perpetual period of time.

Capitalized costs = $P = \dfrac{A}{i}$