

BODY OF KNOWLEDGE

Certified Welding Engineer

The AWS Certified Welding Engineer (CWEng) examination is four parts. Parts 1 and 2 must be successfully completed in order to take Parts 3 and 4. The first two parts of the exam are closed book and cover basic science fundamentals and applied science fundamentals. Parts 1 and 2 are each two hour written multiple-choice exams (total time of four hours). Part 1 is a 35 question multiple choice exam and Part 2 is a 25 question multiple choice exam. They are given together and must be passed together. If the candidate fails only one part, only that part must be repeated.

Parts 3 and 4 of the exam are open book examinations on welding related disciplines and practical welding and related applications. They are each three hours in length. Part 3 is a 45 question essay exam. Part 4 is a 39 question multiple choice exam. Candidates that successfully pass Parts 1 and 2 will be invited to sit for these exams and a separate application must be submitted to AWS.

The exams may be taken at any location where the CWI examinations are given. Candidates are invited to bring any textbooks, articles or codes in their library. Programmable calculators are allowed that do not have audible sounds.

Candidates must pass each of the four examinations with an individual score no less than 60% and attain a minimum weighted percentage of 70% for all 4 parts. Note: The D1.1 2010 edition is applicable to the current CWEng Part 4 exam only (*subject to change*). All applicants shall successfully meet the CWEng requirements as contained in clauses 6 and 7 of AWS B5.16, *Specification for the Qualification of Welding Engineers*.

Approximate subject weights for the four examination parts are as follows:

Part 1 – Basic Science Fundamentals

Mathematics	25%
Physics	50%
Chemistry	25%

Part 3 – Welding Related Disciplines (Essay Exam)

NDE/Weld Discontinuities	10%
Welding Heat Sources and Arc Physics	20%
Welding Processes and Controls	20%
Welding and Joining Metallurgy	20%
Weld Design	20%
Brazing and Soldering	5%
Safety	5%

Part 2 – Applied Science Fundamentals

Strength of Materials	40%
Heat Transfer and Fluid Mechanics	30%
Electricity	30%

Part 4 – Practical Welding and Related Applications

Exam using references on the application of welding engineering concepts in the areas of:	100%
Welding safety, weldment design, welding metallurgy, materials, welding process selection, NDE including visual weld inspection, quality assurance, quality control in accordance with codes, specifications, other standards, and/or drawings.	

Body of Knowledge – Extended Subject Areas as per AWS B5.16:

8.1 Basic Sciences Fundamentals

8.1.1 Mathematics:

- simple calculations (multiple choice)
- special functions (exp, log)
- trigonometric functions (sin, cos, tan, cot, sec, csc, degrees, radians)
- algebraic equations (linear, quadratic, polynomial)
- graphs and equations (slope, intercept, roots, derivatives, minimum, maximum, interpolation, and extrapolation)
- geometry (common geometric shapes)
- hyperbola, parabola
- complex numbers
- calculus (fundamentals of differential equations)
- statistics (population and samples: normal distribution, mean, standard deviation, variance)
- simple correlation: linear regression via least squares

method, r^2 correlation)

8.1.2 Physics:

- unit conversion (dimension, mass, temperature, time, energy, power)
- mass, weight, volume, density
- force, energy, work done, power
- stress, strain, Hooke's Law (elasticity)
- moment and momentum
- temperature, heat, temperature measurement, thermocouples, pyrometers
- thermal properties of materials (thermal conductivity, thermal expansion, thermal stress and strain)

8.1.3 Chemistry:

- symbols (elements and inorganic compounds—gases, fluxes, etc.)
- molecular weight and stoichiometry
- acids and bases
- balance chemical equations
- gas combustion reactions (chemical heat generation) and oxidation-reduction reactions
- ideal gas law (pressure, volume, temperature)
- mass balance (as in E7018 coating decomposition to gas, slag and metal)
- bulk and chemical analysis methodologies
- reactivity, toxicity, environmental effect, disposal.

8.2 Applied Sciences

8.2.1 Strength of Materials:

- load, deformation (elastic and plastic, buckling), stress-strain, Young's Modulus, shear modulus, stress-strain curve (yield stress, ultimate tensile stress, elongation), tensile stress and
- shear stress computation
- welded member cross-section effect
- mechanical testing (tensile, bend, fracture toughness, hardness, creep, and fatigue) and data interpretation
- Law of Conservation of Energy/Momentum
- stress analysis
- typical engineering material properties

8.2.2 Heat Transfer and Fluid Mechanics:

- heat conduction, convection, and radiation, thermal conductivity and diffusivity, heat transfer coefficients of engineering materials, Fourier's Law
- heating rate and cooling rate
- industrial heating methods and power consumption, gas flow rates
- laminar and turbulent flow (Reynold's Number), dew point and relative humidity, pressure and regulators
- venturi effect and gas velocity calculation
- atmospheric pressure and hyperbaric conditions
- vacuum equipment and measurements

8.2.3 Electricity:

- current, voltage, resistance, impedance, and circuits
- Ohm's Law
- Kirchoff's Law
- Resistance loss and current rectification
- power generation
- AC/DC, polarity
- power factor
- electromagnetic properties,
- right-hand rule
- current and voltage measurements (devices and principles)

8.3 Welding Related Disciplines

8.3.1 NDE/Weld Discontinuities:

- NDE processes (radiographic, ultrasonic, magnetic particle, liquid penetrant,
- eddy current, etc.—characteristics, advantages, and limitations)
- NDE symbols

8.3.2 Welding Heat Sources and Arc Physics:

- power source static and dynamic characteristics (open circuit voltage and short circuiting current, slope)
- differences between CC and CV designs (principle of self-adjusting)
- welding arc characteristics (current and voltage relationship, arc length effect)
- electron emission (ionization potential, work function, electrode material, shielding gas, arc stability)
- arc temperature and degree of ionization (shielding gas influence)
- magnetic arc blow (work lead location and condition)
- Lorentz Force (effect on droplet detachment and on adjacent power cables)
- shielding gas drag force (effect on droplet detachment and metal transfer mode) weld penetration and width for different shielding gases

8.3.3 Welding Processes and Controls:

- arc welding processes (SMAW, GMAW, FCAW, GTAW, SAW, PAW)
- resistance welding processes (RW, high frequency RW), high energy density welding processes (LBW, EBW)
- cutting processes (OFC, CAC, and PAC)
- surfacing processing (SW, THSP)
- solid-state welding processes (FRW, FW)

8.3.4 Welding and Joining Metallurgy:

- crystal structure of metals (FCC, BCC, HCP, unit cells, lattice parameter, c/a ratio, atom positions, interstitial positions)
- melting, and solidification, phase transformations and phase diagrams (eutectic, eutectoid, peritectic and monotectic, lever rule calculation) metallurgy and weldability of typical engineering materials (low carbon structural steels, cast irons, stainless steels, nickel alloys, aluminum alloys, titanium alloys, etc.) microstructure (e.g., ferrous alloys—grain boundary ferrite, acicular ferrite, bainite, martensite, austenite, delta ferrite, etc.) and mechanical properties
- carbon equivalent (CEIIW, Pcm, expressions, alloying content and carbon content effect)
- hydrogen assisted cracking (heat-affected zone cracking, cold cracking) base metal matching (e.g., electrodes with high strength steels)
- solidification cracking (segregation of impurity atoms, shrinkage cracking, lamellar tearing)
- delta ferrite in stainless consumables, specifications for consumables (categories; all position, rutile, basic)
- fluxmetal reactions (oxygen and sulfur control in weld pool)
- typical temperature range of a heat source
- temperature distribution in a weldment
- HAZ formation
- multipass thermal experience, reheated weld metal properties
- weld macro and micro-graph interpretation
- solidification profile and preferred grain orientation (epitaxial growth)
- origin of weld ripples
- special attributes of base metal (as-cast structure, deformation texture, oxide on flamecut surfaces)

8.3.4 Welding and Joining Metallurgy (continued):

- thermal treatments (preheat, postheat, interpass influence on weld cooling rate and residual stress distribution)
- solid-state transformations in welds (different forms of ferrite, bainite, and martensite, sigma phase in stainless steels, Guinier-Preston type precipitates zones and aging in aluminum alloys)
- corrosion (sensitization in stainless steel welds, stress corrosion cracking in welds)

8.3.5 Weld Design:

- structural fabrication requirements, sectional properties, stress gradient
- stress triaxiality, weld symbols, hardness and microhardness (e.g., across a weld cross section)
- tensile properties, ductility, toughness, fillet break test (influence of second phase and porosity), ductile fracture, brittle fracture, fatigue (initiation, propagation, failure, high-cycle, low-cycle), temperature and strain rate effect

8.3.6 Brazing and Soldering:

- characteristics of brazing and soldering
- fluxes and substrates
- capillary action
- wetting and spreading
- contact angle
- joint clearance
- viscosity
- liquidus and solidus
- flow of molten filler in horizontal and vertical joints (maximum penetration and rate)
- filler metal systems (Sn-Pb solders, Ni and Cu based alloys, Ag-Cu based brazing alloys)
- intermetallic compound formation

8.3.7 Safety:

- recognize health hazards relating to welding (fumes, toxic gases, noise, radiation)
- recognize safety hazards (electric shock, compressed gases, fire, welding in a confined space, welding on containers and piping, moving equipment)
- recognize precautions to avoid injury
- possess a working knowledge of safety and fire codes

AWS Welding Engineer Examination Preparatory Material

Reference Title	Author	Publisher
ANSI Z49.1 Safety in Welding, Cutting and Allied Processes		AWS
Applied Fluid Mechanics, 4th Ed.	Mott	Merrill Publishing Company
ASM Handbook Vol. 17, NDE		ASM
ASM Handbook Vol. 6 Welding/ Brazing 10th Ed.		ASM
AWS D1.1 Structural Welding Code—Steel		AWS
Design of Weldments	Omer W. Blodgett	The James F. Lincoln Arc Welding Foundation
Engineer in Training Manual		
Essentials of Engineering Economics, 2nd ed.	Riggs & West	McGraw Hill
Fracture & Fatigue Control in Structures, Application of Fracture Mechanics	John M. Barson & Stanley T. Rolfe	Prentice Hall - Second Edition, 1987
Fundamentals of Engineering: The Most Effective FE/EIT Review	Merle C. Potter	Great Lakes Press
Fundamentals of Welding Technology, Modules 1 - 9		CWB Group – cwbstore.org
Handbook of Arc Welding		James F. Lincoln Arc Welding Foundation
HB for Mechanical Engineers	Mark Standard	Avallone or Baumeister
Introduction to the Practice of Statistics ISBN 0 7167 2250 X	Moore & McCabe	Freeman
Introductory Physical Metallurgy of Welding	Easterling	Butterworths
Introductory Welding Metallurgy		AWS
Manufacturing, Engineering & Technology ISBN 0 201 538460	Serope and Kalpakjian	Addison Wesley
Mechanical Metallurgy	Dieter	McGraw Hill
Metals and How to Weld Them		James F. Lincoln Arc Welding Foundation, Second Edition, 1990
Modern Welding Technology	Cary	Prentice Hall
Physics of Arc Welding	J. Lancaster	Pergamon
Product Design for Manufacture and Assembly ISBN 0 8247 9176 2	Boothroyd, Dewhurst & Knight	Marcel Dekker
Quality Control, 5th Ed.	Besterfield	Prentice Hall
Robots & Manufacturing Automation	Asfahl	John Wiley
Stainless Steel	R.A. Lula	ASM International, 1986

Reference Title	Author	Publisher
Statics & Strength of Materials, 3rd Edition, ISBN 0-13-453201-5	Morrow	Prentice Hall
Statics & Strength of Materials: A Parallel Approach to Understanding Structures	Lawrence J. Wolf	Merrill Publishing Company
Weldability of Steels	Stout & Doty	Welding Research Council
Welding Aluminum: Theory and Practice		The Aluminum Association, Second Edition, June 1991
Welding Design, Modules 30-39		CWB Group – cwbstore.org
Welding Encyclopedia	Jefferson	AWS
Welding Handbook Vol. 1, 2, 3, 8th Ed.		AWS
Welding Metallurgy	Sindo Kou	John Wiley & Sons
Welding Metallurgy	Linnert	AWS
Welding Metallurgy	J. Lancaster	Pergamon
Welding Metallurgy, Modules 8, 9, 12, 20-23, 30		CWB Group – cwbstore.org

TO ORDER ANY OF THE ABOVE AWS PUBLICATIONS:
Contact WEX at 888-WELDING or 305-824-1177
Or visit the website at www.awspubs.com