Engineering Economic Analysis

A Handbook of Modern Engineering Economic Analysis

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Preface

This book is an accompanying materials for the course ISE 307, Engineering Economic Analysis, offered in Term 253 (Summer) 2026, by the Industrial & Systems Engineering Department at King Fahd University of Petroleum & Minerals (KFUPM), Saudi Arabia. It has grown into a handbook of modern engineering economic analysis, organized in six parts. Part I builds the foundations: the nature of an engineering economic decision, the time value of money, money management (nominal and effective rates, loans, and financing), and inflation. Part II evaluates alternatives: present worth, annual equivalence, rate of return with incremental comparison, and benefit–cost analysis for public projects. Part III builds real cash flows: cost estimation from engineering data, depreciation and income taxes, and the full project cash-flow statement. Part IV treats risk and flexibility: sensitivity and scenarios, decision trees and the value of information, Monte Carlo simulation, and real options. Part V follows assets over their lives: replacement decisions and sustainability economics. Part VI closes with decision quality in practice: multi-criteria decision analysis, the economics of automation and AI, behavioral pitfalls and forecasting discipline, and a software-and-tools chapter that maps every method in the book to its spreadsheet function. Seven companion Excel workbooks, distributed with the book in the `spreadsheets/` folder, carry live versions of the book's own examples. Each chapter also works a case study drawn from the open research literature, with its own reference list, so the methods are seen doing real work on published numbers. The book is written so that it can be read on its own. You do not need the lecture recordings or the textbook next to you while you read it, although both are useful. Every method is explained from the beginning, every interest factor is derived so that you can see where it comes from, and every kind of problem that appears on the homework, the quizzes, and the major exams is solved here in full, step by step.

How this book is organized

Each chapter follows the order of the course lectures. The body of the page carries the explanation, the derivations, and the worked examples. The wide margin carries supporting material, so you always know where to look:

Definitions. Every technical term, when it is first used, is defined in the margin in green.

Figures. Most of the cash flow diagram and figure are in the margin, next to the sentence that refers to it, so the picture and the words stay together.

References. Pointers to the lecture, the slides, and the external references are placed in the margin at the start of each section.

Startup lens. Gold margin remarks that reread the section's method from the point of view of someone building a new venture: pricing a product, raising money, deciding what to own and what to rent.

Engineering judgment. Maroon margin remarks that show where your engineering knowledge—equipment lives, failure modes, capacity limits, process yields—enters the economic analysis as an input, not an afterthought.

Examples, figures, and tables

Every worked *example* is numbered within its chapter (''Example 2.3'' and so on) so it can be referenced in lecture and in your own notes. Inside each example a small *Solution.* rule separates the problem statement from the worked-out solution, leaving you a natural place to attempt the problem yourself before reading on. Every figure (including every cash flow diagram, even those that appear inside a multi-step solution) and every table is also numbered and listed in the front matter, so the *List of Figures* and *List of Tables* can be used as a quick visual index of the book.

Pre-class quizzes and end-of-chapter exercises

Two kinds of practice are scattered through the book:

Pre-class quizzes. short concept checks placed before a lecture. The questions appear consecutively in a small green block; the answers are collected in a shaded box at the bottom of the same block, so you can answer all of them first and then check.

End-of-chapter exercises. full computational problems drawn from the homework and the quizzes. They are arranged from the most basic single-payment calculations up to mixed cash flows, gradients, and decision problems. Every solution is worked in full, but is collected in the back of the book (the ''Solutions to End-of-Chapter Exercises'' chapter), so that the temptation to glance at the answer while attempting the problem is removed.

Exam-style problems. each chapter's exercises end with problems written in the exact format and difficulty of the major exams and the final, so the step from practice to exam holds no surprises.

Assessing outside recommendations. each chapter also includes problems in which an AI assistant, a vendor, or a consultant has already produced an analysis—and that analysis is wrong or incomplete in some way. Your task is to find the error, explain it, and correct it. Checking someone else's work is a different skill from producing your own, and in practice it is the one you will use most.

Multiple-choice questions, where they appear, list one option per indented line below the stem, so the choices are easy to scan.

Worksheets, and the examinations themselves

The term this book was written for is complete, so the assessment chapter no longer holds anything back. chapter 22 carries the homework sets, the practice quizzes, the practice major-exam packets, and the **final examination as it was actually sat**, each laid out with answer regions sized to the work a grader expects. Appendix D carries the official solutions and answer keys for all of them. Work the paper first and read the key second: the gap between recognising a solution and producing one is exactly the gap between a passing mark and a good one.

If English is not your first language

Most readers of this book study engineering in English and think, at least part of the time, in another language. The chapter that follows this preface exists for that reason. It sets out, in one place, every symbol the book uses, how to read factor notation aloud, the currency and number conventions of the exam papers, a list of ordinary English words that carry a narrower technical meaning here (*worth*, *salvage*, *sunk*, *cushion*, *defender*), and the small fixed set of instruction verbs that examination questions use and what length of answer each one is asking for. None of it is examinable on its own; all of it is assumed on every later page.

A note on numbers and examples

All amounts are in Saudi riyals, written **SAR** after the number, with a comma for thousands and a point for the decimal part: 1,234.56 SAR. The examples are built around two recurring settings: the energy-transition mineral supply chain of Vision 2030 (lithium refining, phosphate plants, haul trucks, flotation cells) and automation and robotics (inspection robots, autonomous fleets, research funds). Both settings are chosen so that the engineering behind the numbers is one you can picture, and both sit in the industrial landscape this book's readers are most likely to work in. Small differences from your own work usually come from rounding, or from the number of decimal places carried in the interest factor tables, and are not errors.

This resource was prepared with the help of generative AI tools and reviewed and corrected by the instructor.

How to Read This Book: Notation, Words, and Conventions

This short chapter is a reference desk. Nothing here is examinable on its own, but everything here is used on every later page. Most readers of this book study engineering in English while thinking, at least part of the time, in another language, so the symbols, the phrases, and the number conventions are all set out once, in one place, rather than being explained the first time they happen to appear. Come back to it whenever a symbol or a phrase in a problem statement is not doing what you expected. The alphabetical glossary in Appendix D is its companion: this chapter is arranged by kind of thing (symbols, then numbers, then words, then exam verbs), the glossary is arranged by name, and every glossary entry says which chapter teaches it.

Symbols used throughout the book

The same letters mean the same things in every chapter, in every worksheet, and on every exam paper in this course.

Symbol	**Meaning**
P	a single amount located at the present, time zero
F	a single amount located at some future period N
A	an amount that repeats, unchanged, at the end of every period
G	the constant amount by which a series grows each period (arithmetic gradient)
g	the constant *rate* at which a series grows each period (geometric gradient)

Symbol	Meaning
i	the interest rate per period, written as a percentage, used as a decimal
r	the nominal annual rate, quoted per year but compounded more often
i_a	the effective annual rate that r actually produces
N, n	the total number of periods; the index of one particular period
MARR	minimum attractive rate of return: the rate a project must beat
PW	present worth: everything the project does, restated at time zero
FW	future worth: the same, restated at period N
AE, AEC	annual equivalent (annual equivalent cost): the same, spread evenly per period
i^*	the rate of return that makes $PW = 0$
I	the cost basis of an asset: what may be depreciated
S	salvage value: what the asset is expected to be sold for at the end
D_n	the depreciation charge taken in period n
B_n, BV	book value: the basis less all depreciation taken so far
t	the marginal income tax rate
TI	taxable income
NI	net income, the bottom line of the income statement
ATCF	after-tax cash flow: the cash the project actually produces after tax
$E[\cdot]$	the expected (probability-weighted average) value of a quantity
σ	the standard deviation: how widely the outcomes scatter
SAR	Saudi riyal, the currency of every amount in this book

Factor notation, and how to say it out loud

Every equivalence calculation in this course is written in *factor notation* before any number is substituted:

$$P = A\,(P/A,\, i,\, N).$$

Read the bracket from left to right as **"P given A, at i percent, for N periods."** The letter before the slash is what you *want*; the letter after the slash is what you *have*. So $(F/P, 8\%, 5)$ is "F given P, at 8 percent, for 5 years": it converts a present amount you already know into the future amount you want. This one habit —

want over have — is enough to pick the right factor without memorizing the table headings.

Two consequences follow, and both are worth checking whenever an answer looks wrong. First, the letters cancel like fractions: $P = F\,(P/F)$ and $F = P\,(F/P)$, so $(P/F)\,(F/P) = 1$. Second, a factor whose top letter is P or A and whose bottom letter is F or P will always be *less* than one when $i > 0$, because moving money backwards in time makes it smaller.

Write the factor notation first, then substitute, then compute. Examiners in this course give partial credit for a correct factor with a wrong arithmetic result, and no credit for a bare number.

Money, numbers, and units

Currency. Every amount is in Saudi riyals and is written **SAR** after the number: 120,000 SAR. No currency symbol is ever placed *before* the number in this book, so the currency never has to be guessed from context and no amount can be misread as dollars.

Thousands and decimals. A comma separates thousands and a point separates the decimal part: 1,234.56 SAR means one thousand two hundred thirty-four riyals and fifty-six halalas. This is the convention used on the exam papers, in the interest factor tables, and in the companion spreadsheets. If your calculator or your operating system is set to the opposite convention (1.234,56), change it before an exam — a misread separator is the single most common avoidable error on graded work.

Rounding. Interest factors are carried to four decimal places, exactly as they appear in Appendix B. Money answers are reported to two decimal places. Round only at the end; rounding a factor early and then multiplying by a large investment can move an answer by hundreds of riyals. When your result differs from the book's by a riyal or two, this is almost always the reason, and it is not an error.

Rates. A rate written 10% is used in a formula as 0.10. A period is one year unless the problem says otherwise; when it does not, say so in your answer rather than assuming.

Signs. Money leaving the firm is negative, money arriving is positive, and a cash flow diagram shows this with the direction of the arrow: down for an outflow, up for an inflow. Costs are therefore entered as negative numbers in a present-worth sum, and an "annual equivalent *cost*" (AEC) is quoted as a positive number whose sign has already been accounted for by calling it a cost. Mixing these two habits inside one calculation is the second most common avoidable error.

End-of-period convention. Unless a problem states otherwise, every cash flow occurs at the *end* of its period, and period 0 is the present instant. An investment made "now" sits at time zero; a first annual payment "starting next year" sits at time one.

Words that carry a technical meaning

These English words are used in engineering economy in a narrower sense than in everyday speech. A dictionary translation of the everyday sense will mislead you, so each is given here in the sense this book uses.

Word	**What it means here**
worth	a value restated at a chosen point in time, not a judgment of quality
equivalent	different in amount and timing but of equal value at a stated interest rate
outlay	cash paid out
salvage value	the amount the asset is expected to sell for at the end of its life
sunk cost	money already spent that no present decision can recover, and which therefore never enters a comparison
cost basis	the one-time amounts needed to acquire an asset and make it ready for use: price, freight, installation — the amount that may be depreciated
book value	basis less depreciation taken so far: an accounting record, not a market price
market value	what the asset would actually sell for today

Word	What it means here
depreciation	a deduction spread over the asset's life; it moves no cash by itself
tax shield	the cash saved because a deduction lowered the tax bill, equal to $t\,D$
overhaul	a large repair in one particular year, entered as a single cash flow in that year
defender	the asset currently owned, in a replacement study
challenger	the candidate asset proposed to replace it
economic service life	the number of years of ownership that makes the annual equivalent cost smallest
capital recovery	the annual cost of owning an asset: purchase less salvage, spread over the life
capitalized cost	the present worth of a cost that repeats forever
incremental	the difference between two alternatives, which is the only thing that can decide between them
mutually exclusive	a set of alternatives from which exactly one may be chosen
cushion	how far an estimate may fall before the decision changes; also called the break-even margin
break-even	the input value at which the decision flips, usually where $PW = 0$
sensitivity	how much the answer moves when one input is changed on its own
scenario	a complete, internally consistent set of inputs, changed together

The verbs used in exam questions

Examination questions in this course use a small, fixed set of instruction words, and each asks for a different amount of writing. Reading the verb before reading the numbers tells you how long the answer should be.

State. Give the quantity or the name, with its units. One line. No derivation is expected.

Compute. Show the factor notation, substitute, and give the number with its units. Full working is required; a final number alone earns little.

Complete. Fill the marked cells of a given table. The unmarked cells are provided so you can check that your basis or your rate is right before you go on.

Explain. Write one or two full sentences, in prose. A formula is not an explanation.

Which statement is FALSE. Exactly three of the four options are true. Find the one that is not; do not look for the "most correct" one.

Recommend / verdict sentence. One sentence that carries the actual numbers you computed and ends in a decision. "Accept" on its own is not a verdict; "accept: the expected present worth is +8,855 SAR, but a 31% chance of loss remains" is.

How the practice in this book works

Two kinds of practice run through every chapter, and both work the same way everywhere, so the rules are given here once instead of at the head of each chapter.

The block before you read on. Each chapter opens its main development with a short set of concept questions in a green block. Answer them before reading further — from what you already know, or by guessing — and only then look at the shaded box at the foot of the block, which holds all the answers together. Guessing first and being corrected is what makes the correction stick; reading the answer first does not.

The exercises at the end. These are the real problems: the in-class activities, the homework, the quizzes, and problems written at exam difficulty. They are ordered from the simplest use of the chapter's method up to problems that combine it with earlier chapters. Every one is solved in full in Appendix D at the back, deliberately far from the question, so that glancing at the answer takes a decision rather than a glance.

Graded work in this course, and every worked solution in this book, follows the same shape. Draw the cash flow diagram. Write the factor notation before any number. Substitute. Box the final answer with its units. End with one sentence that states the decision and carries the numbers that justify it. A bare number, however correct, earns little; the steps are the answer.

Each chapter's exercises also close with two kinds of problem worth naming. *Exam-style problems* are written in the exact format and difficulty of the papers in chapter 22. *Assessing outside recommendations* problems hand you an analysis that somebody else — a vendor, a consultant, an AI assistant — has already produced, and that is wrong or incomplete in some specific way. Your task is to find the error, name it, and correct it. Checking someone else's work is a different skill from producing your own, and it is the one you will use most.

A suggested path through the book

The book is longer than one term. Table 1 shows the route the ISE 307 lectures take through it, and which assessment closes each block. If you are reading the book outside the course, the same route works: each block stands on its own, and each ends with a worksheet you can sit under exam conditions.

Table 1: The route the course takes through the book.

Lectures	**Chapters**	**Closed by**
1–2	1 (decisions)	—
3–7	2 (time value of money)	Homework 1, Quiz 1
8–9	3 (money management: nominal, effective, loans)	Homework 2
10	4 (inflation)	—
11	1–4 review	**Major Exam 1**
12–14	5 (present worth)	Homework 3
15–16	6 (annual equivalence)	Quiz 2
17–18	7 (rate of return, incremental analysis)	—
19	5–7 review	**Major Exam 2**
21	10 (depreciation)	Homework 4
22	10 (income taxes and after-tax cash flow)	—
23	12 (project uncertainty)	Quiz 3
24	21 (software and tools: spreadsheets)	—

Lectures	Chapters	Closed by
25	10, 12, 21 review	**Final Exam**

The remaining chapters — benefit–cost analysis, cost estimation, project cash-flow statements, decision trees, Monte Carlo simulation, real options, replacement, sustainability, multi-criteria analysis, the economics of automation, and behavioral pitfalls — are not examined in ISE 307. They are in the book because the handbook is meant to outlast the term, and because most of them appear in the FE examination or in the first project you will be handed at work.

What to do in the week before an exam

The order matters more than the hours. Work the end-of-chapter exercises of the examined chapters first, with the solutions chapter closed. Then sit the matching worksheet in chapter 22 under real conditions: one sitting, formula sheet and factor tables only, a clock running. Only then open Appendix D and mark yourself. Reading a worked solution feels like learning and is not; producing one under time pressure is. The worksheets in this book are the actual papers sat in this course, including the final examination, so a clean run through them is a reliable measure of where you stand.

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