THE ORIGINAL BOOK OF QUANT INTERVIEW QUESTIONS

**HEARD ON T**HE STREET: Quantitative Questions from Wall Street Job Interviews

REVISED 15TH EDITION

TIMOTHY FALCON CRACK

Heard on The Street: Quantitative Questions from

Wall Street Job Interviews

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Heard on The Street: Quantitative Questions from

Wall Street Job Interviews

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**Preface**

THIS BOOK IS A MUST READ! It is the first and the original book of quantitative questions from finance job interviews, Painstakingly revised over 19 years and 15 editions*, Heard on The Street* has been shaped by feedback from many hundreds of **read**ers. With more than 50,000 copies in print, it is unmatched by any competing **book**

This revised 15th edition contains over 185 quantitative questions collected from actual job interviews in investment banking, **investment management, and options** trading. The interviewers use the same questions year-after-year, and here they are...with solutions! These questions come from all types of interviews (corporate **finance, sales an**d trading, quant research, etc.), but they are especially likely in quantitative capital markets job interviews. The questions come from all levels of interviews (undergraduate, MBA, MS, PhD), but they are especially likely if you have, or almost have, an MBA ON MS. This edition also includes 140 non-quantitative actual interview questions, giving a total of more than 325 actual finance job in **terview q**uestions. There is also a section on interview technique...based on my experiences interviewing candidates for the world's largest institutional asset man ager, and also based on feedback from i**nterviewers worldwide.**

This book bridges the considerable gap between the typical finance education and the knowledge required to successfully answer quantitative finance job inter view questions. The considerable gap arises because Wall Street in**terviewers must separat**e the "wolves" from the "sheep." The s**heep are confine**d by the boundaries of their education; the wolves are not. The in**terview questions** reach beyond these boundaries in order to separate the two classes of interviewees. Hence the gap. Of course, most inte**rviewers are wolve**s. Unfortunately, many interviewees are sheep. The butchering that takes place has been described to me as "horrific." That is why you need this book.

I bridge the above-mentioned gap by presenting quantitative questions from actual finance job interviews. I could not find even one of these questions in any of the three-dozen other "interview books" at a large US bookstore. My solutions and **advice are carefu**lly designed to sharpen your quantitative skills. My advice is based on my experiences as a frontline teaching assistant for MBA students at MIT, as a finance professor at Indiana University, and as the former head of a quant research team for the world's largest institutional asset manager.

My intended audience includes in**terviewees (wolves an**d sheep alike) seeking employment at Wall Street or other finance-related firms; their inte**rviewers, who**

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need to weed out the hapless sheep; university pro**fessors who wa**nt to "spice up" finance courses with Wall Street job interview questions (both for fun and to show the importance of the basic concepts on The Street); students o**f finance who want** to fill in some gaps; and finally, doctoral **students in need of entertainment during** periods of downtime.

Many of the questions collected and presented here are "classics" that appear **year-after-year without fail. However, th**is book is definitely not for people who just want "The Answers" to such questions. Such people are the archetypal sheep in wolves' clothing, and they are quickly identified as such in an interview. To benefit from this book, you must make a serious investment of your time.

I thank MIT students, MIT faculty, and practitioners who supplied me with information. I thank Olivier Ledoit. Cecily Lown, Bingjian Ni, Eva Porro, and Juan Tenorio for their constructive criticism. The first edition of this book **was written** and edited in 1995 while commuting to and from MIT on the subways and buses of the Massachusetts Bay Transit Authority ("Thank you for riding... ...the MBTA").

*TFC/MIT/1995* I revised this book when I was a professor at Indiana University (IU). I thank all the people thanked above (especially Olivier Ledoit). I also thank Sean Curry and The MathWorks Inc for a free copy of MATLAB (used to chec**k answers and** draw figures), MBA Style M**agazine (www.mbastyle**.com) for horror stories, An dres Almazan, Tom Arnold, Mary Chris Bates, Klara Buff, Alex Butler, Victor W. Goodman, Tim Hoel, Taras Klymchuk, Victor H. Lin, Marianne Lown, Alan J. Mar cus, David Maslen, Marc Rakotomalala, Jason Roth, Yi Shen, Valeri Smelyansky, Dahn Tamir, Paul Turner, and students (MBA and undergraduate) at each of MIT, UCLA, and IU.

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I updated this book while working as Head of Quantitative Active Equity Re search (UK/Europe) at the world's largest institutional asset manager. I also thank Jinpeng Chang, Mark Rubinstein, Alex Vigodner, and Nick Vivian.

*TFC London/2001-2003* I updated this book after accepting a chaired professorship in Finance at Otago University in New Zealand. The latest edition contains new questions and improved **answers** to old ones. I particularly thank interviewers at top firms who shared their most recent questions. I now also thank Giulio Agostini, David Alexander, Armen Anjargholi, Arta Babaee, Edward Boyce, HC, **Veeken** Chaglassian, Scott Chaput, Aidong Chen, Jun Chung, Nate Coehlo, Richard Corns, Patrick de Man, Alessio Farhadi, Robin Grieves, James Gwinnutt, Charles Hallion, Chun Han, Eoin Healy, James Hirschorn, Alexander Joura, Philip Koop, Steve Lee, Vince Moshke vich, Stuart O'Neill, RBP, Katie Price, Wolfgang Prymas, Bryan Rasmussen, Adam Rej, CCS, Naoki Sato, Ashish Saxena, Tommaso Sechi, Torsten Schöneborn, Adam Schwartz, Avishalom Shalit, Yirong Shen, Ian Short, Craig Smith, Olaf Torne, and Mikhail Voropaev, Thomas C. Watson, Simon West.

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**Introduction**

This book first appeared in 1995 with que**stions collected from students after in terviews. Nowadays t**he interviewers at top firms frequently send me their new questions directly! For example, one interviewer at a big-name New York invest ment bank sent me the bank's latest full written quantitative interview test with three dozen questions and answers)!

I used to wonder why interviewers at top firms supply me with their interview questions to put in a book to sell to their job **candidates. Now I understand that** they do not mind if the questions are public knowledge because job candidates who **make a serious investm**ent of time in revising the questions deserve to be hired!

All of the quantitative qu**estions are accompani**ed by detailed solutions. The questions are split into four categories: Purely Quantitative and Logic, Derivatives, Other Financial Economics, and Statistics (Chapters 1, 2, 3, and 4, respectively). The solutions appear in Appendices A, B, C, and D, respectively. Chapter 5 p**resents** non-quantitative questions from actual interviews with selected solutions in Ap pendix E). In the text, a name followed by a year (e.g.."Girsanov (1960)") re**fers** to a work cited in the References (following the appendices).

**If you are interview**ing for option jobs and you **need a review book to complement** the interview questions here, then you should buy my book *Basic Black-Scholes,* Crack (2014a). See the advertisement at the end of this book for details, or go directl**y to www.BasicBlackScholes. com*. Basic B****lack-Scholes* started its life as an **exten**ded appendix to this book, but was carved out as a book in its own right, and is now in its revised second edition. The original aim of that book was to help **interview ca**ndidates. So, the writing style should be more suited to you**r interview** preparation than other competing books,

**Questions in This Book**

The questions in this book were collected by me from intervi**ewees, interviewers, and** others. I have taken the liberty of rewording them for **maximum clarity because, unlike in an interview**, you have no opportunity **to ask me for cla**rification. Some times I give only part of a qu**estion that was asked; sometimes I combine related** questions into a larger one. I remain faithful to the original problem statement **wherever possible.**

I sometimes add a footnote to a question. The footnote contains a slight variation

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*I*N*TRODUCTION*

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on the question. Unless otherwise indicated, these "footnote questions are made up by me and are not actual job interview questions. All other questions come from actual job interviews (even the condom question”).

Many of the questions require a serious investment of your time. Knowing the answer is not enough in and of itself. Interviewees should attempt these questions without peeking at the answers. Mastering the problem-solving process gets you the job. This may mean spending days with a problem before you figure it out. Looking at the answer tells you how I did it; it does not tell you how to solve problems by yourself. The path of greatest resistance bears the highest rewards!

Interviewers can use these questions as they stand. However, I strongly encour age you to push candidates very hard for the underlying understanding. Ask them to explain the answer, not to simply solve the problem. This differentiates those who understand the problem from those who merely know the answer. The good ones meet the challenge: the bad ones do not. Many people can solve problems, but only the best genuinely understand what they are doing.

Will the q**uestions in this book become obsolete or dated? The answer is no, for two reason**s: First, many of the questions are "classics" that appear consistently year-after-year; and second, the body of quantitative skills required to solve these questions has remained unchanged for three decades. Even if some of the questions change, the skills required to solve them do not. It is these skills that my book promotes. For these reasons, it follows that these questions are genuinely timeless."

Sometimes the classification of a question (and, therefore, the chapter it should be in) is by no means clear. For example, some of the financial economics questions look like statistics questions, and I have placed questions on stochastic calculus in the derivatives chapter instead of the statistics chapter.

Some questions have more than one solution technique. The "right answer" may be the wrong answer if you use a "brute-force" approach and completely miss an elegant alternative (I often give both techniques).

Some questions are more difficult than others. I have labeled difficult questions with two stars "(\*\*)" and very difficult questions with three stars "(\*\*\*)." By default, all other questions deserve one star. For the two-star or three-star questions, your approach, rather than your solution, may be of more importance. You should be able to set up a general framework for a solution. If you can solve such questions on the spot, you are doing well.

Some of the questions are at a low level, and you may think it beneath your dignity to answer them. I have, **however, intervi**ewed people who c**laim to have** degrees in finance, economics, statistics or mathematics, who **cannot answer basic** finance, economics, statistics, or mathematics questions, respectively. If you think the basic questions are beneath you, then prove it by walking through them like a hot knife through butter. If you cannot answer the basic questions, however, either because you are rusty on the basics, or simply never understood them, then why

***"*At first glance, some questions may seem dat**ed (e.g., "Su**ppose that IBM is trading at $75 per sha**re ..."). However, I could easily have made it “Stock XYZ" (co**ntrary to the original w**ording) **and you would not have noticed. Where possible, I retain the original w**ording for authenticity.

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*INTRODUCTION*

**1**

should anyone hire you? No one will want to put you in front of their team members, clients, or traders, who will have basic questions.

If you are interviewing for a more quantitatively oriented job where knowledge of C (but probably not C++) is required for the interview (and C++ may be required for the job itself), I recommend Mongan, Suojanen and Giguère (2007) to you.

You must have already heard all the ordi**nary interview advice cover letters, appearance, comments** on previous employers, use of bad language, chewing gum, re searching people who will interview you, researching the firm, knowing your strengths **and weaknesses, and** so on); if not, then see Fry (2009). To answer the type of ques tions in this book, however, you may need the *ertraordinary* advice that follows.

Will They A**sk me These Questions?**

Yes, you must assume that they will. You can hope for the best, but you must pre pare for the worst. Some firms use the first round of interviews to get to know you with soft and non-quantitative questions. In this case, a second round typically fol lows with quantitative questions. Other firms use a quantitative first round to screen applicants up **front. However, some firms ask no quantitative questions. There is** thus a chance that you will see no quantitative questions. In this unlikely event, my quantitative q**uestions will have exercised your IQ, and my non-quantitative**

questions (Chapter 5) will have been of most assistance.

On the non-quantitative front, many inte**rviewees have been as**ked, "Where did the Dow close yesterday*?*" or "Where did the Nikkei close?" or "Where is the long bond?" In addition to current knowledge, you should also know how these (and other) basic economic variables have changed over the recent past, and where they are relative to all-time highs and lows...See Chapter 5 for more examples. Even if you are very busy interviewing with many firms, you must not be found ignorant on such basic market knowledge.

**ATQ!**

"ATQ" stands for "Answer The Question!" Let us suppose that I am the inter**viewer** and that I have little patience. I am busy. Damn busy! I have a deadline for my boss on a project that is due tonight (he is in an earlier time zone). I walked away from the stack of work on my desk, and the spreadsheet I desperately need to build just so that I can talk to you. Spending 30 minutes with you means I get home at 10:30PM instead of 8:00PM, because I have to finish my project, and I will miss the last direct train. I earn $250,000, $500,000, $1M, or more per annum. I got my job and kept it because I am efficient and I understand time management. I want to hire a good person, but if you waste my time then I will crucify you; perhaps not to your face, but to my colleagues, both at this firm, and at competing firms thinking of interviewing you.

I know from past experience that people with good resumes are not necessarily knowledgeable in their claimed area of expertise. If you have a degree in finance, or

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*INTRODUCTION*

**mathematics, or whatever, and cannot answer a b**asic question in that area, then how the heck can I let you answer the phone, or bring you to a meeting with a client, or let you talk to our traders, or take you to a meeting with the portfolio **managers, or hav**e you join me in a conference call with my boss? That is, **how can** I hire you if you cannot answer basic questions? I know that there will come a time in this interview or the next when I have to push you to answer some quantitative questions, so that I can see what you understand and what you do not. Some of them will be basic, some of them not. I need to know the limits of your knowledge, and I cannot find them by **asking soft wishy-washy questions about your resume.**

If I ask you a question, then answer the damn question! If you **know the answer,** then tell me it. If you do not know the answer, but can work it out, then tell me that and outline the steps; I may be happy with that, and then not need to see the full derivation. If you have only a passing knowledge of the area, or no hope whatsoever of answering the question, then I need you to say so directly, and without wasting **my time, so that I can ask you other questions. I need to know the boundaries of** your abilities, and to find them I must ask you a mix of questions including ones that you cannot answer at all. Do not waste my time by foundering around and, in effect, drowning yourself in your own ignorance.

For example, suppose it is a bond trading job and I ask you whether the c**urvature** in the plot of bond pr**ice versus yield to matu**rity is caused by changing Macaulay duration as yield changes. Let us suppose that you know the answer, but instead of giving it to me directly, you say;

"W*ell, that's an interesting question*. W*e know that for a standard coupon-bearing bond with no embedded options, the plot of bond price versus yield to maturity is downward* ***sloping an****d concave up. Let me draw that on the whiteboard here (draws picture). As yield* ***rises****, other things being equal, bond price falls, but the dollar rate at which the bond pric*e *falls actually decreas*e*s as yield to maturity rises. That is, the slope becomes less negative. Changing slope means that there is curvature, and sure enough the plot is concave up. Now, some people may think, naively, that the slope of the plot is just the Macaulay duration of the bond. Now, it is well known that as yield to maturity rises, other things being equal, the Macaulay duration of a standard coupon-bearing bond with no embedded options falls.* S*o, these people would deduce, naively and incorrectly, that as yield to maturity rises, the changing slope is simply a reflection of changing Macaulay duration. However, the simple fact that the Macaulay duration of a standard coupon-bearing bond with no embedded options is positive, and that the slope of our plot is negative, tells us that the slope is not the Macaulay duration. It is not the negative of the Macaulay duration either, and we can see that by looking at the case of a zero-coupon bond. Suppose we plot bond price versus yield to maturity for a ten-year zero with no embedded options. The plot is dounward sloping and conc*a*ve up as before, with slope becoming less negative as yield to maturity rises, but the duration is 10 years regardless of the yield-because it is a zero. That is, where the slope is of larye magnitude, the Macaulay duration is ten; where the slope is of intermediate magnitude, the Macaulay d****uration is t****en; where the slop*e *is of small magnitude, the Macaulay duration is ten. Thus, slope does not equal Macaulay duration, or negative Macaulay duration, and the curvature of the plot cannot simply be a reflection of changing Macaulay duration. Now,*

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*INTRODUCTION*

*the slope of the plot of the price of the standard coupon-bearing* ***bond versus its yiel****d to maturity* i*s a function of Macaulay duration, but it is also a function of bond price and yield to maturity. If we write down the slope explicitly, we see that it is - P, where D is Macaulay duration, p is bond price, and r is yield. If we look at n****umerical examples, we*** *can see however, that the duration does not change very much with changing yield. Indeed, as already mentioned, it does not change at all in the case of a zero, and lou-coupon bonds are not that different from ze*rd*es. Rather, it is the bond price that chang****es signifi****cantly with changing yield, and it is this that causes changes in the slope, thus producing curvature.* S*ure enough, in the case of a coupon-bearing bond, the changing Macaulay duration contributes to the change in slope, and thus to the curvature, but its contribution to curvature is much less important than the contribution of changing bond price. So*, no, *it is not changing Macaulay duration, but rather, changing price, that drives the change in slope, thus creating curvatur*e."

Well, you just spent two and one-half minutes of my valuable time saying that. That is ten percent of your **interview ti**me. In your favor, you got to the correct **answer**, which is "no," but in so doing yo**u gave me so many words that I ceased** caring whether you **knew the answer** or not. I did figure out, h**owever**, that if you **were wo**rking on my team, I could not take you to a presentation to clients because you would take *for bloody ever* to answer their questions and bore the pants off them in the process. I also figured out that you really like hearing **the sound of your own voice. You may well be someone who does not realize that time is money, that that** money belongs to my clients, or to the firm, and that that money has a heck of a lot of zeroes on the end of it.

You should have just answered "No, changing bond price drives changing slope **and creates curvatu**re." You should then add that "Changing M**acaulay duration** contributes marginally to curvature for a coupon bearing bond, but not at all in the case of a zero.“ If the question has a "yes" or "no" answer, and you know the **ans**wer, then the first word out of your mouth should be "yes," or "no," respectively. Anything else means you are not getting to the point, and you are wasting my time and your golden opportunity! Obviously, you support your assertion immediately with more words, but **answer th**e question first! ATQ!

I have had people talk a full ten minutes or more before coming anywhere near allowing me to detect whether they know the answer or not. After the first minute **I have already** decided that you are in the wrong building, and I am thinking about **the stack of work on my desk**. I stopped caring about your answer back in the first chapter of your **saga. I am about to can**cel the next person on your inte**rview** schedule because I value his or her time almost as much as I value my own. Unlike me, you get to go home early today.

To repeat, if the answer is "yes," and you know it, then say so! If the **answer** is “no," and you know it, then say so! You can add words after that, to support your answer, but for God's sake, get to the point! Suppose you are on a date with a person you find exceptionally attractive, and you are dancing, and this pe**rson says, "Do you want t**o kiss m*e?*" Are you going to talk to them for ten **minutes about** how you arrive at your decision or are you going to get to the point? Similarly, you

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*INTRODUCTIO*N

must have had a professor at college who when asked a question from the audience mid-lecture would take five minutes giving his answer. *W*hen he got to the end of it you did not know what the answer was he had given, and you just wished he would shut up and move on. He invariably followed it up with "Is that clear now*?*" and no one dared say "no," for fear he would talk more about it. The bottom line is, answer the question! Remember ATQ, or even A*TFQ!,* if it helps hammer it into your skull.

If you do not know the answer, but know enough to try to work it out, than say something like "Hmmm. I do not know, but I think I can work it out. I know that the slope is given by - *P P*, where *D* is duration, *P* is price, and r is yield. I am not sure how much of the change in slope is explained by changes in each of *D* and P, but I do know that a zero has fixed *D*, so I suspect that changing *P* is more important than changing *D*." That is fine. You told me you did not know, and then you tried to work it out. That differs from knowing, but failing to tell me until the end of a saga.

If a question is not clear, be sure to ask for clarification. For example, "Is it a straight bond with no embedded options?" "Are there coupons?," etc.

If the interviewer tells you that your answer is incorrect when you know it is correct, and if you are dead sure of yo**ur answer, then defend yourself t**o the hilt. **Interviewers make mistakes, and you can earn their respec**t and a job) by tactfully correcting them. Good people want you to do that in practice, though do it tactfully in front of their colleagues.

**Other *Ad*vice**

I cannot stress highly enough that you are not just interviewing for the job that was advertised. There are other openings in the firm that have not yet been advertised (and may never be advertised), and there are openings in other firms that your **interviewe**r knows about because he or she knows people there. There will also be other openings at the interviewing firm in the future. If they like you and your CV, but do not think you are suited to that one job, they may recommend you strongly to another team leader within their firm or even at another firm. The implication of this is that if you discover quickly that you are not suited to the position advertised, or the firm, then you should steer the inte**rview toward** your strengths and ask the interviewer to keep you in mind for other positions. He or she may even tell you of another opening.

This works in reverse also. If your interview is awful, the interviewer will happily pass that information to other people who ask about you, or even without being asked if you really stink.

The finance community is small and interwoven and corporate memory is long. If you interviewed at the firm before, your interviewer probably knows about it and will talk to the people you talked to, even if they have moved on. Indeed, if you worked/interviewed*/*studied anywhere in the world, the interviewer can find a former colleague, interviewer, adviser etc., of yours, who is known to them and who

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*INTRODUCTION*

can assess you. Your resume may have circulated widely within the firm, both in its local offices and overseas, before you set foot in the building or pick up the phone. Indeed, your resume might have circulated so widely that no one informs HR, and **no one even remembers where your resume came f**rom; that can explain why you never got any response, not even a rejection.

Your resume is & starting point. Do not inflate it. You *will* be asked about it. When a resume arrives on the desk of the interviewer, he or she looks at it and tries to figure out in advance some questions to ask. If you write on your resume that you took an option pricing class, and got an "A," then if the interviewer is an option pricing nut, you just guaranteed that the interview is going to get hot. If the area is a weakness for you, then do not make yourself a target. If you want to advertise that you took the class, then that is fine, but prepare yourself for incoming questions. Let me add that on 100% of CVs where the candidate lists "attention to detail" as a skill, I have found obvious errors caused by a lack of attention to detail. Get your resume proofread by people for whom English is their first language.

I received three cover letters that stand out in my mind. One from a young **woman** applying for a junior quant position who stated that she had “a lot of love to give," one from a graduate of Rutgers who seemed to think I was sufficiently stupid not to have heard of Rutgers and felt the need to describe the school in great detail, and one from someone saying that they had alw**ays wanted to work** in investment banking (when I was working at that time for an asset management **company). Remember that you have sen**t your CV and cover letter o**ut to act as your ambassador in your absence**! A substandard effort here can kill your opportunity for an interview as surely as any ridiculous social me**dia webpage can.**

Do not smoke just before your interview. Get a stop smoking patch or something similar. The same goes for garlic for 24 hours before your interview. It stinks! Similarly, no one likes shaking hands with a limp dead fish. If your hands drip like a leaky faucet, then put your hand in your pocket (warm and dry), or palm down on your lap right up until you get up to shake hands. It is simple but effective.

One out of every three men I have ever interviewed put their finger up their nose during the interview. I kid you not. They seem to be unaware of it. Perhaps it **is nerves. They expect me to shake hands** with them at the end of the interview, but I always find a way out of it. Keep your damn hands off your face during the **interview!**

Intelligent o**r genuinely humorous sm**all talk is fine, but do **not make a fool of yourself. For example, one guy came back a week later for a second round interview** with me. I went to greet him in the foyer, and he looked at me blankly. Then he suddenly said "I remember you!" and "This is for the quant position, right?" Those were his first words!

Cover letters go in the garbage can, and e-mails are deleted. Make sure your e-mail address and phone number are on your resume. Similarly, buy an answering machine (or get reliable voicemail) and check it often. If HR cannot find you quickly, then someone else can interview for your job before you.

Do not ask how many hours they work, or what they pay. You do not care how

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*INTRODUCTION*

**many hours it takes; You love work**ing long days and nights. You do not care what the pay is; you just want to get your foot in the door.

Show passion. The words "I want this job" should come out of your mouth plainly and clearly during the interview. Why do I say that? Well, surprisingly often, when the job candi**date has gone, we ask ourselves w**hether he*/*she really wanted the job, and we conclude that they did not. Sometimes we are surprised to subsequently hear from some mutual contacts that the candidate was shattered not to get to the next stage. Hell, you acted like you did not want the job! Show some **passio**n; make it plain.

Show that you love the industry and the challenge. Even if the market is bad, and you are out of work, you must be upbeat. If you tell me a tale of woe, all I can think is that “99% of your life is what you make it, and if your life sucks, you suck." Why would I want you sitting next to me at work all day? Be positive. People like people who like them.

Finally, the ex-post probability that you get the job is either zero or one. If you prepare as though it is zero, then it will be. If you prepare as though it can be one, then you can make it so.

Please feel free to send me e-mails with queries, corrections, alternative solutions, but especially with **new interview questions. The errata (with corrections and** comments) can be found at the website below.

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**Chapter 1**

**Purely Quantitative & Logic Questions**

**The only prerequisites for answeri**ng the questions in this chapte**r are elementary** quantitative skills and common sense. Many questions in this chapte**r have two** solution techniques: an elegant technique requiring little or no computation and a **"hammer-an**d-tongs" brute-force approach. The technique you choose is revealing, Solutions for this chapter appear in Appendix A.

**Question** 1.1: You are given two glass jugs. Each contains the same volume,

V, of liquid. One jug contains pure alcohol, and the other jug co**ntains pure** water. A modest quantity, Q, of water is poured from the water jug into the alcohol jug, which is then thoroughly mixed. The same modest quantity, *Q,* of (now diluted) alcohol is then poured back into the water jug to equalize the volumes of the jugs at their initial levels. The initial concentration of alcohol in the alcohol jug equals the initial concen tration of water in the water jug (at 100%). What is the relationship be**tween** the final concentrations of alcohol in the alcohol jug and water in the water

*j*ug?*1*

**Question** 1.2: There are two bells. One rings five times per minute, and the

other rings four times per minute. If they start at the same time, how long will it be until they next ring together?

**Questio**n 1.3: What is the sum of the integers from 1 to 10072

**Question** 1.4: An old style analogue clock falls off the wall and the face breaks

into three pieces. The numbers on each piece add to the same total. **Describe** the pieces.

**This is not a chemistry problem. Please ignore the fact that mixing a volume Vi of water with a volume V2 of alcohol results in a total volume less than V1 + V2.**

**More generally, what is the sum of the integers from 1 to n*?***

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*CHAPTER 1. PURELY QUANTITATIVE & LOGIC QUESTIONS*

**Questio**n 1.5: (\*\*) You are given a set of scales and 12 marbles. The scales are

of the old balance variety. That is, a small dish hangs from each end of a rod that is balanced in the middle. The device enables you to conclude either that the contents of the dishes weigh the same or that the dish that falls lower has heavier contents than the other. The 12 marbles appear to be identical. In fact, 11 of them are identical, and one is of a different weight. Your task is to identify the unusual marble and discard it. You are allowed to use the scales three times if you wish, but no more. Note that the unusual marble may be heavier than the others, or it may be lighter; you do not know which. You are asked to both identify it and determine whether it is heavy or light.

**Question 1**.6: Suppose I inscribe a circle within a square so that the circle just

touches the four sides of the square. Suppose there is exactly enough room to fit a rectangle of dimensions 5 x 10 into one corner of the square so that the rectangle just touches the circle. See Figure 1.1. What is the side length of the square*?*

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Figure 1.1: The Inscribed Circle Problem

Note: A circle is inscribed within a square. A rectangle of dimen sions 5 x 10 just fits in one corner. What is the side length S of **the square?**

**Questio**n 1.7: Interviewer: "You are a bug sitting in one corner of a *cubi*c room.

You wish to walk (no flying) to the extreme opposite corner (the one farthest from you). Describe the shortest path t**hat you can walk. Be sure to mention** direction, length, and so on."

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**Question 1**.8: A mythical city contains 100.000 married couples but no children.

Each family wishes to "continue the male line," but they do not wish to over populate. So, each family has one baby per annum until the arrival of the first boy. For example, if (at some future date) a family has five children, then it must be either that they are all girls, and another child is planned, or that there are four girls and one boy, and no more children are planned. Assume that children are equally likely to be born male or female. Let *p(t*) be the percentage of *children* that are male at the end of year *t*. How is this percentage expected to evolve through time?

**Story: One candidate f**or a futures trading po**sition in Chicago was asked: "Would you rather be beaten up, beat someone up, or run around th**e block **naked?**" The last response did not get him the job. M**y wife was horrified to** hear this story. Welcome to Chicago!

**Question 1**.9: Picture a 10 x 10 x 10 "macro-cube" floating in mid-air. The

**macr**o-cube is composed of 1x1x1 "micro-cubes," all glued together. Weather **damage ca**uses the outermost layer of micro-cubes to become loose. This

outermost layer falls to the ground. **How many m**icro-cubes are on the ground? **Questio**n 1.10: There are two cities, *A* and B, 1,000 miles apart. You have

3,000 apples at City A, and you want to deliver as many as possible of them to City B. The only delivery method available is a truck. There are, however, two problems. The truck can hold at most only 1,000 apples, and if there are any apples at all in the truck, the hungry dishonest driver will steal and eat one apple for every mile he drives. What is the maximum number of apples you can deliver from City A to City B? Note that y**ou are welcome to stop** part way, dump off some apples, and then come back and pick them up later.

**Question 1.11: How many de**grees (if any) are there in the angle between the

hour and minute hands of a clock when the time is a quarter past three?

**Question 1**.12: What is the first time after 3PM when the hour and minute hands

of a clock are exactly on top of each other?

**Question 1**.13: There are 100 light bulbs lined up in a row in a long room. Each

bulb has its own switch and is currently switched off. The room **has an entry** door and an exit door. There are 100 stockbrokers lined up outside the entry door. Each bulb is numbered consecutively from 1 to 100. Each stockbroker is numbered consecutively from 1 to 100. Broker number 1 enters the room, switches on *every* bulb, and exits, Broker number 2 enters and flips the switch on ever*y second* bulb (turning off bulbs 2, 4, 6, ...). Broker number 3 enters and flips the switch on every *third* bulb (changing the state on bulbs 3, 6, 9, ...). This continues until all 100 brokers **have passe**d through the room. What is the final state of bulb number 64? Is it illuminated or dark?

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*CHAPTER 1. PURELY QUANTITATIVE & LOGIC QUESTIONS*

**Question** 1.14: Exactly the same set-up as Question 1.13, with a different final

question: How many of the light bulbs are illuminated after the 100th person

has passed through the room, and which light bulbs are they*?*

**Question** 1.15: Your bedroom sock drawer contains eight red socks and 11 blue

socks that are otherwise identical. The light is broken in your bedroom, and you must select your socks in the dark. What is the mi**nimum number of socks** you need to take out of your drawer and carry into your well-lit) living room to guarantee that you have with you at least a matching pair to choose from*?*

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**Story: One of my students was asked** to "Describe the best boss you have ever had." Watch out for the opposite question: "Describe the worst boss you **have ever had." Your answer may i**ndicate disloyalty to a (former) employer.

**Question** 1.16: You and I are to play a competitive game. We shall take it in

turns to call out integers. The first person to call out "50" wins. The rules are as follows:

1. The player who starts must call out an integer between one and 10,

inclusive; 2. A new number called out must exceed the most recent number called by

at least one and by no more than 10. For example, if the first player calls out "nine," then the range of valid numbers for the opponent is 10 to 19, **inclusive.**

Do you want to go first, and if so, what is your strateg*y?*

**Question** 1.17: You are to **open a safe w**ithout knowing the combination. Be

ginning with the dial set at zero, the dial must be turned counter-clockwise to the first combination number, (then clockwise back to zero), and clockwise to the second combination number, (then counter-clockwise back to zero), and counter-clockwise again to the third and final combination number, whereupon the door shall immediately spring open; there is no handle or key to turn. The dial has numbers from zero to 40, and the zero is not one of the combination numbers. Without knowing the combination numbers, what is the maximum number of trials required to open the safe (one trial equals one attempt to dial a full **three-num**ber combination ?

**Story: 1. During the interview, an alarm clo**ck went off from the candidate's briefcase. He took it out, shut it off, apologized, and said he had **to leave for another interview**. 2. An applic**ant came in wearing only *o*ne shoe. She** explained that the other shoe was stolen off her foot in the bus. **Interview Horror Stories from Recruiters Reprinted by kind permission of *M****BA Style Mag****azine*** ©1996–2014 MBA Style M**agazine, www.mbastyle.com**

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**Question** 1.18: (\*\*) You are given a set of scales and 90 coins (this question is

similar to Question 1.5). The scales are of the old balance variety. That is, a small dish hangs from each end of a rod that is balanced in the middle. The device enables you to conclude either that the contents of the dishes weigh the same or that the dish that falls lower has heavier contents than the other, You must pay $100 every time you use the scales. The 90 coins appear to be identical. In fact, 89 of them are identical, and one is of a different weight. Your task is to identify the u**nusual coin and to discard** it while minimizing the maximum possible cost of weighing. What is your algorithm to *c*omplete this task? What is the most it can cost to identify the unusual coin (assuming your strategy minimizes the maximum possible cost)? Note **that the unusual coin may be heavier than the others, or it may be** lighter. You are asked to both identify it and determine whether it is heavy or light.4

**Question 1**.19: (\*\*\*) Suppose that the function f(z) is complex valued in the

complex plane. Suppose also that *f(*z) is both bounded and entire. Prove that *f*(x*)* must be a constant.

**Story: A st**udent of **mine was taken to a room and asked to choose a place to sit at a lon*g* oval-shaped table. He chose a place at random. Later the interviewer asked why he had chosen tha**t spot. I think the inten**t was to see if he was a lea**der (sitting at the head) or a follower (sitting at the side).

**Question** 1.20: I have dropped 10,000 ants randomly onto a ruler that is one

meter (i.e., 100 centimeters) long and oriented to point north-south. The ants are of very small size and mass. Each ant walks at a steady pace of one centimeter per second in a straight line parallel to the long edge of the ruler. Their initial direction is randomly either north or south. The ants are all from the **same colony and possess a**n inherited vision problem: they have peripheral vision only. This means that they can collide with each other if they meet head on (although very small, they are large enough to collide). If two ants do collide head on, however, then they each turn around instantly and head back the way they came at their steady pace. With so many ants in one small space, a single ant **may experi**ence multiple collisions before it walks off of the ruler. So, how long must you wait to be sure that all the ants have

walked off of the ruler?

3A slight**ly different task is to minimize the expected cost of weighing. Minimizing the ex pected cost of weighing does not necessarily minimize the maximum possible cost. This is a subtle distinction that you should not overlook.**

**\*Does the answer change if you must identify the coin without saying whether it is heavy or light?**

**“Recall that an "entire" function is a function that is analytic in the entire finite complex plane, Thus, *$*(*2)* may be represented by an everywhere*-c*onvergent power series: *f*(**z) = mo anz\*\* **(Holla**nd (1973, p. 5]).

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*CHAPTER 1. PURELY QUA*N*TITATIVE & LOGIC QUESTIONS*

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**Question 1**.21: You start with a single lily pad sitting on an otherwise empty

pond. You are told that the surface area of the lily pad doubles e**very day** and that it will take 30 days for the single lily pad to cover the surface of the pond. 6

If instead of one lily pad you start with eight lily pads (each identical in characteristics to the original single lily pad), how many days will it take for

the surface of the pond to bec**ome covered?**

**Questio**n 1.22: Another lily pad problem. There are 27 lily pads on a pond.

Each of the lily pads is one square foot in area. The pond is 6,000 square feet in area. Each lily pad doubles its size every day. How long until the pond is covered in lily pads?

**Question 1.23: Interviewe**r: “Alright, you're from MIT; you must be a quanti

tative type of person." Interviewee: (confidently, after a slight pause) "Yes indeed." Interviewer: "Give me the decimal equivalent of

of

."

**Questio**n 1.24: A snail is climbing up a 10-foot pole. It climbs up by three **feet**

every day. Each night it sleeps. While sleeping, it slides down by one foot. When does it reach the top of the pole?

**Questio**n 1.25: *(*\*) A windowless room contains three identical light fixtures,

each containing an identical light bulb. Each light fixture is connected to one of three switches outside of the room. Each bulb is switched off at present. You are outside the room, and the door is closed. You may flip any of the external switches in a**ny manner you choose. Af**ter this, you must take your hands off the switches and then you may go into the room and do as you please (but you will not be allowed to damage anything or touch the switches again). How can you tell which switch goes to which light?

**Questio**n 1.26: Inside of a dark closet are five hats: three blue and two red.

Three smart men go into the closet, and each selects a hat in the dark and places it unseen upon his head. Each man knows both that the closet con tains three blue hats and two red and that the other two men have the same knowledge. Once outside the closet, no man can see his own hat. The first man looks at the other two, thinks, and says, "I cannot tell what color my hat is." The second man hears this, looks at the other two, and says, “I cannot tell what color my hat is either." The third man is blind. The blind man says, “Well, I know what color my hat is." What color is his hat, and how does he know*?*

**Questio**n 1.27: *(*\*\*) Find the smallest positive integer that leaves a remainder

of 1 when divided by 2, a remainder of 2 when divided by 3, a remainder of 3 when divided by 4, ... and a remainder of 9 when divided by 10.

The stude**nt who was asked this question says that his interviewer used the number 30. However, he suggested that I use the number 3,000 to make it more complicated. What is wrong with saying that it takes 3,000 days for the lily pad to cover the pond?**

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**Question 1**.28: There are two motorcyclists on a single lane road. They are 25

miles apart. At a signal, they start moving toward each other with constant speeds. The first motorcyclişt rides at 20 mph; the second rides at 30 mph. When the signal goes off, a fly on the helmet of the first motorcyclist is startled and starts flying toward the second motorcyclist at 40 mph. When the fly reaches the second motorcyclist (now moving toward the first), he immediately reverses course and flies back to the first motorcyclist. When the fly gets back to the first motorcyclist, he reverses course again. The Ay continues to fly backwards and forwards between the two motorcyclists until they all collide. **How man**y miles will the fly have traveled before his life is extinguished?

**Question 1**.29: Prove that the area of a triangle is given by

A = *V sés - a*)(s - *b)*(s -c),

where *a, b*, and c are the side lengths, and s = 4+6is half the perimeter.?

**Story: Inst**ead of being asked her grea**test weakness, one of my students was** asked: "Why shouldn't we hire you?" It is pretty difficult to maneuver your **way o**ut of that one!

**Questio**n 1.30: A*, B, C, D, E, F, G, H, a*nd *I*, are the nine integers from one

to nine (not necessarily in order). They satisfy the following constraints:

A + *B + C* + *D = 2*0, ***B + C* + *D + E + F =*** *D+E*+*F*+*G + H =* 20, and

*F+G+ H+1 =* 20

What values are taken by each of A to *I?*

**Question 1.31**: A very large number, N, of people arrive at a convention. There

**are exact**l*y N* single rooms in the hotel where the convention takes place. Each **guest is given a numbered key for a specific room. Before they even go upstairs,** they are all invited to a large party in the banquet hall. To gain admittance to the hall, they have to give up their keys to a doorman. At the end of the evening, the guests are not sober enough to recall their room numbers, so the doorman simply hands out the keys randomly. Each guest ends up spending the night in a random room. What is the probability that at least one guest ends up in the room to which he or **she was or**iginally assigned?

**Question 1**.32: A small boat is floating in a swimming pool. The boat contains

a very small but very heavy rock. If the rock is tossed out of the boat into the pool, what happens to the water level in the pool?

**Mark Rubinstein kindly pointed out to me that this is "H**eron's Formula."

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*CHAPTER 1. PURELY QUANTITATIVE & LOGIC QUESTIONS*

**Questio**n 1.33: (\*\*) In a certain matriarchal town, the women all believe in an

old prophecy **that says there will come a time when a stran**ger will visit the **town and announce whether an**y of the men folk are cheating on thei**r wives,** The stranger will simply say "yes" or "no," without announcing the number of men implicated or their identities. If the stranger arrives and makes his announcement, the women know that they must follow a particular rule: If **on any** day following the **stranger's announcement a women ded**uces that her husband is not faithful to her, she must kick him out into the street at 10AM the next day. This action is immediately observable by every resident in the town. It is well known that each wife is already observant enough to know whether any man (except her own husband) is cheating on his wife**. However, no woman can revea**l that in**formation to an**y other. A cheating husband is **also assumed t**o remain silent about his infidelity.

The time c**omes, and a stranger arrives. He announ**ces that there are cheating men in the town. On the morning of the tenth day following the stranger's arrival, some unfaithful men are kicked out into the street for the first time. How many of them are there*?*

**Questio**n 1.34; In front of you are three poles. One pole is stacked with 64 rings

**ran**ging in weight from one ounce (at the top) to 64 ounces (at the bottom). Your ta**sk is to m**ove all the rings to one of the other two poles so that they end up in the same order. The rules are that you can move only one ring at **a time, you can move a ring only from one pole to another, and you cannot** even temporarily place a ring on top of a lighter ring. What is the minimum number of moves you need to make to achieve the task*?*

**Story: Here are some common thinking quest**ions from Section 5.5: "How many McDonald's fast food outlets are there in the US? How many gas **stations are t**here in the US? How **many elevators** are there in the US?"

**Question** 1.35: Solve the following ordinary differential equation (ODE):

*t”* + 4+ a = 1

**Question** 1.36: Assume that the random variables X and Y are normally dis

tributed: X - N x,c), and Y ~ N*(vy,0*). The correlation between X and Y is *p*. How can you choose constants a and *b* such that you minimize the variance of the random variable sum S *= a*x + *b*y under the constraints that a+*b*=1,0 <a<1, and <b< 178

**Another version of this question asked in interviews is: "You are driving around with one wheel on the gravel and one wheel on the pavement. The variance of the gravel and pavement surfaces are described by *o* and *o*n. Whereabouts on the axle should you sit between I = 0 (right over the wheel on the gravel) and I = 1 (right over the wheel on the pavement) if you want the most comfortable ride?**

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**Question 1**.37: Suppose there is a straight coastline and a lighthouse that is

*L* = 3 miles away from the coast. The light revolves at one revolution per minute. How fast is the beam of light traveling along the coastline? When the **beam is 3*L* away from the coastal** point closest to the light, how fast is the light traveling along the coast?

**Question** 1.38: I have a 20 x 20 chessboard and a very large box of identical

cubes. Each square on the chessboard is the same size as the face of any cube. I am going to arrange piles of cubes on the chessboard in a special pattern. I align one edge of the board so it is running north-south. I start at the northwest corner by placing one cube on that square. Whenever I step to the south or the east, I place a pile of cubes containing one more cube than in the **previous square. T**his produces the pattern in Figure 1.2. How many cubes in total are there on the c**hessboard?**

1 2 3 4 ... 19 20 2 3 4 5 ... 20 21 3 4 5 6 - 21 22 4 5 6 7 ... 22 23 : : : :: : : 19 20 21 22 -- 37 38 20 21 22 23 ... 38 39

Figure 1.2: Number of Cubes on Each Square of a 20 x 20 Chessboard (Q)

**Question 1**.39: You are standing at the center of a circular field of radius *R*. The

field has a low wire fence around it. Attached to the wire fence (and restricted to running around the perimeter) is a large, sharp-fanged, hungry dog who **likes t**o eat any humans he can catch. You can run at speed u. Unfortunately, the dog can run four times as fast, at 40. The dog will do his best to catch you if you try to escape the field. What is your running strategy to escape the field without feeding yourself to the dog?

**Question 1**.40: Please prove that the following relationship holds:

*\*\*e\*\*dx = V*T

**Question** 1.41: What is *sec odd* equal to?

**Question 1**.42: Does the infinite sum e-T conver*g*e*?*

**Similarly, you could see questions on integrals (or derivatives) of sin 8, *cost*, tan 6, cott, and** coseco

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*CHAPTER 1. PURELY QUANTITATIVE & LOGIC QUESTIONS*

**Question** 1.43: One analyst (John) is talking to another (Mary) while working

on a deal book at 2AM. Mary learns that John's sister has three children. "How old are the children?" asks Mary. “Well," replies John, "the product of their ages is 36." Mary thinks for a while and says, "I need more information." "Hmmm, the sum of their ages is the same as this figure right here," says John pointing at the spreadsheet. "Still not enough information," says Mary after thinking for a minute, \*The eldest is dyslexic," says John. How old are the children*?*

**Question 1.44**: You are given eight balls. They appear identical, but one is

heavier than the rest. As in the previous ball questions, you have a pair of scales. How do you find the heavy ball?

**Question** 1.45: What are

m, \*2 and

L\_, *\*?*?

**Question** 1.46: *(*\*\*\*) You have 52 playing cards (26 red, 26 black). You draw

cards one by one. A red card pays you a dollar. A black one fines you a dollar. You can stop any time you want. Cards are not returned to the deck after being drawn. What is the optimal stopping rule in ter**ms of maximizing** expected payoff? Also, what is the expected payoff following this optimal rule?10

**Question** 1.47: We are to play a game on a table in the next room. We each

have an infinite bag of identical quarters (ie, American 25-cent pieces). We will take it in turns to put one quarter on the table. Quarters may not overlap on the table. When there is no room left on the table to put another **quarter,** the winner is the last person to put a quarter on the table. Let me tell you that there does exist a strategy for winning and that this strategy is independent of the size of the table.

1. What is the shape of the table? 2. Do you start? 3. What is your strategy for winning? 4. Is there any case where this does not work?

**Question** 1.48: You have a chessboard (8 x 8) plus a big box of dominoes (each

2 x 1). I use a marker pen to put an "X" in the squares at coordinates (1,1) and (8,8)—a pair of diagonally opposing corners. Is it possible to cover the remaining 62 squares using the dominoes without any of them sticking out over the edge of the board and without any of them overlapping? You must not damage the board or the dominoes in the process or do anything weird like standing them on their ends-jus**t answer th**e question.!!

*1*0lty **the same question with four cards (two red, two black).**

**"Naoki Sato has suggested a follow up question. Place an "X" on two squares: one black, and one white. Can you cover the remaining squares with dominoes? See Answer 1.48 for the solution.**

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**Question 1.49**: One of my students interviewed with some folks who "wanted to

get an idea of his comfort with formulae and with explaining things to clients." They asked why it is that if *p* is a prime number greater than 3, then *p*a - 1 is always divisible by 24 with no remainder.

**Question 1**.50: You are bidding *B* for a firm whose unknown true value is uni

formly distributed **between 0 an**d 1. Although you do not know the true value *S* of the firm, you do know that as soon as people learn that you **have made** a bid this news will cause the value to double to 2*$*. Your bid, however, will be accepted only if it is at least as large as the original value of the firm. How do you bid so as to maximize your expected payoff?

**Question 1**.51: You have a string-like fuse that burns in exactly one minute.

The fuse is inhomogeneous, and it may burn slowly at first, then quickly, then slowly, and so on. You have a match, and no **watch. How do you measure** exactly 30 seconds?

**Question 1**.52: You have two string-like fuses. Each burns in exactly one minute.

The fuses are inhomogeneous, and may burn slowly at first, then quickly, then slowly, and so on. You have a match, and no watch. How do you measure exactly 45 seconds?

**Question 1**.53: How many places are there on the Earth where you can walk

one mile south, one mile east, one mile north, and end up exactly where you started? Assume the Earth is a perfect sphere, that your compass bearing is **const**ant on each leg of the walk, that all parts of the Earth are able to be walked upon, and that your feet are arbitrarily small.

**Question** 1.54: How many consecutive zeroes are there at the end of 100! (100

**fa**ctorial). For example, 129=479,001,600 has two consecutive zeroes at the **end.**

**Question 1**.55: This is an absolute classic. A king demands a tax of 1,000 gold

sovereigns from each of 10 regions of his nation. The tax collectors for each region bring him the requested bag of gold coi**ns at year end. An informant** tells the king that one tax collector is cheating and giving coins that are **consi**stently 10% lighter than they should be, but he does not know which collector is cheating. The king knows that each coin should weigh exactly one ounce. How can the king identify the cheat by using a weighing **device exactly** once*?*

**Question 1**.56: Again, an absolute classic. You hire a man to work in your yard

**for seven days**. You wish to pay him in gold. You have one gold bar with **seven pa**rts-like a chocolate bar. You wish to pay him one gold part per day, but you may snap the bar in only two places. Where do you snap the bar so that you may pay him at the end of each day, and so that on successive days he may use what you paid him previously to make change*?*

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*CHAPTER 1. PURELY QUANTITATIVE & LOGIC QUESTIONS*

**Question 1**.5*7*: You have an array that contains 99 distinct integers from the set

{1,2,3,...,100). How would you write a program to figure out which integer **is missing*?***

**Question 1.58: Why are images in a mirr**or flipped horizontally and not verti

cally? For example, although **I wear my wristwatc**h on my left wrist, and my reflection wears his on his right wrist, my reflection is not standing on his head.

**Question** 1.59: *(*\*\*) I am told this is a genuine finance interview question. It

had to be a trading interview, because no one but a trader would ask this in an interview. I considered transforming the question, but left it as is for authenticity, *A*vert your eyes if you are easily offended! How can three men and one women have mutually safe heterosexual intercourse with just two condoms? Assume that no condom can break or leak, and that you cannot wash a used one. 12

**Question** 1.60: Consider a grid. You start at coordinate (0,0) and move one

step at a time, eventually arriving at coordinate (5,5). With each step you may move only one step east or one step north but never diagonally. How many paths are there from (0,0) to (5,5)?

**Question** 1.61: Six friends go out to lunch. The bill is $132.67. They decide to

add a 20% tip and split the total six ways evenly. What does each person pay?

**Question** 1.62: You walk into a pizza shop. They sell three sizes of pizza: small,

medium, and large. All are perfectly circular, have the same thickness, and have the same density of toppings. The price of a large pizza is equal to the price of a medium pizza plus the price of a small pizza: *PL = PM + Ps.* You see a group of your friends already sitting in the pizza store and they have just had one of each size pizza delivered to their table plus they have been given one empty box to take any leftovers home in. Each of their pizzas has been pre-cut into perfect) sixths. Their box is a (perfect) square. You are looking at your friends' u**neaten pizzas and are trying to choose between ordering one** large pizza for yourself or ordering one medium plus one small for yourself. The cost is the same, but how can you determine which choice gives better value?13

**Question** 1.63: Find all of the roots to the equation 6 = 64 (including the

complex roots).

**Question** 1.64: A rock is dropped from the top of the Empire State Building,

At what speed does it hit the ground, and how long does it take to get there*?*

!? With one **man and three women, the answer i**s of similar type, but di**fferent. This question also appears in Derman (2004, p. 104), which is probably how it drifted to Wall Street,**

**13 In the original question the pizza was not cut, there was no box, but you had a knife. I retained** the spirit of the **question but modified it because it was not, strictly speaking, able to be solved.**

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**ut**

**Question** 1.65: Please express the integral *f*(x) = *s*ome t*hdt* in terms of

*N*(X) (i.€., the cumulative standard normal). **Question** 1.66: What is lime 70 (*V*x2 + 1 - 3)? **Question** 1.67: How do you differentiate r' with respect to z*?*

**Question 1**.68: Can the mean **of two consecutive prime number**s ever be prime?

**Story: Let me give some unorthodox advice.**

**1. A colleague and I were interviewing a candidate for a quant equi ties job in London. After a few questions about his CV, we asked him a simple quant question. He was extremely uncomfortable. He declared it to be "not a proper interview," and to our amazement, he walked out** the door! **He made two fatal mistakes. First, walking out meant he was a quitter. Nobody likes quitters. Second, he should have attempted an answer because even if he was not suited to quant equities at my firm, we had vacanc**ies in other **areas and we knew of vacancies at other firms, and we would have passed his CV on if we thought he was talented.but not** if we thought he **was a quitter. It** is in the inte**rviewer's best interests to** pass good CVs around the firm **and to a network of contacts outsi**de of it **because the favor will be returned eventually. Remember, you are never interviewing f**or that one job only! **If the interview is** going badly, then be **positive and focus on your strengths even if they are not strengths for th**at job!

**2. I was being interviewed for a practitioner job I really wanted. I was up to a**bout the fifth person on my schedule for the day. From the **moment this guy set eyes on me across the tabl**e I could tell he did no**t want** to hire me. He was 100% negative and actually **looked angry! I can read upside down, and, without him noticing, I quickly read the questions he had written on my CV across the table from me. I addressed his questions before he even asked t**hem. That surprised him! **I turned the conversation toward the markets and found some common ground. He became interested, I made a tasteful joke. He smiled. When our half-hour was up, he was 100% positive and I know he recommended that** I be hired. There **was nothing unethical about this manipulation of interview*/*interviewer: I love the markets, wante**d the job, and thought the **firm was a great fit for me.**

**3. The two stories above are about losing and winning, respectively. I think a difference between these outcomes is mental preparation. I was given an inexpensive book call**ed *The Dirty Dozen* written by Sergeant Major (Ret.) Lawrence A. Jordan. Sergeant Major Jor**dan served a 24-year Special Operations career wit**h the U.S. Army Rangers and Special Forces, **His book is about dirty fighting techniques, and C**hapter 2, *Th*e ***Winning Mind,* is about mental preparation for life-or-death hand-to-hand combat in self defen**ce. Although it is u**northodox of me to write this, I recommend that you read *The* W*inning Mind* chap**ter of *The Dirty Doze****n* for interview preparation. If you can stomach** it, it may give you just the edge y**ou need.**

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Chapter 2

**Derivatives Questions**

A prerequisite for answering the questions in this chapter is knowledge of ba sic option pricing theory. I strongly recommend my book *Basic Black-Scholes: Option Pricing and Trading (C*rack (2014a)) as the best resource. It provides a firm foundation in Black-Scholes option pricing, with practical advice about op tion trading. See the advertisement at the end of this book, or go directly to **www. BasicBlackScholes.com**. Solutions for this chapter appear in Appendix B.

**Question** 2.1: All Black-Scholes assumptions hold. Assume no dividends. The

stock price is $100. The riskless interest rate is 5% per annum. Consider a one-year European call option struck at-the-money (i.e., strike equals current spot). If the volatility is zero (i.e., *O* = 0), what is the call worth? After valuing the call, please tell me how to hedge the call (assuming you sold it).

**Question** 2.2: Two standard options have exactly the same features, except that

one has long maturity, and the other has short maturity. Which one has the higher gamma*?*

**Question** 2.3: All Black-Scholes assumptions hold. Assume no dividends. Con

sider a standard European call and a standard European put on the same stock. Assume that each option has the same maturity, and is struck at-the money (1.e., strike equals current spot). For the sake of simplicity, assume that the interest rate is zero. Draw the payoff diagrams for each option (i.e., ter minal payoff to option versus level of underlying).

The put has limited downside potential and no upside; the call has unlimited upside and no downside. Given the random direction of the stock price move **ments between now an**d expiration, the disparity in potential pay**offs seems to** suggest that the call should be worth more than the put. However, put-call parity says that this is not so. Verify the put-call parity implications and reconcile them with the seemingly disparate potential payoffs.

**Question** 2.4: For a standard European call option, draw the graph of the "delta"

as a function of current stock price, *st).*

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2*3*

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*CHAPTER 2. DERIVATIVES QUESTIONS*

**Question** 2.5: Assume a Black-Scholes world without dividends. Consider a

standard European call struck at-the-money (i.e., **strike equals current** spot) with one year to maturity. If the interest rate is T - 0.06, is the option's delta greater or less than 0.5? What does it depend on?

**Question** 2.6: Assume a Black-Scholes world with continuous dividends. Con

sider a standard European call struck at-the-money (i.e., strike equals current spot) with one year to maturity. If the interest rate is r = 0.06, and dividends are at rate - 0.03, can you tell whether the option's delta is greater or less than 0.5? What does it depend on?

**Question** 2.7: You are long a call option on MITCO stock. You have delta

hedged your position. You hear on the radio that the CEO of MITCO has just been arrested for running a massive Ponzi scheme. The stock price plunges $10. How do you adjust your hedge (qualitatively)? That is, do you borrow and buy stock or sell stock and lend? Explain carefully.

**Question** 2.8: How do you calculate an option's delta?

**Question** 2.9: Explain very carefully the terms N(*d*i) and *N(d*)) that appear

in the standard Black-Scholes European call option pricing formula without dividends.?

**Question** 2.10: Consider the European digital option (or "binary option") that

pays à constant *H* if the stock price is above strike price X at expiration and zero otherwise. What is the price of this option, and how is it related to the price of the standard Black-Scholes European call option? Explain carefully.

**Question** 2.11: Consider the European digital option (or "binary option") that

pays *H* if the stock price is above strike price X at expiration and zero oth erwise. How does the price of this option vary with volatility that is, what is *00*)? Intuitively? Rigorously? Explain carefully.

**Question** 2.12: Compare the "delta" of a standard European call option and the

delta of a barrier option, for example a "down-and-out" call option."

**Answer for a standard European call option (with and without dividends), and for an option with no closed-form soluti**on (e.g., a p**lain vanilla American-style put or an exotic).**

**?Now use this explanation to deduce the standard Black-Scholes European put option pricing formula-if you can. Confirm that the pricing formulae v**erify the put-call parity relationship (with

*p =* 0): S*t*) + m(*t*) = x(t) + Xe-*T*o-} + *D.*

**\*This is the "cash-or-nothing" digital option. You should also be able to answer this question for the "asset-or-nothing" digital option (which gives you the Asset if *S*(*T)* > X and nothing otherwise).**

**"Is the answer different for an up-and-out call? Explain carefully. Incidentally, who would buy an up-and-out call? Well, suppose you expect only limited upside on a security. If you wish to participate in this upside without paying for what you consider to be very unlikely further price appreciation, then an up-and-out-call could be just what you want (see Derman and K**ani (1993, Pp. 3–41).

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**Question** 2.13: *(*\*\*) This is an applied theoretical option pricing problem taken

from a telephone interview. *Y*ou are given three time **series of continuously** compounded returns on an industry sector index: the IS150. The time series are daily, weekly, and monthly over the same time period. You are to price a standard European call option written on the level of the I$150 with one **month to expiration.**

You decide to use the trusty Black-Scholes model. You observe all input variables except for the volatility term o?, Unsure of which of your three time **series to use to estimat**e the volatility term, you calculate the sample volatility of each time series. You figure that the estimators (*2,*03,07) should be related as one 42, 2002, and 2 5 %. You could thus get the monthly volatility either explicitly from the monthly estimate or implicitly **from the weekly** or daily estimates. You think the daily data are most reliable **(they have the most observations).** You find, much to your horror, that one > 40, > 200ả, and 6 > 5ôá. Fur ther investigation reveals that these differences are highly statistically signifi cant. Your statistical observation is thus that the monthly volatility implicit in the daily **and weekly time seri**es is significantly smaller than the monthly volatility in the monthly time series,

How do you price the option? Explain yo**ur reasonin**g carefully.

**Story: On**e of my studen**ts went to an interview with a big-name Wal**l Street **firm in New York. He was interviewed by five quantitative guys in a row. Each interview was one hour, and there were absolutely no breaks. He had to work through multiple quantitative problems on t**heir blackboard. They **gave** him no lunch**. He was exhausted and sta**rving by the end. **He was swearing bl**ack and blue about the \*\*&@!#@$%'s" when he got back. He said "The **Russian" was the worst.**

**Question 2.14: Consid**er a plain vanilla American call option on a non-dividend

paying stock. The price of the call is *С(*t) at time t. The "intrinsic value" of the call is max (*S*(*t*) - X,0 (where S*(t*) is stock price at time t, and X is exercise price). The excess of call value over intrinsic value is the "time value" of the option." Draw a graph of the time value, *C(t*)- max($(*t*) - X,0], versus S(t). Explain carefully the different aspects of the plot.

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**Feel free to assume that one week is exactly five days, one month is exactly 20 days, and that there are no missing observations or exchange holidays.**

Hint: **Begin by explaining how and why your statistical observations could arise. What went wrong*? A*sk yourself whether Black-Scholes pricing is still applicable. If not, where do you turn?**

**"Perhaps a more natural definition of intrinsic value is max**[S(t) - Xer\*\*), O (M**erton (1973,** p. 145]; Merton (1992, p. 260); Smith (1976, p. 11])**. What would the plot of time value versus S(*t)* look like with this definition of intrinsic value*?***

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*CHAPTER 2. DERIVATIVES QUESTIONS*

**Questio**n 2.15: It is 10 months since you sold a one-year European call option

to a customer. You have been delta-hedging your exposure to the written call since it was sold. The option is now well in-the-money, and the delta of your replicating portfolio is correspondingly high (at around 0.90, say*)*. Suppose that you watch the underlying stock price falling gently over the last two months of the life of the option. As the stock price falls over this time period, what happens to the delta of the replicating portfolio? That is, are you buying stocks or selling stocks as you watch the stock price fall? You may have to describe different possible scenarios-be clear on the assumptions you make.

Story: She threw up on my desk and immediately started asking questions about the job, like nothing had happened. **Interview Horror Stories from Recruiters Reprinted by kind permission** of *MBA Style Magazine* **© 1996–2014 MBA Style Magazine, www.mbastyle.com**

**Questio**n 2.16: What do you **know about jump processes an**d jump diffusion

processes? Explain when the pricing formula for a call option written on an asset whose price level follows a jump process can and cannot be derived using the Black-Scholes*/*Merton no-arbitrage technique,

**Questio**n 2.17: This question concerns the standard European call option on a

non-dividend-paying stock. You are asked to draw three closely related graphs

as follows:

1. Please draw the graph of call price at maturity (time *T*) versus terminal

stock price, *S(T)*. 2. Please draw the graph of call price at time *t* versus the futures price

*F(t, T*). The futures price *F(t, 7*) is observed at time t, prior to maturity.

The futures contract and the option both mature at the same date *T*. 3. Now draw the graph of call price versus stock price at time *t*, prior to

maturity.

Explain carefully the relationships between the three graphs.

\* Describe the **form of the pricing formula for a European call option written on a stock whose** price level follo**ws a jump diffusion proces**s (using Merton's notation): 4 (Q - *Ik}dt+ odz + da,* **where *d****q* = 0) if the "Poisson event" (i.e., the jump) does not occur, *dq* - *(*Y - 1) is the jump does occur, (Y-1) i**s a spike producing a finite jump in stock price from St**o SY, a is **the instantaneous expected rate of return on the stock, 02 is the instantaneous variance or returns assuming no jump occurs, dZ is a standard Wiener process, is the number of arrivals that you expect per unit time,** *k = E(Y* - 1) wh**ere *E* is the expectation operator over the random variable Y, and dZ is assumed** independent of the **Poisson proc*ess da (*see Merton** (1992, p. 313]).

Futures on sing**le stocks have been tra**ded in the US since 2002. Se**e www.OneChicago.cop for details.**

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**Question 2.18: Consider two E**uropean call options on the same underlying

stock. The options have the same strike price. **Assume constant interest** rates. One option matures in one year; the other option matures in four years, Suppose that you put *o* = 15% into the Black-Scholes formula to value the **one-year opti**on. What value of o do you put into the Black-Scholes formula to value the four-year option? Assume that you set *T-t*-1 in the Black-Scholes formula in both cases (i.e., one unit of time eq**uals four years in the second** case but only one year in the first case).

**Story: Some recent question**s include "What do you **think an investment banke**r does?" Not only that, but “Do you understand the hours investment **bankers work an**d why?" Some of these folks look like Hell when you meet them. Are you sure about this career choice?

**Question** 2.19: (\*\*\*) The Black-Scholes formula is derived assuming the stock

price process S*(t*) follows a geometric Brownian motion: *d*S*(*t*) = u$(t)dt - o$(t)du(t*), where *wt*) is a standard Brownian motion. Suppose **instead that** a stock price process S*(t)* follows an arithmetic Brownian motion; ds*(t*) = *udt* + *Adw(t)*. Derive the pricing formula for a call option on *S(t*). Please assume that the option is at-the-money i.e., *S(t*) = X), that the riskless **interest rate** r = 0, and that the stock pays no dividends.

**Questio**n 2.20: Interviewer: “You are fully familiar with Black-Scholes pricing

aren't you?" Interviewee: confidently, after a slight pause) "Yes indeed." Interviewer: "What is the value of a three-month at-the-money (i.e., S = X) call option on a $100 stock when the implied vol is 40? Please assume r = 0 (it is the least important ingredient anyway) and assume also that the stock pays no dividends. You have 10 seconds to perform the calculation in your head. Now tell me how your answer changes if it is instead a put."

**Question** 2.21: A customer calls up and wants a price on a European 100-day

call option. You quote $100. He calls back a minute later and wants a quote on the same option but with 200 days to maturity. How does the second price quote compare to the first price quote? Explain carefully.

**Question 2.22: Assume a B**lack-Scholes world. You have a one-year European

call option on a stock. There are no dividends, the interest rate is assumed to be zero, and the option is struck at-the-money (i.e., strike equals current spot). The current spot is $100. The standard deviation of terminal stock price (conditional on current stock price is $10.10 Is the call price closer to $1, $5, or $10?11

10 It **follows that the standard deviation of continuously compounded returns is approximately 10% per annum.**

11 If the **standard deviation is $20 per annum, is the call price closer to** $5, $10, or $20?

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*CHAPTER 2. DERIVATIVES QUESTIONS*

**Question** 2.23: You hold a 100-day European call option on a stock with implied

volatility 20. Suppose that you know right now that tomorrow the implied volatility will increase to 25, but that after that it will return to 20 for the remainder of its life. What extension to the life of the call would produce the **same chan**ge in the present value of the call as the above-mentioned single-day increase in volatility **(assuming a constant** implied volatility at 20)? That is, other things being equal, what change in the term to maturity is equivalent to the quoted one-day change in the implied volatility? Explain carefully.

**Question** 2.24: You are long a straddle with a strike of $25. The underlying is

at $25. The straddle costs you $5 to enter. What price **movement are you** looking for in the underlying?

**Question** 2.25: You are considering two contracts: a Eurodollar *futures* con

tract, with six months to maturity, selling at 5%, settled on three-month LI BOR, marked-to-market every day; and a Eurodollar *forward c*ontract, with six months to maturity, selling at 5%, settled on three-month LIBOR at ma turity.

1. Which con**tract do you prefer (or are you indifferent)?** *2*. Do you think there is a mis-pricing? 3. If you go long one and short the other, which one should be long, and

which one should be short (or are you indifferent)?

**Question** 2.26: You are to value a call option using Monte-Carlo simu**lation. Is**

it better to simulate the geometric Brownian motion (GBM) process for the call itself, or the GBM process for the underlying?

**Question** 2.27: Suppose that you hold a long position in mortgage-backed secu

rities. If you are expecting a bond market rally, would you be better off with positive convexity or negative convexity*?*

**Story: T**here is the old story of the candidate who flew to London for an **interview. At the interview, the interviewer excused himself for a few min utes. However, before leaving he asked the interviewee to open a window. Once alone, the interviewee discovered that all the windows were sealed shut. Great! Michael Lewis (in his excellent book L**iar's Poker) talks about this technique in use on Wall Street (Lewis, 1990, p. 27). He sugges**ts that one desperate interviewee threw a cha**ir through Lehman's 43rd floor **window in** Manhattan!

**Question** 2.28: What is wrong with the following strategy for hedging a short

call option: buy one share if the stock price exceeds the strike, and sell the share if the stock price falls below the strike?

**Questio**n 2.29: How fresh is your stochastic calculus? What can you tell me

*t}dt*, where *wst*) is a standard Brownian motion?

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**Question** 2.30: What can you say about f*ou(t)duft),* where w(t) is a standard

**Brownian motion?**

**Question** 2.31: (\*\*) Suppose that IBM is trading at $75 pe**r share. What does**

it cost to construct a derivative security that p**ays exactly one dollar when** IBM hits $100 for the first time? Explain carefully the construction of the security. *Y*ou may ignore IBM's dividends, assume a riskless interest rate of **zero, assume a**ll assets are infinitely divisible, igno**re any short sale restrictions,** and ignore **any taxes or transactions costs.**

**Story:** "During his interview with me, a candidate bit his fingernails and proceeded to bleed onto his tie. When I asked him if he wanted a Band Aid, he said that he chewed his nails all the time and that he'd be fine. He **continued to chew away."**

AUDREY W. HELLINGER Chicago Office of Martin **H. Bauman**

Associates, New York

**"Doomed Days: The Worst Mistakes Recruiters Have Ever Seen,"**

*The Wall Stree****t Journal*, February 25, 1995, PR4. Reprinted by permission of *Th*e W*all Street Journal* ©1995 Dow Jones and Company, Inc. All Rights Reserved Worldwide.**

**Question** 2.32: (\*\*) The payoff to a European-style "power call" is given by

max( S - X,0). Derive the price of a European power call option using

Black-Scholes pricing. 12,13

**Story: "If** we offer you a job right now, will you take it*?*" is **often used by firms who will not make you an offer unless they know you will say yes.**

**Question** 2.33: Why do you get a "smile" effect when you plot implied volatilities

of options against their strike prices?

**Question** 2.34: Is the price of a double-barrier, knock-out option (i.e. one with

both up-and-out and down-and-out barriers) just the price of an up-**and-out** plus the price o**f a down-and-out?**

**Questio**n 2.35: Describe the analytical procedure for deriving (using calculus)

**the values of European** digital asset-or-nothing and digital cash-or-nothing **options.**

*1*2 Try **drawing the payoff diagrams for the cases a > i and a < 1. Add the current call value as a function of stock price to your diagrams.**

**13 Jarrow and T**urnbull (1996, p. 175) describe a "powered option" with payoff (S*(T*) - X]? if **S(*T*) > X and zero otherwise. I give the general result for the case (*S(T*) - X) in the solutions. Try to derive it before you peek at my solutions.**

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*CHAPTER 2. DERIVATIVES QUESTION*S

**Question 2**.36: Consider an American-style double-barrier "out-in" call option.

There is an out barrier above the current stock price (an "up barrier") and an in barrier below the current stock price (a "down barrier"). This option has a payoff only if all three of the following events happen: first, the stock price path includes a fall in price below the down barrier (i.e., the option is “knocked in"); second, the stock price path does not include a rise in price above the up barrier (i.e., the option is not "knocked out"); and third, the option is exercised when the stock price is above the strike (i.e., the option is in-the money at exercise). This option is both path-dependent and American-style. Is there an easy technique for valuing the option?

**Questio**n 2.37: Suppose gold prices follow a Gaussian process. 14 The current

price of gold is $400. The riskless interest rate is zero. The volatility of gold in dollar terms is o - $60 per annum. What is the value today of a digital cash-or-nothing option that pays $1 million in six months if the price of gold is at or above $430?

**Story: H**ere is a quirky thinking question from Section 5.5: "How many ping-pong balls can you fit in a jumbo jet (e.g., Boeing *74*7*)?*"

**Question** 2.38; (\*\*) What is the value of a perpetual (i.e., potentially infinitely

lived) American put option?

**Question** 2.39: Let "*L*" denote the three-month US dollar LIBOR rate. Consider

an interest rate swap arrangement where Party A pays *L* to Party B, and Party B pays 24% -2*x L* to Party A. Can you reverse engineer this deal and express it in simpler terms*?*

**Question** 2.40: If an option is at-the-money, about how many shares of stock

should you hold to hedge the option*?*

**Question** 2.41: Compare the price of an option on a stock if the stock price

follows mean reversion versus if the stock price does not.

**Questio**n 2.42: When can hedging an options position make you take on more

risk?

**Question** 2.43: How do you hedge a written put on a stock if you can neither

short any stock nor use options on any stock?

**Question** 2.44: Another pizza question! You order a pizza for six people. The

diameter of the pizza is 12 inches. What would the diameter have to be to feed eight people? Yes, this is a derivatives question.

**Question** 2.45: When do you want to be short a put option on IBM stock?

*\**\*This is **an arithmetic Brownian** motion. The future price of gold is thus assumed to be normally **distributed (not lognormally as per Black-Scholes).**

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**Question** 2.46: You own two pieces of land—a huge field in Arizona and a tiny

piece of beach in Florida. The field in Arizona is idle; you have no plans to develop the land in any way. The tiny beach in Florida is very popular. In fact, it is so popular that you charge a small entrance fee for beachgoers.

The government has offered to buy the Arizona field for $1 million. Your neighbor has offered to buy the Florida beach for $1 million as well. Other things being equal, which piece of land has the higher forward price?

**Question** 2.47: You have 30 days of "representative" stock price data. How do

you calculate historical volatility g 2 to use in Black-Scholes?

**Question** 2.48: Suppose a “top issuer" (ie., highest-rated financial institution

**used as a referenc**e in setting the swap curve) issues a corporate bond for itself valued at 100. The issuer then re-prices this bond using the swap curve. What price do they get (100, above 100, or below 100)? To clarify, they fix the coupon rate of the bond so that it is priced at par, and then they try pricing this same bond by discounting those previously set coupons using the swap curve. Is the answer par, above par, or below par?

**Question** 2.49: Suppose I don't know any mathematics. How do you explain to

**me w**hy you use the riskless rate instead of the required return on the stock to derive the Black-Scholes formula?

**Question** 2.50: Are you better off using implied standard deviation or historical

standard deviation to forecast volatility?

**Question** 2.51: According to Black-Scholes, which is more valuable: a European

call option that is 10% out-of-the-money, or a European put option that is 10% out-of-the-money?

**Question** 2.52: Why are theta and gamma of opposite signs? Are they always

of opposite signs?

**Question** 2.53: Suppose that the riskless rate is zero. Suppose that a stock is at

$100, and one year from now will be at either $130, or $70, with probabilities 0.80 and 0.20 respectively. There are no dividends. What is the value of a **one-year Europ**ean call with strike $110?

**Question** 2.54; *(*\*\*) Find a formula for the European-style "product call" with

payoff max(Si X S2 - X,0), where Si and Sa are the prices of assets following **geometric Brownian m**otions with correlated random increments. All other Black-Scholes assumptions apply.

**Question** 2.55: Are Asian options cheaper or more expensive than plain vanilla

European-style options?

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*CHAPTER 2. DERIVATIVES QUESTIO*N*S*

**Story: One of my students was asked** to "Describe the best **party you have ever been to**." She said this big-name Wall Stree**t investment bank was** looking for "fun loving" people.

**Question** 2.56: When can a plain vanilla American-style call be treated as a

European-style one? When can a plain vanilla American-style put be treated as a European-style one?

**Question** 2.57: How many nodes are there in a recombining binomial tree with

N time steps? How many nodes are there in a non-recombining binomial tree with *N* time steps?

**Question 2.58: You have insi**de information that a foreign stock will rise for

sure. You can legally trade in the foreign market without being subject to any insider trading rules. You can trade the stock, a forward on the stock, futures on the stock, or options on the stock. Assume interest rates are zero, there **are no transa**ctions costs, the exchange rate will not move, and there are no restrictions on trading the derivatives. What trade should you put on if you can only go long these instruments?

**Question** 2.59: *(*\*\*) A call option is priced at c toda*y*. What is the expected

price tomorrow*?*

**Question** 2.60: *(*\*\*) If in Question 2.59 you **answ**ered that the expected call

price tomorrow is higher than today's call price, then how do you reconcile your answer with time decay? That is, how do you reconcile a positive expected return with negative theta?

**Story:** A friend in the City of London was interviewing a candidate for a **position on a credit derivatives quant team. On asking the candidate why he moved** out of theoretical physics, he replied: “Why does a bank robber rob a bank?" After asking him several probabilistic dice questions, the candidate replied: "I can't be bothered with this shit.” On asking him why he left his **previ**ous job, he replied: "Because they were a bunch of @!#@$%s." This is **a true story!**

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**Chapter 3**

**Other Financial Economics Questions**

As a prerequisite to answering the questions in this chapter, it is expected that **you have completed an introductory course in financial economics (or equivalent** independent study). You also need a good deal of common sense. Solutions for this chapter appear in Appendix C.

**Question** 3.1: Consider the following game: a player tosses & fair coin until a

**head a**ppears; if the head occurs on the heath toss, the player gets a payoff of $2\*, and the game ends.!

1. What is the fair value of the game? That is, what is the expected payoff

to a player*?* 2. A very important customer is on the line and wants you to quote him a

bid-ask spread for exactly one play of the game. "Hurry up, I haven*'*t got all day!" You have 15 seconds.

**Question** 3.2: If the standard deviation of continuously compounded annual

stock returns is 10%, what is the standard deviation of continuously com pounded four-year stock returns?

**Question** 3.3: From the term-structure of interest rates, you see that the five

year spot rate is 10% per annum and the 10-year spot rate is 15% per annum. What is the implied forward rate from year 5 to year 10?

**Question** 3.4: Explain carefully the difference between the "yield" on a bond

and the rate of return" on a bond.

**Question** 3.5: What is "chaos theory"? Can you use it to predict stock returns?

If so, how?

**This game is over 250 years old and is known as the "St. Petersburg Game." It is quoted by Daniel Bernoulli (Latin version 1**738); (English t**ranslation 1**954]).

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*CHAPTER 3. OTHER PINANCIAL ECONOMICS QUESTIONS*

**Story: One** of my students who got a job at a large mutual fund company described his **firm's working environment as follows**: "Dig a hole, fill the hole with water, fill the water with sharks, and promote anything that c**rawls out** alive."

**Question** 3.6: Draw the graph of bond price versus yield-to-maturity. Why is

the curve convex?2

**Question** 3.7: The Capital Asset Pricing Model (CAPM) says that the plot of

*E(*r) versus *8* is an upward sloping line through (0, 1) and (1, *E(*T*M*)](i.e., the Security Market Line SML]). Suppose, however, that when you plot average returns against estimated betas you find something else. Which of the follow ing two scenarios is most likely*?*

1. An upward sloping curve beginning at (0, TD), wholly above the theo

retical SML, initially more steep than the SML, but eventually roughly parallel to the SML

2. An upward sloping curve beginning at (0, rr), wholly below the theo

retical SML, initially less steep than the SML, but eventually roughly parallel to the SML

Which CAPM assumptions (if any) are violated by the above two scenarios?

**Scenario**

***are***

**W**

**Question** 3.8: From the term-structure of interest rates, you see that the two

year spot rate is 7.60% per annum, and the one-year spot rate is 7.15% per **annuin.**

What is the implied forward rate for the second year*?*

**Question 3**.9: Consider a six-month forward contract on a 10-year riskless dis.

count (zero-coupon) bond.

1. Is the bond selling at a forward premium or a forward discount?

2. Does your answer change if the bond is a riskless c*oupon* bond (assume

the coupon rate exceeds the current risk-free rate)?

**Question** 3.10: You believe that the yield curve is going to steepen very soon. It

may be a fall in short-term rates, a rise in long-term rates, or some combination of these. What strategy should you pursue in the bond market to position yourself to profit from your beliefs?

**Can you give economic intuition for this convexity? What about mathematical intuition?**

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**Story: Many p**eople are asked: "Are you married? What religion are you? Do you have children? What does your spouse do? How is your family? Where were you born? How old are you?" These are legal questions in the US, but discriminating on the basis of the answers is not legal. So, **most employers avoi**d even the hint of possible disc**rimination. Nevertheless, you** should be p**repared to answer these questions.**

Describe their properties

**Question** 3.11: Define "duration" and "convexity."

and uses.

**Question** 3.12: Describe briefly the G*A*RCH(1,1) model in qualitative terms.

Now write down the formal GARCH(1,1) model and explain each term care fully,

**Question** 3.13: You have a long position in a $100 million 30-year bond. What

**can you do to limit your ex**posure to only $50 million?

**Question** 3.14: (\*\*) You hold an 8% coupon, 30-year, $1,000 par, Mexican

Brady bond. Interest rates in Mexico do not change. Interest rates in the US increase by 1%. What is the change in the price of your bond? Make any **necessary assumptions.**

**Question 3**.15: You construct a yield curve for (coupon-bearing) **treasuries. A**

particular five-year corporate zero-coupon bond has a default risk premium of 1% over the level of your treasuries yield curve at the five-year mark. You believe that the yield curve is going to flatten in such a way that the default risk premium of the five**-year corporate *z*ero remains constant (short-term** rates rise, long-term rates fall, and the yield on the **five-year coupon-bearing trea**sury and five-year corporate zero remain unchanged). What strategy should you pursue using the five-year zero-coupon corporate bond and treasuries to position yourself to profit from your beliefs?

**Question** 3.16: The five-year interest rate is 10%, and the 10-year interest rate

is 15%. You conclude that the **forward rate from year** 5 to year 10 is approx imately 20%. Explain, *using plain English,* why the forward rate has to be *highe*r than the 20% approx**imate value mentioned above.**

**\***

**Question** 3.17: Here is a simple game. You get to toss a fair coin now. If it

is heads, you get seven dollars 18 months from now. If it is tails, you lose two dollars immediately. The one-year interest rate is 12% per annum. The **two-year i**nterest rate is 18% per annum. How much are you prepared to pay to play this game?

**Note that GARCH is an acronym for Generalized AutoRegressive Conditional Heteroskedas ticity. How do you estimate the model? Why was it introduced?**

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*CHAPTER 3. OTHER FINANCIAL ECONOMICS QUESTIONS*

**Question 3.18: T**here are 20 traders in a room. They trade in 100 stocks. They

trade for their ow*n* accounts and only amongst themselves—it is a "closed economy." Halfway through their morning trading session, a group of SEC officials arrives and announces that one of the traders has inside information on one stock and has been trading on it. The trader is not yet identified. The SEC officials seat themselves in the room to watch. What happens to trading volume after the SEC announcement? Explain carefully.

**Story: One interviewee was as**ked, "If you are holding a dinner pa**rty, and you can invite any three dead** people (presumably resurrec**ted), who would you choose? Please do not choose any relatives." Give it som**e thought.

**Questio**n 3.19: Two stocks have the same expected return. One has standard

deviation of returns of 20%, and the other has standard deviation of returns of 30%. The correlation between their returns is 50%. How do I allocate money **between these so as to minimize my risk.**

**Question** 3.20: The same question as Question 3.19 but with var**iance or returns**

10% and 40%, respectively, and correlation 50%.

**Story: "On**e cocky job **candidate interviewed with several male managers at** a major bank before being ushered into **an interview with a female manager. He sat across f**rom her, put his feet on her desk and said, 'Get me a Coke."

MICHAEL ZW**ELL** Michael *Z*well ***&* Associates, Chicago**

"Doomed Days: The Worst Mis**takes Recruiters Have Ever Seen,"**

*Th*e W*all Street Jour*nal, February 25, 1995, PR4. Reprinted b**y permission** o*f The* W*all Street Journal* ©1995 D**ow Jones and Company, Inc.** All Righ**ts Reserved Worldwide.**

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**Chapter 4**

**Statistics Questions**

The only prerequisites for answering the statistics questions in this chapter are **elementary stati**stical skills. Solutions for this chapter appear in Appendix D.

**Question 4**.1: Supp**ose we draw two random num**bers X and Y each distributed

uniform on the interval (0,1. If X and Y are independent, what is the prob ability that their product is greater than 1/2?

**Question 4**.2: Consider the following game. The player tosses a die once only.

The payoff is $1 for each sdot" on the upturned face. *A*ssuming a fair die, at what level should you set the ticket price for this game?

**Question 4.**3: I am going to toss four coins. You are going to toss five coins.

You win if you get strictly more heads than I do. What is the probability that you win*?*

**Question 4**.4: I will roll a single die no more than three times. You can stop me

**immediately after t**he first roll, or immediately after the second, o**r you can** wait for the third. I will pay you the same number of dollars as there are dots on the single upturned face on my last roll (roll number three unless you stop **me soon**er). What is your playing strateg*y?*

**Story: O**ne of my MIT students was exceptionally well qualifie**d. He was** also one of the nicest guys I **have ever met. He was quiet and soft-spoken. He was very understat**ed (the kind of guy you might not notice). His starting **salary at a big-name Wall Street firm was about four times the average MIT starting salary that year. The moral of the story: I don't care how hot you think you are...brains wins.**

**If you were running this game, how much would you charge players for repeated plays of the game? Suppose instead an amended game is played: I roll a single die three times without pause, and the payoff to the player is the maximum of the three rolls. What is the expected payoff to the player*?* Can you tell up front whether the original or amended game has the higher expected payoff?**

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*CHAPTER 4. STATISTICS QUESTIONS*

**Question 4**.5: The correlation between X and Y is *p*. What is the correlation

**between X** + 5 and Y? What is the correlation between 5X and Y?

Story: One interviewee told me that the **interviewers aim** to put you under **as much pressure as possible, and that "you never know when they are going** to bring out the guy in the chicken suit."

**Question 4**.6: (\*\*) Two sealed envelopes are handed out. You get one and your

competitor gets the other. You understand that one envelope contains *m* dollars, and the other contains *2m* dollars (where *m* is unstated).2

1*. If* you peek into your envelope, you see $X. However, you do not know

whether your opponent has $2X or $. X. W*ithout peeking,* what is your expected benefit to switching envelopes? What is your opponent's ex pected benefit to switching envelopes (assuming your opponent sees $Y)? Should you switch? If you do, do you do it **again for the same reason**

**(assumin**g neither of you peeked)? 2. Suppose that you both peek into your envelopes initially. What is the

payoff to switching? Should you switch? If you do, do you do it again for the same reason?

**Question 4***.7*: They call this the "World Series" problem in the US. Sports **teams**

"A" and "B" are to play each other until one has four wins and is declared the series winner. You have $100 to bet on Team A to win the series. You are, however, only allowed to bet on individual games, not the final **outcome** directly, and, you must bet a positive amount on each game. So, if Team A **wins the series, you must walk away** with $200, but if Team A loses the series, you must walk away with zero, and you must do so having placed a non-zero bet on every game. Your be**st assessment is that Team A has a 70% chance** of winning any game and Team B has a 30% chance. How do you place your bets*?*

**Question 4**.8: You have three children, but only one apple. You want to toss a

fair coin to determine which child gets the apple. You want each child to be equally likely to get the apple. What is your strategy*?*

**Question 4**.9; A follow up question to Question 4.8: What is the expected num

ber of tosses needed to complete this strategy*?*

**Question 4**.10: Another follow up question to Question 4.8: You have a fair coin

and you want to simulate an event that has probability 1/3, and an event that has probability 2*/*3. How do you do it?

**Question 4**.11: You and I are to play a game. You roll a die until a number

other than a one appears. When such a number appears for the first time, I

?This problem is o**ver 40 years old and is known as t**he "Exchange Paradox."

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pay you the same number of dollars as there are dots on the upturned face of the die, and the game ends. What is the expected payoff to this game?

**Question 4**.12: You are dealt exactly two playing cards from a well-shuffled stan

dard 52-card deck. The standard deck contains exactly four Kings. What is the probability that both of your cards are Kings?

**Story: It is many years ago now, but I know of a** well-qualified MIT student who got a job offer of $X from a well-known firm (a good offer at that time). He declined, telling them that they had misjudged him. They called him back a couple of days later and offered him $X X 1.67 instead! Amazing! He took the job.

**Question 4**.13: *(*\*\*) This is one version of the famous "Let's Make a Deal" or

"Monty Hall" game show question. It is your turn to be on **a weekly game** show. There are three doors. You know that there is a prize behind one of them, and nothing behind the other two. The game show host tells you that you shall receive whatever is behind the door of your choice. However, before you choose, he tells you that he knows the actual location of the prize, and he promises you that rather than immediately opening the door of your choice to reveal its contents, he will first open one of the other two doors to reveal that it is empty. He will then give you the option to change your mind and instead choose the remaining door that he did not open. You may assume that whoever set up the doors and prizes placed the prize uniformly randomly behind a door i.e., each door had an equal probability of being chosen as the prize location). Yo**u may assum**e that if you initially choose a door that has the prize, then the host is uniformly random in revealing one of the two remaining do**ors as empty. You may as**sume that the host must reveal an empty door.3 You choose Door 3. He opens Door 2 and reveals that it is empty. You now know that the prize lies behind either Door 3 or Door 1. Should you switch your choice to Door 1? **I st**rongly recommend that you not loo**k at the answer until you have done** your best.

**Question 4.14**: (\*\*) Now we will ask you the **same question as the previous**

**one**, except that when it comes time for the host to reveal an empty door, he instead selects s**omeone from the audience who chooses randomly and by** chance chooses & door that is revealed to be empty. Should you switch? Note: There **are two ways to interpret this question. You could assume that** the game can be played repeatedly with an audience member always revealing

**\*You can imagine variations of the problem where the host is not required to open another door if doing so helps you, or where he does not open doors with equal likelihood. The solution may differ in those cases.**

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*CHAPTER 4.* S*TATISTICS QUESTIO*NS

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a door to be empty, or you could assume a one-off game where the audience member ignorant of the prize's location) just happe**ns to have chosen an** empty door. Try answering both.

**Story: A st**udent interviewing with a top bulge bracket fir**m was asked how he would mo**ve Mount Fuji. One of my colleagues suggested the **answer "Call Mohammed."**

**Question 4**.15: You are presented with two empty jars and 100 marbles on a

table. There are 50 white marbles and 50 blac**k marbles. You ar**e to put all 100 of the marbles into the two jars in any way you choose. I will then blindfold you. I will shake the jars up to ensure good mixing, and I will rearrange the placing of the jars on the table so that you do not know which one is which. **You may then request** either the "left-hand" or the "right-hand" jar. You get **to choose exa**ctly one jar, you **are allowed to withdraw at most one marble** from the jar, and you do not get a second chance if you are unhappy with your choice.

How many of each color marble should you place in each jar to maximize the probability that your blindfolded random draw obtains a white marble?!

**Question 4**.16; *(*\*\*\*) Your name is Mr. 10. You are standing in a field with

two opponents: Mr. 30 and Mr. 60. Each of you has a gun and plenty of **amm**unition. Each of you is in clear sight of the others and well within firing range. The goal is to maximize the probability of survival. Unfortunately, you are not a very good shot. If you take a shot at one of your opponents, you have only a 10% chance of killing him. Mi, 30 is a better shot; he has a 30% chance of killing whomever he shoots at. Mr. 60 is even better; he has a 60% chance of killing his target. You take turns shooting in a pre-arranged order: first you, then Mr. 30, then Mr. 60, and then through this cycle again and again until only one pe**rson remains.**

You get to shoot first. At whom do you shoot*?*5

**Question 4**.17: Basketball! Your team is down two points, you are the best

player, and you have the ball. There are only a few seconds left before the buzzer. You can take a shot from three-point land or move up and take one from two-point land. Historically, you have a 40% probability of getting the shot in from three-point land and a 70% probability of getting the shot in from two-point land. Should you try for the three-point shot (a certain win if you make it), or should you try for the two-point shot? Note that a two-pointer produces a tie

**Can you answer the same question except that you are to *minimize* the probability of a white marble? Does minimizing the probability of a white marble maximize the probability of a black one?**

**Does the answer chan**ge if the order is first you, then Mr. 60, then Mr. 30, then you, and so on*?*

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and puts you into overtime. We assume your team has a fifty-fifty chance of winning in overtime.

**Question 4**.18: I will spin a fair roulette wheel with only five sections. Four of

the five sections pay $1; the fifth pays $5.

1. If the cost is $1.50 per spin, and you may play as often as you want,

should you play the game? 2. If the cost is $1.50 per spin, and you **may play exact**ly once, should you

play the game?

**Question 4**.19: If you like gambling and you like betting on the outcome of sports

matches, then you may like the parlay card." A parlay card lets you bet on **the outcome**s of more than one match. In order to win a parlay bet, you must be correct on each of the matches you bet upon, Parlay cards offer big payoffs if you are right on every match (some even offer a payoff for "almost wins"). Suppose that your bookie will give you 10-to-1 odds for a parlay bet that covers four sports matches (with no almost wins). Should you take the bet?“

**Question 4**.20: What is the standard deviation of (1,2,3, 4, 5)?

**Question 4**.21: Welcome to your interview. Sit in this chair. Excuse me while

I tie your arms and legs to the chair. Thank you. Now we are going to play "Russian roulette." I have a revolver with six empty chambers. Watch me as I load the weapon with two contiguous rounds (i.e., two bullets side-by-side in the cylindrical barrel). Watch me as I spin the barrel. I am putting the gun against your head, Close your eyes while I pull the trigger. Click! This is your lucky day: you are still alive! Our game **differs from r**egular Russian roulette because I am not going to add any bullets to the barrel before we continue, and I am not going to give you the gun. My question for you: I am going to shoot at you once more before we talk about your resume. Do you want me to spin the barrel once more, or should I just shoot?

**Question 4**.22: You have a large jar containing 999 fair pe**nnies and one two**

headed penny. Suppose you pick one coin out of the jar and flip it 10 times and get all heads. What is the probability that the coin you chose is the

two-headed one? **Questio**n 4.23: Four cards are shuffled and placed face down in front of you.

Their faces (hidden) display the four elements: water, earth, wind, and fire. You are to turn the cards over one at a time until you either win or lose. You win if you turn over water and earth. You lose if you turn over fire. What is

the probability that you win? **Should you take th**e bet if the odds are 25-to-1?

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*CHAPTER 4. STATISTICS QUESTIONS*

**Story: "I**n his first meeting with me, a candidate made himself a little too comfortable. Not only did he liberally pepper his co**nversation with** profanities, he also pulled his chair right up to the edge of my desk and **started examining papers and knickknacks."**

NINA PROCT Martin H. Bauman Associates, New York

"Doomed Days: The Worst Mistakes Recruiters Have Ever Seen," *The Wall Street Journal*, February 25, 1995, PR4. **Reprinted by permission of** *The Wall Street Journal* **©1995 Dow Jones and Company, In**c. All Rights **Reserved Worldwide.**

**Question 4.24: Tw**o players A and *B* play a marble game. Each player has both

a red and a blue marble. They present one marble to each other. If both present red. A wins $3. If both present blue. A wins $1. If the colors do not match, *B* wins $2. The winnings come from an external source, not from the other player. Is it better to be A, or *B,* or does it matter*?*

**Question 4**.25: A coin-making machine produces pennies. Each penny is man

**ufactured to have a p**robability *P* of turning up heads. However, the machine draw*s P* randomly from the uniform distribution on (0,1 so *P* can differ for each coin produced. A coin pops out of the machine. You flip it once, and it comes up heads. Given this information, what is the conditional) distribu tion function *Fpup*) for the probability of a head for that coin (where "*H"* denotes conditioning on the head)? What is the conditional) distribution function for the probability of a head if you flip the coin 1,000 times and get 750 heads?

**Question 4**.26: Suppose that X is distributed normal with mean 0 and variance

*0*4. What is *E*(e\*)? **Question 4.27: Two games are offered to** you. In Game One, you roll a die once

and you are paid $1 million times the number of dots on the upturned face of the die. In Game Two, you roll a die one million times. For each roll you are paid $1 times the number of dots on the upturned face of the die. You are risk averse. Which game do you prefer*?*

**Story:** 1. Took a brush out of my purse, brushed his hair and left. 2. Pulled out a Polaroid camera and snapped a flash picture of me. Said he collected **photos of everyone who interviewed him. Interview Horror Stories from Re**

cruiters **Reprinted b**y kind permission of M*BA Style Magazine* © 1996-2014 MBA Style Mag**azine, www.ebastyle.com**

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**Question 4**.28: What is the expected number of tosses of an unfair coin needed

to get two heads in a row (assume probability *p* of a head)? Same question with three heads in a row.

**Question 4.29: In a surv**ey of 1,000 people, 60% said they would vote for Can

didate A for president (and 40% said they would vote for someone else). How can you calculate a margin of error on the 60% estimate?

**Question 4.30**: A disease occurs with probability 0.5% in the population. There

is a test for the disease. If you have the disease, the test returns a positive for sure. If you do not have the disease, the te**st returns a fa**lse positive 7% of the time. A random stranger is given the test and it returns a positive. What is the probability that the stranger has the disease?

**Question 4.31: H**ow many different ways can you invest $20,000 into five funds

in increments of $1,000? For example, one way to do it is

($0; $4,000; $1,000; $2,000; $13,000).

**Question 4**.32: *(*\*\*) You are making chocolate chip cookies. You add *N* chips

**rand**omly to the cookie dough, and you **random**ly split the dough into 100 equal cookies. How many chips should go into the dough to give a probability of at least 90% that every cookie has at least one chip?

**Question 4.33**: You will roll a fair die until the game stops. The game stops

when you get a 4, 5, or 6. For every number 1, 2, or 3 you have thrown your score increases by +1. If the game stops with a 4 or 5, you get paid the accumulated score. If the game stops with a 6 you get nothing. What is the expected payoff of this game?

**Question 4.34**: Consider four boxes in a row numbered 1, 2, 3, and 4. You start

with a pebble in Box 1. We toss a fair coin. If it is heads you move the pebble forward one step to Box 2, but if it is tails you move the pebb**le forward two** steps to Box 3. Then we toss the coin again. If it is heads, you move the pebble back to Box 1, but if it is tails **you advan**ce it to Box 4. If you reach **Box 4 the game is over. If you are back in Box 1, however, then we toss again** following the same rules. What is the expected number of coin tosses it will **tak**e to reach Box *4?*

**Question 4.**35: "Take a stick and break it randomly into three pieces (i.e., two

randomly placed breaks on the stick). What is the probability you can form a triangle from the pieces?

**Question 4.**36: *(*\*\*) A variation on the previous question: What is the expected

length of the longest piece*?"*

**...and what about the expected length of the shortest piece*?*** ...o**r the medium piece?**

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*CHAPTER 4. STATISTICS QUESTIONS*

**Question 4**.37: I tell you that I have two children and that one of them is a girl

(I say nothing about the other). What is the probability that I have two girls? Assume that boys and girls are equally likely to be born and that the gender of one child is independent of gender of another.

**Question 4.38**: I tell you that I have two children and that one of them is a

girl (I say nothing about the other). You knock on my front door and you are greeted by a girl who you correctly deduce to be my daughter. What is the probability that I have two girls? Compare and contrast yo**ur answer to** the answer to the pre**vious question. Assu**me that boys and girls are equally likely to be born and that the gender of one child is independent of gender of another.

**Question 4.39**: You and I are to meet tomorrow under the big clock at the train

station. We have agreed to meet somewhere between 1PM and 2PM. We have agreed that each of us will wait no more than 15 minutes for the other, and that neither of us will arrive before 1PM or remain after 2PM. What is the probability that we will actually meet?

**Story: "E**very morning I see job candidates who spend a day here. I talk to **them, answer questions** about our company, tell them whom they'll inte**rview** with, and send them off. At the end of the day, when they come back, I determine whom they'd most like to work for, brief them on employee benefits, and tell them what happens next. I went through the morning ritual recently with one young candidate and then told him I'd see him about 4P.M. 'I don't w**ant to come back h**ere,' he said, quite emphatically. "I've already talked to a guy I know who has been here before, and he told me **everything** you're *g*oing to tell me.' "

ED GULICK Recruiting Coordinator, Sandia National

Laboratory, Albuquerque, N.M.

**"Doomed D**ays: The Worst Mistakes Recruiters Have Ever Seen," *The Wall Street Journal,* February 25, 1995, PR4. **Reprinted by permission** of *The Wall Street Journal*

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**Chapter 5**

Non-Quantitative **Questions**

You probably picked this book up for the **same reason I wrote it: you like solving** quantitative problems. If you are anything like me, you probably hate those **invasive,** wishy-washy, touchy-feely, namby-pamby, non-quantitative **interview questions that you cannot solve using mathematics. If you have prepared for the quantitative** questions, but you are dreading those wishy-washy, non-quantitative ones, then you need to read this chapter.!

Some of these questions have a single correct answer (great!). Others are roughly what you might expect in some sort of Freudian couch session after having been arrested for machine-gunning all the bag boys in your local supermarket. Some of the questions depend upon knowledge of financial management; others depend upon how many drinks you had at that last party you went to (and you might not get the job if you did not have any drinks at the last party or if you do not go to parties).

Speaking of parties, I saw some guy turn up to an interview without a tie, and another turned up wearing white shoes. You are not expected to own a $5,000 suit, but you are expected to look sensible, not like you are going to a retro 1970's party.

My non-quantitative questions are broken into five categories: Questions About You, Questions About Your Job Awareness, Questions About the Markets or The Economy, Questions About Financial Management, and "Thinking Questions." In **the rare cases where I deem an answer necessary**, the question is labeled with an "(*A*)," and its sugges**ted answer app**ears in Appendix E.

This chapter benefited very much from interview questions collected by second year MBA students at MIT's Sloan School of Management and MBA students at Indiana University. I also than**k many interviewers at investment banks for sharing** their questions with me.

**WITH**

**As mentioned in the introductory chapter, you can buy interview books containing general non-quantitative questions. However, these books do not cover finance-related non-quantitative questions or the quirky questions unique to investment banking interviews. Of these interview books, I recommend Fry (2009). He presents non-quantitative questions and weighs up good and bad responses.**

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*CHAPTER 5. NON-QUANTITATIVE QUESTIONS*

**5.1 Questions about You**

**Question** 5.1.1: Tell me about yourself.

**Questio**n 5.1.2: Walk me through your resume.

**Question** 5.1.3: What are your career goals? How will you achieve those goals*?*

**Question** 5.1.4: What do you see yourself doing in five *y*ears? Is this different

from what you imagined when you entered the degree program at your college (if so, how so)?

**Question** 5.1.5: Describe your life experiences, explaining any major decisions

you have made to date.

**Questio**n 5.1.6: What two or three accomplishments have given you particular

satisfaction over your lifetime?

**Question** 5.1.*7:* Tell me in detail what you did while working for this company

(that appears on your resume).

**Question** 5.1.8: How would you value yourself in financial terms?

**Question 5.1.9:**

**How do you evaluate your success or the success of others*?***

**Question** 5.1.10: How would you describe yourself? How would your friends

describe you? How would a former supervisor describe you?

**Question** 5.1.11: What is your greatest strength?

**Question** 5.1.12: Describe a situation where you successfully sold your ideas.

**Question** 5.1.13: What is your greatest weakness*?*

**Question** 5.1.14: What areas of your performance need improvement?

**Question** 5.1.15: Why shouldn't we hire you*?* ...a tough spin on the traditional

"what is your greatest **weakness" question.**

**Question** 5.1.16: Tell me something you tried but ended up quitting on.

**e so**

wut +

**Question** 5.1.17: What is the biggest risk you have taken in your life?

**Question** 5.1.18: Rate yourself on & scale of 1 to 10 on the type of risk taker

you are. Tell me why and give examples to support your claims.

**Question** 5.1.19: Tell me about a goal you set for yourself in the past that turned

out to be either too easy or too hard to achieve. What did you learn from the situation?

**Question** 5.1.20: What distinguishes you from other candidates we might hire?

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*5.1. QUESTIONS A****BOUT YOU***

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Question 5.1.21: What do you do for fun?

**Question** 5.1.22: Describe the best party you have ever been to.

**Question** 5.1.23: What is the biggest investment mistake you have ever made?

**Question** 5.1.24. Tell me about a time when you had to deal with a highly

ambiguous situation. What did you do? How did you deal with it?

**Questio**n 5.1.25: Please describe an ethical dilemma you have faced at work,

and tell me how you handled the situation.

**Question** 5.1.26: How good are your writing skills? Please give me some con

vincing evidence.

**Question** 5.1.2*7*: If you could go on a cross-country car trip with any three

people, who would you choose*?*

**Question** 5.1.28: If you were holding a dinner party, and you could invit**e any**

**three dea**d people (presumably resurrected), who would you choose? Please do not choose any relatives.

**Question** 5.1.29: Why did you decide to apply to your MBA college? Did you

apply to other MBA programs (if so, which ones and why)?

**Question** 5.1.30: What do you do if the picture-in-picture" does not work on

your television? Yes, one of my students was asked this in a banking interview!

**Question** 5.1.31: How would you evaluate your experiences at your MBA col

lege?

**Question** 5.1.32: What are the strengths a**nd weaknesses of** your MBA program*?*

**Question** 5.1.33: Describe a situation in which you had to make a decision based

on very little information.

**Question** 5.1.34. Tell me about a situation when you were chosen as a leader by

the members of your group.

**Question** 5.1.35: Repeat the conversation that you had with your team mates

when things did not go well in your group.

**Question** 5.1.36: What have you enjoyed most about your experiences at your

MBA college*?* What would you change*?*

**Question** 5.1.37: What is your GPA at your college? What about your GMAT

score*?*

**Question** 5.1.38: Which courses did you enjoy most at your MBA college (and

why)?

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*CHAPTER 5.* N*O*N*-QUANTITATIVE QUESTIONS*

**Question** 5.1.39: How has your course work at your MBA college helped you to

develop skills relevant to this job?

**Question** 5.1.40: What has been most difficult for you at your MBA college,

and how have you dealt with it?

**Question** 5.1.41: How much of your education did you personally fund?

**Question** 5.1.42: How do you spend your time outside of school and work? How

do you balance your life?

**Question** 5.1.43: Describe your typical day,

**Question** 5.1.44: Are you innately intelligent, or do you have to work really

hard?

**Question** 5.1.45: At interview end: "Is there anything important you have not

had a chance to tell me?"

**Question 5.1.46: At interview end: "Do you have any questions you wo**uld like

to ask me*?*" You must have questions; Candidates with no questions appear unmotivated*/*uninterested. Saying no is like slapping your interviewer in the **fa**ce. That is no way to end the interview! Your **questions must be ones whose answers can**not be found easily online. For example, "What is the biggest challenge facing your division over the ne**xt two year**s?" "Why did you join the company?," "What do you personally find most satisfying about working for this company?"

**Story: "D**uring a lunch interview with me, a candidate ordered a bowl of French onion soup. When he started to eat the l**ayer of cheese on t**op, it **became stringy, an**d with his hands he tried to pull the strings of cheese apart. He pulled at those **strings of cheese f**or a lo-n-g time."

**AUDREY W, HELLINGER Chicago Office of Martin H. Bauman**

**Associate**s, New York

"Doomed Days: The Worst Mistakes **Recruiters Have Ever Seen,"** *The Wall Street Jour*nal, February 25, 1995, PR4. **Reprinted by permission** of *The* W*all Street Journal* **©1995 Dow Jones and Company, Inc. All Rights Reserved Worldwide.**

***5*.2**

**Questions about Your Job *A*wareness**

**Question** 5.2.1: What do you know about us? What makes us different that

appeals to you?

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*5.2. QUESTIONS ABOUT YOUR JOB* A*WARENESS*

**Question** 5.2.2: **How does this position in this company fit into your career**

development plans? What other **career options are you consi**dering?

**Question** 5.2.3: Why do you want to work for this employer*?*

**Question** 5.2.4: Sell yourself to me. Prove to me that you are someone I should

seriously consider for our firm.

**Question** 5.2.5: What motivates you to put forth your best effort? What type

**of work environment brings out your best eff**ort?

**Questio**n 5.2.6: What rewards do you seek from work? What rewards do you

**seek f**rom this particular job (or company)?

**Question** 5.2.7: Tell me about a recent deal our company did. Walk me through

the details of the deal.

**Question** 5.2.8: Why are you not better matched with Firm X (our competitor)?

**Question 5.2.9: Do you have any geographical preferences? What are your**

thoughts about travel or relocation?

**Question** 5.2.10: What do you see yourself contributing to our organization,

both in the short term and in the long term*?*

**Question** 5.2.11: What other companies are you interviewing with, and how do

we compare*?*

**Question** 5.2.12: (A) What do you think of our tombstone in today's *Wall Street*

*Journal?*

**Question** 5.2.13: Why fixed income rather than equities?

**Question** 5.2.14: What do you think it takes to be successful in this position or

this organization)?

**Question** 5.2.15: Why do you want to work as a trader?

**Questio**n 5.2.16: What do you think traders do?

**Question** 5.2.17: If you were in my position, interviewing candidates for this

position, what qualities would yo**u seek? How would you evaluate candidates*?***

**Question** 5.2.18: Describe the best boss you have ever had. How would you

define the qualities of a good manager*?*

**Question** 5.2.19: What do you think an investment banker does?

**Questio**n 5.2.20: Do you understand the hours inves**tment bankers work and**

why*?*

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*CHAPTER 5. NON-QUANTITATIVE QUESTIONS*

**Question** 5.2.21: Describe how you build relationships in a new job.

**Question** 5.2.22: Imagine you have received three job offers. How will you decide

which one to accept?

**Question** 5.2.23: If you were to get two other job offers in addition to one from

us, from which firms would they most likely come, would you take them, and why?

**Question** 5.2.24: Some people say investment banking is not value adding How

do you refute that?

**Question** 5.2.25: Imagine you are giving a presentation to a client and they tell

you your numbers are wrong. What would you do?

**Question** 5.2.26: If we offer you a job right now, will you take it?

**Question** 5.2.2*7*: (A) With your abilities, you seem to not fit in this position

(or this firm). Perhaps you should consider a job in ...

5.3 Quest**ions about the Markets or the Economy**

**Questio**n 5.3.1: Where is the DOW, or S&P500, or **NIKKE**I, or FTSE, or Hang

Seng, or....? How does it compare now to where it has been over the last two years? Where do you see it two weeks from now (or six months from now)?

**TI**

**Question** 5.3.2: Where is the JPY, or GBP, or CAD, or EUR, or....? How does

it compare now to where it has been over the last two years? Where do you see it two weeks from now (or six months from now*)?*

**Question** 5.3.3: What does Company X (a well-known company) actually do?

**Question** 5.3.4: Do you trade? Do you own stock? What made you choose those

stocks?

**Question** 5.3.5: What would you do if I gave you $10,000 to trade with? (Note

that if you have never opened a brokerage account, you must not give lack of funds as an excuse. If you cannot generate $2,000 to open a brokerage account, then why should I hire you?)

**Question** 5.3.6:

(A) Do you believe that markets are efficient?

**Question** 5.3.7: What is LIBOR, and what is today's LIBOR rate*?2*

2They **probably mean the benchmark three- or six-month US dollar LIBOR rates, but they** might **not say that. There are several different dimensions here: you should understand the distinction betwee*n* USD LIBOR and GBP LIBOR, between three-month USD LIBOR and six-month USD LIBOR, between LIBOR (London InterBank Offered Rate*)* and EURIBOR (Euro Interbank Offered Rate), and between euro LIBOR and EURIBO**R. If you do not, loo**k in your favorite investments book, or use a WWW search engine.**

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*5.3. QUESTIONS ABOUT THE MARKETS OR THE ECONOMY*

**Question** 5.3.8: Why invest in a particular market (e.g., Korea, Russia, Ger

many)?

**Question** 5.3.9:

Tell me how you keep up with the news.

**Question** 5.3.10: Talk me through a transaction/event/deal in the finance indus

try that caught your eye recently. What is a problem with this deal? What's another problem? What's another problern? Why is this a problem? They may push and push until you cannot go any further or until you get to the problem they want you to identify).

**Question** 5.3.11: How would the following affect interest rates: A relative of

Saddam Hussein starts making trouble in the Middle East; there is another Asian currency crisis; Monica **Lewinsky** (alleged mistress of the US president Clinton hits the headlines again as the alleged mistress of the current US president.

**Question** 5.3.12: (A) When inflationary fears arise, the government has two

forms of macroeconomic policy to try to slow the economy down. Name these and explain them in a fe**w words.**

**Question** 5.3.13: What stock do you recommend and why*?*

**Question 5.3.14**: What sector should I be short? What sector should I be long?

**Question** 5.3.15: Tell me about a stock you like or hate and why.

**Question** 5.3.16: What should be the (CAPM) beta for Intel Corp.?

**Question** 5.3.17: Where do you think the US economy will go over the next

**year? Question** 5.3.18: *(*A) What are the “Dow Jones Dogs"?

**Question** 5.3.19: Tell me how the Dow Jones Industrial Average is calculated. **Question** 5.3.20: Draw the yield curve showing 3M, 6M, 1YR, 2YR, 5YR, 10YR,

30YR rates.

w

**Question** 5.3.21: Do you think the stock market is efficient (in an EMH sense)?

A very popular question for asset management.

**Question** 5.3.22: Suppose you are actively investing to beat the market. Are

there more opportunities (i.e., inefficiencies) in the S&P500 or in the 500 largest stocks in Europe?

**Question** 5.3.23: What is a black swan? What do black swans mean for the use

of VaR and other conventional statistical methods employed in quantitative **finan**ce? This obviously refers to the black swan concept in Nassim Taleb's books *Fooled by Randomne*ss and *The Black* S*wan.* A black swan is a surprise

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*CHAPTER 5. NON-QUANTITATIVE QUESTIONS*

event with a major impact. After the fact we typically try to rationalize it as if it could have been anticipated.

**Story:** "We had narrowed our search for a senior-level executive at a major **financial institution to three candidates and** felt that one in particu**lar was** the best choice in terms of experience and background. We prepped all three for their interviews with the company's general counsel, but we really spent time prepping the top candidate. When he got into the in**terview, it** suddenly seemed he'd come from another planet. He asked about his office furniture, his expense-account allowances and health-care plan. He asked nothing **whatsoever a**bout the functions of the job and his qualifications for it. I sat there in horror."

**ARNOLD M. HUBERMAN** Arnold Huberman Associates, New York

**"Doomed Days: The Worst Mistakes Recruiters Have Ever Seen,"** *The* W*all Street Journal*, February 25, 1995, PR4. **Reprinted by permission** of *The* W*all Street Journal*

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**5.4 Financial Management Questions**

**Question** 5.4.1: How would you go about preparing a 2-3 page analyst report

proposing to a client the acquisition of a waste management firm? How would you collect the information necessary for the valuation?

**Question** 5.4.2: How would you value a company? (This is a very popular ques

tion.) The main approaches include DCF methods, Comparables methods, and the LBO method (Crack, 2014b, Chapter 2).

**Question 5.4**.3: Explain what a discount rate is, and how you calculate it for

a publicly traded company. What is the WACC? How would you **estimate a** firm's beta? How would you calculate the required rate of return for equity holders for a company? What would you use for a market risk premium? How would you estimate the cost of debt for a company assume that there is no publicly traded debt for that company outstanding)?

**Question 5.4.4: W**hat exactly is a beta and what does it measure? What is

systematic risk and how does it differ from active risk?

**Question** 5.4.5: Compare the betas of an airport and a retailer 3

Mullins (1982) ha**s a lovely table in it that lists betas by industry, ranging from Air Transport** (1.80) **downt to Gol**d (0.35). **The article pre-dates the Fama-French critique of the CAPM by 10 years (Fama and Fren**ch (1992, 1993)) but gives excellent intuition for the CAPM. Watch out for **the use of a riskless rate of 10% per annum and an expected return on the market of 19% per annu**m—which r**eflect the time period it was written in.**

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*5.4. FINANCIAL MANA*G*EMENT QUESTIONS*

**Question 5.4.6: If you were asked** to put together a two-page analyst report on

a company, what sort of information would you include? What specific ratios would you include?

**Question 5.4**.*7*: Suppose that the S&P500 index has a P*/*E ratio of 20. How

would y**ou value a manufacturing company with earnings** of one million dollars?

**Question 5**.4.8: What key financial ratios do you look at when trying to deter

mine a firm's financial health from its balance sheet?

**Question** 5.4.9: Why do pharmaceutical companies increase drug prices when

they come off patent protection?

**Question** 5.4.10: Describe the CAPM.

**Question 5**.4.11: Can a company function without working capital?

**Question** 5.4.12: What happens to a company's balance sheet if the company

**buys an asset? Walk me th**rough the steps.

**Question** 5.4.13; (*A)* When is a motor vehicle that is owned by the company

not recorded on the balance sheet as PPE ("physic**al plant and equipment" or** \* property plant and equipment")?

**Question 5**.4.14: How would you market this financial product (e.g., a struc

tured note)?

**Question** 5.4.15: How do you use DCF to value a skyscraper in order to sell it?

You need to come up with current revenue, costs, net income, es**timates of** future cash flows, and a discount rate.

**Question 5**.4.16: Kirk Kekorian attempted to force Chrysler to rid itself of what

he called "excess cash" —through higher dividends and a stock buy back. What do you think of this?

**Question 5**.4.17: How would you market this company to our clients?

**Question** 5.4.18: Have you ever had to fire someone? If so, how did you handle

this sit**uation?**

**Question** 5.4.19: Forecast the income statement for Duracell for this year.

**Question** 5.4.20: (A) In the calculation of free cash flow (i.e., FCF), does the

level of long-term debt matter*?*

**Question** 5.4.21: How do you calculate VaR (i.e., Value at Risk)?

**Question** 5.4.22: Have you heard of LTCM?

**Question** 5.4.23: What is the difference between default risk and **prepayment**

**risk?**

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*CHAPTER 5. NON-QUANTITATIVE QUESTIONS*

**Question** 5.4.24: What is kurtosis?

**Story: A student of mine was asked “How would** you value yourself?" That is, put a dollar figure on your value using discounted cash flow analysis.

**5.5**

**Thinking Questions**

These "thinking questions" lie between quantitative and non-quantitative. Most of these questions have in common that they have some sort of precise solution. **Howev**er, if you know exactly how many McDonald's outlets there are in the US (one of the questions) and say so directly, then you have missed the point. The **interviewer want**s you to work the answer out and describe your reasoning. These are thus “thinking questions," not calculation ones.

**Question** 5.5.1: If a cannonball is dropped in the deepest part of the Earth's

oceans, how long will it take to reach the ocean floor?

(*A*) How many McDonald's fast food outlets are there in the

**Question** 5.5.2:

US?

**Question** 5.5.3: How many gas stations are there in the US?

**Question** 5.5.4: *(*A*)* You are in a jail cell alone stripped of your possessions. It

is Friday afternoon, and you desperately need a cigarette. How do you force the guard to give you one?

**Question 5**.5.5: How many elevators (i.e., "lifts" if you are British) are there in

the US?

**Question** 5.5.6: How would you value an option on (famous basketball player)

Michael Jordan?

**Question** 5.5.7: (A) I toss a coin 100 times and get 100 heads in a row. What

is the probability that the next outcome will be a head?

**Question** 5.5.8: How many ping-pong balls can you fit in a jumbo jet (e.g., Boe

ing 74*7)?*

**Question** 5.5.9: How would you move Mount Fuji?

**Question** 5.5.10: (A) How do you weigh a jet aeroplane without using scales?

**Question** 5.5.11: You have a five-gallon jar and a three-gallon jar. You can

have as much water as you want. How do you put exactly four gallons into the five-gallon container? This is too easy for me to supply an answer.

**Question** 5.5.12: Estimate the annual demand for car batteries.

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5.*5. THINKING QUESTIO*N*S*

**m**

**..."**

**Question** 5.5.13: What would you estimate to be the size of the racquetball

market in the US?

**Question 5**.5.14: You are to build a plant for Coors to serve all beer customers

in the state of Ohio. How large would you build it? That is, specifically how **many can**s of the new wide-mouth variety) do you anticipate being **demanded** for the year?

**Question** 5.5.15: Why do beer cans have tapered tops and bottoms*?*

**Question** 5.5.16: (A) Explain why aeroplanes can fly.

**Question** 5.5.17: How many fish are there in the Earth's oceans?

**Question 5.5.18: How many ba**rbers are there in Chicago*?*

**Question** 5.5.19: What is

204,000?

**Question** 5.5.20: *(A*) Finally, why are manhole covers round?

**Story: A student of mine interviewin**g at a top bulge bracket firm **was asked** to draw a picture of himself! They gave him pencil and paper, and he drew a picture into his picture he also drew books, friends, and other goofy stuff to indicate that he was not retarded).

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**Appendix A**

**Purely Quantitative & Logic Answers**

This appendix contains answers to the questions posed in Chapter 1.

**Answer** 1.1: This question has appeared over and over again. Although simple,

it is rarely answered well. No calculation is required to determine the **answer. If you used *any a*lgebra whatsoever, stop now, go ba**ck, reread the question, and try again. When the quantity Q of water is poured into the alcohol jug, the co**ncentration** of alcohol in the alcohol jug becomes yo. After mixing and pouring some back, the concentration of alcohol in the alcohol jug does not change **again** (because no new water is added). However, when the diluted alcohol is poured back into the water jug, the concentration of water in the water jug **changes** from 100% to vyo. That is, the final *c*oncentrations are identical. How do you see that the final concentrations must be identical? Remember, you do not need any calculations at all. In fact, the only reason for any calculation is if you **also want t**o find out what the final concentrations are (you were not asked this, but if you wish to work it out, your calculations need not go beyond those of the previous paragraph). Here is how it works. At the end of the process, both jugs contain the same volume of fluid as they did at the start. The only way for the concentration of alcohol (for example) to have changed from 100% is i**f some alcohol was** displaced by water. Similarly, the only wa*y* for the concentration of water to **hav**e changed from 100% is if **some water was displaced by alco**hol. Volume is **conser**ved (both total volume and volume in each jug), so all that has happened is that identical quantities of water and alcohol have traded places and **these** identical quantities are slightly less than Q). By symmetry, the conc**entrations** of alcohol in the alcohol jug and water in the water jug must be identical. If you are still stuck, here is another way of thinking about it. Imagine a black bucket with 1,000 black marbles in it and a white bucket with 1,000

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*APPENDIX* A*. PURELY QUANTITATIVE E LOGIC* A*N*SW*ERS*

white marbles in it. Suppose I take 100 black marbles out of the black bucket and put them in the white bucket and mix it up really well. Then I have 1,100 marbles in the white bucket, and the great majority of them are white. Suppose I then take 100 marbles from those 1,100 and use them to top the black bucket back up to 1,000 marbles. Then both buckets have 1,000 marbles again. Let us suppose that 91 (i.e., the great majority) of the 100 marbles used to top up the black bucket were white. That means I must **have return**ed only 9 of the original 100 black marbles back to the black bucket when I topped it up. That means I must have left 91 black marbles behind in the white bucket...the same as the number of white marbles that migrated over to the black bucket. So, the proportions are identical!

**Answer** 1.2: If you answered 20 i.e.. 4 5) minutes, then go back to the ques

tion and think again. You need to be hardwired to ignore such "pickpocket **answer**s" (as mentioned on p. 194). Although not stated, we should assume the bells ring at equal spaced intervals. If one bell rings five times per minute, then that is every 12 seconds. The other, at four times per minute, rings every 15 seconds. They will next ring together at the 60 second mark. The answer is one minute.

**Answer** 1.3: This is a very common question, and a very simple one. You need

to figure out the sum: 1+ 2+ 3 - - • -994 100. There are several ways to do this. *FIRST* S*OLUTIO*N A simple technique is to note that the first and last terms add to 101. The second and second-to-last terms also add to 101. The same is true of the third and third-to-last terms. Continuing in this fashion, you soon find yourself with 50 pairs of numbers adding to 101; 50 times 101 is 5,050. S*ECO*N*D SOLUTIO*N*I* A simple technique you can picture easily is the following:

1 2 3 n - 1 n *n* n-1 n - 2 - 2 1 n+1 1+1 *n* +1 ..*. 1*+1 *n* + 1

There are *n* terms each equal to *n* 1. The required sum is half the grand total: n(n+1*) THIRD SOLUTION* I read somewhere many years ago that the high school drop-out Albert Einstein devised the following alternative solution technique at age 15. Think of each summand, *1*. in the sum y i as a group of marbles in a r**ow from i = 1 to** *1* = 100 (see the array following). Stacking each row of marbles on top of each previous row, you get the array including both the diagonal and the lower

triangular off-diagonal. Were the array full, it would contain 100 x 100 = 1002

I thank Tom Arnold for this solution techniq**ue; any errors are mine.**

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marbles. So, your answer must be roughly half this (roughly 50 x 100). This is not exact because although the array contains two triangular-shaped off diagonals (upper and lower), there is only one diagonal. If you add another diagonal, and *then* split the total in two, you get the right answer. The diagonal contains 100 marbles, so the right answer must be 100+100 = 5,000 + 50, as **before.**

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More generally, the sum from 1 to n may be written down as n = 117+*1)*, Just picture the square array of side length n, add another diagonal, and split the total in half. To calculate y quickly in your head, note that one of *n or n* + 1 must be even and thus divisible by tw*o*. *Y*ou should divide the e**ven number by two** and multiply the odd number remaining by the result. In our case,

100 x 101 100

x 101 - 50 x 101 = 5,050.

Finally, note that two more solutions appear in the answers to Question 1.45, starting on p. 96.

**Answer** 1.4: The numbers on the dial add to 78 in total (recall that I =

2*2* - 6x 13). So, each piece must have a total of 26 on it. My initial attempt was to find slices (like pizza slices) that satisfy the constraint. Walking around the dial looking for consecutive numbers that add to 26, you soon find that 5-6-7-8 adds to 26, and 11-12-1-2 adds to 26, but nothing else works. So, none of the pieces is pizza-slice shaped. They are 5-6-7-8, 11-12-1-2, and a band across the middle with 10-9-3-4.

**Answer** 1.5; This question has been very popular. Sometimes it is golf balls,

**sometimes ma**rbles, sometimes coins. Most people find it very challenging.2

"My solution co**mbines independent contributions of Juan Ten**orio, Bingjian Ni, Yi Shen, and **Jinpeng Chang; any errors are mine. *O*ne of my readers who tried this at home said that the method given here, while successful in theory, would not work in practice. He said he would need to add use of a marker pen to the problem statement to keep track of which marble was which when swapping marbles between the dishes on the balance.**

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*APPENDIX A. PURELY QU*AN*TITATIVE & LOGIC* ANS*WERS*

The first step is to split the 12 marbles into three groups of four. Each group of four has two subgroups, a singleton and a triplet: {{1}A, {3}A}: {{1}B,{3}}, and {{1}c {3}c). Compare {{1}A, {3}A} with {{1}B, {3}x}. If they balance, then the odd ball is in group C. In this case, compare {3}c to {3}B. If {3}c is heavier (or lighter), then comparing any two marbles from within (3)c immediately locates the odd one; if (3}c balances {3}B, then compare (1}c to {1}B to see whether {1}c is heavier or lighter If the initial comparison is unbalanced, say {{1}A, (3}A} is heavier than {{1}B, {3}B}, then rotate groups {3}A. {3}*B*, and {3}c and compare group ing {{1}A, {3}B} with {{1}B: {3}c} (while holding out {{1}c, {3}A}). If they balance, then a heavy marble is in {3}A and comparing any two marbles from within {3}A immediately locates the odd one. Suppose they do not balance. If {{1}A, {3}B) is heavy, then either {1}A is heavy, or {1}o is light. Compare (1) A with {1}c to finish. If {{1}A{3}B} is light, then {3}B is light and **comparing any two mar**bles within {3}B immediately locates the light one. In each case, only three weighings are needed. This technique is generalized in Answer 1.18 (the "90-coin problem").

**Answer** 1.6: I have drawn a right-angle triangle on Figure A.1 usin*g R*, the

radius of the circle. Once we solve for *R*, the side length is S = *2R.*

***R* - 10**

Figure A.1: The Inscribed Circle Answer

Note: A circle is inscribed within a square. A rectangle of dimen sions 5 x 10 just fits in one corner. What is the side length S of the square? The radius satisfies *R*

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From Figure A.1 we deduce that *R2 = (R* - 10) *(R*-5)2 (via Pythagoras' Theorem). Collecting terms, we quickly fnd that *R*\* - 30*R* + 125 - 0. It follows (using the quadratic formula) that this polynomial has two roots *R* and R2 given by

*B*

*B 2* – 4*AC*

30 + V900 - 500 – 15 + 10 = 5.25.

*R1, R*2

Only one of those, *R-*25, has a sensible physical interpretation in our case. It follows that *S=2R* = 50.

**Answer** 1.7: You (the bug) cannot fiy; you have to walk. You must find the

shortest path from corner to corner. In any world, the shortest path between two points is called a "geodesic." On a spherical world (eg., the Earth's surface), a geodesic is an arc of a "great circle." *A g*reat circle is a circle on the surface of the sphere with diameter equal to the diameter of the sphere. For example, aeroplanes typically follow great circles above the Earth (because it is the shortest path and, the**refore,** the most fuel-efficient path). Like a spherical world, the cubic-room world has a two dimensional surface. However, the lack of curvature in the cubic-room world means that the shortest distance between two points must be a straight line rather than an arc of a **great c**ircle (in a world without curvature, geodesics are straight lines). If the cubic room is opened up and flattened out it can be seen that the shortest path is a straight line from one corner to the other. In the un-flattened room, this straight line corresponds to two line segments that meet exactly halfway up one wall-floor or wall-wall boundary. Direct computation using Pythagoras

Theorems reveals that the total path length is *V*5 units.

**Answer** 1.8: People tend to overlook the brilliantly simple situation described.

If you did any mathematics whatsoever, you probably missed the point. No calculation is needed to see that at each stage an equal number of male babies and female babies are expected to be born. The proportions of male and female children are, therefore, expected to remain equal at 50%. Still stuck? Here are the details (standing at t = 0 and looking at expected outcomes only): by the end of the first year, the 100.000 families have 50,000

Recall Py**thagoras Theorem. Consider a triangle with** side lengths X, Y, and 2. If the angle **between the sides of length X and Y is 90°, then it is a right-angle triangle. The side of length 2** (the "h**ypotenuse") must be the longest side, and it must be that** Xa fi Y2 = 7.

**\*Note that the case *R -* 5 corresponds to $ - 10, in which case the corner of the box touches the far side of the circle, not the near side. This is inconsistent with the diagram drawn by the interviewer.**

**Sin this case, the path is the hypotenuse of a triangle of side lengths 2 and 1 in the flattened-out room or two hypotenuses of triangles each of side lengths 1 and in the un-flattened room. In either case, the path is of total leng**th v5.

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*APPENDI*X A*. PURELY QUANTITATIVE & LOGIC ANSWERS*

boys and 50,000 girls. The proportion of male children stands at 50%. By the end of the second year, half of the 100,000 families (the ones without a son) have another child. This adds 25,000 boys and 25,000 girls. There are now 75,000 boys and 75,000 girls. The proportion of male children still stands at 50%. There are still 25,000 families without a son. They add another 12,500 boys and an equal number of girls, and so on.

Some people are tempted to suppose that because all large **families have many** daughters and a single son, there must be more girls than boys. However, there are not many large families.

**Answer** 1.9: The 10 x 10 macro-cube question has been very popular. The most

common mistake is for people to *count* the number of 1 x 1 micro-cubes on each face and add them up. Even if you do the mathematics correctly (and most people do not), you miss the whole point. If you focus on the 1 x 1 micro-cubes on the faces and how to count them directly (e.g., **How many faces? How many on each face? How ma**ny edges?), then you have been bumped by the pickpocket's accomplice (as mentioned on p. 194). Go back now and figure out a better way. As I stated before, the path of greatest resistance bears the highest rewards, so read no further unless you did it a better **way.**

You must look for structure in a problem that leads you to a simple and speedy solution. The most structure here is to be found in the macro-cube you start with and the (now slightly smaller) macro-cube that remains. The difference **between t**heir volumes is how many micro-cubes fell.

**2. That result is a special**

**'In fact, the average number of children per family is only S case of a more *g*eneral series result derived as follows:**

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*f(3*) = 12 + 1)2, for (01>1.

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The volume of a cube of side length n i*s n* cubed; that is, n. The answer is, therefore, 103\_83

How do you calculate this without a calculator? You should know that 10\* is a 1 with k zeroes attached, so 10% = 1,000. You should know that 8 = 23 and, therefore, that 83 = 23x3 = 29. You should definitely know that 210 is 1,024. Thus, 2® is half of 210 and, therefore, equal to 512. The **answer is** 1,000 - 512 = 488. A common mistake is for people to think the answer is 108 93 – 271, because only "one layer" fell off (you should of course know what 93 is also without having to work it out).

**Answer** 1.10: If not for the ability to stop and dump apples along the way, you

could not deliver any apples at all. So, the key is to make repeated trips where you dump apples in a pile at the side of the road and then you subsequently pick up and deliver apples from that apple dump. For example, suppose you made three trips where each time you left City A with 1,000 apples and dumped 500 uneaten apples at the 500-mile marker. You would then have accumulated 1,500 apples at the 500-mile marker and you could deliver 500 of those to City B (0.g., in one trip of 1,000 apples where 500 are delivered uneaten, and 500 are left to rot at 500-mile marker).

To find the optimal strategy, we must put some bounds on what is sensible. If you are driving away from City A, or away from an apple dump at the side of the road, then if there are 1,000 or more apples available, it would never **make** sense to leave with fewer than 1,000 apples on the truck. For example, suppose your very first move was to drive away from City A with only 900 apples. Well, no matter where you dump the uneaten balance, **you missed** out on giving an extra 100 apples a free ride to that spot, and that must be suboptimal. It follows that we should drive away from City A only three times, with 1,000 apples on board each time.

The next question is whether, for any one of these three departures from City A, we dump the uneaten apples at only one apple dump, or wheth**er we** dump them at more than one location. Suppose on one trip we dump 100 apples at the 100-mile marker, and then the uneaten balance at some later spot. That cannot be sensible, because again, no matter where you dump the uneaten balance, you missed out on giving an extra 100 apples a free ride to that spot. It follows that we need to choose a single dump location for each **run.**

Could it be that the dump locations differ by run? Well, as long as we can get the dump contents to cumulate to a multiple of 1,000 (see below), they should all be dumped in the same place. Suppose instead that on the third run we dump apples beyond the location of the dump from the first two runs. Then driving that odd-lot of apples to a further location unnecessarily burns apples because it subsequently forces the truck to leave the earlier apple dump with **fewer tha**n 1,000 apples. So, not only must we dump the apples in only one

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*APPENDIX A. PURELY QUANTITATIVE & LOGIC AN*S*WERS*

location on any given trip, but we must dump them at the same location on each trip. So, where do we dump the apples on the three departures from City A, before subsequently loading up from that combined dump and carrying them further on? Well, if we dump them at the k-mile marker, we will end up with a total of *T* = 3 X (1000 - k) apples at the dump site. The arguments already given tell us that it makes no sense to drive away from the dump site with fewer than 1,000 apples on board (unl**ess we have fewer th**an 1,000 apples available). So, we will carry the first 3,000 apples (spread over three trips) until we can dump them in a pile of 2,000 apples. In general, starting with N X 1,000 apples, we will carry them (spread over N trips) until we can dump (*N*-1) x 1,000 apples. If we dump the apples at the k-mile marker, it must be that N X (1,000*K)* = *(*N-1) 1,000. Solving for *k* yields k – 1 . So, to *g*o from 3,000 apples down to 2,000 apples we dump them at the mile marker. Assuming we cannot slice apples up to get a continuous solution, let us dump them at the 333-mile marker. We will have *T* = 2,001 apples dumped there. Ignore one apple. Using the same argument again, we will drive the 2,000 apples in two trips. dumping them in two batches after another W

= 500 miles. Then we will have 1,000 apples at the 833-mile marker. We can then drive them on the remaining 167 miles in one trip, delivering 833 apples." Extra notes. First, if we dumped the apples at the 334-mile marker instead of the 333-mile marker, the final answer would be unchanged. Second, we can think about the problem in terms of rate of apple consumption. When we leave City *A*, we are burning three apples per mile (one apple per mile per run). We would like to be running at this costly rate for the shortest distance possible. As soon as we get to the 333-mile marker, we can reduce this to two apples per mile (by dumping and then making two runs burning one apple per mile per run). As soon as we have driven those 2,000 apples another 500 miles, we can cut the burn rate down to one apple per mile. You could argue that dumping 2,400 apples at the 200-mile marker would also let you cut the burn rate from three to two apples per mile. You would, however, leave 400 apples behind to rot. So, it is better to burn 399 of those 400 apples (over three runs) while carrying the other 2,001 apples an extra 133 miles closer to City B. Finally, this problem is isomorphic to one where we have N X 1,000 apples and *N* trucks. After the N trucks drive the first w miles, one truck can be decommissioned and it's uneaten load redistributed to top up the remaining *N* - 1 trucks. After another con miles we decommission another truck and it's uneaten load is redistributed to top up the remaining *N -* 2 trucks, and

so on.

**If we could slice the apples up, the continuous solution would be to dump them first at the** 333-mile **marker, then again at t**he 833 mile marker, ultimately delivering 833 **apples.**

\*If N **is a very big number, and assuming a continuous solution, then using harmonic series**

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**Answer** 1.11; People have given me answers to this one ranging from 0° to 750

**(and many answers in between**). The big hand is on the three; the little hand is one-quarter of the way between the three and the four. The answer must be one-quarter of one-twelfth of 360°. That is, one-quarter of 30°. That is, 7.*5*0 *(*or radians if you like measuring angles in radians)." You should focus on what you know the angle is non-zero, the big hand is on the three, one hour is one-twelfth of the full circle, and 15 minutes is one

quarter of one hour) and make sure that y**our answer ac**cords with intuition. For example, if you get 75°, then something is wrong with yo**ur reasoni**ng (or you have never owned an analogue wristwatch).

**Answer** 1.12: I present three different solutions: first, an approximation that

draws upon the answer to the previous question; second, an exact algebraic solution; and, third, an exact and slightly more elegant algebraic solution. *FIR*S*T* S*OLUTION* An approx**imate answer i**s a great place to start.10 There are 360° around the clock face. The minute hand therefore travels at 6° per minute. At 3:15 the minute hand is 7.5° behind the hour hand (from the previous **answer). To** travel that distance takes 7.5*/*6 = 1.25 minutes. That is, one minute and 15 **seconds**, or *7*5 seconds. So, at 3:16:15 the minute hand will arrive where the hour hand wa*s 7*5 seconds ago. Of course, the hour hand will have moved ever so slightly during that 75 seconds. So, maybe you need to wait another, say, five seconds until the two hands are perfectly coincident. That would be at 3:16:20. The exact solutions following are less than two seco**nds away from** this appr**oximate answer.** SE*COND SOLUTIO*N The question asks the first time after 3PM when the hour and minute hands of a clock are coincident. More generally, we can ask the first time after nPM when the hour and minute hands are coincident, for n = 1,2,...,11 (we miss out the 12 because the hands are not coincident after 12 and before 1). Assume we start at nPM, for one of n =1,2,...,11. By the time the minute hand whips around to the n on the dial, the hour hand will have moved slowly on already. When the minute hand finally catches up with the hour hand, the hour hand will have moved by a total of *8(*n) degrees past the n on the dial, say. The minute hand whips around the dial 12 times faster than the hour hand. So, while the hour hand covers *O(*n) degrees, the minute hand covers 12.0(*n*) degrees.

and the Euler-Mascheroni result lim - #21 - In(n)] = y, where ay is the Euler-**Mascheroni constant, I was able to show that you end up delivering a proportion of your apples (roughly** 36.8%). With N= 3 (3,000 app**les), we deliver only 833 appl**es *(*27.8%), bu**t this number rises steadily with *N,* converging to**

**“There are *27* radians in a fu**ll circle. Thus, 360o *2* radians; 180o = \* **radian**s; 90o = **radians, and so on. It is just another way of measuring angles,**

**101 thank Eoin Healy for suggesting this approximation,**

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A*PPENDIX* A. *PURELY QUANTITATIVE & LOGIC A*N*SWERS*

**Wwwmmmmm*m*m**

**90**

**1**

We can also state that the minute hand must have covered 30n +*8(n)* deg**rees.** That is 30n degrees to get around to the n on the dial, and another *O(n*) degrees to finally catch the hour hand. So, we may write 30n + *O(n)* 12*.0*n), and thus, *7(n*) = 30n*/*11 degrees.11

So, the first time after 3PM that the hands are coincident is when the minute hand has traveled 15 minutes to get to the 3 on the dial and then another *0(*3) = 90/11 degrees past the 3 on the dial. One minute is six degrees. So, 90/11 degrees is o*ne*

minutes. So, the hands are coincident at 16 and it's of a minute after 3PM. *THIRD* S*OLUTIO*N At high noon, the hands are coincident. At midnight, the hands are coinci dent. The time between noon and midnight is cut into 11 equally-space**d time** intervals of one-eleventh of 12 hours (1:05:27*.*27). At the end of each of these intervals, the hands are coincident. For the question at hand, the answer is three times one-eleventh of 12 hours: 3:16:21.82. The full set of "coincident times" are as follows:

1:05:2*7.*2*7* 2:10: 54.55 3:16:21.82 4:21 : 49.09 5:27 : 16.36 6:32 : 43.64 7:38: 10.91 8:43: 38.18 9:49 : 05.45 10:54 : 32.73 12:00:00.00

**Answer 1**.13: Well now, this looks pretty complicated the first time you see it.

**However, th**ere is a simple way to figure it out. If you think about it, you see that the only brokers who touch the switch for light bulb number 64 are those whose numbers are divisors of 64.

That is, light bulb number 64 has its state of illumination changed by brokers whose numbers are factors of 64. That is, brokers 1, 2, 4, 8, 16, 32, and 64 flip the switch. Because light bulb 64 is originally *off,* it must be that after this odd number of switches it is o*n.* See Answer 1.14 for a closely related but more general solution technique.

**Answer** 1.14: If you now know the answer to Question 1.13, you should be able

to figure this one out swiftly. If you have not yet figured out Question 1.13, then read no further-solve that one first.

?? It also follows that 0*(*n*)* = 1*.0*(1) for n = 1, 2.., 11, where *0*(1) = 30/11 degrees.

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The only way for a light bulb to be illuminated after the 100th person has **passed t**hrough is if its switch was flipped an odd number o**f times. The** switch for light bulb number K gets flipped only by people whose numbers are factors of *K*. Thus, the only light bulbs illuminated at the conclusion are those with a number that has an odd number of factors. **However, fact**ors for numbers go in pairs. For example, 32 has factors (1,32), (2,16), and (4,8). This means that 32 has an even number of factors, and bulb 32 is not illuminated at the conclusion. In fact, at first glance, all numbers **have an even number of factors.** However, you do get an odd number of factors if two factors (one pair) are identical. For example, 64 has (8,8) as one pair. If one pair of factors are identical, then the original number must be a "perfect square." Therefore, the only numbers with an odd number of factors are the perfect squares. **There are exa**ctly 10 perfect squares between 1 and 100, and they are 1, 4, 9, 16, 25, 36, 49, 64, 81, and 100 (i.e., 1o, 22, 3, ... 104). These are the numbers of the 10 bulbs that are illuminated after the 100th person has passed through the room.

***A*nswer 1**.15: This is an old favorite. I have tried this out on people and have

received almost all imaginable responses. The answer is three, and it cannot be anything else. Two socks can be different, but a third must match one of **the first two giving a matching pair.**

**Answer** 1.16: You get the answer by working backwards. If I am your opponent,

and I am able to call out “39," then you cannot reach 50, but I can after you **say whatever you say. So**, my goal is to call out "39." However, if I am able to call out "28," then you cannot get to 39, but I can after yo**u say whatever** you say. So, my goal is to call out “28." To get to 28, I need only to be able to call out "17," and to do this, I need only to be able to call out "6." So, my strategy, as your opponent, is to get onto the series 6, 17, 28, 39, 50 at whichever point I can. If you get to go first, you should call out "6." As long as you know the winning numbers and stick to them, you cannot lose. If you start with anything other than 6, I cannot lose.

**Answer** 1.17: Safe-cracking in a finance interview? Yes indeed. The naive an

swer is that there are 40 possible numbers for the first combination, 40 for the second, and 40 for the third. It would then take at most 40% possible trials to get the safe open. That is 64,000 trials. There are two factors that reduce this number considerably. The first you should have figured out; the second **you are excused.** The first factor is that although three numbers are required to open the safe, you need only find the first two of them. If you dial the first two numbers correctly, then you need only turn the dial until the safe pops open. You do not need to know the last number. This gives 402 possible combinations. That

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