

Solution and Answer Guide

Striebig, Papadakis, Heine, Ogundipe, Environmental Engineering and Sustainable Design 2e,
9780357675854, Chapter 1: Sustainability, Engineering, and Design

Chapter 1 End of Section Exercise Solutions

- 1-1 Genetically modern humans appeared on Earth about 200,000 years ago and biologically and behaviorally modern humans appeared about 70,000 years ago. The number of people and their effects upon the planet were negligible, or as Douglas Adams says, “as near nothing as makes no odds,” for most of the history of the planet. When did the planet’s population reach 1 billion people? If the population has grown exponentially since that time, what was the time interval required to increase by 1 billion people—for up to 7 billion people, the approximate global population in 2012?

Solution

From Figure 1-3, the planet reached 1 billion people in approximately 1800. October 31, 2011 was declared by the United Nations, as the day the world population reached 7 billion.

$$A_t = A_o e^{k(t-t_o)}$$

Solve for k .

$$\frac{A_t}{A_o} = e^{k(t-t_o)}$$

$$\ln \frac{A_t}{A_o} = k(t - t_o)$$

$$k = \frac{\ln \frac{A_t}{A_o}}{(t - t_o)}$$

$$k = \frac{\ln \frac{7,000,000,000}{1,000,000,000}}{(2012 - 1850)}$$

$$k_{1850-2012} = \frac{1.95}{162} = 0.012 = 1.2\%$$

The time frame for each increment of 1 billion people can be estimated using the calculated exponential rate constant:

$$\ln \frac{A_t}{A_o} = k(t - t_o)$$

Solution and Answer Guide: Striebig, Papadakis, Heine, Ogundipe, Environmental Engineering and Sustainable Design 2e, 9780357675854, Chapter 1: Sustainability, Engineering, and Design

$$dt = \frac{\ln \frac{A_t}{A_o}}{k}$$

$$dt_{1-2} = \frac{\ln \frac{2,000,000,000}{1,000,000,000}}{(0.012)} = 58 \text{ years}$$

$$dt_{2-3} = \frac{\ln \frac{3,000,000,000}{2,000,000,000}}{(0.012)} = 34 \text{ years}$$

$$dt_{3-4} = \frac{\ln \frac{4,000,000,000}{3,000,000,000}}{(0.012)} = 24 \text{ years}$$

$$dt_{4-5} = \frac{\ln \frac{5,000,000,000}{4,000,000,000}}{(0.012)} = 19 \text{ years}$$

$$dt_{5-6} = \frac{\ln \frac{6,000,000,000}{5,000,000,000}}{(0.012)} = 15 \text{ years}$$

$$dt_{6-7} = \frac{\ln \frac{7,000,000,000}{6,000,000,000}}{(0.012)} = 13 \text{ years}$$

- 1-2 List the three dimensions and four categories used to calculate the Human Development Index (HDI) for a country.

Solution

Dimensions: The Life Expectancy index
The Educational Index
The Income Index

Categories: Very High Human Development
High Human Development
Medium Human Development
Low Human Development

- 1-3 Calculate the HDI for Australia given the following information: life expectancy at birth = 83.1, mean years of schooling = 12.9, expected years of schooling = 22.9, GNI per capita in purchasing power parity (PPP) terms (constant 2011 international \$) = 43,560.

Solution

Life Expectancy (LE) at birth using the 2018 Life Expectancy Index:

$$\text{Life Expectancy Index (LEI)} = \frac{(\text{LE}-20)}{(85-20)} \tag{1.1}$$

$$(\text{LEI}) = \frac{(83.1-20)}{(85-20)} = 0.971$$

The Education Index (EI) based upon the Mean Years of Schooling Index (MYSI) and Expected Years of Schooling Index (EYSI), where:

Solution and Answer Guide: Striebig, Papadakis, Heine, Ogundipe, Environmental Engineering and Sustainable Design 2e, 9780357675854, Chapter 1: Sustainability, Engineering, and Design

$$\text{MYSI} = \text{Mean Years of Schooling}/15 = 0.860 \quad (1.2)$$

$$\text{EYSI} = \text{Expected Years of Schooling}/18 = 1.272 \quad (1.3)$$

$$\text{EI} = (\text{MYSI} \times \text{EYSI})/2 = (0.860 + 1.272)/2 = 1.066 \quad (1.4)$$

And the Income Index (II) which is based upon the Gross National Income (GNI_{pc}) at purchasing power parity per capita, which is an estimate and standardization of each individuals' income in a country:

$$\text{II} = \{\ln(\text{GNI}_{pc}) - \ln(100)\}/\{\ln(75,000) - \ln(100)\} = 0.918 \quad (1.5)$$

The Human Development Index is determined from the geometric mean of the Life Expectancy, Education and the Income Index:

$$\text{HDI} = (\text{LEI} \times \text{EI} \times \text{II})^{1/3} = (0.971 \times 1.066 \times 0.918)^{1/3} = 0.983 \quad (1.6)$$

- 1-4 Calculate the HDI for Japan given the following information: life expectancy at birth = 83.9, mean years of schooling = 12.8, expected years of schooling = 15.2, GNI per capita in PPP terms (constant 2011 international \$) = 38,986.

Solution

See Problem 1-3 for the procedure to the solution to HDI calculations

$$\text{Life Expectancy Index (LEI)} = 0.983$$

$$\text{MYSI} = \text{Mean Years of Schooling}/15 = 0.853$$

$$\text{EYSI} = \text{Expected Years of Schooling}/18 = 0.844$$

$$\text{EI} = (\text{MYSI} \times \text{EYSI})/2 = 0.849$$

$$\text{Income Index: II} = \{\ln(\text{GNI}_{pc}) - \ln(100)\}/\{\ln(75,000) - \ln(100)\} = 0.901$$

$$\text{HDI} = (\text{LEI} \times \text{EI} \times \text{II})^{1/3} = 0.909$$

- 1-5 Calculate the HDI for Turkey given the following information: life expectancy at birth = 76.0, mean years of schooling = 8.0, expected years of schooling = 15.2, GNI per capita in PPP terms (constant 2011 international \$) = 24,804.

Solution

See Problem 1-3 for the procedure to the solution to HDI calculations

$$\text{Life Expectancy Index (LEI)} = 0.862$$

$$\text{MYSI} = \text{Mean Years of Schooling}/15 = 0.553$$

$$\text{EYSI} = \text{Expected Years of Schooling}/18 = 0.844$$

$$\text{EI} = (\text{MYSI} \times \text{EYSI})/2 = 0.689$$

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$$\text{Income Index: II} = \{\ln(\text{GNI}_{pc}) - \ln(100)\} / \{\ln(75,000) - \ln(100)\} = 0.833$$

$$\text{HDI} = (\text{LEI} \times \text{EI} \times \text{II})^{1/3} = 0.791$$

- 1-6 Calculate the HDI for Viet Nam given the following information: life expectancy at birth = 76.5, mean years of schooling = 8.2, expected years of schooling = 12.7, GNI per capita in PPP terms (constant 2005 international \$) = 5,859.

Solution

See Problem 1-3 for the procedure to the solution to HDI calculations

$$\text{Life Expectancy Index (LEI)} = 0.869$$

$$\text{MYSI} = \text{Mean Years of Schooling}/15 = 0.547$$

$$\text{EYSI} = \text{Expected Years of Schooling}/18 = 0.706$$

$$\text{EI} = (\text{MYSI} \times \text{EYSI})/2 = 0.626$$

$$\text{Income Index: II} = \{\ln(\text{GNI}_{pc}) - \ln(100)\} / \{\ln(75,000) - \ln(100)\} = 0.615$$

$$\text{HDI} = (\text{LEI} \times \text{EI} \times \text{II})^{1/3} = 0.694$$

- 1-7 Calculate the HDI for Argentina given the following information: life expectancy at birth = 76.7, mean years of schooling = 9.9, expected years of schooling = 17.4, GNI per capita in PPP terms (constant 2005 international \$) = 18,461.

Solution

See Problem 1-3 for the procedure to the solution to HDI calculations

$$\text{Life Expectancy Index (LEI)} = 0.872$$

$$\text{MYSI} = \text{Mean Years of Schooling}/15 = 0.660$$

$$\text{EYSI} = \text{Expected Years of Schooling}/18 = 0.967$$

$$\text{EI} = (\text{MYSI} \times \text{EYSI})/2 = 0.813$$

$$\text{Income Index: II} = \{\ln(\text{GNI}_{pc}) - \ln(100)\} / \{\ln(75,000) - \ln(100)\} = 0.788$$

$$\text{HDI} = (\text{LEI} \times \text{EI} \times \text{II})^{1/3} = 0.824$$

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- 1-8 Calculate the HDI for Vanuatu given the following information: life expectancy at birth = 72.3, mean years of schooling = 6.8, expected years of schooling = 10.9, GNI per capita in PPP terms (constant 2005 international \$) = 2,995.

Solution

See Problem 1-3 for the procedure to the solution to HDI calculations

$$\text{Life Expectancy Index (LEI)} = 0.805$$

$$\text{MYSI} = \text{Mean Years of Schooling}/15 = 0.453$$

$$\text{EYSI} = \text{Expected Years of Schooling}/18 = 0.606$$

$$\text{EI} = (\text{MYSI} \times \text{EYSI})/2 = 0.529$$

$$\text{Income Index: II} = \{\ln(\text{GNI}_{pc}) - \ln(100)\}/\{\ln(75,000) - \ln(100)\} = 0.514$$

$$\text{HDI} = (\text{LEI} \times \text{EI} \times \text{II})^{1/3} = 0.603$$

- 1-9 Calculate the HDI for Niger given the following information: life expectancy at birth = 60.4, mean years of schooling = 2.0, expected years of schooling = 5.4, GNI per capita in PPP terms (constant 2005 international \$) = 906.

Solution

See Problem 1-3 for the procedure to the solution to HDI calculations

$$\text{Life Expectancy Index (LEI)} = 0.622$$

$$\text{MYSI} = \text{Mean Years of Schooling}/15 = 0.133$$

$$\text{EYSI} = \text{Expected Years of Schooling}/18 = 0.300$$

$$\text{EI} = (\text{MYSI} \times \text{EYSI})/2 = 0.217$$

$$\text{Income Index: II} = \{\ln(\text{GNI}_{pc}) - \ln(100)\}/\{\ln(75,000) - \ln(100)\} = 0.333$$

$$\text{HDI} = (\text{LEI} \times \text{EI} \times \text{II})^{1/3} = 0.355$$

- 1-10 For each country listed in the accompanying table, calculate
- Life Expectancy Index
 - Educational Index
 - Income Index
 - Human Development Index

Solution and Answer Guide: Striebig, Papadakis, Heine, Ogundipe, Environmental Engineering and Sustainable Design 2e, 9780357675854, Chapter 1: Sustainability, Engineering, and Design

COUNTRY AND 2011 DATA	LIFE EXPECTANCY AT BIRTH (YEARS)	EXPECTED YEARS OF SCHOOLING	MEAN YEARS OF SCHOOLING	GNI PER CAPITA IN PPP TERMS (CONSTANT 2005 INTERNATIONAL \$)
Australia	81.9	18.0	12.0	34,431
China	73.5	11.6	7.5	7,476
Ireland	80.6	18.0	11.6	29,322
Kenya	57.1	11.0	7.0	1,492
South Africa	52.8	13.1	8.5	9,469

Source: Based on UN (2011a). *Human Development Report 2011, Sustainability and Equity: A Better Future for All*. United Nations Development Programme.

Solution

See Problem 1-3 for the procedure to the solution to HDI calculations

Country and 2011 Data	Life Expectancy Index	Educational Index	Income Index	Human Development Index
Australia	0.952	0.900	0.882	0.911
China	0.823	0.572	0.652	0.678
Ireland	0.932	0.887	0.858	0.896
Kenya	0.571	0.539	0.408	0.503
South Africa	0.505	0.647	0.687	0.611

- 1-11 For each country listed in the accompanying table, calculate
- Life Expectancy Index
 - Educational Index
 - Income Index
 - Human Development Index

Solution and Answer Guide: Striebig, Papadakis, Heine, Ogundipe, Environmental Engineering and Sustainable Design 2e, 9780357675854, Chapter 1: Sustainability, Engineering, and Design

COUNTRY AND 2011 DATA	LIFE EXPECTANCY AT BIRTH (YEARS)	EXPECTED YEARS OF SCHOOLING	MEAN YEARS OF SCHOOLING	GNI PER CAPITA IN PPP TERMS (CONSTANT 2005 INTERNATIONAL \$)
Canada	81.0	16.0	12.1	35,166
Japan	83.4	15.1	11.6	32,295
Mexico	77.0	13.9	8.5	13,245
Nigeria	51.9	8.9	5.0	2,069
United Kingdom	80.2	16.1	9.3	33,296

Source: Based on UN (2011a). *Human Development Report 2011, Sustainability and Equity: A Better Future for All*. United Nations Development Programme.

Solution

See Problem 1-3 for the procedure to the solution to HDI calculations

Country and 2011 Data	Life Expectancy Index	Educational Index	Income Index	Human Development Index
Canada	0.938	0.848	0.886	0.890
Japan	0.975	0.806	0.873	0.882
Mexico	0.877	0.669	0.738	0.757
Nigeria	0.491	0.414	0.458	0.453
United Kingdom	0.926	0.757	0.877	0.851

- 1-12 For each country listed in the table, calculate
- Life Expectancy Index
 - Educational Index
 - Income Index
 - Human Development Index

COUNTRY AND 2011 DATA	LIFE EXPECTANCY AT BIRTH (YEARS)	EXPECTED YEARS OF SCHOOLING	MEAN YEARS OF SCHOOLING	GNI PER CAPITA IN PPP TERMS (CONSTANT 2005 INTERNATIONAL \$)
Benin	56.1	9.2	3.3	1,364
Costa Rica	79.3	11.7	8.3	10,497
India	65.4	10.3	4.4	3,468
Malta	79.6	14.4	9.9	21,460
New Zealand	80.7	18.0	12.5	23,737
Rwanda	55.4	11.1	3.3	1,133

Source: Based on UN (2011a). *Human Development Report 2011, Sustainability and Equity: A Better Future for All*. United Nations Development Programme.

Solution

Example calculation for Benin:

Life Expectancy (LE) at birth using the 2011 Life Expectancy Index:

$$\text{Life Expectancy Index (LEI)} = (\text{LE} - 20) / (85 - 20) \quad (1.1)$$

$$(\text{LEI}) = (56.1 - 20) / (85 - 20) = 0.555$$

The Education Index (EI) based upon the Mean Years of Schooling Index (MYSI) and Expected Years of Schooling Index (EYSI), where:

$$\text{MYSI} = \text{Mean Years of Schooling} / 15 = 3.3 / 15 = 0.220 \quad (1.2)$$

$$\text{EYSI} = \text{Expected Years of Schooling} / 18 = 9.2 / 18 = 0.511 \quad (1.3)$$

$$\text{EI} = (\text{MYSI} \times \text{EYSI}) / 2 = (0.220 + 0.511) / 2 = 0.366 \quad (1.4)$$

And the Income Index (II) which is based upon the Gross National Income (GNI_{pc}) at purchasing power parity per capita, which is an estimate and standardization of each individuals' income in a country:

$$\text{II} = \{\ln(\text{GNI}_{pc}) - \ln(100)\} / \{\ln(75,000) - \ln(100)\} \quad (1.5)$$

$$\text{II} = \{\ln(1,364) - \ln(100)\} / \{\ln(75,000) - \ln(100)\} = 0.395$$

The Human Development Index is determined from the geometric mean of the Life Expectancy, Education and the Income Index:

$$\text{HDI} = (\text{LEI} \times \text{EI} \times \text{II})^{1/3} = (0.555 \times 0.366 \times 0.395)^{1/3} = 0.431 \quad (1.6)$$

Country and 2011 Data	Life Expectancy Index	Educational Index	Income Index	Human Development Index
Benin	0.555	0.366	0.395	0.431
Costa Rica	0.912	0.602	0.703	0.728
India	0.698	0.433	0.536	0.545
Malta	0.917	0.730	0.811	0.816
New Zealand	0.934	0.917	0.826	0.891
Rwanda	0.545	0.418	0.367	0.437

- 1-13 What are the HDI categories defined by the United Nations? For each of the four categories, describe what you think people may drink, eat, and wear, the type of homes they may live in, the types of school they are likely to attend, and the type of transportation they are most likely to use.

Solution

Categories Very High Human Development
 High Human Development
 Medium Human Development
 Low Human Development

- 1-14 Describe, using your own words, the purpose of human development.

Solution

Answers will vary.

- 1-15 Define the following terms:

- Urban
- Suburban
- Peri-urban
- Rural

Solution

Answers will vary.

- 1-16 What is the “Brundtland definition” of sustainable development?

Solution

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

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1-17 How would you describe sustainability to a 12-year-old student at your local school?

Solution

Answers will vary.

1-18 Create a graph with an x-axis as a linear sustainability scale. Sort the 30 companies that make up the Dow-Jones Industrial Average from "least sustainable" to "most sustainable" and place them along this axis. Describe the characteristic units of measure on the scale of the sustainability axis you created.

Solution

Answers will vary.

1-19 Look up and describe one of the formative written works related to sustainable development. Research this work more and summarize its main premise in a short 500-word essay.

Solution

Answers will vary.

1-20 Create a sustainability indicator (similar to the HDI or the ecological footprint). What actions, processes, or goods would you measure for your indicator? How would you collect and find the data for your indicator? What are the advantages and disadvantages of your proposed indicator? Note: Useful web sites include the United Nations Development Program (UNDP), UNICEF web page, the World Bank web page, and the U.S. Environmental Protection Agency web page.

Solution

Answers will vary.

1-21 What characteristics define unsustainable development? Make a table of characteristics that might negatively affect development. Mark which of these characteristics are important in the following:

- a. Very High Human Development countries
- b. Low Human Development countries
- c. Both Very High and Low Human Development countries

Solution

Answers will vary.

1-22 Create a schematic or cartoon that communicates how the following concepts are related or the trends toward change in:

- a. Human population
- b. Resource consumption
- c. Educational resources
- d. Economic resources

Solution

Answers will vary.

- 1-23 List and describe in your own words the United Nations Sustainable Development Goals. Specifically, describe the economic, environmental, social, and technical challenges associated with meeting each of the goals within the next five years.

Solution

The 17 sustainable development goals (SDGs) to transform our world (actual answers are expected to be much shorter):

1) **GOAL 1: No Poverty**

Targets

- By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than \$1.25 a day.
- By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions.
- Implement nationally appropriate *social protection systems and measures for all*, including *floors*, and by 2030 achieve *substantial coverage* of the poor and *the vulnerable*.
- By 2030, ensure that all men and women, in particular the poor and *the vulnerable*, *have equal rights to economic resources*, as well as access to basic services, ownership and control over land and other forms of 13 property, inheritance, natural resources, appropriate new technology and financial services, including micro-finance.
- By 2030, build the resilience of the poor and *those in vulnerable situations* and reduce their exposure and vulnerability to climate-related extreme events and other economic, social, and environmental shocks and disasters.
- Ensure significant mobilization of resources from a variety of sources, including through enhanced development cooperation, in order to provide adequate and predictable means for developing countries, in particular least developed countries, to implement programs and policies to end poverty in all its dimensions.
- Create sound policy frameworks at the national, regional, and international levels, based on pro-poor and gender-sensitive development strategies, to support accelerated investment in poverty eradication actions

2) **GOAL 2: Zero Hunger**

Targets

- By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious, and sufficient food all year round.
- By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of

age, and address the nutritional needs of adolescent girls, pregnant and lactating women, and older persons

- By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists, and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment
- By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding, and other disasters and that progressively improve land and soil quality
- By 2020, maintain the genetic diversity of seeds, cultivated plants, and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional, and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed
- Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries
- Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round
- Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility

3) **GOAL 3: Good Health and Well-being**

Targets

- By 2030, reduce the global maternal mortality ratio to less than 70 per 100,000 live births
- By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births
- By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases, and other communicable diseases
- By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being
- Strengthen the prevention and treatment of substance abuse, including narcotic drug abuse and harmful use of alcohol