CE 11: Quiz #2 Calculation Based Solutions

Question 4: Estimate the electric power output in kilowatts (kW) for a wind turbine with a swept area A = 7 500 m2 and an upstream wind speed of 7 m/s. Assume that the average wind speed downstream of the turbine is reduced to 5 m/s, and that air density is 1.2 kg/m3. Round your answer to the nearest kW, and enter only a numerical value without units. Neglect power losses within the nacelle.

From *L12: Wind Power,* the equation for the actual power output of a wind turbine is

$$P_{output} = \frac{\rho A}{4}(v_1^{\ 2} - v_2^{\ 2})(v_1 + v_2)$$

Where ρ = air density
A = swept area
v_1 = upwind velocity
v_2 = downwind velocity

$$P_{output} = \frac{(1.2\ kg/m^3)(7{,}500\ m^2)}{4}[(7m/s)^2 - (5m/s)^2][(7m/s) + (5m/s)] = 648{,}000\ W$$ = **648 kW**

Question 6: Suppose 10 grams of radioactive radon gas are present at time zero inside a well-sealed room. How much radon will remain two days (48 hours) later? Round your answer to the nearest 0.1 gram. The half-life of radon is 3.8 days.

From *L15: Nuclear Power Part 2*, the equation radioactive decay and half-life is

$$N(t) = N_0 e^{-kt}$$

where $N(t)$ = amount of radioactive material present at time t
N_0 = original amount of radioactive material
k = decay constant
t = amount of time passed

and the equation for the decay constant k is

$k = \frac{0.693}{\tau_{1/2}}$ where $\tau_{1/2}$ = half-life of the radioactive material

$k = \frac{0.693}{(3.8\ days)}$ = 0.18 $days^{-1}$

$N(2\ days) = (10g)e^{-(2\ days)(0.18\ days^{-1})}$ **= 6.9 g**

Question 7: What would be the total amount of electricity generated over one year at a power plant with 3 x 1.3 GW nuclear reactors that operate with a capacity factor of 90%. Enter your answer as an integer value in units of TWh.

$1\ year(\frac{365\ days}{1\ year})(\frac{24\ hours}{1\ day}) = 8760\ hrs$

$Capacity\ factor = \frac{actual\ generated\ energy}{maximum\ energy\ generation}$

$Maximum\ energy\ generation = 1.3\ GW * 8760\ hrs * 3\ reactors = 34,164\ GWh$

$Actual\ generated\ energy = maximum\ energy\ generation * Capacity\ factor$
$= (34,164\ GWh)(0.9)$
$= 30,747\ GWh\ (\frac{1\ TWh}{1000\ GWh})$
= 31 TWh

Question 12: Suppose the crankshaft of a gasoline engine is turning at 2500 revolutions per minute (rpm). At this engine speed, how long does each stroke of the four-stroke engine operating cycle last? Enter your answer in milliseconds, rounded to the nearest integer value.

Remember, in a four-stroke engine, there are two revolutions in one cycle, and 4 strokes in each cycle.

$2,500\ \frac{rev}{min}(\frac{1\ cycle}{2\ rev})(\frac{4\ strokes}{1\ cycle}) = 5,000\ \frac{strokes}{min} = 0.0002\ \frac{min}{stroke}(\frac{60\ min}{1\ min})(\frac{1000\ ms}{1\ s})$ **= 12 milliseconds**

Question 13: To achieve a 90% reduction in CO2 emissions from gasoline-powered cars, average fuel consumption would need to decrease from 10 to 1 liters of gasoline burned per 100 km traveled. What is the value of fuel economy (FE) that corresponds to FC = 1 L / 100 km? Give your answer in units of miles per gallon (mpg), rounded to the nearest integer value. Unit conversions: 1 gallon = 3.8 L and 1 mile = 1.6 km.

Remember, FC and FE are reciprocals of each other.

$FE = \frac{1}{FC} = \frac{100\ km}{1L}(\frac{1\ mile}{1.6\ km})(\frac{3.8\ L}{1\ gallon}) =$ **238 mpg**

Question 16: Suppose an electric vehicle is equipped with a 500-kg lithium ion battery that has an energy density of 150 Wh/kg. Assume the EV starts fully charged and is equipped with a 90% efficient direct current (DC) motor that must deliver 15 kW of mechanical power output to maintain a steady driving speed of 100 km/h on the highway. Calculate the driving range of the vehicle for these conditions. Enter your answer for driving range as an integer value, rounded to the nearest kilometer.

Find how much energy this lithium battery provides

$$500\ kg\ (\frac{150\ Wh}{1\ kg})(\frac{1\ kWh}{1000\ Wh})\ = 75\ kWh$$

The equation for efficiency of the motor is

$$\eta = \frac{P_{mechanical}}{P_{electrical}}$$

$$P_{electrical} = \frac{P_{mechanical}}{\eta} = \frac{15\ kW}{0.9} = 16.67\ kW$$

How many hours can the lithium battery provide the required electrical power to move the car at a speed of 100 km/h?

$$Time\ = \frac{75\ kWh}{16.67\ kW} = 4.5\ h$$

How far will a vehicle with a speed of 100 km/h drive in 4.5h?

$100\ \frac{km}{h}\,(4.5h)$ = **450 km**