LAST NAME SOLUTION Alphabetic # _____

FIRST NAME _____

Quiz 8

1. Suppose a wind turbine has a cut-in wind speed of 5 m/s and a furling wind speed of 25 m/s. If the winds the turbine sees have Rayleigh statistics with an average wind speed of 9 m/s,

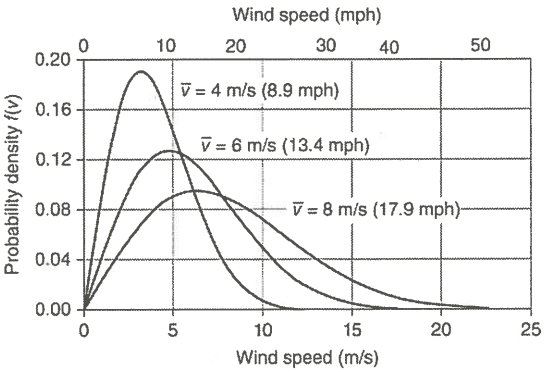


Fig 7.27 Rayleigh pdf w/ varying wind speeds

a. (2.5 pts) For how many hours per year will the turbine be shut down because of excessively high-speed winds?

CUM. RAYLEIGH DIST.: $P(v<V) = 1-\exp\left[\frac{-\pi}{4}\left(\frac{V}{\bar{v}}\right)^2\right]$

1.5 PTS

$P(v>V) = 1-P(v<V) = \exp\left[\frac{-\pi}{4}\left(\frac{V}{\bar{v}}\right)^2\right]$

CORRECT SETUP

$P(v>25) = e^{-\frac{\pi}{4}\left(\frac{25}{9}\right)^2} = .0023$

EXPECTED HOURS = $8760 \cdot (.0023) = 20.44$ HRS/YR

$\bar{v}$ = 9 m/s, V > 25 m/s

.5 PTS FOR SETUP.

.5 PTS FOR MATH/CALC

$$\frac{d\,(\text{energy})}{dt} = 8760 \cdot 0.087 \cdot \bar{V} - \frac{2P_R}{D^2}$$

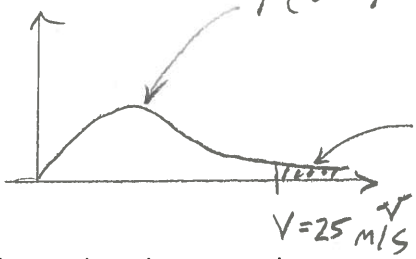
$$CF = \frac{\text{Energy delivered}}{\text{Energy@full pwr}} = 0.087 \cdot \bar{V} - \frac{P_R}{D^2}$$

$$f(v) = \frac{\pi v}{2\bar{v}^2} e^{-\frac{\pi}{4}\left(\frac{v}{\bar{v}}\right)^2}$$

$$CF = 0.0435 \cdot \bar{V}$$

b. (2.5 pts) Draw a picture showing the portion of the probability distribution function comprising your answer in part a.

$P(v<V) = 1-e^{-\frac{\pi}{4}\left(\frac{V}{\bar{v}}\right)^2}$



$P(v>V) = 1-\left(1-e^{-\frac{\pi}{4}\left(\frac{V}{\bar{v}}\right)^2}\right) = e^{-\frac{\pi}{4}\left(\frac{V}{\bar{v}}\right)^2} = .0023$

c. (2.5 pts) For how many hours per year will the turbine be shut down because winds are too low?

1.5 PTS CORRECT SETUP

$P(v<5) = 1-e^{\frac{\pi}{4}\left(\frac{5}{9}\right)^2} = 1-.7847 = .2152$

EXPECTED HOURS (v<5) = $.2152 \cdot 8760 = 1885$ HOURS ANS.

.5 PTS FOR SETUP

.5 PTS FOR MATH/CALC

d. (2.5 pts) If this is a 1-MW turbine, how much energy (kWh/yr) would be produced for winds blowing at or above the rated wind speed of 12 m/s?

$\bar{v}$ = (9 m/s) $P(12 \le v \le 25)$

1.5 PTS SETUP

$P(v>12) = 1-\left(1-\exp\left[\frac{-\pi}{4}\left(\frac{V}{\bar{v}}\right)^2\right]\right) = e^{\frac{-\pi}{4}\left(\frac{12}{9}\right)^2} = .2475$

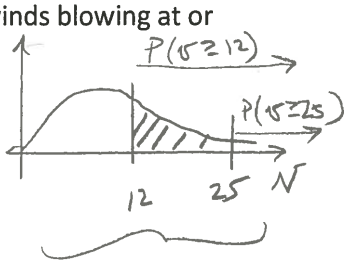
$P(v \ge 25)$ – FROM PART a – $= .0023$

.5 PTS SETUP

$P(12 \le v \le 25) = .2475 - .0023 = .2424$

$E = .2424 \cdot 8760 \cdot 1\text{MW} = 2{,}123$ MWh/yr

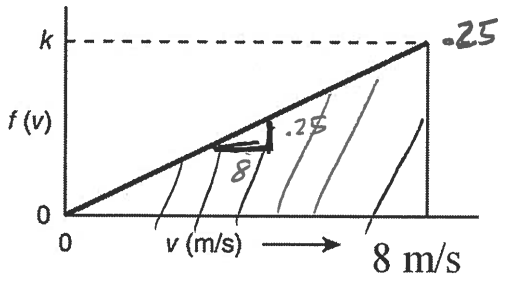
.5 PTS FOR MATH/CALC



VISUALIZATION OF PROBABILITY REGION OF INTEREST.

NAME SOLUTION

2. Consider the following probability density function for wind speed:



a. (2.5 pts) What is the appropriate value for k for this to be a valid probability density function?

SHADED AREA UNDER TRIANGLE MUST = 1

$\therefore \quad 1 = \frac{1}{2}(8)k \Rightarrow k = \frac{1}{4} = .25$

b. (2.5 pts) What is the average power in these winds(W/m²) under standard temperature and pressure conditions (i.e. $\rho = 1.225\ kg/m^3$)?

1.5 PTS FOR THIS EXPRESSION

$$(v^3)_{AVG} = \int_0^8 v^3 f(v)\,dv = \int_0^8 v^3 \cdot (.03125)\, v\, dv = \int_0^8 .03125\, v^4\, dv$$

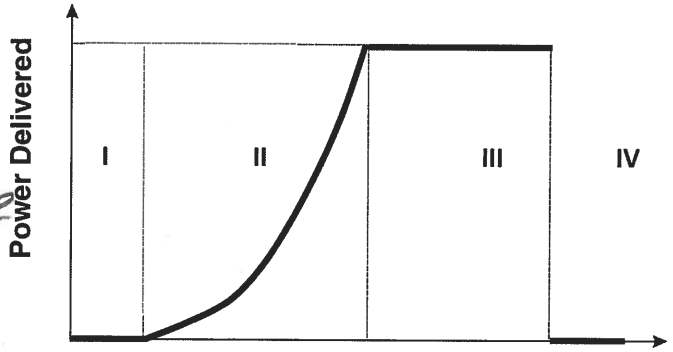
$$= .03125 \left.\frac{v^5}{5}\right|_0^8 = \frac{.03125}{5}\left[8^5 - 0\right] = 204.8$$

.5 PTS

$$P_{AVG} = \frac{1}{2}\rho A (v^3)_{AVG} = \frac{1}{2}(1.225)A(204.8) \Rightarrow \frac{P_{AVG}}{A} = 250.8\ \frac{W}{M^2}$$ ANS.

MATH/CALC - .5 PTS

c. (5 pts) Identify the four regions (I-IV) on the idealized wind turbine curve and ~~brief explanation of~~ its significance.



Idealized Wind Turbine Power Curve

I - WIND SPEED IS BELOW CUT-IN SPEED. INSUFFICIENT ENERGY EXTRACTED TO PRODUCE POWER

II BELOW RATED POWER, NON-LINEAR INCREASE IN POWER EXTRACTED AS v INCREASES

III WIND SPEED HAS REACHED TURBINES RATED POWER. TURBINE SHEDS WIND ABOVE RATED POWER

IV WIND SPEED EXCEEDS MAX ALLOWABLE SAFE SPEED; BLADES "FURL", SO NO POWER IS EXTRACTED.

BONUS (2 pts) Define leadership INFLUENCING PEOPLE TO ACT TO COMMON PURPOSE.

(2 pts) Define management THE ALLOCATION OF RESOURCES