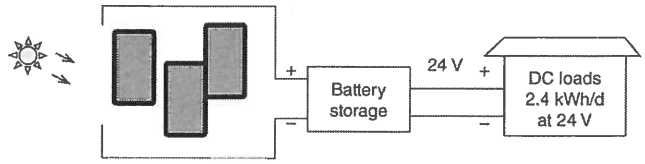
LAST NAME SOLUTION Alphabetic # _____

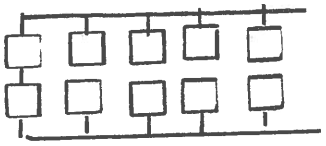
FIRST NAME _____

Quiz 10

1. Design a 24-V, all-dc, standalone system to meet a 2.4 kWh/d demand for a small, isolated cabin. Size the PV array to meet the load in a month having average insolation of 5.0 kWh/m²/day average.



The available PV panels are rated at 1-sun MPP at V_R = 18 V and I_R = 5 A. Assume a 0.80 derate factor for dirt, wiring, module mismatch (i.e. 20% loss).



The available batteries are rated 200 Ah, 12 V with 100% Coulomb efficiency.

a. (4 pts) How many PV modules are needed and how must they be wired? Justify your answer with appropriate calculations. Sketch the wired array.

A·h REQUIREMENT: $I = \frac{P}{V} = 2400 \frac{Wh}{d} \cdot \frac{1}{24V} = 100 A \cdot h/d$

1 SUN = 1 kW/m²

PANELS DELIVER 5 kWh/m² DAILY

$h = \frac{5 kWh/m^2}{1 kWh/m^2} = 5 hrs/day$

VOLTAGE

24 V BATTERY ⇒ 2 18V PANELS IN SERIES > 24V

⇒ 5A

CURRENT

100Ah = 5A · .8 · # SERIES PANELS · 5

SERIES PANELS = $\frac{100}{20} = 5$

⇒ 10 PANELS (SKETCH ABOVE)

b. (4 pts) How many 200 Ah, 12 V deep cycle batteries are required to store energy for 3 days without sun and assuming maximum discharge depth is 75%. Sketch the batteries and their wiring.

EACH BATTERY PROVIDES CURRENT = 200Ah · 75% = 150Ah (75% MAX DISCHARGE)

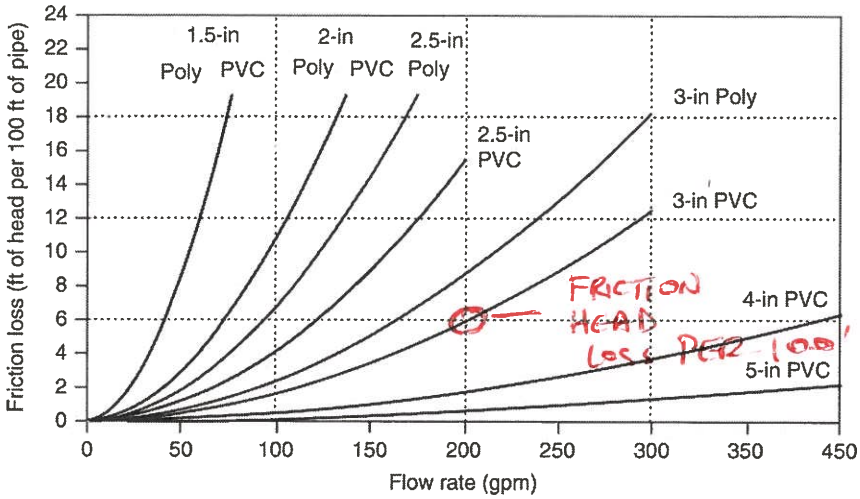
- WIRE 2 BATTERIES IN SERIES FOR 24 V
- NEED TO SUPPLY 100 A·h · 3 days = 300 Ah

⇒ NEED 2 || SETS OF SERIES BATTERY PAIRS (2 · 150Ah = 300 A·h)

c. (2 pts) Explain how the PV array's terminal voltage supports lead acid battery charging requirements.

THE PV ARRAYS PROVIDE 24 < V < 36 BATTERY CHARGING REQUIRES VOLTAGE HIGHER THAN NOMINAL TERMINAL VOLTAGE ~ 15V ACROSS 1 BATTERY, SO 36V IS SUFFICIENT TO CHARGE 2 BATTERIES IN SERIES

NAME _____



Energy Head = $z + \frac{p}{\gamma} + \frac{v^2}{2g}$

z = elevation above a reference height (m) or (ft)

p = pressure (N/m2) or (lb/ft2)

γ = specific weight (N/m3) or (lb/ft3)

v = average velocity (m/s) or (ft/s)

g = gravitational acceleration (9.81 m/s2) or (32.2 ft/s2)

$$P = \frac{Energy}{time} = \frac{weight}{volume} \cdot \frac{volume}{time} \cdot \frac{energy}{weight} = \gamma \cdot Q \cdot H$$

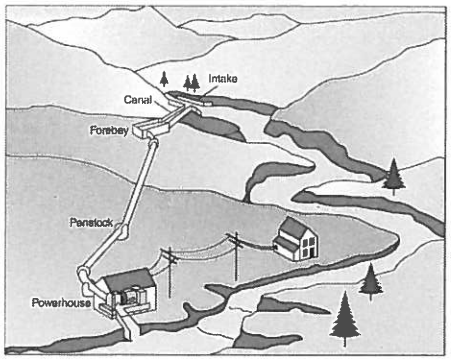
$$P_{ideal}\,(kW) = \frac{Q[gpm] \cdot H_G[ft]}{5300} = 9.81 \cdot Q\left[\frac{m^3}{s}\right] H_G[m]$$

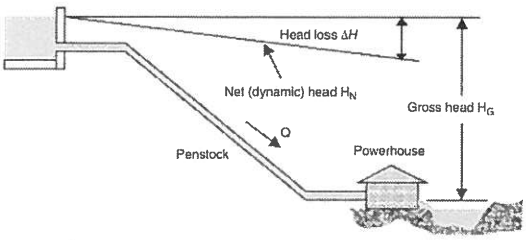
$$P_{mech\,@\,gen}\,(kW) = \frac{Q[gpm] \cdot H_N[ft]}{5300} = 9.81 \cdot Q\left[\frac{m^3}{s}\right] H_N[m]$$

$$P_{elect\,del}\,(kW) = \frac{\eta\, Q[gpm] \cdot H_N[ft]}{5300} = 9.81 \cdot \eta \cdot Q\left[\frac{m^3}{s}\right] H_N[m]$$

NAME SOLUTION

2. Suppose 200 gal/min of water is taken from a creek and delivered through 800 ft of 3-in diameter PVC pipe to a turbine 100 ft lower than the source. The turbine/generator has an efficiency η = 40%.





a. (3 pts) Determine the **gross head** and **friction head**? What is the system's **net head**?

H_G : GROSS HEAD = 100' ANS.

FRICTION HEAD (FROM CHART FACING PAGE)

LOSS @ 200 gpm = 6'/100'

$= \frac{6}{100} \cdot 800 = 48'$ ANS.

H_N $= 100 - 48 = 52'$ ANS (NET HEAD)

b. (2 pts) What is the **mechanical power delivered** to the generator ?

$$P = \frac{Q[gpm]\, H_N[ft]}{5300} = \frac{200 \cdot 52}{5300} = 1.96\,kW \text{ ANS.}$$

c. (2 pts) What is the **power** delivered to the **electrical system**?

$$1.96 \cdot \eta = 1.96 \cdot 4 = 7.84\,W \text{ ANS.}$$

d. (3 pts) Energy head is expressed in length and is composed of three terms: potential, pressure, and velocity. **(1 pt)** Identify each in the energy head expression. **(2 pts)** Reconcile the seeming "units" inconsistency between "energy head" (*length*) and power expressions (*kW*)

POTENTIAL z PRESSURE $\frac{p}{\gamma}$ VELOCITY $\frac{v^2}{2g}$

ENERGY HEAD $= z + \frac{p}{\gamma} + \frac{v^2}{2g}$

ENERGY HEAD IS IN LENGTH — IMPLICIT UNDERSTANDING IS THAT "ENERGY" IS length · mass · GRAVITATIONAL FORCE

i.e. $M \cdot kg \cdot \frac{M}{s^2}$

MASS (WATER) & g ARE CONSTANT AND THEREFORE "UNDERSTOOD" BY CONVENTION

Bonus (2 pts) Define management: