Common Systems Applications Sample Questions Agricultural and Biological Engineering Professional Engineering Examination

I.A. Pump Principles (e.g., type, materials, sizing, selection)

A pump draws from an ambient reservoir to provide 200 liters per minute of water at room temperature and 10 meters of head. The pump efficiency is 55%, and the motor efficiency is 80%. If the pump runs constantly each day all year long, and electricity costs $0.15 per kWh, the annual operating cost of the pump is most nearly:

A. $428

B. $535

C. $779

D. $973

Correct Answer (D)

Ref. NCEES Reference Handbook (version 9.0, 2013). p. 105 for pump formulae, p. 93 for ρ (water density), p. 1 for g (acceleration of gravity), p. 2 for conversion from cubic feet to gallons.

Solution:

$$Purchased\ Power = \dot{W}_p = \frac{Pump\ (brake)power}{\eta_{motor}}$$

$$Pump\ (brake)\ power = \dot{W} = \frac{Fluid\ Power}{\eta_{pump}}$$

$$Fluid\ Power = \dot{W}_{fluid} = \rho g h Q$$

$$\rho = density = \frac{997kg}{m3} * \frac{1000L}{m3} = \frac{0.997kg}{L}$$

$$g = acceleration\ due\ to\ gravity$$

$$= 9.807\ m/s^2$$

$$h = head = 10\ m$$

$$Q = flow = 200\ L/min$$

$$\dot{W}_p = \frac{0.997\frac{kg}{L} * 9.807\frac{m}{s2} * 10m * 200\frac{L}{min}}{60\frac{sec}{min} * 0.55 * 0.80} = \frac{325.9\ Watts}{0.55 * 0.80} = \frac{592.6\ Watts}{0.80} = 740.7\ Watts$$

$$\Delta t = 24\frac{hours}{day} * 365\frac{days}{year} = 8{,}760\frac{hours}{year}$$

$$E = \dot{W}_p * \Delta t = 740.7\ Watts * 8{,}760\ hours = 6{,}488{,}532\ Watt * hours = 6{,}488.5\frac{kWh}{year}$$

$$Cost = E * rate = 6{,}488.5\ kWh * 0.15\frac{\$}{kWh} = \$973\ per\ year$$

I.B. Energy balances

A processor wishes to mix 1 ton per hour of dry ground corn with 2 ton per hour of well water in a well-mixed, adiabatic tank to produce a mash. The corn is entering at 50°F and the well water is entering at 40°F. The desired mash exit temperature is 90°F. Assuming the specific heat of corn is 0.2 $BTU/lb_m \cdot °F$, the rate of energy addition (BTU/hr) required to heat the mash is most nearly:

A) 198,000

B) 216,000

C) 280,000

D) 852,000

Correct Answer (B)

Reference: NCEES FE Reference Handbook v9.0, 2013 (p. 85)

Solution:

For an adiabatic, well-mixed tank, no heat is lost to surroundings so all added heat is used to raise the enthalpy of each separate component of the mash:

$$\dot{Q}_{added} = \dot{m}_{corn} c_{P_{corn}} (T_{mash} - T_{corn}) + \dot{m}_{water} c_{P_{water}} (T_{mash} - T_{water})$$

$\dot{m}_{corn}$ = 1 ton/hr = 2000 lb_m/hr

c_{Pcorn} (given) = 0.2 $BTU/lb_m \cdot °F$

T_{mash} = 90°F

T_{corn} = 50°F

m_dot_water $\dot{m}_{water}$ = 2 ton/hr = 4000 lb_m/hr

c_{Pwater} = 1.0 $BTU/lb_m \cdot °F$ [from p.93 of NCEES Reference or memory]

$\dot{Q}_{added}$= 2000 lb_m/hr * 0.2 $BTU/lb_m \cdot °F$ * (90°F – 50°F) + 4000 lb_m/hr * 1.0 $BTU/lb_m \cdot °F$ * (90°F – 40°F)

= 16,000 + 200,000 BTU/hr

= 216,000 BTU/hr

I.C. Piping systems (e.g., gravity, pressure, components, layout)

Thrust blocks are required in all of the following locations during the installation of PVC irrigation piping with rubber gasket joints ***except***?

(A) at pipe enlargements

(B) at pipe size reductions

(C) at "in-line" valves

(D) at the end of a capped pipeline

Correct answer (A)

Reference: ASAE Standard S376.2

Thrust blocks are required at the following locations.

8.4.1.1 Where the pipe changes the direction of the water (i.e., ties, elbows, crosses, wyes and tees).
8.4.1.2 Where the pipe size changes (i.e., reducers, reducing tees and crosses).
8.4.1.3 At the end of the pipeline (i.e., caps and plugs).
8.4.1.4 Where there is an in-line valve.

I.D. Energy sources (e.g.,fossil fuels, solar, wind, biomass, hydro)

A 500,000-Btu/hr biomass boiler is being incorporated into the heating system for a machine shed. Available biomass fuels for firing the boiler are listed in the table below.

Bulk and Energy Density for Residual Biomass Materials		
Biomass	Bulk Density (lb/ft^3)	Energy Density (Btu/lb)
Wheat straw	3.2	7,480
Switchgrass	6.6	7,990
Sugarcane bagasse	7.0	8,150
Corn stover	4.1	7,700

Based on the properties provided for the biomass fuels, the volume of storage (ft^3) to hold a 3-week supply of the product requiring the largest storage capacity would be most nearly:

(A) 4,400
(B) 4,800
(C) 8,000
(D) 10,500

Correct answer (D)

Reference: *FE Reference Handbook v9.0, 2013 (p. 1 &21-22)*

Wheat straw has the lightest bulk density and the smallest energy density so it will require the greatest volume to hold a 3-week supply. This volume will be the minimum volume to hold all four biomasses. Volume = (500,000 Btu/hr × 24 hr/day × 7 days/week × 3 weeks)/(3.2 lb/ft^3 × 7,480 Btu/lb) = 10,528 ft^3

I.E. Engineering economics analysis (e.g., life-cycle costs, budgeting, replacement decisions, benefit-cost, time value of money, fixed and operating costs)

As owner and operating manager of a large fleet of farm equipment, you are contracting currently with an outside mechanics shop to have all full engine overhauls for tractors, combines, and harvesters completed at the rate of $7,200 per engine. To lower costs, you are considering overhauling the engines yourself and have determined the investment needed to construct a new building and equip it for the overhauls would be $180,000. Assuming the operating cost to perform engine overhauls at your facility is $5,500 per engine and interest rate is 7% per year, the minimum number of engines you need to overhaul per year to make the investment in equipment and facilities pay back within 10 years is:

(A) 4
(B) 5

(C) 16
(D) 22

Correct answer (C)

References: *FE Reference version 9 page 127*

Cost comparisons must be made on an equal time basis. Convert both costs to an annual basis. Determining the annual cost of the investment for the building and equipment:

$$A_1 = P\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] = \$180{,}000\left[\frac{0.07(1.07)^{10}}{(1.07)^{10} - 1}\right]$$

$$A_1 = \$180{,}000(0.142378) = \$25{,}628$$

The annual costs for overhauling X engines per year with your own equipment and facilities is

$$\$25{,}628 + \$5{,}500\ X$$

By comparison, the annual costs for having X engines per year overhauled by the outside mechanic shop is \$7,200X. Solving for the number of engines at which these two costs are equal:

$$\$25{,}628 + \$5{,}500X = \$7{,}200X$$

$$X = \frac{\$25{,}628}{(\$7{,}200 - \$5{,}500)} = 15.07 \rightarrow 16 \text{ engines}$$

Rounding up, the minimum number of engines to make the investment economically feasible is 16.

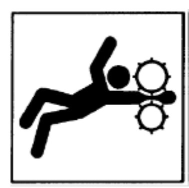
I.H. Health and Safety (e.g., operating procedures, manuals, human exposure, operator interface, protective clothing)

Which of the following pictorials provides the best representation to warn of arm entanglement in feed rolls?


A


B


C


D

(A) A
(B) B
(C) C
(D) D

Correct answer (D)

Reference: *ANSI/ASABE Standard* AD11684:1995 Tractors, machinery for agricultural and forestry, powered lawn and garden equipment —Safety signs and hazard pictorials — General principles Section 7, Mechanical-cutting hazards

I.I. Statistics application (e.g., experimental design, manufacturing and process control)

You have been tasked with determining the coefficient of variation (C_v) for water discharge for a prototype microirrigation system emitter. Provided the information in the table below, the C_v for the prototype emitter is most nearly:

(A) 0.049

(B) 0.054

(C) 0.237

(D) 0.280

Water Discharge (gph) from Six Prototype Microirrigation System Emitters		
Emitter No.	x_i, Discharge Rate (gph)	$(x_i\text{-}x_{ave})^2$, Square of Deviation from Mean (gal^2/hr^2)
1	4.1	0.09
2	4.3	0.01
3	4.5	0.01
4	4.8	0.16
5	4.4	0
6	4.3	0.01
Mean	4.4	0.05

Correct answer (B)

Reference: *ASABE Standards*, *NCEES FE Reference Handbook v. 9 p.33*

Coefficient of variation, according to ASAE EP405.1, is defined as standard deviation of the discharge of the emitters (s) divided by the mean discharge of the emitters ($\bar{x}$) in the sample as noted below.

$$C_v = \frac{s}{\bar{x}} = \frac{\left[\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}\right]^{1/2}}{\bar{x}} = \frac{\left[\frac{0.28}{5}\right]^{1/2}}{4.4} = 0.054$$

I.K. Process analysis (e.g., efficiency, capacity, performance, durability, cost per ton)

Your company manufactures a line of small, general-purpose implements. The forecasted demand for the first three months of next year is shown below.

Month	Unit Demand
January	50
February	55
March	60

You would like to estimate the time requirements for your assembly department. The only data available for this task are the units assembled and time expended in a recent five-month period as shown below.

Month	Units Assembled	Time Expended (hours)
June	40	1500
July	30	1500
August	50	2000
September	40	1750
October	60	2350

Assuming a linear model is appropriate for forecasting time needed for assembly given demand for units, the total forecasted time (hours) needed for the next three months is most nearly:

(A) 6,825

(B) 6,525

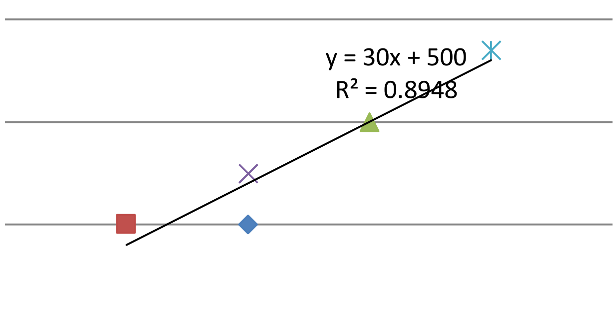
(C) 5,460

(D) 2,165

Correct answer (B)

Reference: FE Reference Handbook v9.0, 2013 (p. 18 & 35-36)

A solution can be arrived at through several ways but two typical ways may include roughing out a plot as depicted below and eyeballing the number of hours at 55 units (i.e., the three-month average) or plugging the *units assembled* and *time expended* data into the linear regression program in one of the NCEES allowable calculators.



Using the rough plot, a value slightly less than 2,200 hours/month is found or for three months, the time expended would be near 6,600 hours. From regression, an equation of $y = 30x + 500$ would calculate 2,150 hours/month or 6,450 hours for three months. Average of these extreme values (6,600 and 6,450 hours) is 6,525 hours.

I.M. Materials selection (e.g. corrosion resistance, weight, elasticity, cost, strength, machinability, constructability)

A multi-member linkage is to be used in positioning products on a processing line. The linkage component will experience significant temperature differences as part of a process requiring very consistent translational tolerance (i.e. positioning products to the same location on the processing line predictably without feedback). Assuming all other influences are negligible, which of the following materials will provide the linkage component with the greatest dimensional stability over process temperature range?

A) magnesium

B) bronze

C) aluminum

D) steel

Correct Answer (D)

Reference: FE Reference Handbook, NCEES, version 9. P. 76 (formula), p. 80 (table of coefficients).

Solution: The problem as framed comes down to a comparison of the coefficients of thermal expansion among the materials listed.

$\delta_t = \alpha L(T - T_o)$, where

δ_t = deformation caused by a change in temperature

α = temperature coefficient of expansion

L = length of member

T = final temperature

T_o = initial temperature

α_magnesium = $14.0*10^{-6}$°F

α_bronze = $10*10^{-6}$ °F

α_aluminum = $13*10^{-6}$°F

α_steel = $6.5*10^{-6}$°F

Steel has the lowest coefficient of thermal expansion and will therefore deform the least over the temperature range.

I.P. Codes, regulations, and standards in specific areas of practice (e.g., air quality, water quality, fire protection, EPA, ANSI, ASABE, NIOSH, GMPs, HACCP, IBC, NRCS, NEC)

Based on information contained in Annex C of ASABE/ISO 15077:2008 Standard (see below), the color that shall be used for a fog lights hand control on a piece of agricultural equipment is:

(A) pewter

(B) yellow

(C) red

(D) orange

Colour		Controls
C.2.1	Red	Single-function engine stop controls. Where key switches, ignition switches or hand throttles are used to stop the engines, the "off" or "stop" positions shall be indicated with red lettering and/or symbols.
C.2.2	Orange	Machine ground motion controls only. EXAMPLE Engine speed controls, transmission controls, parking brakes, park-locks, independent emergency brakes. Exceptions: — where the engine speed and engine stop controls are combined, the controls may be red; — steering wheels or steering controls may be black or any colour other than red or yellow.
C.2.3	Yellow	Function controls which involve the engagement of mechanisms only. EXAMPLE PTO, separators, cutterheads, feed rolls, picking units, elevators, unloading augers.
C.2.4	Black or any other colour except red, orange or yellow	All controls not covered by C.2.2, C.2.2 or C.2.3. EXAMPLE 1 Component lift or position such as implement hitch, header height, blade shift and reel lift. EXAMPLE 2 Control for unloading components such as spout cap, unloading auger swing and bin dump. EXAMPLE 3 Setting and adjustment mechanisms such as chokes, cylinder speed, concave space, seat adjustment, steering column, transmission disconnect, concave lock, lift stops, rockshaft stops, reel speed, and flow dividers. EXAMPLE 4 Machine lights such as headlights, work lights or floodlights, taillights, flashers, and turn signals. EXAMPLE 5 Cabin comfort such as pressurizer, cooling, heating and windshield wipers.

Correct answer (A)

Since the fog light indicator does not control engine stop (red), does not control ground motion nor is a steering control (orange), nor is a component lift control (yellow), the fog light control could be black or any other color. Thus the fog light is covered by C.2.4 of the standard.

I.P. Codes, regulations, and standards in specific areas of practice (e.g., air quality, water quality, fire protection, EPA, ANSI, ASABE, NIOSH, GMPs, HACCP, IBC, NRCS, NEC)

The soil cone penetrometer is recommended as a measuring device to provide a standard uniform method of characterizing the penetration resistance of soils. The rate of travel (mm/s) at which the cone should be pushed into the soil is most nearly:

(A) 30

(B) 40

(C) 50

(D) 72

Correct answer (A)

Reference: ASABE Standard EP542 section 5.1

I.Q. Electrical circuits and controls (e.g. determining load, conductor selection, controls, overload protection, grounding, power factor.

The overcurrent protection rating (amps) required for conductors in a circuit containing only a 50 hp three-phase, 460V electric irrigation pump motor is most nearly:

(A) 55

(B) 65

(C) 75

(D) 85

Correct answer (D)

Reference: *Fundamentals of Electricity for Agriculture* by Gustafson and Morgan

From reference tables, full load for a 50 hp, 460 V, three-phase induction type AC motor is 65 A. NEC requires 125% of full load for conductors, 65 × 1.25 = 82 A.

$$Q = \frac{C_v A_2}{\sqrt{1-(A_2/A_1)^2}}\sqrt{2g\left(\frac{P_1-P_2}{\gamma}\right)}$$

$$C_v = 0.98\ (dimensionless)$$

$$P_1 - P_2 = \Delta P = 20\ inch\ H2O = \frac{(20\ in)\left(62.4\frac{lb}{ft^3}\right)}{\left(12\frac{in}{ft}\right)^3} = 0.722\frac{lb}{in^2}$$

$$A_2 = \frac{\pi {D_2}^2}{4} = \frac{3.14(5\ in)^2}{4} = 19.6\ in^2 = 0.136\ ft^2$$

$$A_1 = \frac{\pi {D_1}^2}{4} = \frac{3.14(10\ in)^2}{4} = 78.5\ in^2 = 0.545\ ft^2$$

$$\gamma = \rho g = 49.2\ \frac{lb}{ft^3}$$

$$Q = \frac{(0.98)(0.136ft^2)}{\sqrt{1-\left(\frac{0.136ft^2}{0.545ft^2}\right)^2}}\sqrt{(2)\left(32.2\frac{ft}{s^2}\right)\left(\frac{0.722\frac{lb}{in^2}144\frac{in^2}{ft^2}}{49.2\frac{lb}{ft^3}}\right)}$$

$$Q = (0.138ft^2)\left(11.67\frac{ft}{s}\right) = 1.61\frac{ft^3}{s} = 96.6\frac{ft^3}{min} = \mathbf{723}\ \boldsymbol{\frac{gal}{min}}$$