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Detailed Solutions

BPSC Main Exam 2019
ASSISTANT ENGINEER

CIVIL ENGINEERING
Subjective Paper

Test 4

Q.1 Solution:

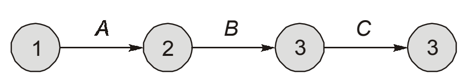
(i) Difference between Activity and Event

Activity: Activity is the actual performance of the job. It required both, time and resources for the completion.

Example: 1. Excavation of trench **2.** Mixing of concrete

In A-O-A system, Activities are represented by 'Arrows' and total number of activities in a Network are equal to total number of arrows.

An activity may be start, finish or dual role activity.

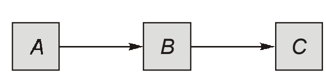


Here, *A* is start activity

B is dual role activity

C is finish activity

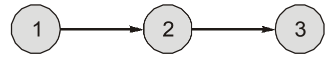
In *A*-0-*N* system, activities are represented by 'Nodes'.



Event: An Event is either start or completion stage of an activity. So event is an instantaneous stage which occur either at completion of an activity or beginning of an activity. It neither require time nor resources.

Example:1. Excavation completed 2. Mixing of concrete completed 3. Pipe Line Laid

In *A*-0-*A* Networks, Events are represented by nodes which may be circular, square or rectangular. Commonly circular shape is used to represent event.



An Event may also be start, finish or dual role.

Event 1 = Start event or tail event

Event 2 = Dual role event

Event 3 = Finish event

(ii) Optimum Time Estimate and Most Likely Time Estimates: This is the minimum possible time in which an activity can be completed under ideal conditions. This time estimate is represented by t_0.

Most Likely time Estimate: This is the normal time required under ordinary conditions where conditions are normal, things are usual and there is nothing exciting. This time estimate lies between the optimistic and pessimistic times estimates. This time estimate is represented by t_m.

(iii) Meaning of PERT and Critical Path: PERT stands for programme Evaluation and Review Technique. PERT analysis is event oriented and based on probabilistic approach which is suitable for non-repeated type of projects such as launching of space aircraft. It account for uncertainties in time estimate, so three time estimates are made for each activity; t_0, t_m and t_p.

On the basic of three time estimates, expected completion time of activity is computed as

$$t_e = \frac{t_0 + t_p + 4t_m}{6}$$

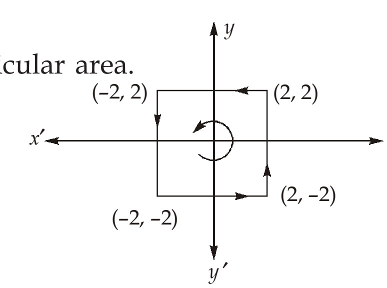
Meaning of critical path: Critical path is time wise longest path in a network. All activities along critical path are critical, delay in any activity will cause delay in completion of project.

An event is critical if its slack is zero. Usually critical path is shown by dotted or dark lines.

Q.2 Solution:

Circulation is defined as the line integral of velocity vector taken along a closed loop.

$$\Gamma = \oint \vec{v} \cdot d\vec{r}$$



This parameter represents the total strength of rotation in a particular area.

Circulation is also given by, $\Gamma = \mho \times A$

Where $\mho$ = vorticity and A = Area

Given : $u = x^2 + y;\ v = -2xy$

closed square $\Rightarrow$ (2, 2), (2, –2), (–2, 2), (–2, –2)

Sign convention: Anticlockwise is positive,

Circulation, $\Gamma = \oint \vec{v} \cdot d\vec{r}$

or, $$\Gamma = \int_{-2}^{2} u_{y=-2} \cdot dx + \int_{-2}^{2} v_{x=2} \cdot dy + \int_{2}^{-2} u_{y=2} \cdot dx + \int_{2}^{-2} v_{x=-2} \cdot dy$$

or, $$\Gamma = \int_{-2}^{2} (x^2 + y)_{y=-2} dx + \int_{-2}^{2} (-2xy)_{x=2} dy + \int_{2}^{-2} (x^2 + y)_{y=2} \cdot dx + \int_{2}^{-2} (-2xy)_{x=-2} \cdot dy$$

or, $$\Gamma = \int_{-2}^{2} (x^2 - 2) \cdot dx + \int_{-2}^{2} -4y \cdot dy + \int_{2}^{-2} (x^2 + 2) dx + \int_{2}^{-2} 4y \cdot dy$$

or, $$\Gamma = \left[\left(\frac{x^3}{3} - 2x \right) \Bigg|_{-2}^{2} + (-2y^2) \Big|_{-2}^{2} + \left(\frac{x^3}{3} + 2x \right) \Bigg|_{2}^{-2} + (2y^2) \Big|_{2}^{-2} \right]$$

∴ $$\Gamma = \left(\frac{8}{3} - 4 + \frac{8}{3} - 4 \right) + (-8 + 8) + \left(-\frac{8}{3} - 4 - \frac{8}{3} - 4 \right) + (8 - 8) = -16$$

Q.2 (b) Solution:

Given : $d = 2.5$ cm; $F = 784.53$ N; $\gamma = 10$ kN/m^3

Let us take, $g = 10$ m/sec^2

Area of jet, $$a = \frac{\pi}{4} \times d^2 = \frac{\pi}{4} \times (0.025)^2 = 4.909 \times 10^{-4} \text{ m}^2$$

Let jet strike with velocity v,

Now, $$F_x = \rho \cdot a \cdot v^2$$

$$784.53 = 1000 \times 4.909 \times 10^{-4} \times v^2$$

∴ $$v = 39.977 \text{ m/s}$$

∴ Discharge, $$Q = a \cdot v = 4.909 \times 10^{-4} \times 39.977$$

$$= 0.0196 \text{ m}^3/\text{sec} = 19.6 \; l\text{ps}$$

Q.3. Solution:

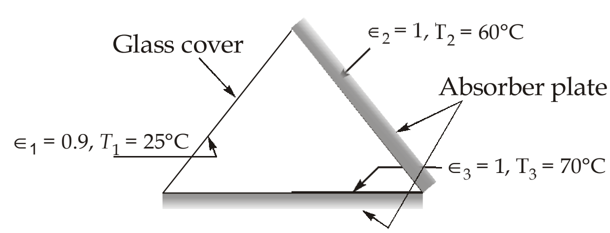
Assumption:

(i) Isothermal surfaces with uniform radiosity.

(ii) Absorber plates behave as black bodies.

(iii) Duct end effects are negligible.

(iv) Cover plate is diffuse and gray.

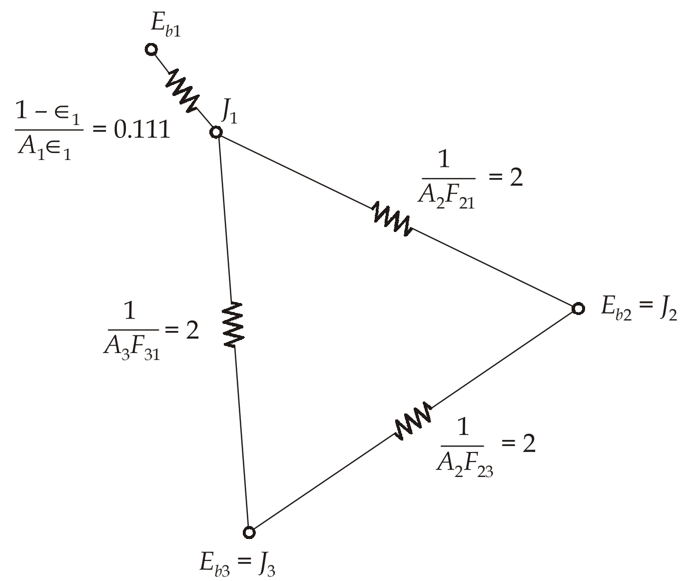


For the cover plate,

Glass cover $\in_1 = 0.9$ (gray body)

$\in_2 = \in_3 = 1.0$ (black body)

Radiation network for two black surfaces connected by third gray surface



$$A_1 = A_2 = A_3 = 1 \text{ m} \times l \text{ m} \quad \text{(where } l \text{ is the length of duct)}$$

$$T_1 = 25°\text{C} = 298\text{K}$$

$$T_2 = 60°\text{C} = 333 \text{ K}$$

$$T_3 = 70°\text{C} = 343\text{K}$$

$$F_{12} = F_{21} = 0.5$$

$$F_{13} = F_{31} = 0.5$$

The radiosity J_1 can be calculated by setting the sum of heat currents entering node J_1 to zero.

$$\frac{E_{b1}-J_1}{\left(\frac{1-\in_1}{A_1\in_1}\right)} + \frac{J_2-J_1}{\frac{1}{A_2F_{21}}} + \frac{J_3-J_1}{\frac{1}{A_3F_{31}}} = 0$$

$$\frac{\sigma T_1^4 - J_1}{\frac{1-0.9}{1\times l\times 0.9}} + \frac{\sigma T_2^4 - J_1}{\frac{1}{1\times l\times 0.5}} + \frac{\sigma T_3^4 - J_1}{\frac{1}{1\times l\times 0.5}} = 0$$

$$\frac{5.67\times10^{-8}\times298^4 - J_1}{0.111} + \frac{5.67\times10^{-8}\times333^4 - J_1}{2} + \frac{5.67\times10^{-8}\times343^4 - J_1}{2} = 0$$

$$J_1 = 476.526 \text{ W/m}^2$$

Net heat transfer rate to surface (1)

$$\frac{(q_1)_{\text{total}}}{l} = \frac{J_1 - E_{b1}}{\frac{1-\in_1}{\in_1 A_1}} = \frac{476.526 - 5.67\times10^{-8}\times298^4}{0.111}$$

$$\frac{(q_1)_{\text{total}}}{l} = 264.7 \text{ W/m}$$

Q.4 Solution:

Corrosion in Pipes (Metals): When water flows through a metal pipe (such as a cast iron or a steel pipe), it attacks and disintegrates the surface of the pipe. The material of the pipe thus gets dissolved and rusted, thereby reducing the life and carrying capacity of the pipe. This phenomenon which leads to the disintegrating of the pipe is known as corrosion. The corrosion of pipes reduces their life and carrying capacities, and may also impart colour and odour to the flowing water. There are various factor responsible for corrosion:

- Oxygen content of the water
- pH valve
- Temperature and Soil bacteria
- Moisture content
- Composition of pipe material

In general, the corrosion of metal pipes may occur if iron enter solutions as positive ions (i.e Fe^{++} ions) and combines with the negative ions of water (i.e. OH^- ions), thus forming ferrous hydroxide [$Fe(OH)_2$]

$$Fe^{++} + 2\,OH^- \rightarrow Fe\,(OH)_2$$

When water is alkaline and free from carbon dioxide

$$2Fe(OH)_2 + \frac{1}{2}O_2 + H_2O \rightarrow 2Fe\,(OH)_3 \text{ (Ferric hydroxide sticks to anode i.e. pipe surface)}$$

When water is acidic and contains free CO_2

$$Fe(OH)_2 + 2CO_2 \rightarrow Fe\,(HCO_3)_2 \quad \text{Ferrous bicarbonate}$$

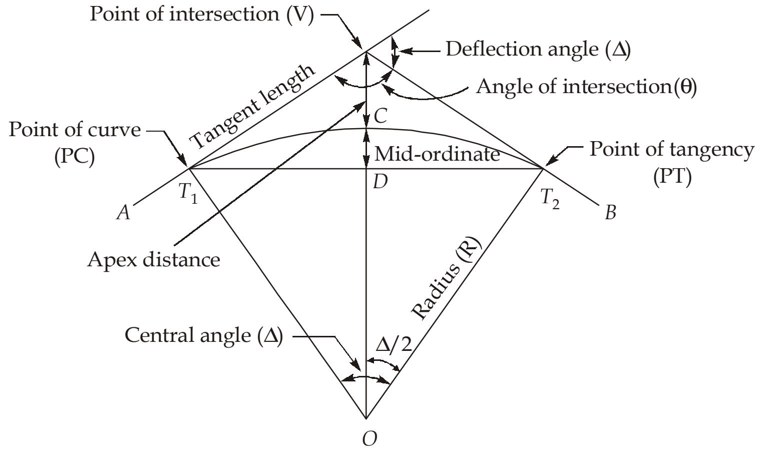
$$2Fe(HCO_3)_2 + O_2 + H_2 \rightarrow 2Fe\,(OH)_3 + 4\,CO_2\uparrow \quad \text{(Ferrous hydroxide sticks to anode)}$$

This ferric hydroxide [$Fe(OH)_3$] is in the form of insoluble red precipitate and gets deposited on the pipe surface. This leads to the formation of tubercules of ferriec hydroxide on the inside surface of the pipe, this process is known as "tuberculation". Tuberculation leads to increase in pipe roughness and hence reduce the carrying capacity.

Corrosion of metal pipes can be avoided by various ways as described below:

1. **Protective Coating :** Pipe surfaces are coated with coatings of paint, galvanizing bituminous compounds, cement lining. etc. Red lead paint and zinc pigment are used for painting the exteriors of the pipes.
2. **Selecting proper pipe material:** The pipe metal may be chosen to be more resistant to corrosion. Certain alloys of iron or steel with chromium, copper or nickel found to be better than the pure iron and steel. If steel or iron are to be used then they should be as pure as possible.
3. **Quality of water:** The water passing through the pipe should be made as less corrosive as possible.This can be accomplished by raising the pH of water by adding alkalinity in the form of lime or powdered chalk. By reducing the dissolved O_2 and CO_2. By adding chemical compound which reduces tuberculation such as sodium hexa-metaphosphate.
4. **Cathodic protection:** Electrolytic corrosion can be prevented by connecting the pipe with negative terminal of a D.C. generator and positive terminal with blocks of zinc or magnesium buried in the ground near the pipe.

Q.5 (a) Solution:



1. **Angle of deflection:** It is the external angle between the two intersecting straights. Δ is deflection angle shown in figure.
2. **Point of commencement :** The point T_1 where the circular curve begins is known as point of commencement of curve.
3. **Long chord :** The chord joining the point of curve and the point of tangency is known as long chord. T_1T_2 is long chord.
4. **Tangent distance:** The distance between the point of tangent and point of intersection is the tangent distance.
   IT_1 and IT_2 are known as tangent lengths and are equal in the lengths.

Q.5 (b) Solution:

Let l be true distance/chain length and l' be faulty length of chain. Then,

Case I: 20 m chain,

$$\text{True distance} = \left(\frac{l'}{l}\right) \times \text{Measured distance}$$

$$\Rightarrow \quad \text{True distance} = \frac{19.95}{20} \times 2500 = 2493.75 \text{ m} \quad \text{...(i)}$$

Case II: 30 m chain,

$$\text{True distance} = \frac{\text{Faulty length of 30 m chain}}{\text{True length of 30 m chain}} \times \text{Measured distance}$$

$$\Rightarrow \quad 2493.75 = \frac{l'}{30} \times 2460$$

$$\Rightarrow \quad l' = 30.4116 \text{ m}$$

$$\therefore \quad \text{Error in 30 m chain length} = 30.4116 - 30$$

$$= +0.4116 \text{ m}$$

It means 30 m chain was 41.16 cm too long at time of the measurement.

Q.6 Solution:

According to parallelogram law of forces

$$R = \sqrt{F_1^2 + F^2 + 2F_1F_2\cos\theta}$$

or $$R^2 = F_1^2 + F_2^2 + 2F_1 F_2 \cos\theta$$

In first case,

Thus, $$(2k+1)\sqrt{F_1^2 + F_2^2} = \sqrt{F_1^2 + F^2 + 2F_1F_2\cos\theta}$$

or $$(2k+1)^2 (F_1^2 + F_2^2) = F_1^2 + F_2^2 + 2F_1F_2\cos\theta$$

or $$(4k^2 + 4k + 1)(F_1^2 + F_2^2) = F_1^2 + F_2^2 + 2F_1F_2\cos\theta$$

or $$(4k^2 + 4k + 1 - 1)(F_1^2 + F_1^2) = 2F_1F_2\cos\theta$$

or $$(4k^2 + 4k)(F_1^2 + F_2^2) = 2F_1F_2\cos\theta \qquad \text{... (i)}$$

In second case θ is replaced by 90° – θ,

$$R_2 = (2k-1)\sqrt{F_1^2 + F_2^2}$$

Thus $$(2k-1)^2 (F_1^2 + F_2^2) = F_1^2 + F_2^2 + 2F_1 F_2 \cos(90° - \theta)$$

or $$(4k^2 - 4k + 1)(F_1^2 + F_2^2) = F_1^2 + F_2^2 + 2F_1F_2\cos(90° - \theta)$$

or $$(4k^2 - 4k + 1 - 1)(F_1^2 + F_2^2) = 2F_1 F_2 \sin\theta$$

or $$(4k^2 - 4k)(F_1^2 + F_2^2) = 2F_1F_2\sin\theta \qquad \text{... (ii)}$$

Dividing equation (ii) by (i) we get,

$$\frac{4k^2 - 4k}{4k^2 + 4k} = \frac{\sin\theta}{\cos\theta}$$

or $$\tan\theta = \frac{4k(k-1)}{4k(k+1)} = \frac{k-1}{k+1}$$ Hence Proved.

Q.7 Solution:

At inlet condition: $p_1 = 500$ kPa

$T_1 = 520°C = (520 + 273)\,K = 793$ K

At exit condition: $p_2 = 100$ kPa

$T_2 = 300°C = (300 + 273)\,K = 573$ K

Heat lost: $q = 10$ kJ/kg

Surroundings condition: $p_0 = 98$ kPa

$T_0 = 20°C = (20 + 273)\,K = 293$ K

$c_p = 1.005$ kJ/kgK

$R = 0.287$ kJ/kgK

The actual work is calculated by application of steady flow energy equation.

According to steady flow energy equation per unit mass

$$h_1 + \frac{V_1^2}{2} + gz_1 + q = h_2 + \frac{V_2^2}{2} + gz_2 + w$$

Neglecting the change in kinetic and potential energies.

$$h_1 + q = h_2 + w$$

or

$$w = (h_1 - h_2) + q$$
$$= c_p(T_1 - T_2) + q$$
$$= 1.005(793 - 573) - 10 = 211.1 \text{ kJ/kg}$$

Maximum work output per unit mass,

$$w_{max} = (h_1 - h_2) + T_0 \Delta s_{sys}$$
$$= c_p(T_1 - T_2) - T_0\left(c_p \log_e \frac{T_1}{T_2} - R\log_e \frac{p_1}{p_2}\right)$$
$$= 1.005(793 - 573) - 293\left(1.005 \log_e \frac{793}{573} - 0.287\log_e \frac{500}{100}\right)$$
$$= 221.1 - 293(0.3265 - 0.4619)$$
$$= 221.1 - 293(-0.1354) = 221.1 + 39.67$$
$$= 260.77 \text{ kJ/kg}$$

(i) Irreversibility: $I = w_{max} - w = 260.77 - 211.1 = \mathbf{49.67\ kJ/kg}$

OR

$$I = T_0 \Delta s_{uni} = T_0[\Delta s_{sys} + \Delta s_{surr}]$$
$$= T_0\left[c_p \log_e \frac{T_2}{T_1} - R\log_e \frac{p_2}{p_1} + \frac{q}{T_0}\right]$$
$$= 293\left[1.005 \log_e \frac{573}{793} - 0.287 \log_e \frac{100}{500} + \frac{10}{293}\right]$$
$$= 293[-0.3265 + 0.4619 + 0.034] = \mathbf{49.66\ kJ/kg}$$

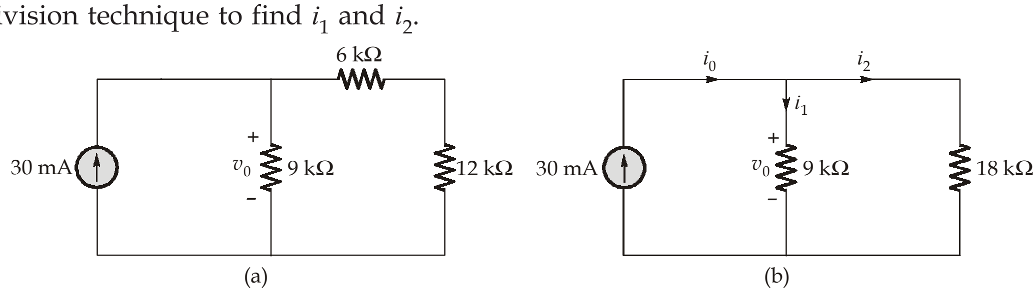
(ii) Decrease in availability or change in availability

$$\psi_1 - \psi_2 = w_{max} = \mathbf{260.77\ kJ/kg}$$

(iii) Maximum work : $w_{max} = \mathbf{260.77\ kJ/kg}$

Q.8 Solution:

(*i*) The 6 kΩ and 12 kΩ resistors are in series so that their combined value is 6 + 12 = 18 kΩ. Thus the circuit in figure (a) reduces to that shown in figure (b). We now apply the current division technique to find i_1 and i_2.



$$i_1 = \frac{18000}{9000 + 18000}(30 \text{ mA}) = 20 \text{ mA}$$

$$i_2 = \frac{9000}{9000+18000}(30\text{ mA}) = 10\text{ mA}$$

Notice that the voltage across the 9 kΩ and 18 kΩ resistors is the same, and $v_0 = 9000 i_1 = 18000 i_2 = 180$ V, as expected.

(*ii*) Power supplied by the source is $P_0 = v_0 i_0 = 180\ (30)$ mW = 5.4 W

(*iii*) Power absorbed by the 12 kΩ resistor is $P = i_2^2 R = (10\times10^{-3})^2(12000) = 1.2\text{ W}$

Power absorbed by the 6 kΩ resistor is $P = i_2^2 R = (10\times10^{-3})^2(6000) = 0.6\text{ W}$

Power absorbed by the 9 kΩ resistor is $P = i_1^2 R = (20\times10^{-3})^2(9000) = 3.6\text{ W}$

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