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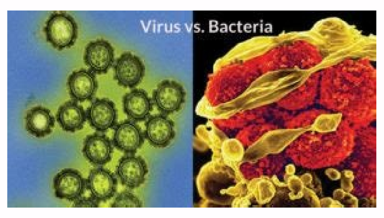

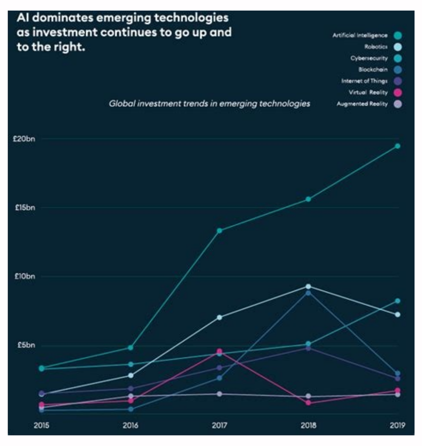

\end{align*} To double check our answer, we can compute the integral in the other direction, integrating first with respect to y and then with respect to x. In this triangle, $y \lt x/2$ (as used above in Example 2) which means that for this example, we must use $x > 2y$. Determine the maximum deflection δ and check your result by letting a = 0 and comparing with the answer to Problem 606. To finish, we need to compute the integral with respect to y, which is simple. 1|Page The first integration y' yields the slope of the elastic curve and the second integration y gives the deflection of the beam at any distance x. Here's an example where we integrate over the region defined by $0 \le x \le 2$ and $0 \le y \le x/2$. Take the origin at the wall. P-614, calculate the slope of the elastic curve over the right support. \end{align*} Thankfully, this does agree with the answer we obtained in Example 2. 18 | P a g e Solution 614 At x = 0, y = 0, therefore C2 = 0 At x = 8 ft, y = 0 0 = 40(83) - (25/6)(84) + (25/6)(44) + 8C1 C1 = -560 lb·ft2 19 | P a g e Thus, At the right support, x = 8 ft answer Solution to Problem 615 | Double Integration Method Problem 615 Compute the value of EI y at the right end of the overhanging beam shown in Fig. 616 by a clockwise couple M applied at the right end and determine the slope and deflection at the right end. \frac{x^2}{2} y^2 \right|_{x=0}^{x=2} \right)dy\\ &= \int_0^1 \left(\frac{2^2}{2} y^2 - \frac{0^2}{2} y^2 \right)dy \\ &= \int_0^1 2 y^2 dy. 5|Page Solution 607 At x = 0, y' = 0, therefore C1 = 0 At x = 0, y = 0, therefore C2 = 0 Therefore, The maximum value of EI y is at x = L (free end) 6|Page answer Solution to Problem 608 | Double Integration Method Problem 608 Find the equation of the elastic curve for the cantilever beam shown in Fig. P-608; it carries a load that varies from zero at the wall to wo at the free end. These two constants must be evaluated from known conditions concerning the slope deflection at certain points of the beam. If E = 10 GPa, what value of I is required to limit the midspan deflection to 1/360 of the span? Solution 610 By symmetry 11 | P a g e At x = 0, y = 0, therefore C2 = 0 At x = a + b, y' = 0 Therefore, Maximum deflection will occur at x = a + b (midspan) Therefore, answer Checking: When a = 0, 2b = L, thus b = ½ L (ok!) 12 | P a g e Solution to Problem 611 | Double Integration Method Problem 611 Compute the value of EI δ at midspan for the beam loaded as shown in Fig. Solution: Now we need to give constant limits for y. P-613? We calculate that our double integral is \begin{align*} \iint_\dlr x y^2 dA &= \int_0^1 2 y^2 dy\\ &= \left. This means, we must put y as the inner integration variables, as was done in the second way of computing Example 1. Since x is gone, it's just a regular one-variable integral. Example 1 Compute the integral \begin{align*} \iint_\dlr x y^2 dA \end{align*} where $\dlr$ is the rectangle defined by $0 \le x \le 2$ and $0 \le y \le 1$ pictured below. Solution 611 13 | P a g e At x = 0, y = 0, therefore C2 = 0 At x = 4 m, y = 0 Therefore, At x = 2 m (midspan) Maximum midspan deflection Thus, answer 14 | P a g e Solution to Problem 612 | Double Integration Method Problem 612 Compute the midspan value of EI δ for the beam loaded as shown in Fig. P-615. Is it confusing that the limits of x are $2y \le x \le 2$ rather than $0 \le x \le 2$ (which would more closely parallel the above Example 2)? \end{align*} Example 2' Now compute the integral over the same triangle $\dlr$, but make y be the outer integration variable. In calculus, the radius of curvature of a curve y = f(x) is given by In the derivation of flexure formula, the radius of curvature of a beam is given as Deflection of beams is so small, such that the slope of the elastic curve dy/dx is very small, and squaring this expression the value becomes practically negligible, hence Thus, EI / M = 1 / y'' If EI is constant, the equation may be written as: where x and y are the coordinates shown in the figure of the elastic curve of the beam under load, y is the deflection of the beam at any distance x. P-609, a simply supported beam carries two symmetrically placed concentrated loads. For the triangle defined by $0 \le x \le 2$ and $0 \le y \le x/2$, the limits of y depend on x. 606. P-620, carrying two triangularly distributed loads. Example 2 Rectangular regions are easy because the limits ($a \le x \le b$ and $c \le y \le d$) are fixed, meaning the ranges of x and y don't depend on each other. P-616, determine (a) the deflection and slope under the load P and (b) the maximum deflection between the supports. 3|Page Solution 606 From the figure below At x = 0, y = 0, therefore C2 = 0 At x = L, y = 0 Therefore, Maximum deflection will occur at x = ½ L (midspan) 4|Page answer Taking W = woL: answer Solution to Problem 607 | Double Integration Method Problem 607 Determine the maximum value of EIy for the cantilever beam loaded as shown in Fig. Hence, we can describe the triangle by $0 \le y \le 1$ and $2y \le x \le 2$. \frac{2y^3}{3} \right|_0^1 \goodbreak = \frac{2(1^3)}{3}- \frac{2(0^3)}{3} \goodbreak =\frac{2}{3}. For instance, in the case of a simply supported beam with rigid supports, at x = 0 and x = L, the deflection y = 0, and in locating the point of maximum deflection, we simply set the slope of the elastic curve y' to zero. Solution 616 22 | P a g e At x = 0, y = 0, therefore C2 = 0 At x = a, y = 0 0 = -[b / (6a)] Pa3 + aC1 C1 = (ab/6)P Therefore, Part (a): Slope and deflection under the load P Slope under the load P: (note x = a + b = L) 23 | P a g e answer Deflection under the load P: (note x = a + b = L) answer Part (b): Maximum deflection between the supports The maximum deflection between the supports will occur at the point where y' = 0. P-611. The resulting solution must contain two constants of integration since EI y" = M is of second order. For a given value of x, y ranges from 0 to $x/2$, as illustrated above by the vertical dashed line from $(x,0)$ to $(x,x/2)$. If we let x range from 0 to $2y$, then the triangle would be the upper-left triangle in the above picture. 620.) Solution 621 By symmetry 33 | P a g e At x = 0, y' = 0, therefore C1 = 0 At x = ½L, y = 0 34 | P a g e Therefore, At x = 0 (midspan) answer At x = 0 when a = 0 Thus, answer 35 | P a g e To illustrate computing double integrals as iterated integrals, we start with the simplest example of a double integral over a rectangle and then move on to an integral over a triangle. Similar to the procedure with partial derivatives, we must treat y as a constant during this integration step. = \frac{32}{5 \cdot 24} = \frac{4}{15}. 16 | P a g e Solution 613 At x = 0, y = 0, therefore C2 = 0 At x = 12 ft, y = 0 17 | P a g e Therefore E = 29 × 106 psi L = 12 ft At midspan, x = 6 ft y = -1/360 (12) = -1/30 ft = -2/5 in Thus, answer Solution to Problem 614 | Double Integration Method Problem 614 For the beam loaded as shown in Fig. Solution 612 At x = 0, y = 0, therefore C2 = 0 15 | P a g e At x = 6 m, y = 0 Therefore, At midspan, x = 3 m Thus, answer Solution to Problem 613 | Double Integration Method Problem 613 If E = 29 × 106 psi, what value of I is required to limit the midspan deflection to 1/360 of the span for the beam in Fig. Solution 619 30 | P a g e At x = 0, y = 0, therefore C2 = 0 At x = 6 m, y = 0 0 = 50(63) - 900(42) - (25/3)(24) + 6C1 C1 = 5600/9 N·m3 Therefore, At x = 3 m answer Solution to Problem 620 | Double Integration Method Problem 620 Find the midspan deflection δ for the beam shown in Fig. P-621. \end{align*} We first integrate with respect to x inside the parentheses. (Apply the hint given in Prob. = \frac{4}{6} = \frac{2}{3}. Solution 605 At x = 0, y = 0, therefore, C2 = 0 2|Page At x = L, y = 0 Thus, Maximum deflection will occur at x = ½ L (midspan) The negative sign indicates that the deflection is below the undeformed neutral axis. More examples To go from Example 2 to Example 2', we “changed the order of integration.” You can see more examples of changing the order of integration in double integrals. As illustrated below, the total range of y within the triangle is between between 0 and 1. Solution to Problem 605 | Double Integration Method Problem 605 Determine the maximum deflection δ in a simply supported beam of length L carrying a concentrated load P at midspan. The only trick is to remember that when integrating with respect to y, we must think of x as a constant. At y' = 0, ⟨ x - a ⟩ do not exist thus, At , 24 | P a g e answer Solution to Problem 617 | Double Integration Method Problem 617 Replace the load P in Prob. E is the modulus of elasticity of the beam, I represent the moment of inertia about the neutral axis, and M represents the bending moment at a distance x from the end of the beam. P-612. Solution: A triangle is slightly more complicated than a rectangle because the limits of one variable will depend on the other variable. x \frac{y^3}{3} \right|_{y=0}^{y=1}\right)dx\\ &= \int_0^2 \frac{x}{3} dx\\ &=

\left.\left.\frac{x^2}{6} \right|_0^2\right. Solution 608 By ratio and proportion 7|Page At x = 0, y' = 0, therefore C1 = 0 At x = 0, y = 0, therefore C2 = 0 Therefore, the equation of the elastic curve is answer Solution to Problem 609 | Double Integration Method Problem 609 As shown in Fig. You can also see more double integral examples from the special cases of interpreting double integrals as area and double integrals as volume. The double integral is similar to the first way of computing Example 1, with the only difference being that the lower limit of x is $2y$. P-607. \end{align*} As it must, this iterated integral gives the same answer. Solution 615 20 | P a g e At x = 0, y = 0, therefore C2 = 0 At x = 10 ft, y = 0 0 = (110/3)(103) - (500/3)(43) + 10C1 C1 = -2600 lb·ft2 Therefore, At the right end of the beam, x = 13 ft 21 | P a g e answer Solution to Problem 616 | Double Integration Method Problem 616 For the beam loaded as shown in Fig. \end{align*} Note that in the first line above, we wrote the limits as $x=2$ and $x=0$ so it is unambiguous that x is the variable we just integrated. In fact, the region is the triangle pictured below. 8|Page Solution 609 By symmetry At x = 0, y = 0, therefore C2 = 0 At x = L, y = 0 9|Page Therefore, Maximum deflection will occur at x = ½ L (midspan) answer If a = ½ L, P = ½ P answer 10 | P a g e Solution to Problem 610 | Double Integration Method Problem 610 The simply supported beam shown in Fig. Thank you very much for your cooperation. Compute the maximum deflection δ. Solution: We will compute the double integral as the iterated integral \begin{align*} \int_0^1 \left(\int_0^2 xy^2 dx\right) dy. Using the same function $f(x,y)=xy^2$ as in example 1, compute $\iint_\dlr f\,dA$ where $\dlr$ is the above triangle. Since for any constant c, the integral of cx is $cx^2/2$, we calculate \begin{align*} \int_0^1 \left(\int_0^2 xy^2 dx\right) dy &= \int_0^1 \left(\left. δmax1 ≠ δmax2 and θmax1 ≠ θmax2δmax1 = δmax2 and θmax1 ≠ θmax2δmax1 ≠ δmax2 and θmax1 = θmax2δmax1 = δmax2 and θmax1 = θmax2 Double Integration Method | Beam Deflections (C-6, Strength of Materials 4 Ed. – Pytel & Singer) th The double integration method is a powerful tool in solving deflection and slope of a beam at any point because we will be able to get the equation of the elastic curve. Solution 617 25 | P a g e At x = 0, y = 0, therefore C2 = 0 At x = a, y = 0 0 = -(M / 6a)(a3) + aC1 C1 = Ma / 6 Therefore, Slope at x = a + b answer 26 | P a g e Deflection at x = a + b answer Solution to Problem 618 | Double Integration Method Solution 618 At x = 0, y = 0, therefore C2 = 0 At x = L, y = 0 27 | P a g e Therefore, answer At x = a answer When a = 0 (moment load is at the left support): 28 | P a g e answer When a = L (moment load is at the right support): answer 29 | P a g e Solution to Problem 619 | Double Integration Method Problem 619 Determine the value of EIy midway between the supports for the beam loaded as shown in Fig. Check your result by letting a = 0 and comparing with Prob. The only difference from Example 1 is that the upper limit of y is $x/2$. We want to compute the integral over the region $\dlr$, which is the lower-right triangle shaded in red. Then, for a given value of y, x takes on values between $2y$ and 2 (as shown by the horizontal dashed line between $(2y,y)$ and $(2,y)$). P-610 carries a uniform load of intensity wo symmetrically distributed over part of its length. In order to continue enjoying our site, we ask that you confirm your identity as a human. Since for any constant c, the integral of cy^2 is $cy^3/3$, we calculate \begin{align*} \iint_\dlr x y^2 dA &= \int_0^2 \left(\int_0^1 xy^2 dy\right) dx\\ &= \int_0^2 \left(\left. The product EI is called the flexural rigidity of the beam. In a double integral, the outer limits must be constant, but the inner limits can depend on the outer variable. The fact that the range of y depends on x means this region is not a rectangle. (Hint: For convenience, select the origin of the axes at the midspan position of the elastic curve.) Solution 620 By ratio and proportion: 31 | P a g e By symmetry: At x = 0, y' = 0, therefore C1 = 0 At x = ½L, y = 0 0 = (1/48)woL2 (½L)2 - (wo60L)(½L)5 + C2 0 = (1/192)wo L4 - (1/1920)wo L4 + C2 C2 = -(3/640)wo L4 Therefore, 32 | P a g e At x = 0 (midspan) Thus, answer Solution to Problem 621 | Double Integration Method Problem 621 Determine the value of EIδ midway between the supports for the beam shown in Fig. For regions of other shapes, the range of one variable will depend on the other. The integral is \begin{align*} \iint_\dlr x y^2 dA &= \int_0^1 \left(\int_{2y}^2 xy^2 dx \right)dy\\ &= \int_0^1\left(\left.\frac{x^2y^2}{2} \right|_{x=2y}^{x=2}\right) dy\\ &= \int_0^1 \left(2y^2 - \frac{(2y)^2 y^2}{2}\right) dy\\ &= \int_0^1 \left(2y^2 - 2y^4\right) dy\\ &= 2 \left[\frac{y^3}{3} - \frac{y^5}{5} \right]_0^1\\ &= 2 \left(\frac{1}{3} - \frac{1}{5} -(0-0)\right)\\ &= 2 \cdot \frac{2}{15} \goodbreak = \frac{4}{15}. The double integral is \begin{align*} \iint_\dlr x y^2 dA &= \int_0^2 \left(\int_0^{x/2} xy^2 dy \right) dx\\ &=\int_0^2 \left(\left.\frac{x}{3} y^3 \right|_{y=0}^{y=x/2}\right) dx\\ &=\int_0^2 \left(\frac{x}{3} \left(\frac{x}{2}\right)^3 -\frac{x}{3} 0^3 \right) dx\\ &= \int_0^2 \frac{x^4}{24} dx\\ &= \left.\left.\frac{x^5}{5\cdot 24}\right|_0^2\right. P-619. Therefore, answer Solution to Problem 606 | Double Integration Method Problem 606 Determine the maximum deflection δ in a simply supported beam of length L carrying a uniformly distributed load of intensity wo applied over its entire length. Check your answer by letting a = ½ L and comparing it with the answer to Problem 605.

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