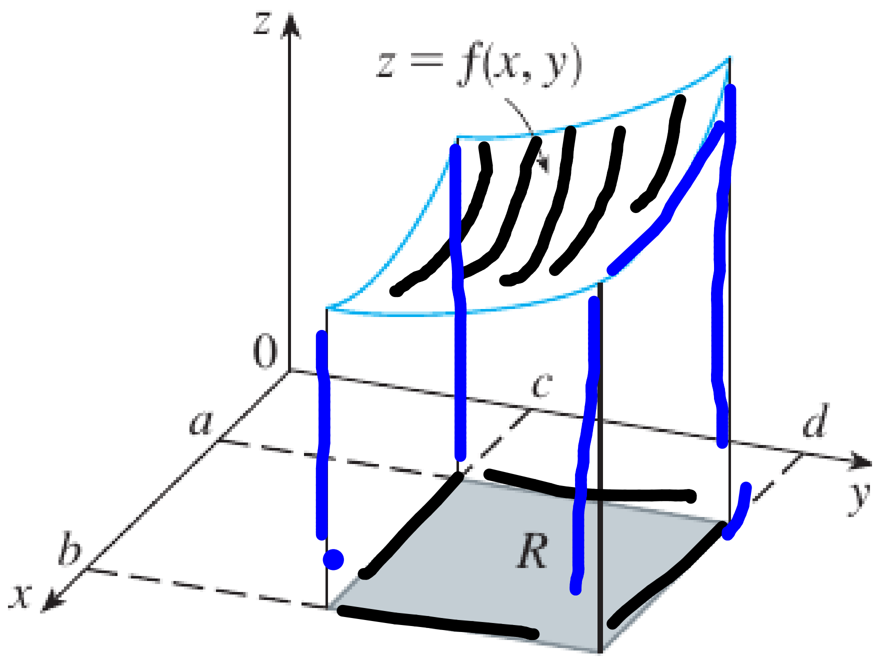
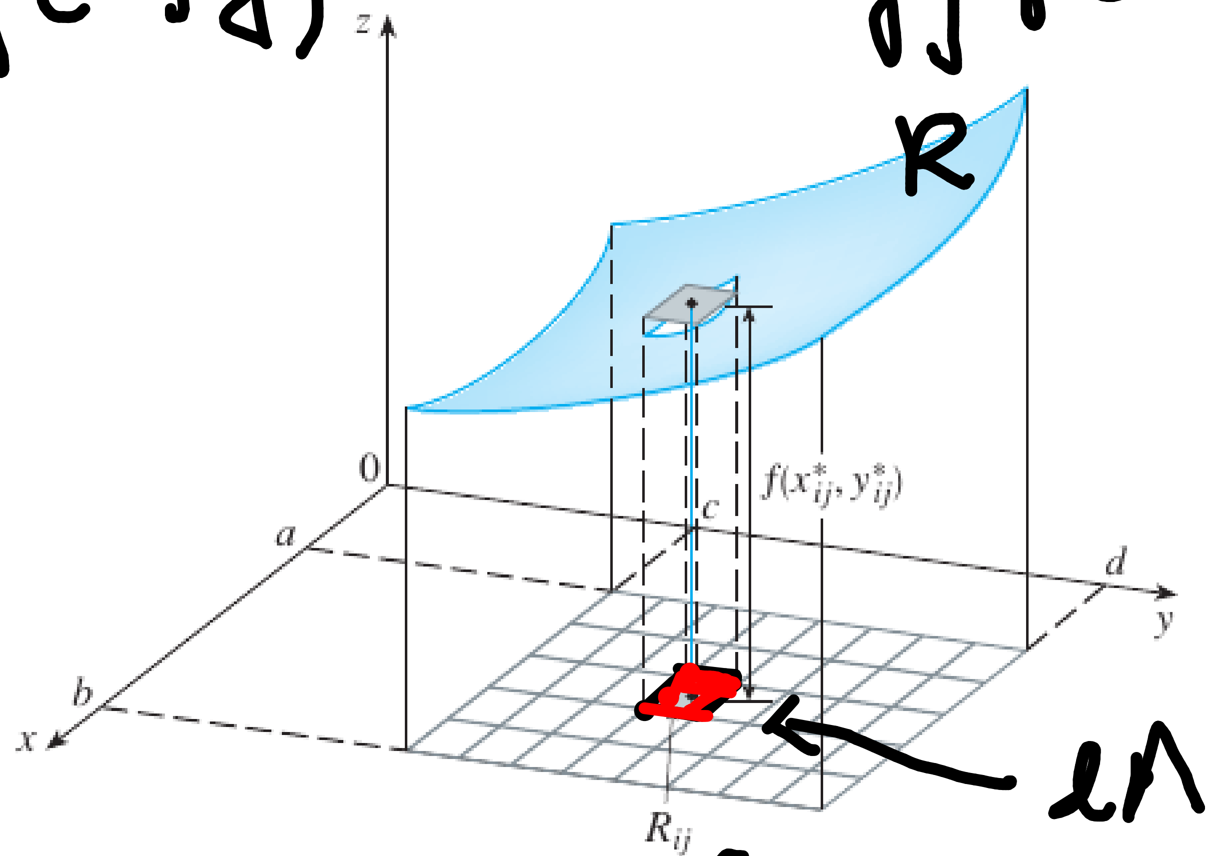
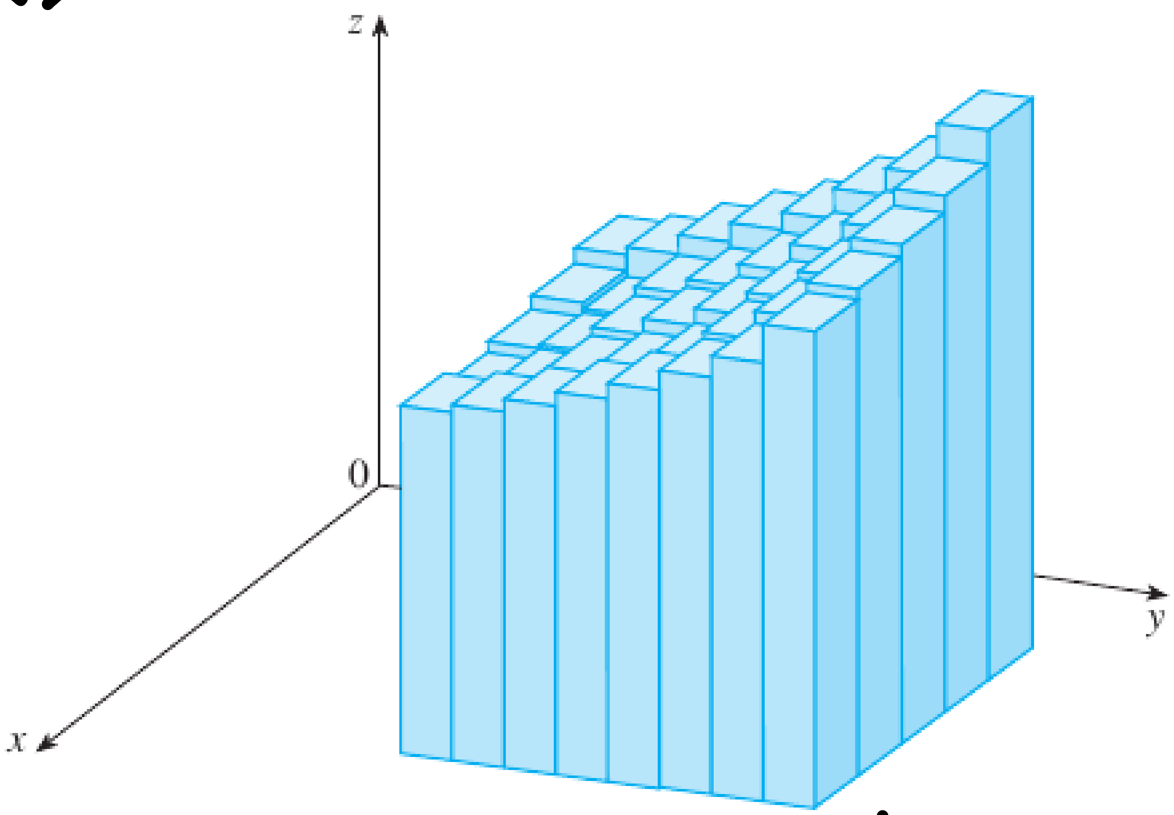
12 MULTIPLE INTEGRALS

$f(x, y)$

$\iint f(x, y)\, dA$

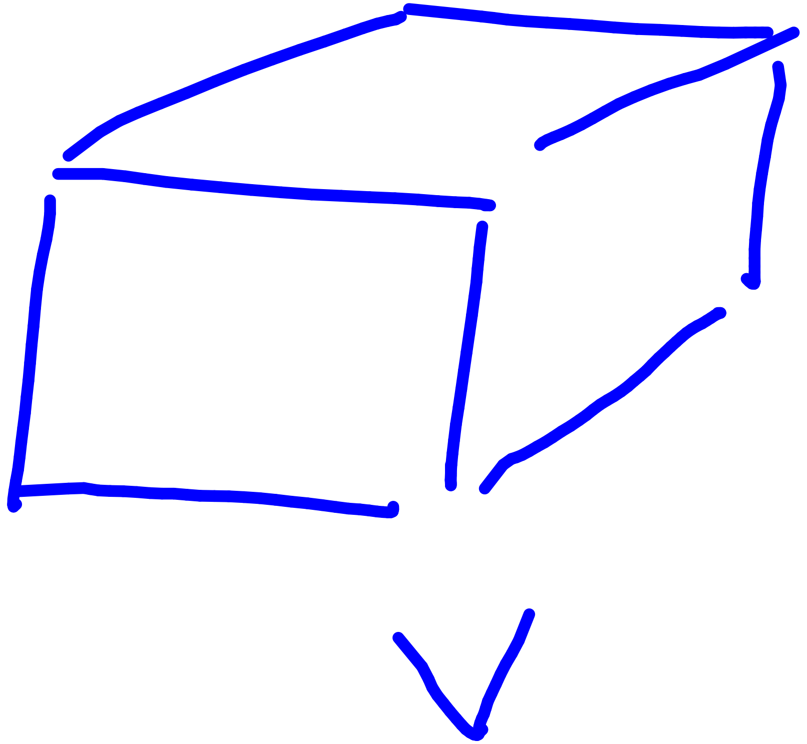




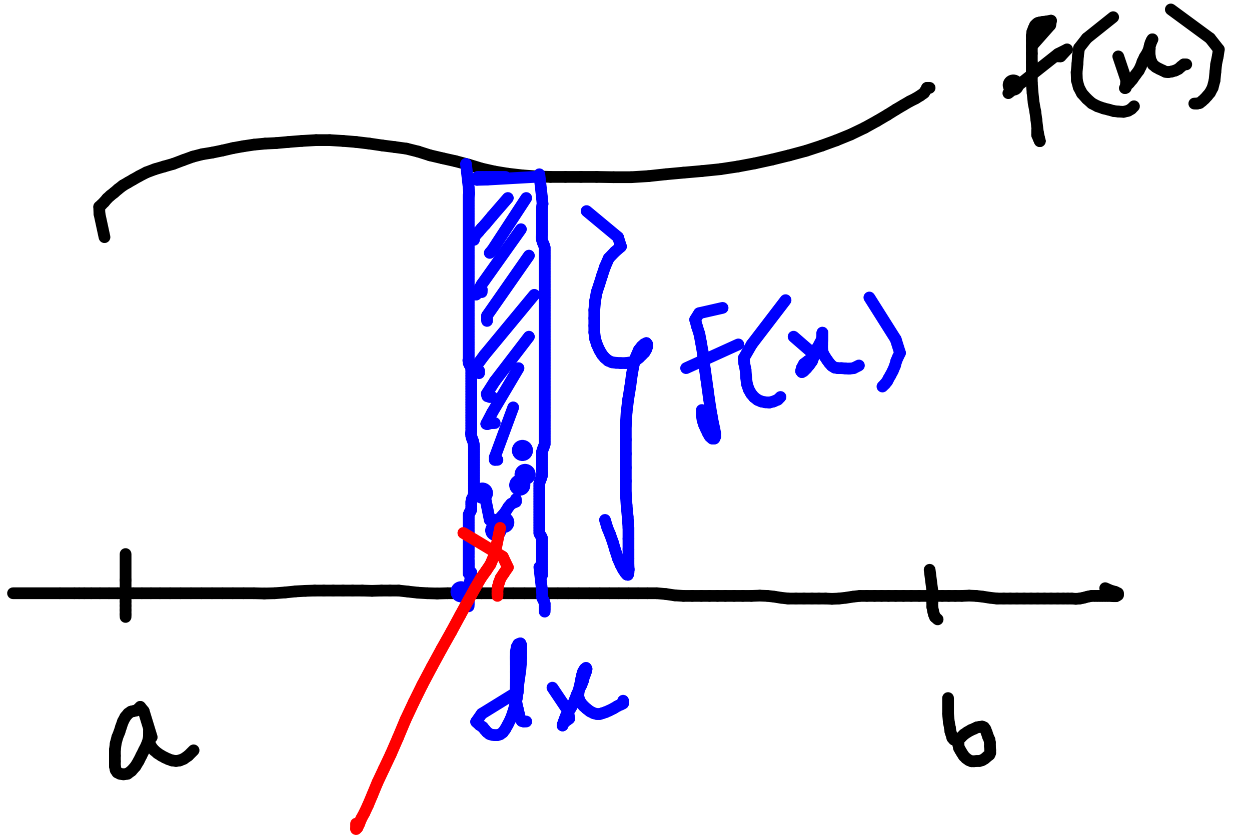


$$\iint_R f(x, y)\, dA = \text{volume with } f(x, y) \text{ on top}$$

& R as base



$$\iiint_V f(x, y, z)\, dV$$



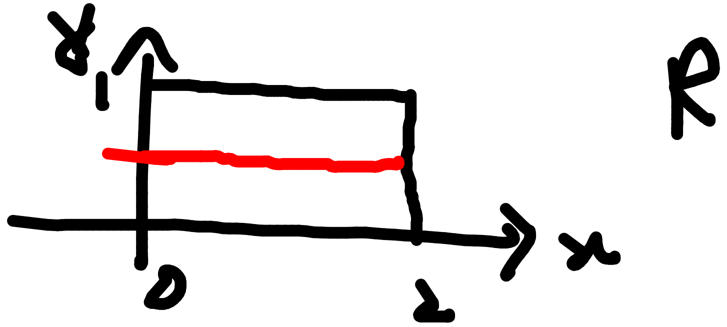
$$\int_a^b f(x)\,dx$$

$f(x)\,dx$

area $= f(x)\,dx$

$\int f(x)\,dx =$ infinite sum of $f(x)\,dx$

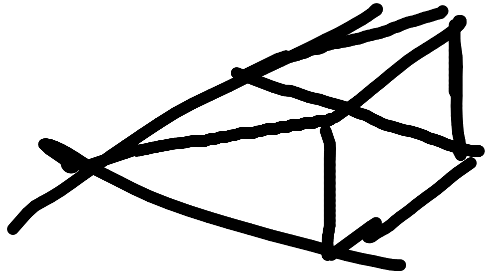
d. $f(x,y) = x$



$$\iint_R x \, dA = ?? = \int_0^2 \left(\int_0^1 x \, dy \right) dx$$

$$= \int_0^2 \left[xy \Big|_{y=0}^{y=1} \right] dx = \int_0^2 x \, dx$$

$$= 2$$

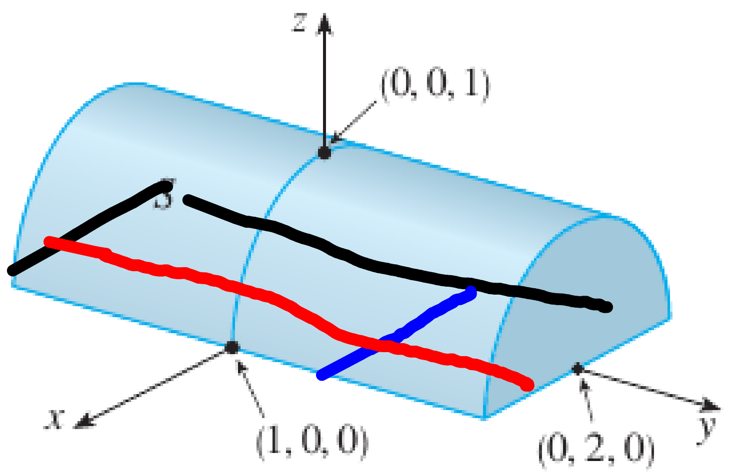


$$= \int_0^1 \left(\int_0^2 x \, dx \right) dy$$

$$= \int_0^1 2 \, dy = 2$$

EXAMPLE 2 If $R = \{(x, y) \mid -1 \leqslant x \leqslant 1, -2 \leqslant y \leqslant 2\}$, evaluate the integral

$$\iint_R \sqrt{1 - x^2}\, dA$$



$$f(x,y) = \sqrt{1-x^2}$$

$$z = \sqrt{1-x^2}$$

$$z^2 + x^2 = 1$$

$$= \int_{-2}^{2}\int_{-1}^{1} \sqrt{1-x^2}\, dx\, dy$$

$$= \int_{-1}^{1}\int_{-2}^{2} \sqrt{1-x^2}\, dy\, dx$$

$$= \int_{-1}^{1} 4\sqrt{1-x^2}\, dx = 2\pi$$

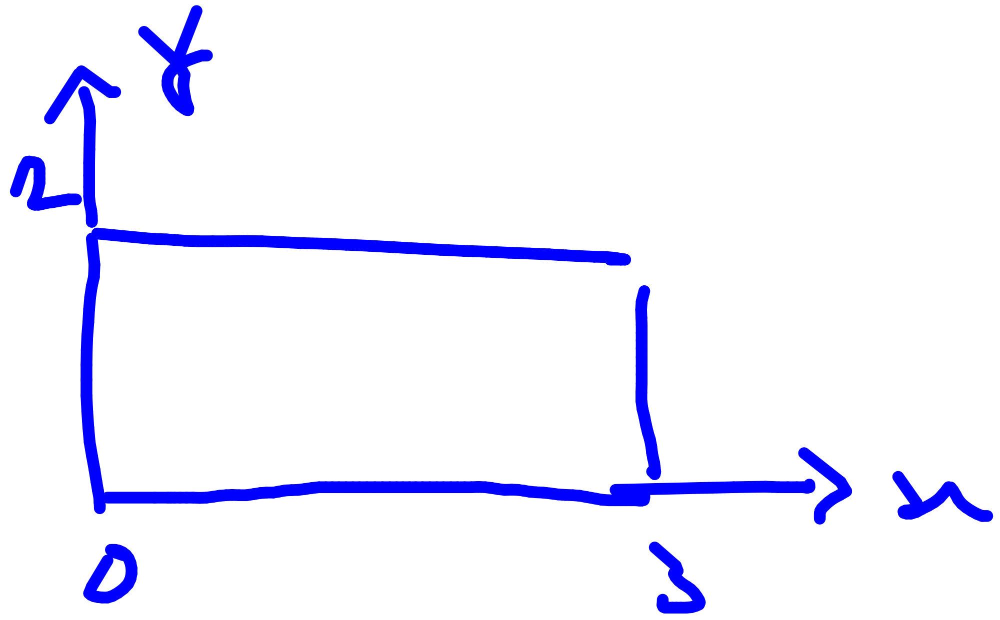
EXAMPLE 4 Evaluate the iterated integrals.

(a) $\int_0^3 \int_1^2 x^2 y \, dy \, dx$

$\frac{27}{2}$

(b) $\int_1^2 \int_0^3 x^2 y \, dx \, dy$

$\frac{27}{2}$

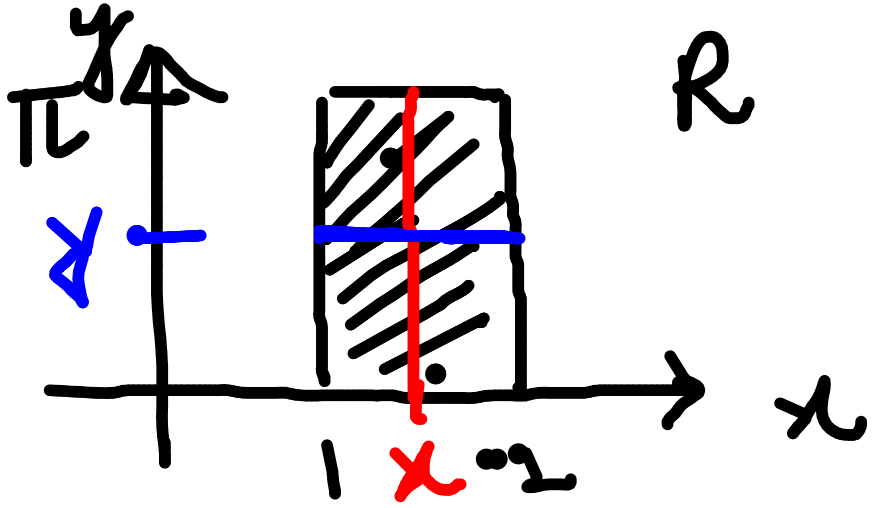


10 FUBINI'S THEOREM If f is continuous on the rectangle $R = \{(x, y) \mid a \leqslant x \leqslant b, c \leqslant y \leqslant d\}$, then

$$\iint_R f(x, y)\, dA = \int_a^b \int_c^d f(x, y)\, dy\, dx = \int_c^d \int_a^b f(x, y)\, dx\, dy$$

Evaluate $\iint_R y \sin(xy)\, dA$, where $R = [1, 2] \times [0, \pi]$.

x y



$$\iint_R y \sin(xy)\, dA = \int_1^2 \left(\int_0^\pi y \sin(xy)\, dy \right) dx$$

$$= \int_0^\pi \left(\int_1^2 y \sin(xy)\, dx \right) dy$$

Then, start integrating inside out

$$\int_1^2 y\sin(xy)\,dx = \left[-\cancel{y}\frac{\cos(xy)}{\cancel{y}}\right]_{x=1}^{x=2}$$

$$= \cos(y) - \cos(2y)$$

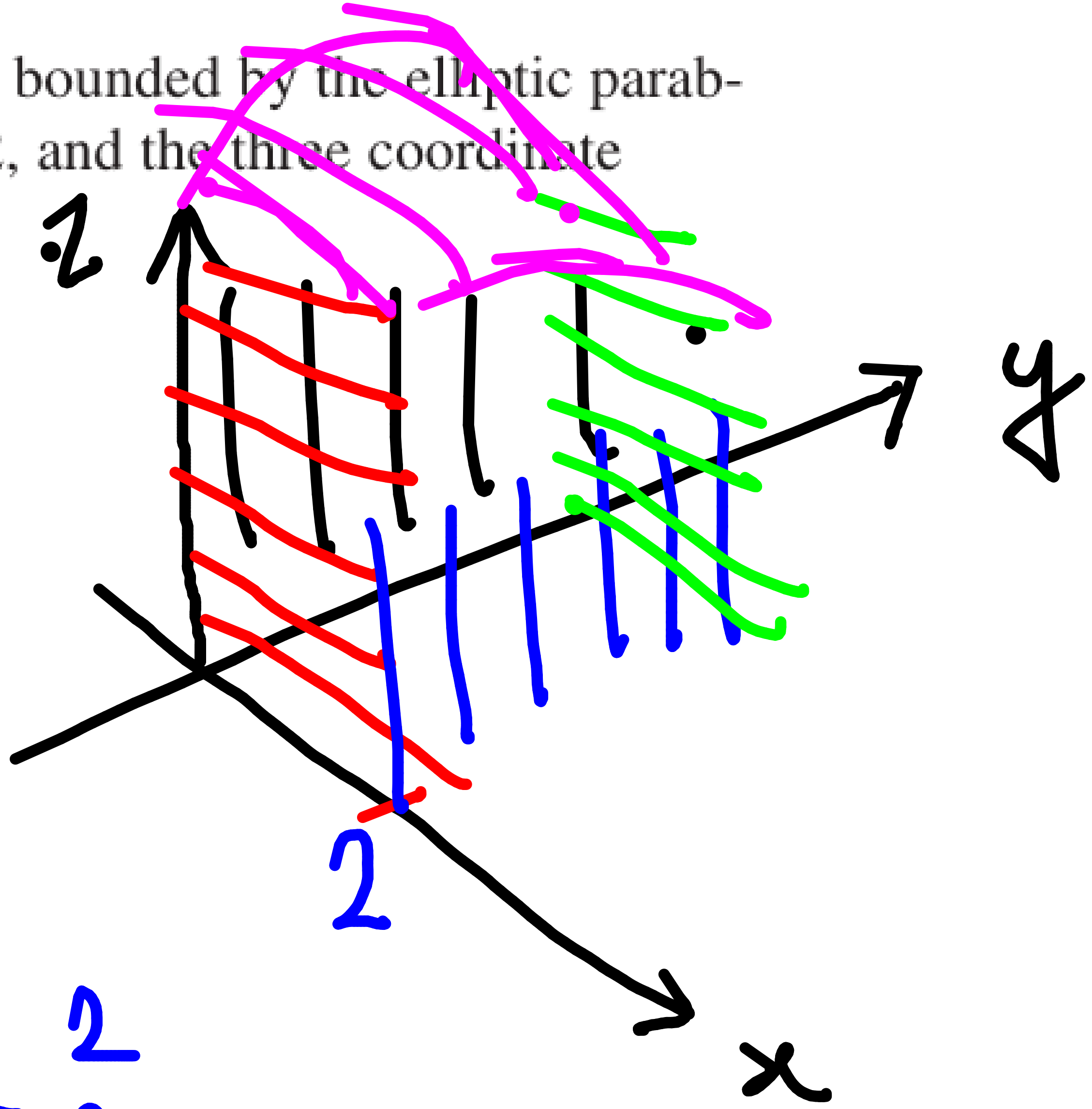
$$\iint_R y\sin(xy)\,dA = \int_0^{\pi}\left[\cos(y) - \cos(2y)\right]dy$$

$$= 0$$

EXAMPLE 7 Find the volume of the solid S that is bounded by the elliptic paraboloid $x^2 + 2y^2 + z = 16$, the planes $x = 2$ and $y = 2$, and the three coordinate planes.

$$x^2 + 2y^2 + z = 16$$

$$z = 16 - x^2 - 2y^2$$



$$V = \iint_{[0,2]\times[0,2]} 16 - x^2 - 2y^2 \, dA$$

$$= \int_0^2 \int_0^2 (16 - x^2 - 2y^2) \, dy \, dx$$

$$\int_0^2 (16 - x^2 - 2y^2)\,dy = \left[16y - x^2 y - \frac{2y^3}{3}\right]_{y=0}^{y=2}$$

$$= 32 - \frac{16}{3} - 2x^2$$

$$\int_0^2 \left(32 - \frac{16}{3} - 2x^2\right) dx = 48$$

PROPERTIES OF DOUBLE INTEGRALS

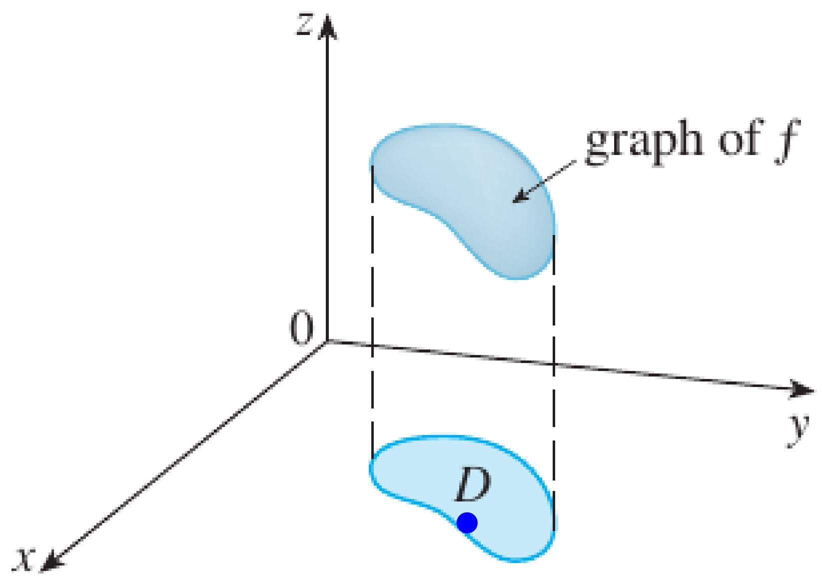
12 $$\iint_R [f(x, y) + g(x, y)]\, dA = \iint_R f(x, y)\, dA + \iint_R g(x, y)\, dA$$

13 $$\iint_R cf(x, y)\, dA = c \iint_R f(x, y)\, dA \qquad \text{where } c \text{ is a constant}$$

If $f(x, y) \geqslant g(x, y)$ for all (x, y) in R, then

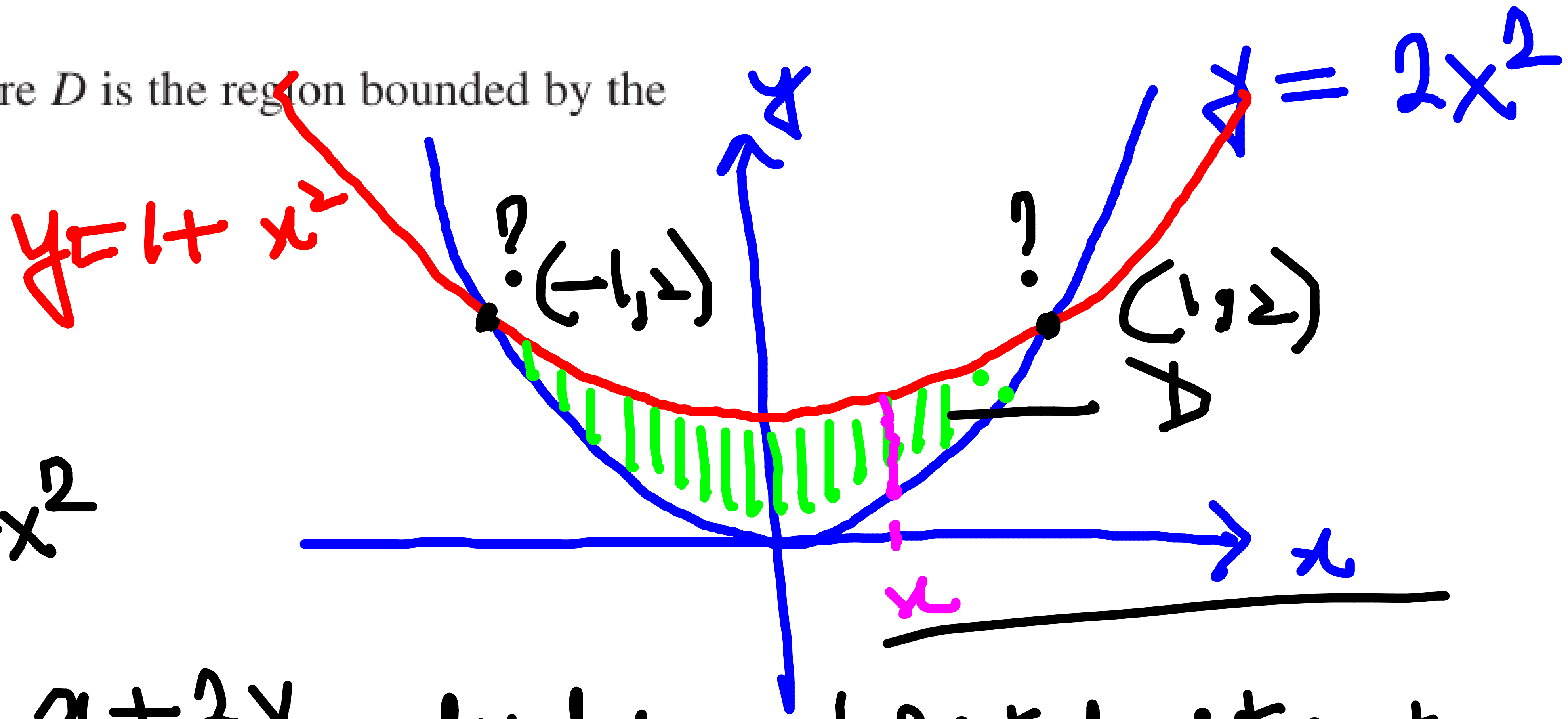
14 $$\iint_R f(x, y)\, dA \geqslant \iint_R g(x, y)\, dA$$

12.2 DOUBLE INTEGRALS OVER GENERAL REGIONS



V EXAMPLE 1 Evaluate $\iint_D (x + 2y)\, dA$, where D is the region bounded by the parabolas $y = 2x^2$ and $y = 1 + x^2$.

$z = x + 2y$



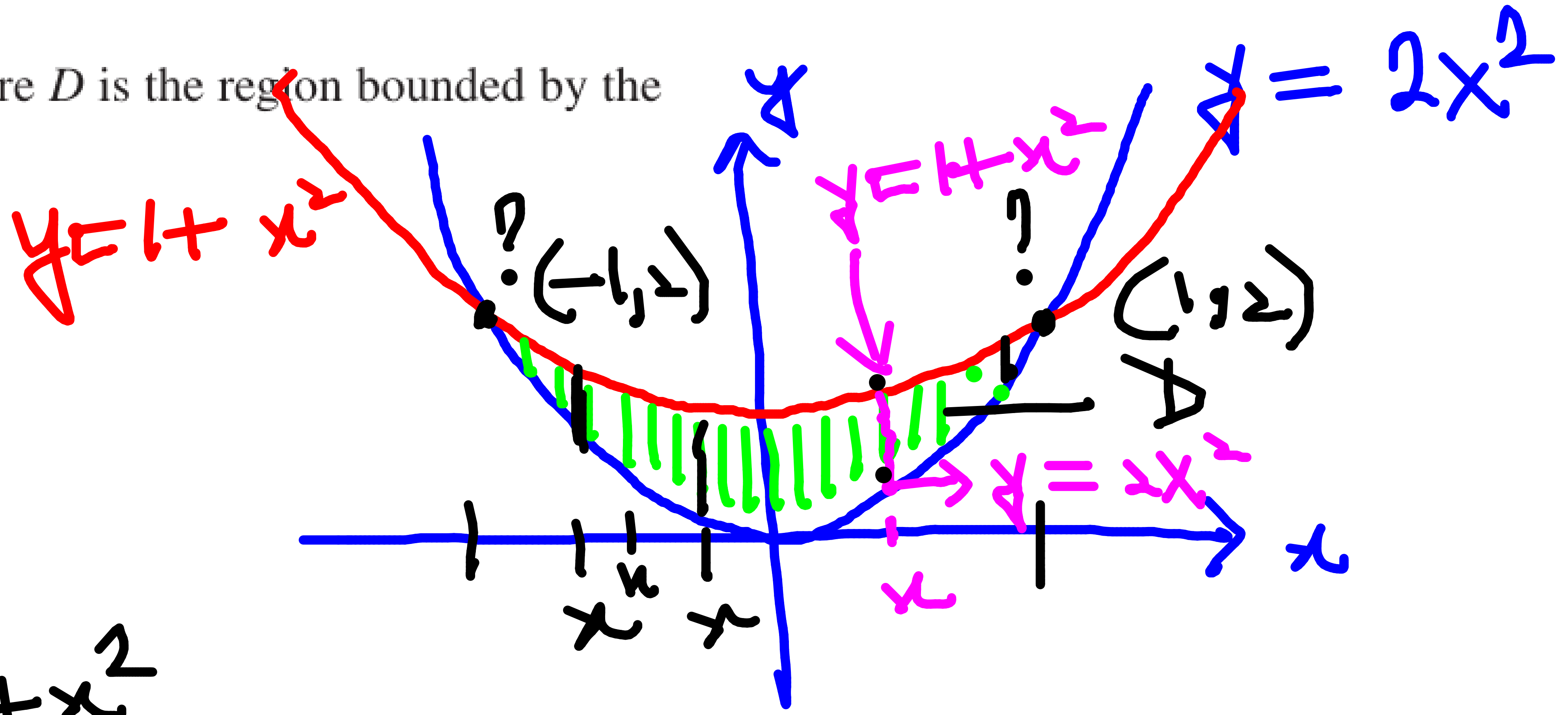
$$\iint_D (x+2y)\,dA = \int_{-1}^{1} \int_{2x^2}^{1+x^2} x+2y \; dy\,dx$$

Point of intersection

$$2x^2 = 1 + x^2$$

$$x = \pm 1$$

V EXAMPLE 1 Evaluate $\iint_D (x + 2y)\, dA$, where D is the region bounded by the parabolas $y = 2x^2$ and $y = 1 + x^2$.



$z = x + 2y$

$$\iint_D (x+2y)\, dA$$

$$= \int_{-1}^{1} \int_{2x^2}^{1+x^2} x + 2y \; dy \; dx$$

$$\int_{2x^2}^{1+x^2} (x+2y)\,dy = \Big[xy + y^2\Big]_{y=2x^2}^{y=1+x^2}$$

$$= \underline{x(1-x^2)} + (1+x^2)^2 - (2x^2)^2$$

$$\iint_D (x+2y)\,dA = \int_{-1}^{1} x(1-x^2) + (1+x^2)^2 - (2x^2)^2 \, dx$$

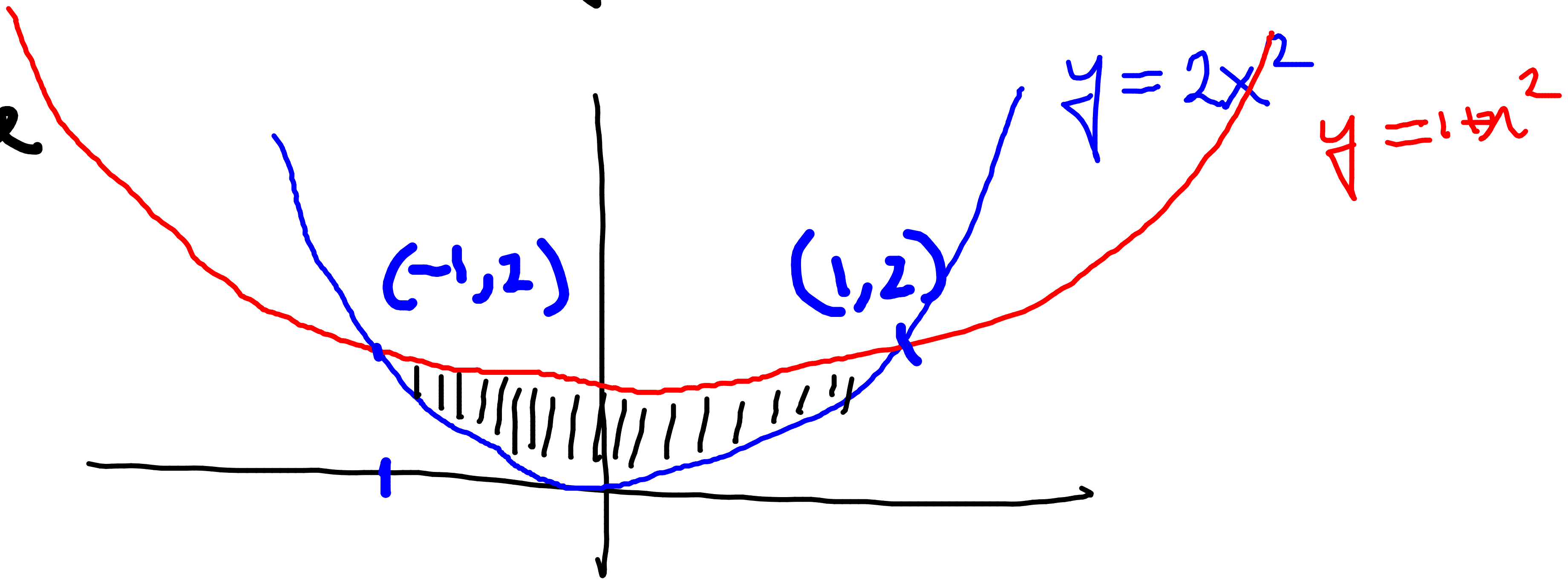
$$= \text{whatever} = \frac{32}{15}$$

Today's agenda

- 12.2 continued

Q: $\iint_R (x+2y)\, dA$, where R is the region bounded by the graph of $y = 2x^2$ & $y = 1+x^2$

$$= \int_A^B \left(\int_C^D x+2y \, dy \right) dx$$



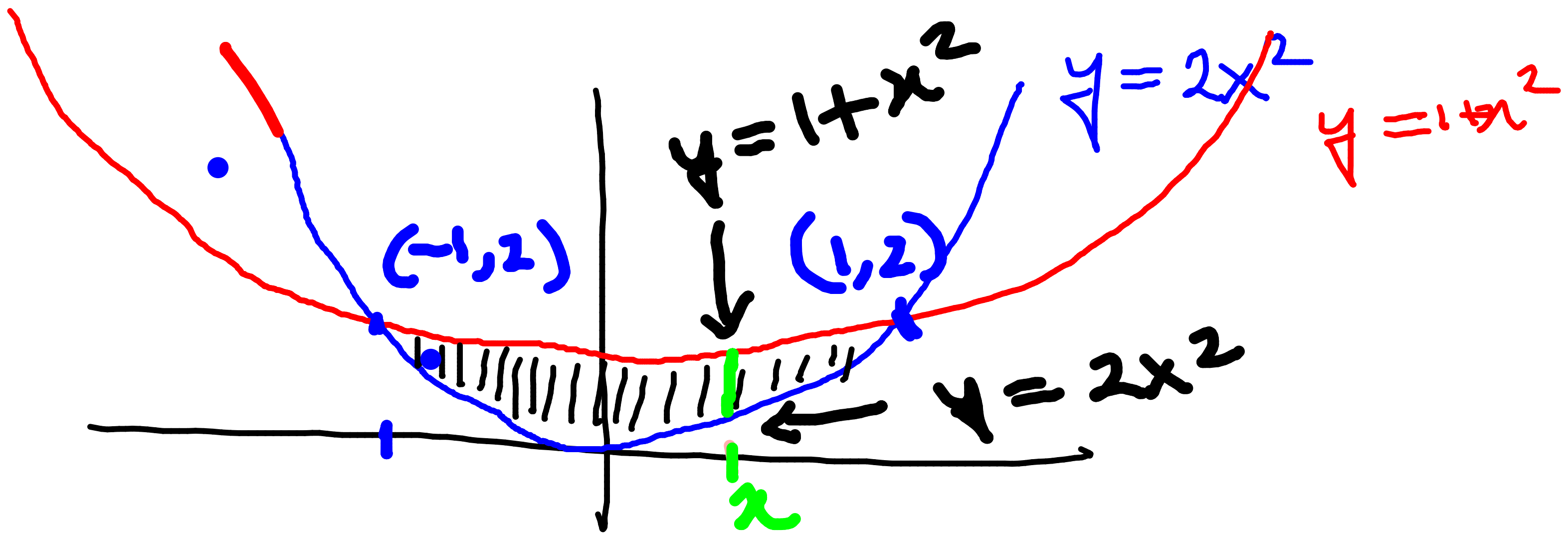
Q: $A, B, C, D = ??$

$A = -1$, $B = 1$, $C = 2x^2$ & $D = 1+x^2$

Q:

$$\iint_R (x+2y)\, dA \,,$$

where R is the region bounded by the graph of $y = 2x^2$ & $y = 1+x^2$



$$2x^2 = 1+x^2$$

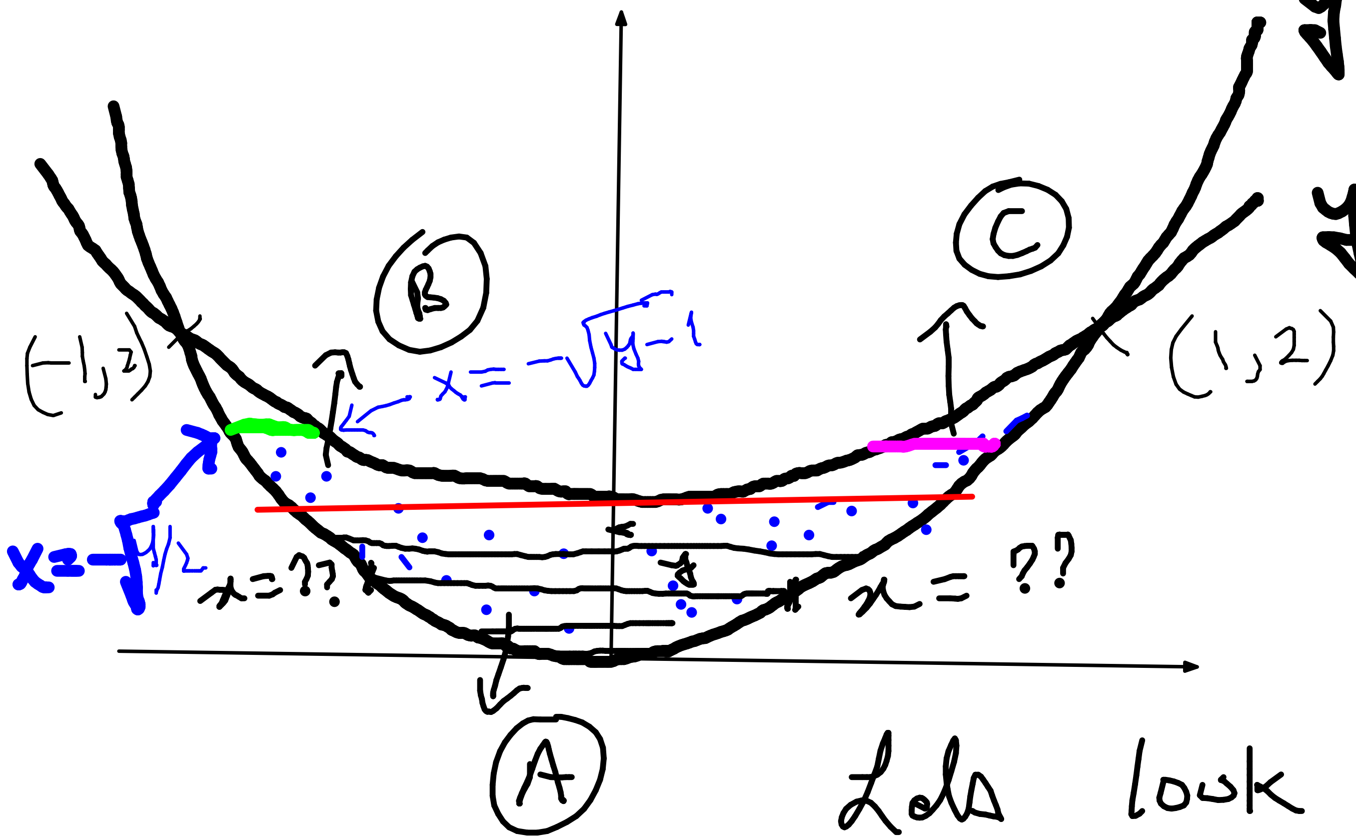
$$x = \pm 1,\ y = 2$$

$$\int_{-1}^{1} \int_{2x^2}^{1+x^2} (x+2y)\, dy\, dx$$

Q.

$$\iint_R (x+2y)\, dA \,,$$

where R is the region bounded by the graph of $y = 2x^2$ & $y = 1+x^2$



$$\int_0^2 \int_?^? x+2y \; dx\, dy$$

$$= \iint_{A} + \iint_{B} + \iint_{C}$$

Lets look for limits of x in A, B, C

$$\iint_{C} (x+2y)\,dx\,dy = \int_{1}^{2} \int_{\sqrt{y-1}}^{\sqrt{y/2}} (x+2y)\,dx\,dy$$

$$\iint (x+2y)\,dx\,dy = \int_{1}^{2}\int_{-\sqrt{y/2}}^{-\sqrt{y-1}} (x+2y)\,dx\,dy$$

B

A

$$y = 2x^2 \quad , \quad x = \pm\sqrt{\frac{y}{2}}$$

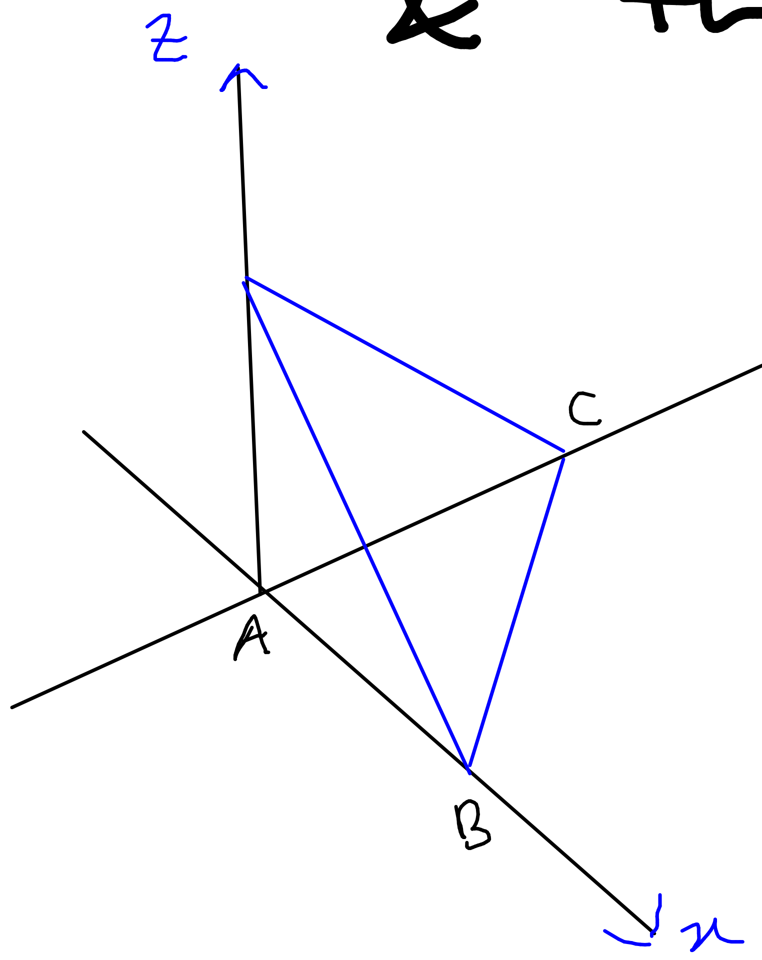
$x = -\sqrt{y/2}$ left half ,

$x = \sqrt{y/2}$ right half

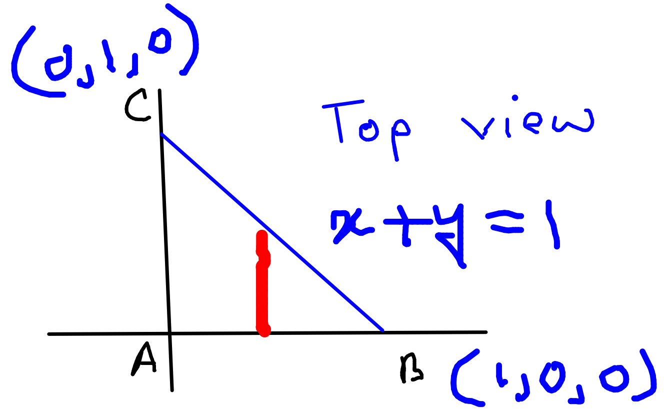
$$\iint (x+2y)\,dx\,dy = \int_{0}^{1}\int_{-\sqrt{y/2}}^{\sqrt{y/2}} (x+2y)\,dx\,dy$$

A

Q. Find the lume of the tetrahedron bounded by the plane $x+y+z=1$ & the other standard planes, xy, yz, xz



$$V = \iint_{\Delta ABC} (1-x-y)\, dA = \int_0^1 \int_0^{1-x} (1-x-y)\, dy\, dx$$



$$= \int_0^1 \int_0^{1-y} (1-x-y)\, dx\, dy$$

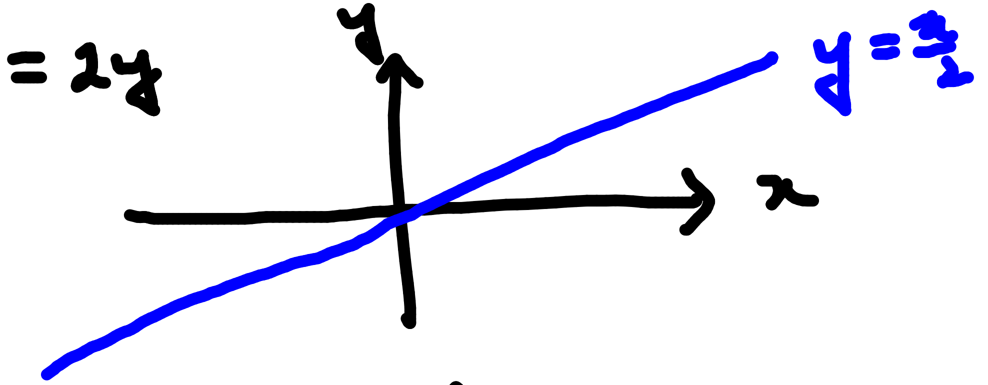
EXAMPLE 4 Find the volume of the tetrahedron bounded by the planes $x + 2y + z = 2$, $x = 2y$, $x = 0$, and $z = 0$.

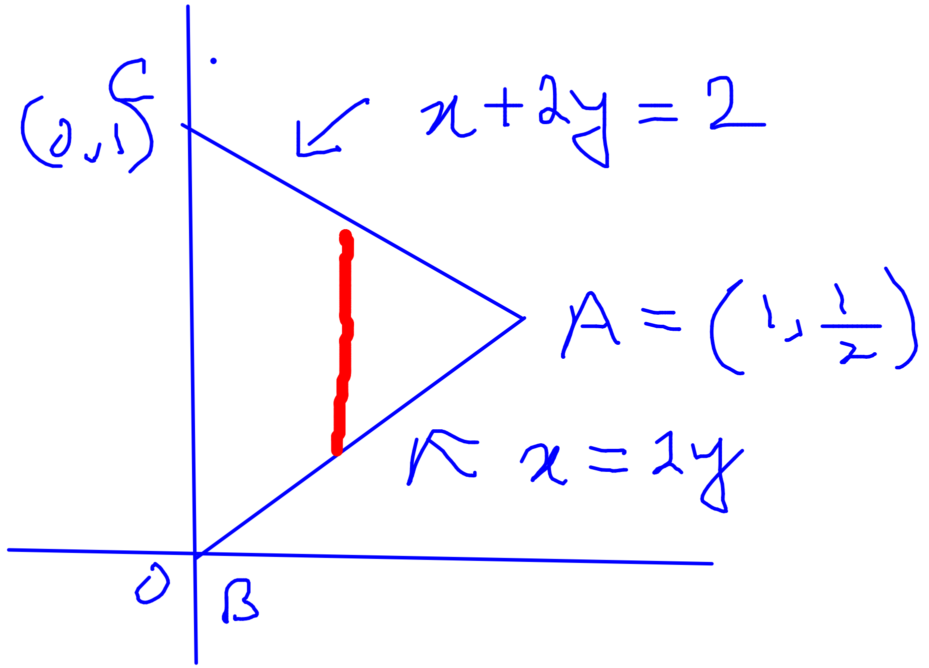
$\Delta ABC: \; x + 2y + z = 2$

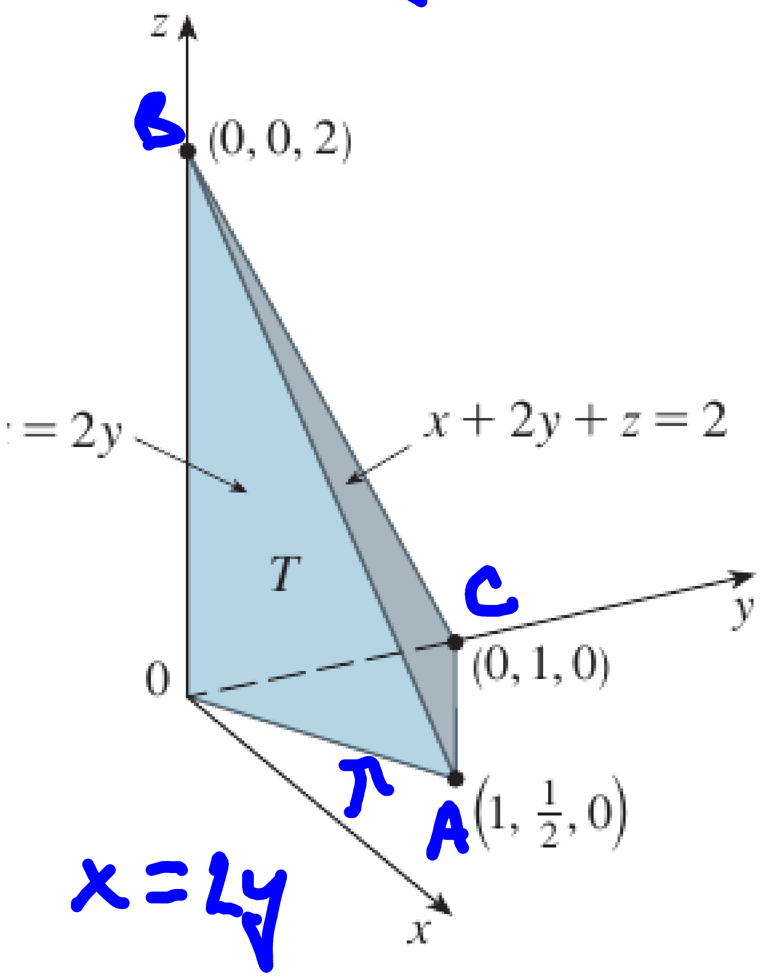
$z = 0 \rightarrow xy$ plane

$x = 0 \rightarrow yz$ plane

$x = 2y$







$$\text{volume} = \iint_{\Delta OAC} (2 - x - 2y)\, dA$$

ΔOAB : vertical plane above the line $x = 2y$

$$= \int_0^1 \int_{x/2}^{(2-x)/2} (2 - x - 2y)\, dy\, dx = \text{Ans ??} = \frac{7}{12}$$

H.W.

•

EXAMPLE 2 Find the volume of the solid that lies under the paraboloid $z = x^2 + y^2$ and above the region D in the xy-plane bounded by the line $y = 2x$ and the parabola $y = x^2$.

V EXAMPLE 3 Evaluate $\iint_D xy\, dA$, where D is the region bounded by the line $y = x - 1$ and the parabola $y^2 = 2x + 6$.

1–6 ▪ Evaluate the iterated integral.

1. $\int_0^1 \int_0^{x^2} (x + 2y)\, dy\, dx$

2. $\int_1^2 \int_y^2 xy\, dx\, dy$

31–36 ▪ Sketch the region of integration and change the order of integration.

$$\int_0^3 \int_0^{\sqrt{9-y}} f(x, y)\, dx\, dy$$

31–36 ▪ Sketch the region of integration and change the order of integration.

$$\int_0^4 \int_0^{\sqrt{x}} f(x, y)\, dy\, dx$$

37–42 ▪ Evaluate the integral by reversing the order of integration.

$$\int_0^1 \int_{3y}^3 e^{x^2}\,dx\,dy$$