Student: _____ **Date:** _____ **Time:** _____	**Instructor:** Hoi Nguyen **Course:** AU14 MATH 2173 - ENG MATH B (20686) COL **Book:** Ohio State University: Calculus: Early Transcendentals, Second Custom Edition	**Assignment:** Homework #6

1. Evaluate the following integral.

$$\int_{-3}^{2}\int_{2}^{5}\int_{1}^{e}\frac{x^2y^2}{z}\,dz\,dx\,dy$$

$\int_{-3}^{2}\int_{2}^{5}\int_{1}^{e}\frac{x^2y^2}{z}\,dz\,dx\,dy =$ ☐ (Simplify your answer.)

Answer: 455

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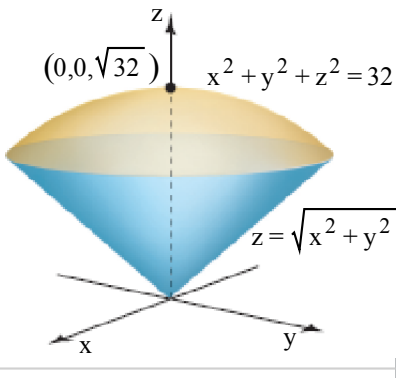
2. Use a triple integral to find the volume of the solid bounded below by the cone $z=\sqrt{x^2+y^2}$ and bounded above by the sphere $x^2+y^2+z^2=32$.



Set up the triple integral that should be used to find the volume of the solid as efficiently as possible. Use increasing and symmetric limits of integration wherever possible.

$\int_{\square}^{\square}\int_{\square}^{\square}\int_{\square}^{\square}(\square)\,dz\,dy\,dx$

(Type exact answers.)

The volume of the solid is $\square$ units. / cubic units. / square units.

(Type an exact answer.)

Answers
-4
4
$-\sqrt{32-x^2}$
$\sqrt{32-x^2}$
$\sqrt{x^2+y^2}$
$\sqrt{32-x^2-y^2}$
1
$\frac{256\pi(\sqrt{2}-1)}{3}$
cubic units.

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3. Evaluate the integral $\int_0^4 \int_0^{\sqrt{16-x^2}} \int_0^{\sqrt{16-x^2}} dz\, dy\, dx$.

$\int_0^4 \int_0^{\sqrt{16-x^2}} \int_0^{\sqrt{16-x^2}} dz\, dy\, dx =$ ☐

(Type a simplified fraction.)

Answer: $\frac{128}{3}$

4. Rewrite the following integral using the indicated order of integration and then evaluate the resulting integral.

$\int_0^9 \int_{-1}^0 \int_0^{8x+8} dy\, dx\, dz$ in the order $dz\, dx\, dy$

$\int_0^9 \int_{-1}^0 \int_0^{8x+8} dy\, dx\, dz = \int_{\square}^{\square} \int_{\square}^{\square} \int_{\square}^{\square} dz\, dx\, dy =$ ☐ (Simplify your answer.)

Answers
0
8
y / 8 − 1
0
0
9
36

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5. Use a triple integral to compute the volume of the parallelepiped (slanted box) with vertices (0,0,0), (4,0,0), (0,5,0), (4,5,0), (0,1,4), (4,1,4), (0,6,4), and (4,6,4). (Use integration and find the best order of integration.)

Set up the triple integral that should be used to find the volume of the parallelepiped as efficiently as possible. Use increasing and symmetric limits of integration wherever possible.

$\int_{\square}^{\square}\int_{\square}^{\square}\int_{\square}^{\square}(\square)\,dy\,dx\,dz$

The volume of the parallelepiped is $\square$ cubic unit(s). square unit(s). unit(s).

Answers
0
4
0
4
$\frac{z}{4}$
$\frac{z}{4}+5$
1
80
cubic unit(s).

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6. Identify and sketch the following set in cylindrical coordinates.

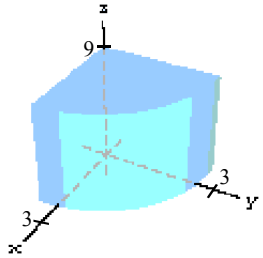
$\{(r,\theta,z): 3r \le z \le 9\}$

Identify the set in cylindrical coordinates. Choose the correct answer below.

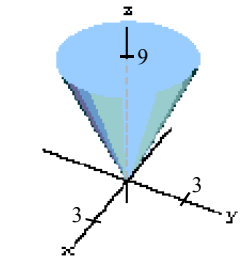
- ○ A. Cylinder
- ○ B. Wedge
- ○ C. Cone
- ○ D. Cylindrical shell

Sketch the set in cylindrical coordinates. Choose the correct graph below.

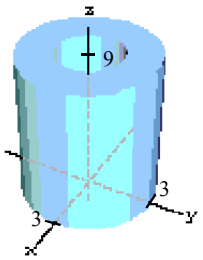
○ A.



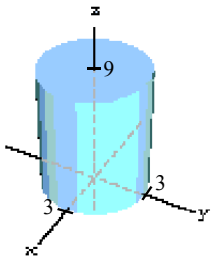
○ B.



○ C.



○ D.



Answers C

B

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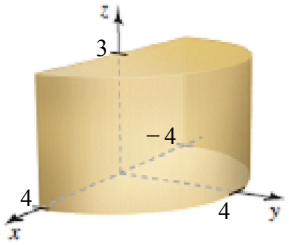
7. Evaluate the following integral in cylindrical coordinates.

$$\int_{-4}^{4}\int_{0}^{\sqrt{16-x^2}}\int_{0}^{3}\frac{1}{1+x^2+y^2}\,dz\,dy\,dx$$



$$\int_{-4}^{4}\int_{0}^{\sqrt{16-x^2}}\int_{0}^{3}\frac{1}{1+x^2+y^2}\,dz\,dy\,dx = \square$$

(Type an exact answer, using π as needed.)

Answer: $\frac{3}{2}\pi \ln 17$

8. For $0 \le r \le 1$, the solid bounded by the cone $z = 3 - 3r$ and the solid bounded by the paraboloid $z = 3 - 3r^2$ have the same base in the xy-plane and the same height. Which object has the greater mass if the density of both objects is $\rho(r,\theta,z) = 10 - 5z$?

Set up the triple integral using cylindrical coordinates that should be used to find the mass of the cone as efficiently as possible. Use increasing limits of integration and assume that the solid is bounded below by the xy-plane.

$$\int_{\square}^{\square}\int_{\square}^{\square}\int_{\square}^{\square}(\square)\,dz\,dr\,d\theta$$

Set up the triple integral using cylindrical coordinates that should be used to find the mass of the paraboloid as efficiently as possible. Use increasing limits of integration and assume that the solid is bounded below by the xy-plane.

$$\int_{\square}^{\square}\int_{\square}^{\square}\int_{\square}^{\square}(\square)\,dz\,dr\,d\theta$$

Which object has the greater mass? Choose the correct answer below and fill in the answer boxes to complete your choice.
(Type exact answers, using π as needed.)

- ○ The mass of the paraboloid is larger. The mass of the paraboloid is ▢. The mass of the cone is ▢.
- ○ The mass of the cone is larger. The mass of the cone is ▢. The mass of the paraboloid is ▢.

Answers
2π
0
1
0
$3 - 3r$
$(10 - 5z)r$
2π
0
1

8. (cont.)

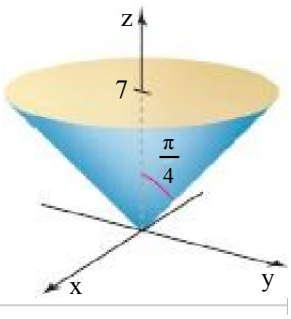
0

$3-3r^2$

$(10-5z)r$

The mass of the paraboloid is larger. The mass of the paraboloid is $\frac{15}{2}\pi$. The mass of the cone is $\frac{25}{4}\pi$.

9. Evaluate the following integral in spherical coordinates. This integral calculates the volume of the figure to the right, which is not drawn to scale.



$$\int_0^{2\pi}\int_0^{\frac{\pi}{4}}\int_0^{7\sec\varphi}\rho^2\sin\varphi\,d\rho\,d\varphi\,d\theta$$

$$\int_0^{2\pi}\int_0^{\frac{\pi}{4}}\int_0^{7\sec\varphi}\rho^2\sin\varphi\,d\rho\,d\varphi\,d\theta = \square$$

(Type an exact answer, using π as needed.)

Answer: $\frac{343\pi}{3}$

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10. Convert the equation $\rho^2 = -9 \sec 2\varphi$, where $\pi / 2 < \varphi < 3\pi / 4$, to rectangular coordinates and identify the surface.

Convert the equation to rectangular coordinates.

$z =$ ☐

(Type an exact answer, using radicals as needed.)

Identify the surface. Choose the correct answer below.

- ○ Cylinder
- ○ Cone
- ○ Lower half of a hyperboloid of one sheet
- ○ Paraboloid

Answers $-\sqrt{x^2 + y^2 - 9}$

Lower half of a hyperboloid of one sheet

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11. Find the mass of the solid cylinder $\{(r,\theta,z): 0 \le r \le 5,\ 0 \le \theta \le 2\pi,\ -1 \le z \le 1\}$ with a density $\rho(r,z) = (2-|z|)(4-r)$.

Set up the triple integral using cylindrical coordinates that should be used to find the mass of the solid cylinder as efficiently as possible. Use increasing limits of integration.

$$\int_{\square}^{\square}\int_{\square}^{\square}\int_{\square}^{\square}(\square)\,dz\,dr\,d\theta$$

(Do not simplify.)

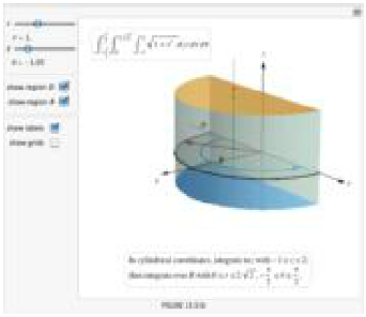
The mass is $\square$.

(Type an exact answer, using π as needed.)

Answers
2π
0
5
-1
1
$(2-|z|)(4-r)r$
50π

12. Without using calculus, evaluate the integral if the integrand $\sqrt{1+r^2}$ is replaced with 1.

(Use the interactive figure to find your answer.)



Click here to launch the interactive figure.

The answer is $\square$.

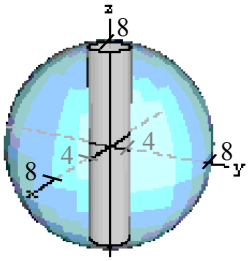
(Type an exact answer, using π as needed.)

Answer: 12π

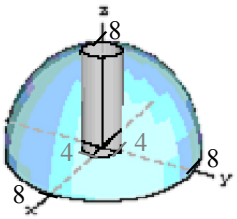
13. If possible, write iterated integrals in cylindrical coordinates for the region outside the cylinder $r = 4$ and inside the sphere $\rho = 8$ for $z \geq 0$ in the orders $dz\,dr\,d\theta$, $dr\,dz\,d\theta$, and $d\theta\,dz\,dr$. Sketch the region of integration.

Sketch the region of integration. Choose the correct graph below.

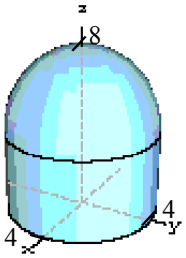
○ A.



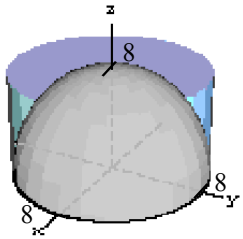
○ B.



○ C.



○ D.



Write the integral in cylindrical coordinates for the given region in the order $dz\,dr\,d\theta$. Choose the correct answer below.

○ A. $\int_0^{2\pi}\int_0^{8}\int_4^{\sqrt{64-r^2}} f(r,\theta,z)\,r\,dz\,dr\,d\theta$

○ B. $\int_0^{2\pi}\int_4^{8}\int_0^{\sqrt{64-r^2}} f(r,\theta,z)\,r\,dz\,dr\,d\theta$

○ C. $\int_0^{2\pi}\int_4^{8}\int_0^{8} f(r,\theta,z)\,r\,dz\,dr\,d\theta$

○ D. It is not possible to write the iterated integral for the given region for this order.

Write the integral in cylindrical coordinates for the given region in the order $dr\,dz\,d\theta$. Choose the correct answer below.

13. (cont.)

A. $\int_0^{2\pi}\int_4^8\int_0^{\sqrt{64-z^2}} f(r,\theta,z)\, r\, dr\, dz\, d\theta$

B. $\int_0^{2\pi}\int_0^{4\sqrt{3}}\int_4^{\sqrt{64-z^2}} f(r,\theta,z)\, r\, dr\, dz\, d\theta$

C. $\int_0^{2\pi}\int_4^8\int_0^{\sqrt{64-r^2}} f(r,\theta,z)\, r\, dr\, dz\, d\theta$

D. It is not possible to write the iterated integral for the given region for this order.

Write the integral in cylindrical coordinates for the given region in the order $d\theta\, dz\, dr$. Choose the correct answer below.

A. $\int_4^8\int_0^{\sqrt{64-r^2}}\int_0^{2\pi} f(r,\theta,z)\, r\, d\theta\, dz\, dr$

B. $\int_4^{\sqrt{64-z^2}}\int_4^8\int_0^{2\pi} f(r,\theta,z)\, r\, d\theta\, dz\, dr$

C. $\int_0^8\int_4^{\sqrt{64-r^2}}\int_0^{2\pi} f(r,\theta,z)\, r\, d\theta\, dz\, dr$

D. It is not possible to write the iterated integral for the given region for this order.

Answers B
B
B
A

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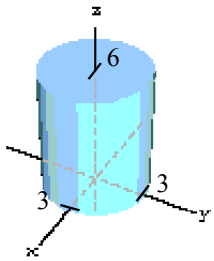
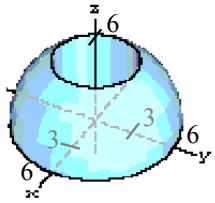
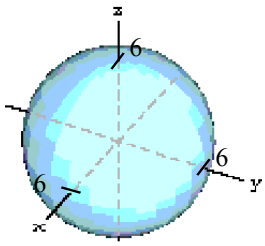
14. If possible, write iterated integrals in spherical coordinates for the following region in the orders $d\rho\, d\theta\, d\varphi$ and $d\theta\, d\rho\, d\varphi$. Sketch the region of integration. Assume that f is continuous on the region.

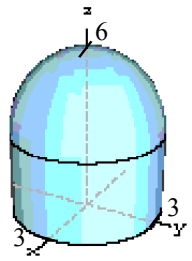
$$\int_0^{2\pi}\int_{\pi/6}^{\pi/2}\int_{3\csc\varphi}^{6} f(\rho,\varphi,\theta)\rho^2 \sin\varphi\, d\rho\, d\varphi\, d\theta$$

Sketch the region of integration. Choose the correct graph below.

○A. 

○B. 

○C. 

○D. 

Write the integral in spherical coordinates for the given region in the order $d\rho\, d\theta\, d\varphi$. Choose the correct answer below.

○A. $\displaystyle\int_{\pi/6}^{\pi/2}\int_{0}^{2\pi}\int_{3\csc\varphi}^{6} f(\rho,\varphi,\theta)\rho^2 \sin\varphi\, d\rho\, d\theta\, d\varphi$

○B. $\displaystyle\int_{\pi/6}^{2\pi}\int_{0}^{\pi/2}\int_{3\csc\varphi}^{3} f(\rho,\varphi,\theta)\rho^2 \sin\varphi\, d\rho\, d\theta\, d\varphi$

○C. $\displaystyle\int_{\pi/6}^{\pi/2}\int_{0}^{2\pi}\int_{3\csc\theta}^{6} f(\rho,\varphi,\theta)\rho^2 \sin\varphi\, d\rho\, d\theta\, d\varphi$

○D. It is not possible to write the iterated integral for the given region for this order.

Write the integral in spherical coordinates for the given region in the order $d\theta\, d\rho\, d\varphi$. Choose the correct answer below.

14. (cont.)

A. $\int_{\pi/6}^{\pi/2}\int_{3}^{6}\int_{\csc\varphi-1}^{2\pi} f(\rho,\varphi,\theta)\rho^2 \sin\varphi \, d\theta \, d\rho \, d\varphi$

B. $\int_{\pi/6}^{\pi/2}\int_{3}^{6}\int_{\csc\varphi}^{2\pi} f(\rho,\varphi,\theta)\rho^2 \sin\varphi \, d\theta \, d\rho \, d\varphi$

C. $\int_{\pi/6}^{2\pi}\int_{3}^{6}\int_{\csc\rho-1}^{\pi/2} f(\rho,\varphi,\theta)\rho^2 \sin\varphi \, d\theta \, d\rho \, d\varphi$

D. It is not possible to write the iterated integral for the given region for this order.

Answers B
A
B

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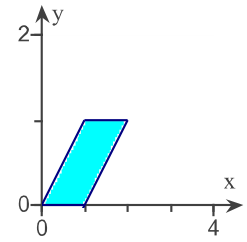
1. Evaluate the following integral using a change of variables. Sketch the original and new regions of integration, R and S.

$$\int_0^1 \int_y^{y+2} \sqrt{x-y}\ dxdy$$

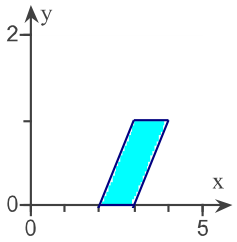
Sketch the original region, R, in the xy-plane. Choose the correct graph below.

1

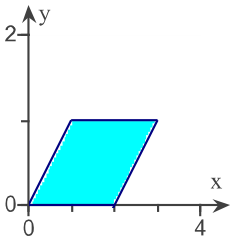
○ A.



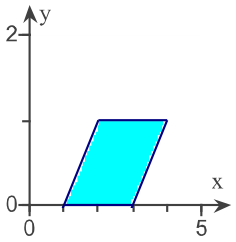
○ B.



○ C.

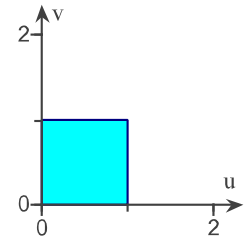


○ D.

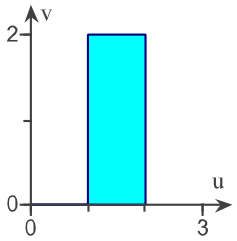


While many changes of variables are correct, for this problem use the change of variables that makes the new integral the simplest by making $u = x - y$ and $v = y$. Sketch the new region, S, in the uv-plane. Choose the correct graph below.

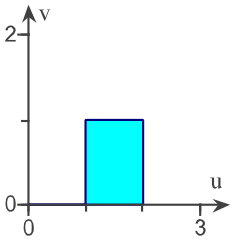
○ A.



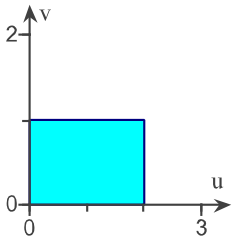
○ B.



○ C.



○ D.



Perform the change of variables and write the new integral in the uv-plane.

$$\int_0^1 \int_y^{y+2} \sqrt{x-y}\ dxdy = \int_{\square}^{\square} \int_{\square}^{\square} (\square)\ dudv$$

(Type exact answers.)

Evaluate the integral.

$$\int_0^1 \int_y^{y+2} \sqrt{x-y}\ dxdy = \square$$

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1. (cont.) (Type an exact answer. Use integers or fractions for any numbers in the expression.)

Answers

C

D

0

1

0

2

$\sqrt{u}$

$\frac{4\sqrt{2}}{3}$

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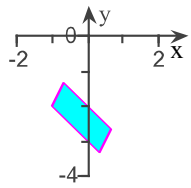
2. Evaluate the following integral using a change of variables. Sketch the original and new regions of integration, R and S.

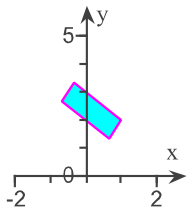
$\iint_R \left(\frac{y-x}{y+2x+1}\right)^4 dA$, where R is the parallelogram bounded by $y-x=2$, $y-x=3$, $y+2x=0$, and $y+2x=4$

Sketch the original region, R, in the xy-plane. Choose the correct graph below.

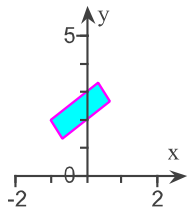
○ A.



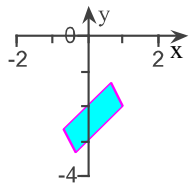
○ B.



○ C.

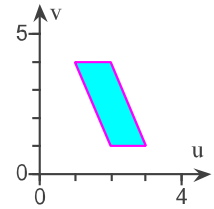


○ D.

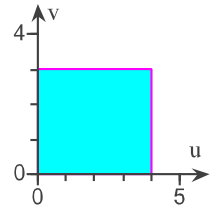


While many changes of variables are correct, for this problem use the change of variables that makes the new integral the simplest by making $u = y - x$ and $v = y + 2x$. Sketch the new region, S, in the uv-plane. Choose the correct graph below.

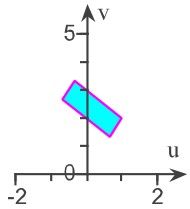
○ A.



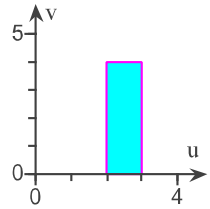
○ B.



○ C.



○ D.



Perform the change of variables and write the new integral in the uv-plane.

$\iint_R \left(\frac{y-x}{y+2x+1}\right)^4 dA = \int_{\square}^{\square}\int_{\square}^{\square} (\square)\, dudv$

(Type exact answers.)

Evaluate the integral.

$\iint_R \left(\frac{y-x}{y+2x+1}\right)^4 dA = \square$ (Simplify your answer.)

Answers C

2. (cont.)

D

0

4

2

3

$\frac{1}{3}\left(\frac{u}{v+1}\right)^4$

$\frac{26,164}{5,625}$

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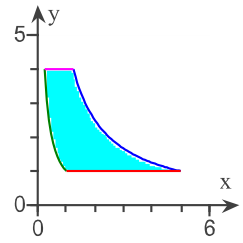
3. Evaluate the following integral using a change of variables. Sketch the original and new regions of integration, R and S.

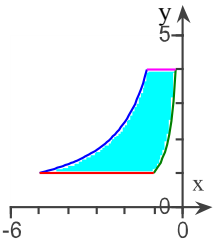
$\iint_R xy\,dA$, where R is the region bounded by the hyperbolas $xy = 1$ and $xy = 5$, and the lines $y = 1$ and $y = 4$

Sketch the original region, R, in the xy-plane. Choose the correct graph below.

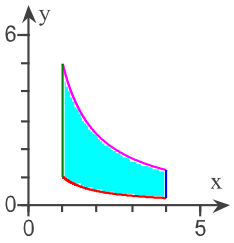
○ A.



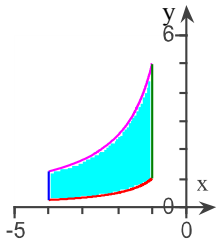
○ B.



○ C.

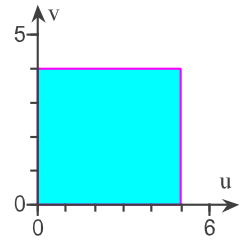


○ D.

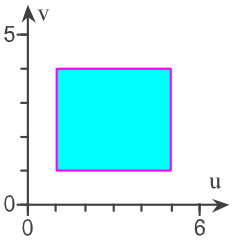


While many changes of variables are correct, for this problem use the change of variables that makes the new integral the simplest by making $u = xy$ and $v = y$. Sketch the new region, S, in the uv-plane. Choose the correct graph below.

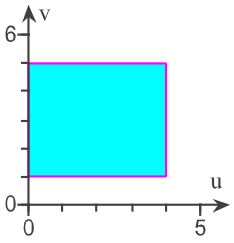
○ A.



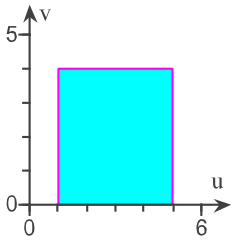
○ B.



○ C.



○ D.



Perform the change of variables and write the new integral in the uv-plane.

$\iint_R xy\,dA = \int_{\square}^{\square}\int_{\square}^{\square} (\square)\,dudv$

(Type exact answers.)

Evaluate the integral.

3. (cont.) $\iint_R xy\ dA =$ ☐ (Type an exact answer.)

Answers

A

B

1

4

1

5

$\frac{u}{v}$

$12 \ln 4$

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4.

Let R be the region bounded by the ellipse $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$, where $a > 0$ and $b > 0$ are real numbers.

Let T be the transformation $x = au$, $y = bv$. Evaluate $\iint_R |xy|\, dA$.

First, find the Jacobian for the given transformation.

$J(u,v) =$ ☐

Perform the change of variables and write the new integral in the uv-plane.

$\int_{\square}^{\square}\int_{\square}^{\square} (\square)\, dvdu$

(Type exact answers.)

Now evaluate the integral.

$\iint_R |xy|\, dA =$ ☐

Answers

ab

0

1

0

$\sqrt{1-u^2}$

$4a^2b^2uv$

$\frac{a^2b^2}{2}$

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5. Use a change of variables to evaluate the following integral.

$\iiint_D xy\ dV$; D is bounded by the planes $y - x = 0$, $y - x = 3$, $z - y = 0$, $z - y = 1$, $z = 0$, $z = 7$.

Which of the following is a potential transformed triple integral? Choose the correct answer below.

A. $\int_0^7 \int_0^1 \int_0^3 (-u - v + w)(-v + w)w\ dudvdw$

B. $\int_0^7 \int_0^1 \int_0^3 (u - v - w)(v - w)\ dudvdw$

C. $\int_0^7 \int_0^1 \int_0^3 (-u - v + w)(-v + w)\ dudvdw$

D. $\int_0^3 \int_0^1 \int_0^7 (-u - v + w)(-v + w)\ dudvdw$

Evaluate the integral.

$\iiint_D xy\ dV =$ ☐ (Simplify your answer.)

Answers C

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6. Use a change of variables to evaluate the following integral.

$\iiint_D z\,dV$; D is bounded by the paraboloid $z = 81 - x^2 - 9y^2$ and the xy-plane. Use $x = 9u\cos v$, $y = 3u\sin v$, $z = w$.

Perform the change of variables and write the new integral in the uvw-space.

$\int_{\square}^{\square}\int_{\square}^{\square}\int_{\square}^{\square}(\square)\,dwdudv$

(Type exact answers.)

Evaluate the integral.

$\iiint_D z\,dV = \square$

(Type an exact answer. Use integers or fractions for any numbers in the expression.)

Answers
- 0
- 2π
- 0
- 1
- 0
- $81 - 81u^2$
- $27uw$
- $\frac{59{,}049\pi}{2}$

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7. Let D be the solid bounded by the ellipsoid $\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1$, where $a>0$, $b>0$, and $c>0$ are real numbers. Let T be the transformation $x=au$, $y=bv$, $z=cw$. Find the average square of the distance between points of D and the origin.

Perform the change of variables and write the new integral in the uvw-space.

$\int_{\square}^{\square}\int_{\square}^{\square}\int_{\square}^{\square}(\square)\,dwdvdu$

(Type exact answers.)

The average square of the distance between points of D and the origin is $\square$.

Answers
- -1
- 1
- $-\sqrt{1-u^2}$
- $\sqrt{1-u^2}$
- $-\sqrt{1-u^2-v^2}$
- $\sqrt{1-u^2-v^2}$
- $\frac{3}{4\pi}(a^2u^2+b^2v^2+c^2w^2)$
- $\frac{a^2+b^2+c^2}{5}$

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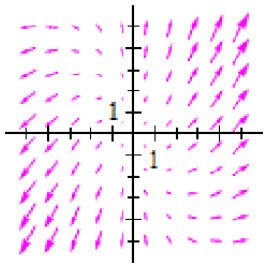
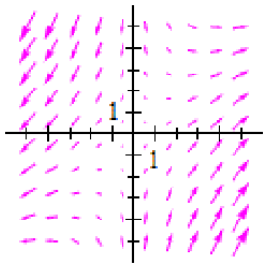
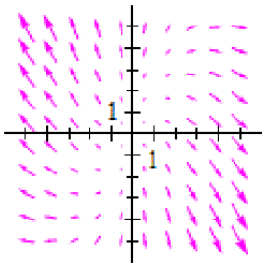
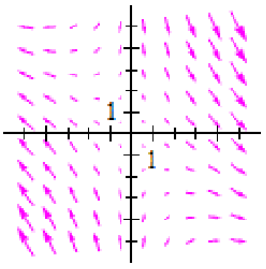
1. Sketch the vector field $\mathbf{F} = \langle 6x, 5y - 6x \rangle$.

Choose the correct answer below.

A. 

B. 

C. 

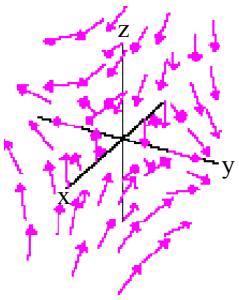
D. 

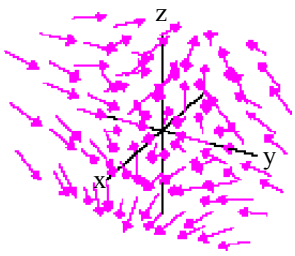
Answer: C

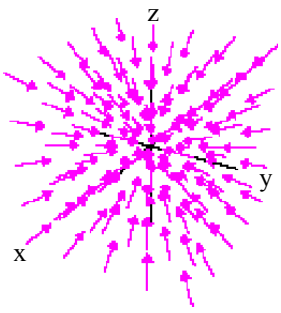
2. Sketch a few representative vectors of the following vector field.

$$\mathbf{F} = \frac{\langle -x, -y, -z \rangle}{\sqrt{x^2 + y^2 + z^2}}$$

Choose the correct vector field below.

A. 

B. 

C. 

Answer: C

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3. Find the gradient field $\mathbf{F} = \nabla\varphi$ of the potential function $\varphi(x,y,z) = (x^2 + 3y^2 + 2z^2)^{-1/2}$.

$\nabla\varphi = \langle \square, \square, \square \rangle$.

Answers $-x(x^2 + 3y^2 + 2z^2)^{-\frac{3}{2}}$

$-3y(x^2 + 3y^2 + 2z^2)^{-\frac{3}{2}}$

$-2z(x^2 + 3y^2 + 2z^2)^{-\frac{3}{2}}$

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4. The electric field in the xy-plane due to an infinite line of charge along the z-axis is a gradient field with a potential function $V(x,y) = c\ \mathbf{ln}\left(\frac{r_0}{\sqrt{x^2+y^2}}\right)$, where $c > 0$ is a constant and r_0 is a reference distance at which the potential is assumed to be 0. Use this information to answer parts **a** through **c**.

a. Find the components of the electric field in the x- and y-directions, where $\mathbf{E}(x,y) = -\nabla V(x,y)$. Choose the correct answer below.

A. $\mathbf{E} = \frac{c}{x^2+y^2}\langle x,y\rangle$

B. $\mathbf{E} = \frac{c}{r_0(x^2+y^2)}\langle x,y\rangle$

C. $\mathbf{E} = \frac{c}{\sqrt{x^2+y^2}}\langle x,y\rangle$

D. $\mathbf{E} = \frac{cr_0}{\sqrt{x^2+y^2}}\langle x,y\rangle$

b. Show that the electric field at a point in the xy-plane is directed outward from the origin and has magnitude $|\mathbf{E}| = \frac{c}{r}$, where $r = \sqrt{x^2+y^2}$. Rewrite **E** in terms of **r**. Choose the correct answer below.

A. $\mathbf{E} = \frac{cr_0}{|\mathbf{r}|^2}$

B. $\mathbf{E} = \frac{c}{r_0|\mathbf{r}|}\mathbf{r}$

C. $\mathbf{E} = \frac{c}{|\mathbf{r}|}\mathbf{r}$

D. $\mathbf{E} = \frac{c}{|\mathbf{r}|^2}\mathbf{r}$

Rewrite **E** again. Choose the correct answer below.

4. (cont.)

A. $\mathbf{E} = \frac{c}{|\mathbf{r}|}\frac{|\mathbf{r}|}{\mathbf{r}}$

B. $\mathbf{E} = \frac{c}{r_0}\frac{\mathbf{r}}{|\mathbf{r}|}$

C. $\mathbf{E} = \frac{c\mathbf{r}}{|\mathbf{r}|}\frac{r_0}{|\mathbf{r}|}$

D. $\mathbf{E} = \frac{c}{|\mathbf{r}|}\frac{\mathbf{r}}{|\mathbf{r}|}$

Therefore, by definition, the electric field has magnitude $|\mathbf{E}| = \frac{c}{r}$.

c. Show that the vector field is orthogonal to the equipotential curves at all points in the domain of V. Plot the equipotential curves of V. What are the resulting shapes?

- Ellipses
- Parabolas
- Hyperbolas
- Circles

What is a vector **t** that is always tangent to this shape?

A. $\mathbf{t} = \langle -x, y \rangle$

B. $\mathbf{t} = \langle -x, -y \rangle$

C. $\mathbf{t} = \langle -y, -x \rangle$

D. $\mathbf{t} = \langle -y, x \rangle$

Find the dot product of **E** and **t**. What is the result?

☐ (Simplify your answer.)

Therefore, by definition, the vector field is orthogonal to the equipotential curves at all points in the domain of V.

4. (cont.)

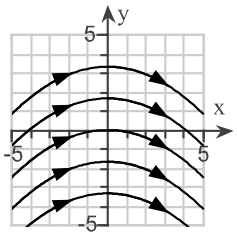
Answers
A
D
D
Circles
D
0

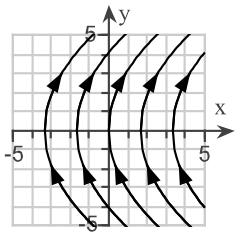
5. Let $\mathbf{F}(x,y) = \langle f(x,y), g(x,y) \rangle$ be defined on $\mathbf{R}^2$. Find and graph the streamlines for the vector field $\mathbf{F} = \langle y, 5 \rangle$.

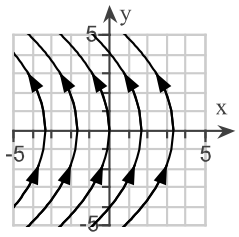
What is the equation that gives the streamlines of the vector field?

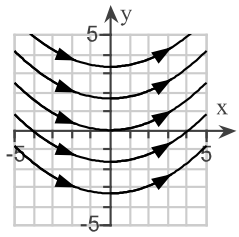
- $y = \sqrt{10x + C}$
- $y = \frac{x^2}{10} + C$
- $y = -\frac{x^2}{10} + C$
- $y = \sqrt{-10x + C}$

Choose the correct graph below.

A. 

B. 

C. 

D. 

Answers
$y = \sqrt{10x + C}$
B

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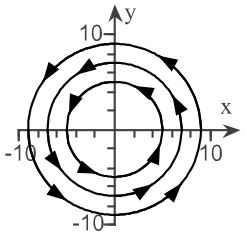
6. Let $\mathbf{F}(x,y) = \langle f(x,y), g(x,y) \rangle$ be defined on $\mathbf{R}^2$. Find and graph the streamlines for the vector field $\mathbf{F} = \langle -2y, 2x \rangle$.

What is the equation that gives the streamlines of the vector field?

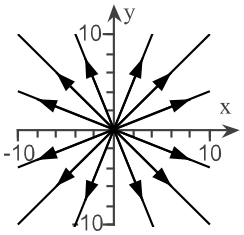
- $y = \sqrt{2x + C}$
- $y = \sqrt{\frac{x^2}{4} + C}$
- $C = \frac{x^2}{4} + \frac{y^2}{2}$
- $C = x^2 + y^2$

Choose the correct graph below.

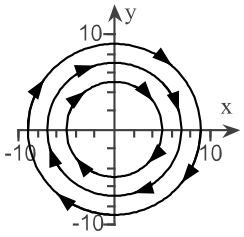
A.



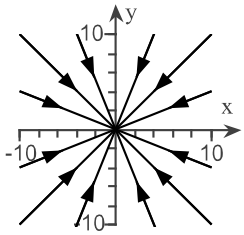
B.



C.



D.



Answers $C = x^2 + y^2$

A

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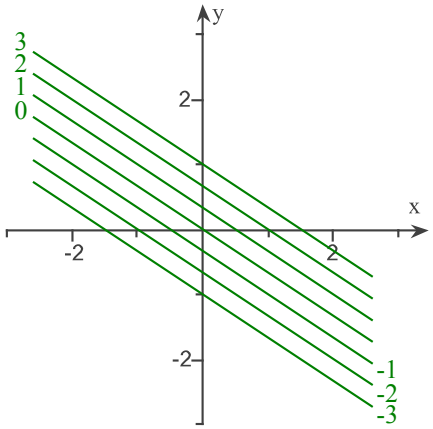
7. Consider the following potential function and the graph of its equipotential curves to the right. Then answer parts **a** through **d**.

$\varphi(x,y) = 2x + 3y$



a. Find the associated gradient field $\mathbf{F} = \nabla\varphi$.

$\mathbf{F} = \langle \square, \square \rangle$

b. Show that the vector field is orthogonal to the curve at the point (1,1). What is the slope of the equipotential curve at any point?

- A. $\frac{dy}{dx} = -\frac{2}{3}$
- B. $\frac{dy}{dx} = \frac{3}{2}$
- C. $\frac{dy}{dx} = -\frac{3}{2}$
- D. $\frac{dy}{dx} = \frac{2}{3}$

What is the vector tangent to the curve at the point (1,1)?

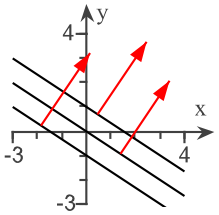
- A. $\left\langle \frac{2}{3}, 1 \right\rangle$
- B. $\langle -1, -1 \rangle$
- C. $\left\langle 1, -\frac{3}{2} \right\rangle$
- D. $\left\langle 1, -\frac{2}{3} \right\rangle$

Find $\mathbf{F}(1,1)$.

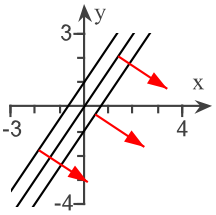
$\mathbf{F}(1,1) = \langle \square, \square \rangle$

d. Sketch two flow curves representing **F** that are everywhere orthogonal to the equipotential curves. Choose the correct graph below.

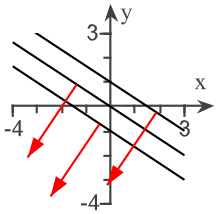
A.



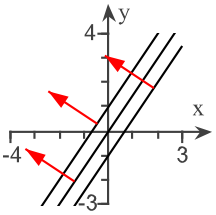
B.



C.



D.



7. (cont.)

Find the dot product of the vector tangent to the curve and gradient vector at (1,1). What is the result?

□

c. Show that the vector field is orthogonal to the equipotential curve at all points (x,y). In general, what vector is parallel to the line tangent to the curve at (x,y)?

- A. $\langle -y,x \rangle$
- B. $\langle 2,-3 \rangle$
- C. $\langle x,-y \rangle$
- D. $\left\langle 1,-\frac{2}{3} \right\rangle$

What is the vector field at the point (x,y)?

⟨□,□⟩

Find the dot product of the vector tangent to the curve and gradient vector at (x,y). What is the result?

□

Answers
2
3
A
D
2
3
0
D

7. (cont.)

2

3

0

A

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8. The electric field in the xy-plane due to an infinite line of charge along the z-axis is a gradient field with a potential function $V(x,y) = c\ \mathbf{ln}\left(\frac{r_0}{\sqrt{x^2+y^2}}\right)$, where $c > 0$ is a constant and r_0 is a reference distance at which the potential is assumed to be 0. Use this information to answer parts **a** through **c**.

a. Find the components of the electric field in the x- and y-directions, where $\mathbf{E}(x,y) = -\nabla V(x,y)$. Choose the correct answer below.

A. $\mathbf{E} = \frac{c}{\sqrt{x^2+y^2}}\langle x,y\rangle$

B. $\mathbf{E} = \frac{c}{x^2+y^2}\langle x,y\rangle$

C. $\mathbf{E} = \frac{cr_0}{\sqrt{x^2+y^2}}\langle x,y\rangle$

D. $\mathbf{E} = \frac{c}{r_0(x^2+y^2)}\langle x,y\rangle$

b. Show that the electric field at a point in the xy-plane is directed outward from the origin and has magnitude $|\mathbf{E}| = \frac{c}{r}$, where $r = \sqrt{x^2+y^2}$. Rewrite **E** in terms of **r**. Choose the correct answer below.

A. $\mathbf{E} = \frac{c}{|\mathbf{r}|^2}\mathbf{r}$

B. $\mathbf{E} = \frac{c}{r_0|\mathbf{r}|}\mathbf{r}$

C. $\mathbf{E} = \frac{cr_0}{|\mathbf{r}|^2}$

D. $\mathbf{E} = \frac{c}{|\mathbf{r}|}\mathbf{r}$

Rewrite **E** again. Choose the correct answer below.

8. (cont.)

A. $\mathbf{E} = \frac{c}{r_0}\frac{\mathbf{r}}{|\mathbf{r}|}$

B. $\mathbf{E} = \frac{c\mathbf{r}}{|\mathbf{r}|}\frac{r_0}{|\mathbf{r}|}$

C. $\mathbf{E} = \frac{c}{|\mathbf{r}|}\frac{\mathbf{r}}{|\mathbf{r}|}$

D. $\mathbf{E} = \frac{c}{|\mathbf{r}|}\frac{|\mathbf{r}|}{\mathbf{r}}$

Therefore, by definition, the electric field has magnitude $|\mathbf{E}| = \frac{c}{r}$.

c. Show that the vector field is orthogonal to the equipotential curves at all points in the domain of V. Plot the equipotential curves of V. What are the resulting shapes?

- Parabolas
- Hyperbolas
- Ellipses
- Circles

What is a vector **t** that is always tangent to this shape?

A. $\mathbf{t} = \langle -x, -y \rangle$

B. $\mathbf{t} = \langle -x, y \rangle$

C. $\mathbf{t} = \langle -y, -x \rangle$

D. $\mathbf{t} = \langle -y, x \rangle$

Find the dot product of **E** and **t**. What is the result?

☐ (Simplify your answer.)

Therefore, by definition, the vector field is orthogonal to the equipotential curves at all points in the domain of V.

8. (cont.)

Answers

B

A

C

Circles

D

0

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1. Find the average value of $f(x,y) = \sqrt{4 + 9y^{2/3}}$ on the curve $y = x^{3/2}$, for $0 \le x \le 5$.

The average value is $\square$.

Answer: $\dfrac{1431}{268}$

2. Given the following vector field and oriented curve C, evaluate $\int_C \mathbf{F} \cdot \mathbf{T}\, ds$.

$\mathbf{F} = \langle -y, x \rangle$ on the semicircle $\mathbf{r}(t) = \langle 7\cos t, 7\sin t \rangle$, for $0 \le t \le \pi$

$\int_C \mathbf{F} \cdot \mathbf{T}\, ds = \square$

(Type an exact answer, using π as needed.)

Answer: 49π

3. Given the following vector field and orientated curve C, evaluate $\int_C \mathbf{F} \cdot \mathbf{T}\, ds$.

$\mathbf{F} = \dfrac{\langle x,y \rangle}{(x^2+y^2)^{3/2}}$ on the curve $\mathbf{r}(t) = \langle 2t^2, 3t^2 \rangle$, for $1 \le t \le 3$

The value of the line integral of $\mathbf{F}$ over C is $\square$.

(Type an exact answer, using radicals as needed.)

Answer: $\dfrac{8}{9\sqrt{13}}$

4. Given the force field $\mathbf{F} = \dfrac{\langle x,y,z \rangle}{x^2+y^2+z^2}$, find the work required to move an object on the line segment from $(3,3,1)$ to $(15,15,5)$.

The work required is $\square$.

(Type an exact answer.)

Answer: $\ln 5$

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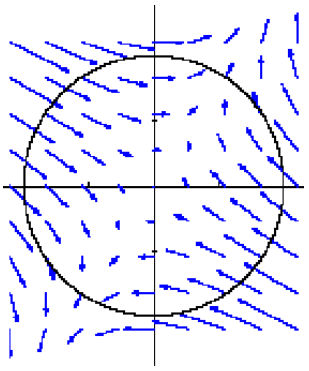
5. Consider the vector field $\mathbf{F} = \langle y - x, x \rangle$ and curve C: $\mathbf{r}(t) = \langle 9\cos t, 9\sin t \rangle$ for $0 \le t \le 2\pi$.

a. Based on the picture, make a conjecture about whether the outward flux of **F** across C is positive, negative, or zero.

b. Compute the flux for the vector field and curve.



a. Complete the sentence below.

The number and average length of the vectors crossing the boundary and pointing inward seem to be [greater than / less than / about the same as] the number and average length of the vectors crossing the boundary and pointing outward. That means the outward flux should be [negative. / positive. / zero.]

b. The outward flux is [ ].

(Type an exact answer, using π as needed.)

Answers greater than

negative.

-81π

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6. For what values of b and c does the vector field $\mathbf{F} = \langle by, cx \rangle$ have zero circulation on the unit circle centered at the origin and oriented counterclockwise?

Choose the correct answer below.

- ○ A. The circulation is zero as long as $b + c = 0$.
- ○ B. The circulation is zero as long as $b - c = 0$.
- ○ C. The circulation is only zero when $b = c = 0$.
- ○ D. The circulation is zero for all real values of b and c.
- ○ E. There are no real values of b and c for which the circulation is zero.

Answer: B

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7.

Consider the radial field $\mathbf{F} = \dfrac{\mathbf{r}}{|\mathbf{r}|^p} = \dfrac{\langle x,y,z\rangle}{|\mathbf{r}|^p}$, where $p > 1$ (the inverse square law corresponds to $p = 3$). Let C be the line from (1,1,1) to (a,a,a), where $a > 1$, given by $\mathbf{r}(t) = \langle t,t,t\rangle$, for $1 \le t \le a$.

a. Find the work done in moving an object along C with $p = 2$. Write $|\mathbf{r}|$ in terms of the parameter t.

$|\mathbf{r}| =$ ☐

Then use this result, $\mathbf{r}(t) = \langle t,t,t\rangle$, and $p = 2$ to write the vector field in terms of t.

$\mathbf{F} =$ (☐) $\langle 1,1,1\rangle$

Use these results to write the work integral in terms of t.

$W = \int_1^a$ (☐) dt

Evaluate this integral.

$W =$ ☐

b. If $a \to \infty$ in part (a), is the work finite?

- ○ No
- ○ Yes

c. Find the work done in moving an object along C with $p = 4$. Use the same process as part a to write the work integral in terms of t.

$W = \int_1^a$ (☐) dt

Evaluate this integral.

$W =$ ☐

d. If $a \to \infty$ in part (c), is the work finite?

7. (cont.)

○ No

○ Yes

e. Find the work done in moving an object along C for any $p > 1$, where $p \neq 2$. Use the expression for $|\mathbf{r}|$, $\mathbf{r}(t) = \langle t,t,t \rangle$, and $\mathbf{F} = \dfrac{\mathbf{r}}{|\mathbf{r}|^p}$ to write the vector field in terms of t.

$\mathbf{F} = (\square)\ \langle 1,1,1 \rangle$

Then write the work integral in terms of t.

$W = \int_1^a (\square)\ dt$

Evaluate this integral for $p \neq 2$.

$W = \square$

f. If $a \to \infty$ in part (e), for what values of p is the work finite?

○A. The work is finite for $p <$ ■

○B. The work is finite for $p >$ ■

Answers $t\sqrt{3}$

$\dfrac{1}{3t}$

$\dfrac{1}{t}$

ln a

No

$\dfrac{1}{3t^3}$

$\dfrac{1}{6} - \dfrac{1}{6a^2}$

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7. (cont.)

Yes

$$\frac{1}{t^{p-1}\sqrt{3^p}}$$

$$\frac{1}{t^{p-1}\sqrt{3^{p-2}}}$$

$$\frac{1}{(2-p)\sqrt{3^{p-2}}}(a^{2-p}-1)$$

B, 2

8. The area of a region R in the plane, whose boundary is the curve C, may be computed using line integrals with the following formula.

$$\text{area of } R = \int_C x\,dy = -\int_C y\,dx$$

Let R be the rectangle with vertices (0,0), (a,0), (0,b), (a,b) and let C be the boundary of R oriented counterclockwise. Compute the area of R using the formula $A = \int_C x\,dy$.

$\int_C x\,dy =$ ☐ (Simplify your answer.)

Answer: ab

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1. Find the volume of the region bounded by the coordinate planes and the planes $z = x + y$ and $z = 8$.

A. $\frac{512}{3}$

B. 128

C. 256

D. $\frac{256}{3}$

Answer: D

2. Evaluate the integral by changing the order of integration in an appropriate way.

$$\int_0^5 \int_y^5 \int_0^{\pi} \frac{\sin z \sin x}{x} \, dz \, dx \, dy$$

A. $2(1 - \cos 5)$

B. $2(1 + \sin 5)$

C. $2 \sin 5$

D. $2 \cos 5$

Answer: A

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3. Evaluate the integral by changing the order of integration in an appropriate way.

$$\int_0^8 \int_0^5 \int_{\sqrt[3]{x}}^2 \frac{z}{y^4 + 1}\, dy\, dz\, dx$$

A. $\frac{25}{4} \ln 9$

B. $\frac{25}{8} \ln 17$

C. $\frac{25}{8} \ln 9$

D. $\frac{25}{4} \ln 17$

Answer: B

4. Find the average value of $F(x,y,z) = xyz$ over the rectangular solid in the first octant bounded by the coordinate planes and the planes $x = 3$, $y = 7$, and $z = 9$.

A. $\frac{189}{16}$

B. $\frac{63}{4}$

C. $\frac{189}{8}$

D. $\frac{21}{2}$

Answer: C

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5. Find the average value of $F(x,y,z) = x^2 + y^2 + z^2$ over the rectangular solid in the first octant bounded by the coordinate planes and the planes $x = 6$, $y = 4$, and $z = 2$.

A. $\frac{88}{3}$

B. $\frac{128}{3}$

C. $\frac{56}{3}$

D. $\frac{64}{3}$

Answer: C

6. Evaluate the cylindrical coordinate integral.

$$\int_0^{\pi/2} \int_3^6 \int_{1/r^2}^{1/r} \cos\theta \, dz \, r \, dr \, d\theta$$

A. $3\pi + \ln 2$

B. $6 - \ln 2$

C. $3 - \ln 2$

D. $6\pi + \ln 2$

Answer: C

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7. Use cylindrical coordinates to find the volume of the region bounded below by the xy-plane, laterally by the cylinder $r = 7\cos\theta$, and above by the plane $z = 10$.

A. $\frac{245}{2}\pi$

B. 1225π

C. 175π

D. $\frac{35}{2}\pi$

Answer: A

8. Use cylindrical coordinates to find the volume of the region bounded by the cylinders $r = 4$ and $r = 7$, and the planes $z = 8$ and $z = 9$.

A. 33π

B. 66π

C. 99π

D. 132π

Answer: A

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9. Change the order of integration and evaluate the integral.

$$\int_3^6 \int_0^{\pi/2} \int_0^{\pi/2} \rho \sin\phi \, d\theta \, d\phi \, d\rho$$

A. $\frac{27}{4}\pi$

B. $\frac{27}{4}$

C. $\frac{9}{2}$

D. $\frac{9}{2}\pi$

Answer: A

10. Change the order of integration and evaluate the integral.

$$\int_0^{\pi/2} \int_4^6 \int_0^{\pi/2} \rho^3 \sin\phi \, d\phi \, d\rho \, d\theta$$

A. $\frac{520}{3}\pi$

B. $\frac{1040}{9}\pi$

C. 130π

D. 260π

Answer: C

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11. Use the given transformation to evaluate the integral.

$u = x + y,\ v = -2x + y;$

$$\iint_R -3y\ dx\ dy,$$

where R is the parallelogram bounded by the lines $y = -x + 1,\ y = -x + 4,\ y = 2x + 2,\ y = 2x + 5$

A. $-\frac{51}{2}$

B. $-\frac{51}{4}$

C. $-\frac{39}{2}$

D. $-\frac{39}{4}$

Answer: A

12. Use the given transformation to evaluate the integral.

$u = -9x + y,\ v = 7x + y;$

$$\iint_R (7x + y)\ dx\ dy,$$

where R is the parallelogram bounded by the lines $y = 9x + 2,\ y = 9x + 8,\ y = -7x + 3,$ $y = -7x + 9$

A. $\frac{27}{2}$

B. 6,912

C. 27

D. 3456

Answer: A

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13. Use the given transformation to evaluate the integral.

$x = 6u,\ y = 2v,\ z = 7w;$

$$\iiint_R \left(\frac{x^2}{36} + \frac{y^2}{4} + \frac{z^2}{49}\right)^{\pi} dx\, dy\, dz,$$

where R is the interior of the ellipsoid $\frac{x^2}{36} + \frac{y^2}{4} + \frac{z^2}{49} = 1$

A. $\frac{168\pi}{\pi + 1}$

B. $\frac{336\pi}{\pi + 2}$

C. $\frac{336\pi}{\pi + 1}$

D. $\frac{336\pi}{\pi + 3}$

Answer: D

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14. Use the given transformation to evaluate the integral.

$x = 9u,\ y = 6v,\ z = 8w;$

$$\iiint_R x^2y^2z^2\ dx\ dy\ dz,$$

where R is the interior of the ellipsoid $\frac{x^2}{81} + \frac{y^2}{36} + \frac{z^2}{64} = 1$

A. $\frac{32}{35}\pi$

B. $\frac{288}{35}\pi$

C. $\frac{64}{35}\pi$

D. $\frac{576}{35}\pi$

Answer: C

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15. Use the given transformation to evaluate the integral.

$u = 2x + y - z,\ v = -x + y + z,\ w = -x + y + 2z$

$\iiint_R (2x + y - z)\ dx\ dy\ dz,$

where R is the parallelepiped bounded by the planes $2x + y - z = 2$, $2x + y - z = 9, -x + y + z = 5, -x + y + z = 7, -x + y + 2z = 9, -x + y + 2z = 10$

A. $\frac{77}{3}$

B. $\frac{308}{3}$

C. 231

D. $\frac{77}{2}$

Answer: A

16. Find the gradient field **F** of the function f.

$f(x,y,z) = \frac{xz + xy + yz}{xyz}$

A. $\mathbf{F} = -\frac{1}{x^2yz}\mathbf{i} - \frac{1}{xy^2z}\mathbf{j} - \frac{1}{xyz^2}\mathbf{k}$

B. $\mathbf{F} = \frac{1}{x^2yz}\mathbf{i} + \frac{1}{xy^2z}\mathbf{j} + \frac{1}{xyz^2}\mathbf{k}$

C. $\mathbf{F} = \frac{1}{x^2}\mathbf{i} + \frac{1}{y^2}\mathbf{j} + \frac{1}{z^2}\mathbf{k}$

D. $\mathbf{F} = -\frac{1}{x^2}\mathbf{i} - \frac{1}{y^2}\mathbf{j} - \frac{1}{z^2}\mathbf{k}$

Answer: D

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17. Find the gradient field **F** of the function f.

$$f(x,y,z) = \ln\left(\frac{(x+y)^4}{z^3}\right) + z^4$$

A. $\mathbf{F} = \frac{4}{x+y}\mathbf{i} + \frac{4}{x+y}\mathbf{j} + \left(4z^3 + \frac{3}{z}\right)\mathbf{k}$

B. $\mathbf{F} = \frac{4}{x+y}\mathbf{i} + \frac{4}{x+y}\mathbf{j} + \left(4z^3 - \frac{3}{z}\right)\mathbf{k}$

C. $\mathbf{F} = \frac{4}{x}\mathbf{i} + \frac{4}{y}\mathbf{j} + \left(4z^3 - \frac{3}{z}\right)\mathbf{k}$

D. $\mathbf{F} = \frac{4}{x}\mathbf{i} + \frac{4}{y}\mathbf{j} + \left(4z^3 + \frac{3}{z}\right)\mathbf{k}$

Answer: B

18. Find the gradient field **F** of the function f.

$$f(x,y,z) = \left(\frac{x+y}{y+z}\right)^5$$

A. $\mathbf{F} = \frac{5(x+y)^4}{(y+z)^5}\mathbf{i} + \frac{5(x+y)^4(z-x)}{(y+z)^6}\mathbf{j} - 5\frac{(x+y)^5}{(y+z)^6}\mathbf{k}$

B. $\mathbf{F} = 5\left(\frac{x+y}{y+z}\right)^4\mathbf{i} + \frac{5(x+y)^4(z+x)}{(y+z)^6}\mathbf{j} + 5\frac{(x+y)^5}{(y+z)^6}\mathbf{k}$

C. $\mathbf{F} = 5\left(\frac{x+y}{y+z}\right)^4\mathbf{i} + \frac{5(x+y)^4(z-x)}{(y+z)^6}\mathbf{j} + 5\frac{(x+y)^5}{(y+z)^6}\mathbf{k}$

D. $\mathbf{F} = 5\left(\frac{x+y}{y+z}\right)^4\mathbf{i} + \frac{5(x+y)^4(z+x)}{(y+z)^6}\mathbf{j} - 5\frac{(x+y)^5}{(y+z)^6}\mathbf{k}$

Answer: A

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19. Find the work done by **F** over the curve C in the direction of increasing t.

$$\mathbf{F} = -\frac{1}{16x^2}\mathbf{i} + \frac{7z}{4x}\mathbf{j} + \frac{1}{112x^2}\mathbf{k};\ C:\ \mathbf{r}(t) = \frac{\cos 4t}{4}\mathbf{i} + \frac{\sin 4t}{4}\mathbf{j} + 7t\mathbf{k},\ 0 \le t \le \frac{\pi}{16}$$

A. $W = \frac{\sqrt{2}}{4} + \frac{49}{256}\pi^2$

B. $W = \frac{\sqrt{2}}{4} + \frac{49}{512}\pi^2$

C. $W = \frac{\sqrt{2}+2}{4} + \frac{49}{512}\pi^2$

D. $W = \frac{\sqrt{2}}{8} + \frac{49}{512}\pi^2$

Answer: B

20. Calculate the circulation of the field **F** around the closed curve C.

$\mathbf{F} = xy\mathbf{i} + 4\mathbf{j}$, curve C is $\mathbf{r}(t) = 3\cos t\mathbf{i} + 3\sin t\mathbf{j},\ 0 \le t \le 2\pi$

A. 2

B. 14

C. 8

D. 0

Answer: D

Student: _____ **Date:** _____ **Time:** _____	**Instructor:** Hoi Nguyen **Course:** AU14 MATH 2173 - ENG MATH B (20686) COL **Book:** Ohio State University: Calculus: Early Transcendentals, Second Custom Edition	**Assignment:** Further practice problems for Midterm #2

21. Calculate the circulation of the field **F** around the closed curve C.

F = $(-x-y)\mathbf{i} + (x+y)\mathbf{j}$, curve C is the counterclockwise path around the circle with radius 10 centered at $(10,4)$

A. 200π

B. $200(1+\pi)+560$

C. $200(1+\pi)$

D. 400π

Answer: A

22. Calculate the flux of the field **F** across the closed plane curve C.

F = $x\mathbf{i} + y\mathbf{j}$; the curve C is the counterclockwise path around the circle $x^2 + y^2 = 144$

A. 0

B. 288π

C. 576π

D. 24π

Answer: B

23. Calculate the flux of the field **F** across the closed plane curve C.

F = $(x+y)\mathbf{i} + xy\mathbf{j}$; the curve C is the closed counterclockwise path around the rectangle with vertices at $(0,0)$, $(4,0)$, $(4,4)$, and $(0,4)$

A. 0

B. 80

C. 64

D. 48

Answer: D

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24. Find the mass of the wire that lies along the curve r and has density δ.

$\mathbf{r}(t) = \left(\frac{\sqrt{7}}{2}t^2 - 4\right)\mathbf{i} + 3t\mathbf{j},\ 0 \le t \le 1;\ \ \delta = 5t$

A. $\frac{185}{14}$ units

B. $\frac{5}{2}$ units

C. $\frac{185}{21}$ units

D. $\frac{65}{3}$ units

Answer: C

25. Find the mass of the wire that lies along the curve r and has density δ.

$\mathbf{r}(t) = (3\ \mathbf{cos}\ t)\mathbf{i} + (3\ \mathbf{sin}\ t)\mathbf{j} + 3t\mathbf{k},\ 0 \le t \le 2\pi;\ \ \delta = 6$

A. $6\pi\sqrt{2}$ units

B. $36\pi\sqrt{2}$ units

C. $108\pi\sqrt{2}$ units

D. 12π units

Answer: B