Mathematical Analysis II, Department of Economics
academic year 2018/19, summer semester, D – solutions
Colloquium I, April 4, 2019

1. Calculate the indefinite integral $\int \frac{1}{(2x+1)x^2}\,dx$. **answer:**..

$$\int \frac{1}{(2x+1)x^2}\,dx = \int \left(\frac{4}{2x+1} - \frac{2}{x} + \frac{1}{x^2}\right) dx = 2\ln|2x+1| - 2\ln|x| - \frac{1}{x} + C.$$

2. Calculate the definite integral $\int\limits_1^e x^{-1}\cos(\ln(x))\,dx$. **answer:**..

$$\int\limits_1^e x^{-1}\cos(\ln(x))\,dx = \in_0^1 \cos t\,dt = \sin t|_0^1 = \sin 1$$

3. Calculate the improper integral $\int\limits_0^\infty x^2 e^{-x}\,dx$. **answer:**..

By parts you can get that:

$$\int x^2 e^{-x}\,dx = -e^{-x}(x^2+2x+2) + C,$$

so

$$\int\limits_0^\infty x^2 e^{-x}\,dx = \lim_{b\to\infty}(-e^{-x}(x^2+2x+2))|_0^b = \lim_{b\to\infty}\frac{-(b^2+2b+2)}{e^b} + 2 = 0 + 2 = 2.$$

4. Is the set $\{(x,y) \in \mathbb{R}^2 : x^2+y^2 \leqslant 1,\ |x| > 1/2\}$:

open	**Yes/No**: ....
closed	**Yes/No**: ....
bounded	**Yes/No**: ....
compact	**Yes/No**: ....
connected	**Yes/No**: ....
convex	**Yes/No**: ....

It is two parts of the unit circle split by vertical lines $x = \pm 1/2$ (on the left of the left line, and on the right of the right one), without the lines but with the pieces of the circle. Thus it is bounded, but neither closed nor compact nor open nor connected nor convex.

5. Find the following limit or state that it does not exist:

$$\lim_{n\to\infty}\left(\frac{\ln 3n}{n},\ \sqrt[3n]{n},\ \left(1+\frac{1}{n}\right)^{3n}\right),$$

answer: ....

The limit is $(0,1,e^3)$.

6. Find the following limit or state that it does not exist:

$$\lim_{(x,y)\to(0,0)}\frac{xy^2}{x^2+y^4}$$

answer: ....

It does not exist. For $x=0, y=1/n$ we get 0, and for $x=1/n, y=1/n^2$, we get 1/2.

7. Determine whether the function $f:\mathbb{R}^2\to\mathbb{R}$,

$$f(x,y)=\begin{cases}(x^2+y^2)^2\text{arctan}\left(\dfrac{1}{x^2+y^2}\right) & \text{for } (x,y)\neq(0,0)\\ 1 & \text{for } (x,y)=(0,0)\end{cases}$$

is continuous. **Yes/No:**....................

For $r=\sqrt{x^2+y^2}$ we get

$$\lim_{(x,y)\to(0,0)}(x^2+y^2)^2\text{arctan}\left(\frac{1}{x^2+y^2}\right)=\lim_{r\to 0}\frac{\text{arctan}\,1/r^2}{1/r^4}=\lim_{r\to 0}\frac{-4\frac{1}{r^5}\cdot\frac{1}{1/r^4+1}}{-2\frac{1}{r^3}}=0,$$

so it is not continuous.

8. Let $f:\mathbb{R}^3\to\mathbb{R}$ be the function given by the formula

$$f(x,y,z)=ln(2x^2-2x+2zy+z^2-2z+1).$$

Which unit vector v gives the direction of maximum rate of increase of f at the point $(0,0,0)$?

answer: ....

$$f'(x,y,z)=$$
$$\left[(2x-2)/(2x^2+2zy+z^2+1), 2z/(2x^2+2zy+z^2+1), (2y+2z-2)/(2x^2+2zy+z^2+1)\right],$$
$$f'(0,0,0)=[-2,0,-2],$$
$$v=\frac{[-2,0,-2]}{\sqrt{8}}.$$

9. Let f : be the function described in question 8. Give the value of the directional derivative

$$\frac{\partial f}{\partial v}(0,0,0)$$

where $v = (1, 2, 3)$.

answer: ....

$$\langle(-2, 0, -2), (1, 2, 3)\rangle = -8.$$

10. Let (u, v) denote coordinates on $\mathbb{R}^2$ and let $f : \mathbb{R}^2 \to \mathbb{R}$ be a function described in the coordinates (u, v). If $g(x, y) = f(2x - y, x + y)$, then find A and B such that

$$\frac{\partial g}{\partial x}(x, y) - \frac{\partial g}{\partial y}(x, y) = A\frac{\partial f}{\partial u}(u, v) + B\frac{\partial f}{\partial v}(u, v).$$

Hint: Compute $\frac{\partial g}{\partial x}$ and $\frac{\partial g}{\partial y}$ using the chain rule.

answer: ....

$$h(x, y) = (2x - y, x + y),$$

so

$$h' = \begin{bmatrix} 2 & -1 \\ 1 & 1 \end{bmatrix},$$

so

$$g' = \left[2\frac{\partial f}{\partial u} + \frac{\partial f}{\partial v}, -\frac{\partial f}{\partial u} + \frac{\partial f}{\partial v}\right].$$

Thus,

$$\frac{\partial g}{\partial x}(x, y) - \frac{\partial g}{\partial y}(x, y) = 2\frac{\partial f}{\partial u} + \frac{\partial f}{\partial v} - \left(-\frac{\partial f}{\partial u} + \frac{\partial f}{\partial v}\right) = 3\frac{\partial f}{\partial u}.$$

Thus, $A = 3, B = 0$.