TEACHING INSTRUCTIONAL DESIGN (BRP)

COURSE

MATHEMATICAL METHODS IN PHYSICS 1

Dr. Budhy Kurniawan
Dr. Vivi Fauzia, M.Si.

Undergraduate Program in Physics
Faculty of Mathamatics and Natural Sciences
Universitas Indonesia
Depok
May 2016

PREFACE

Teaching Instructional Design (BRP) of Mathematical Methods in Physics 1 course is the first part systematic teaching design from two sequential courses, Mathematical Methods in Physics 1 and Mathematical Methods in Physics 2. This course is held on Semester 3 with Basic Mathematics 2 as its prerequisite course. On this course, students will learn about the vector analysis, ordinary differential equations, partial differential equations, coordinate transformation and tensor analysis. We hope this BRP can be a reference of learning process for lecturers and students so the contents of this course can be delivered appropriately.

Depok, May 2016

Dr. Budhy Kurniawan
Dr. Vivi Fauzia, M.Si.

I. General Information

1.	Name of Program / Study Level	:	Physics / Undergraduate
2.	Course Name	:	Mathematical Methods in Physics 1
3.	Course Code	:	SCFI602211
4.	Semester	:	3
5.	Credit	:	3 credits
6.	Teaching Method(s)	:	Cooperative and Self-Direct Learning
7.	Prerequisite course(s)	:	Basic Mathematics 2
8.	Requisite for course(s)	:	Mathematical Methods in Physics 3, Physics of Energy
9.	Integration Between Other Courses	:	None
10.	Lecturer(s)	:	1. Dr. Budhy Kurniawan 2. Dr. Vivi Fauzia, M.Si.
11.	Course Description	:	On this course students learn about the vector analysis, ordinary differential equations, partial differential equations, coordinate transformation and tensor analysis

II. Course Learning Outcome (CLO) and Sub-CLOs

A. CLO

Students are able to apply the concepts of mathematics in the form of vector analysis, coordinate system and coordinate transformation, ordinary differential equations, partial differential equations and tensor analysis in solving basic physics problems. (ELOs 1, 2, 6)

B. Sub-CLOs

1. To explain the concept of vector analysis (C2)
2. To calculate of vector operation, differential and integral of vector (C3)
3. To implement the concept of vector analysis for solving physical problems (C3)
4. To describe the concept of coordinate system and coordinate transformation (C2)
5. To calculate coordinate, curvilinear coordinates and differential operators on curvilinear coordinates (C3)
6. To implement (C3) the concept of coordinate system and coordinate transformation for solving physics problems (C3)
7. To describe the concept of ordinary differential equation (C2)
8. To calculate the first and second order Ordinary Differential Equation with Frobeniu method (C3)
9. To apply the concept of Ordinary Differential Equation for problem solving in Physics
10. To describe the concept of partial differential equation (C2)
11. To implement the concept of Partial Differential Equation for problem solving in Physics (C3)
12. To explain the concept of Tensor Analysis (C2)
13. To calculate the tensor transformation, Jacobian, differential and calculus of tensor (C3)
14. To apply the concept of tensor analysis for problem solving in Physics (C3)

III. Teaching Plan

Week	Sub-CLO	Study Materials	Teaching Method	Time Required	Learning Experiences (*O-E-F)	Sub-CLO Weight on Course (%)	Sub-CLO Achievement Indicator	References
1	1	Vector Analysis	Cooperative &Self-Directed Learning	150 minutes	O : Orientation (30%) E : Exercise (40%) F :Feedback (30%)	6	to describe the concept of vector analysis	No. 3 pp 123-124
2	2	Vector Analysis	Cooperative &Self-Directed Learning	150 minutes	O : Orientation (30%) E : Exercise (40%) F :Feedback (30%)	6	to calculate the concept of vector operation, differential and integral of vector	No. 3 pp 143-159
3	3	Vector Analysis	Cooperative &Self-Directed Learning	150 minutes	O : Orientation (30%) E : Exercise (40%) F :Feedback (30%)	6	to implement the concept of vector analysis for problem solving in Physics	No. 3 pp 125-132
4	4	Coordinate system and coordinate transformations	Cooperative &Self-Directed Learning	150 minutes	O : Orientation (30%) E : Exercise (40%) F :Feedback (30%)	6	to explain the concept of Coordinate system and coordinate transformations	No. 3 pp 133-139
5	5	Coordinate system and coordinate transformations	Cooperative &Self-Directed Learning	150 minutes	O : Orientation (30%) E : Exercise (40%) F :Feedback (30%)	6	to calculate the coordinate transformations, curvilinear coordinates, and differential operator in curvilinear coordinates	No. 3 pp 140-172
6	6	Coordinate system and coordinate transformations	Cooperative &Self-Directed Learning	150 minutes	O : Orientation (30%) E : Exercise (40%) F :Feedback (30%)	6	to implement the concept of coordinate system and coordinate transformations for problem solving in Physics	No. 3 Hal 173-182

7	**Mid-Term Exam**							
8	7	Ordinary Differential Equation	Cooperative &Self-Directed Learning	150 minutes	O : Orientation (30%) E : Exercise (40%) F :Feedback (30%)	8	to explain the concept of Ordinary Differential Equation	No. 3 pp 329-345
9	8	Ordinary Differential Equation	Cooperative &Self-Directed Learning	150 minutes	O : Orientation (30%) E : Exercise (40%) F :Feedback (30%)	8	to calculate the first and second order Ordinary Differential Equation with Frobeniu method	No. 3 pp 346-358
10	9	Ordinary Differential Equation	Cooperative &Self-Directed Learning	150 minutes	O : Orientation (30%) E : Exercise (40%) F :Feedback (30%)	8	to apply the concept of Ordinary Differential Equation for problem solving in Physics	No. 3 pp 359-380
11	10	Partial Differential Equation	Cooperative &Self-Directed Learning	150 minutes	O : Orientation (30%) E : Exercise (40%) F :Feedback (30%)	8	to explain the concept of Partial Differential Equation	No. 3 pp 401-432
12	11	Partial Differential Equation	Cooperative &Self-Directed Learning	150 minutes	O : Orientation (30%) E : Exercise (40%) F :Feedback (30%)	8	to implement the concept of Partial Differential Equation for problem solving in Physics	No. 3 pp 433-446
13	12	Tensor Analysis	Cooperative &Self-Directed Learning	150 minutes	O : Orientation (30%) E : Exercise (40%) F :Feedback (30%)	8	to explain the concept of Tensor Analysis	No. 3 pp 205-217
14	13	Tensor Analysis	Cooperative &Self-Directed Learning	150 minutes	O : Orientation (30%) E : Exercise (40%) F :Feedback (30%)	8	to calculate the tensor transformation, Jacobian, differential and calculus of tensor	No. 3 pp 218-242
15	14	Tensor Analysis	Cooperative &Self-Directed Learning	150 minutes	O : Orientation (30%) E : Exercise (40%) F :Feedback (30%)	8	To apply the concept of tensor analysis for problem solving in Physics	No. 3 pp 243-250
16	**Final Exam**							

*) O : Orientation

E : Exercise
F : Feedback

References:

1. M.L. Boas, Mathematical Methods in The Physical Sciences 3rd ed, John Wiley & Sons, 1983
2. B.D. Gupta, Mathematical Physics, Vikas Publishing, 1993
3. G.B. Arfken and H.J. Weber, Mathematical Methods for Physicists, Academic Press, 1995
4. L.A. Pipes and L.R. Harvill, Applied Mathematics for Engineers and Physicist, McGraw Hill,1970.

IV. Assignment Design

Week	Assignment Name	Sub-CLOs	Assignment	Scope	Working Procedure	Deadline	Outcome
1-3	Individual assignment	1, 2, 3	Problem set	a. Vector operation , differential and integral of vector b. Vector analysis application in Physics problems	In Class	100 minutes	Presentation file in power point format, Assignment answer sheet
4-6	Individual assignment	4,5, 6	Problem set	a. Coordinate transformations, kurvilinear coordinates, and differential operator on kurvilinear coordinates b. Coordinate transformation application in Physics problem	In Class	100 minutes	Presentation file in power point format, Assignment answer sheet
7	**Mid-Term Exam**						
8-10	Group-Assignment	7,8,9	Problem set	a. First order of Ordinary Differential Equation, constant coefficient of Ordinary Differential Equation, second order of linear Ordinary Differential Equation and series solution- Frobenius Method b. First and second order Ordinary Differential Equation application in Physics problems	Group discussion consist of 3-4 students	100 minutes	Presentation file in power point format
11-12	Group-Assignment	10,11	Problem set	a. First and second order of partial Differential Equation, separation of variables b. First and second order of partial Differential Equation application in Physics problems	Group discussion consist of 3-4 students	100 minutes	Presentation file in power point format
13-15	Group-Assignment	12,13,14	Problem set	a. Properties of transformations, Jacobian, differential and calculus of tensor b. Tensor analysis application in Physics problems	Group discussion consist of 3-4 students	100 minutes	Presentation file in power point format
16	**Final Exam**						

V. Assessment Criteria (Learning Outcome Evaluation)

Evaluation Type	Sub-CLO	Assessment Type	Frequency	Evaluation Weight (%)
Personal Assignment	1-6	Answer sheet	3	25
Group-Assignment	7-14	Presentation	2	25
Mid-Term Exam	1-6	Answer sheet	1	25
Final Exam	7-14	Answer sheet	1	25
Total				**100**

VI. Rubric(s)

A. Criteria of Presentation Score

Score	Presentation Delivery
85-90	Group is able to deliver the explanation logically, fluently, and punctual and be able to answer the questions from other students and lecturer
75-84	Group is able to deliver the explanation logically and fluently and be able to answer the questions from other students and lecturer, but be less punctual on delivering the explanation
65-74	Group is able to deliver the explanation fluently, but be less able to deliver the reasoning logic of the explanation
55-64	Group is less able to deliver the explanation fluently and punctual and be less able to deliver the reasoning logic of the explanation
<55	

B. Criteria of Assignment and Exam Score

Score	Answer Quality
100	Answer is very precise and all the concept and main component are explained completely
76-99	Answer is fairly precise and the concept and main component are explained fairly complete
51-75	Answer is less precise and the concept and main component are explained less complete
26-50	Answer is poorly precise and the concept and main component are explained poorly complete

VII. Appendix: Example of Exam Problems

A. Mid-Semester Exam

1. Determine:
   a. The Laplacian from the scalar field $\varphi(x,y,z) = xy^2(x^2 - 2y^2 + z^2)e^{\sqrt{x^2+y^2}}$.
   b. Curl from the vector field $\vec{F}(r) = \frac{\hat{r}}{r^2}$.

2. Maxwell equation in vacuum space without charge and current can be written as:
$$\vec{\nabla}.\vec{E} = 0$$
$$\vec{\nabla}.\vec{B} = 0$$
$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$
$$\vec{\nabla} \times \vec{B} = \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t}$$
   Which $\vec{E}$ and $\vec{B}$ are electric and magnetic field.
   a. Show that by operating the curl to the equations, we can get 2 electric and magnetic wave equations (electromagnetic)
$$\nabla^2 E = \mu_0 \epsilon_0 \frac{\partial^2 E}{\partial t^2}$$
$$\nabla^2 B = \mu_0 \epsilon_0 \frac{\partial^2 B}{\partial t^2}$$
   b. With the value of $\epsilon_0 = 8{,}85 \times 10^{-12} C^2/Nm^2$, and $\mu_0 = 4\pi \times 10^{-7} N/A^2$ show that the electromagnetic field propagates with light velocity $c \approx 3 \times 10^8 m/s$.

3. In classical physics, angular momentum can be defined as $\vec{L} = \vec{r} \times \vec{p}$, which $\vec{p}$ is linear momentum. In quantum mechanics, momentum is an operator which is linear momentum can be defined as $\vec{p} = -i\hbar\,\vec{\nabla}$. Show that the angular momentum operator in cartesian coordinate can be determined as:
$$L_x = -i\hbar\left(y\frac{\partial}{\partial z} - z\frac{\partial}{\partial y}\right)$$
$$L_y = -i\hbar\left(z\frac{\partial}{\partial x} - x\frac{\partial}{\partial z}\right)$$
$$L_z = -i\hbar\left(x\frac{\partial}{\partial y} - y\frac{\partial}{\partial z}\right)$$

4. The paraboloid coordinate system (u, v, φ) can be defined as
$$x = uv\cos\varphi$$
$$y = uv\sin\varphi$$
$$z = \frac{1}{2}(u^2 - v^2)^2$$
   Which $u \geq 0$, $v \geq 0$, $2\pi > \varphi \geq 0$. Determine

i. The gradient
ii. Curl
iii. Laplacian coordinate

B. Final-Semester Exam

1. The Corona of the Sun model equation is explained by heat transfer:
   $\nabla.(k\nabla T) = 0,$

   Which k is thermal conductivity that proportional to $T^{\frac{5}{2}}$. Show that the heat transfer equation applies for $T = T_0\left(\frac{r_0}{r}\right)^{\frac{2}{7}}$.

   Hint: for $f = f(r)$ apply $\vec{\nabla} f = \hat{r}\frac{df}{dr}$ and $\vec{\nabla}.(\hat{r}f) = \frac{2f}{r} + \frac{df}{dr}$.

2. In quantum mechanics is known that $\vec{L} = \vec{r} \times \vec{p} = -i\hbar\hat{r} \times \vec{\nabla}$.
   a) Using the cartesian coordinate system for the operator ∇, write the operator form for $L_x, L_y,$ and L_z
   b) In the spherical coordinate show that
   $$\frac{\partial}{\partial x} = \sin\theta\cos\varphi\frac{\partial}{\partial r} + \cos\theta\cos\varphi\frac{1}{r}\frac{\partial}{\partial\theta} - \frac{\sin\varphi}{r\sin\theta}\frac{\partial}{\partial\varphi}$$
   $$\frac{\partial}{\partial y} = \sin\theta\sin\varphi\frac{\partial}{\partial r} + \cos\theta\sin\varphi\frac{1}{r}\frac{\partial}{\partial\theta} + \frac{\sin\varphi}{r\sin\theta}\frac{\partial}{\partial\varphi}$$
   $$\frac{\partial}{\partial z} = \cos\theta\frac{\partial}{\partial r} - \sin\theta\frac{1}{r}\frac{\partial}{\partial\theta}$$
   c) Use the result above to show that
   $$l_z = -i\hbar\frac{\partial}{\partial\varphi}$$

3. Determine $y(x)$ as a solution from the differential equation below:
   a) $3x^2y' + 3y^3 = 1$
   b) $y'' - 4y' + 4y = 0$
4. Radium decays into an unstable Radon, then Radon also decays into Polonium.
   At $t = 0$ there is only a radium sample N_0, and at sometimes the number of samples of Radium, Radon, and Polonium respectively N_1, N_2, N_3.
   a) Write the differential equation for N_1, N_2, and N_3.
   b) Determine N_1, N_2, and N_3 as the solution from the differential equation above.