

# Bibliography

## *Lie Algebras*

- Bourbaki, N.: Groupes et Algèbres de Lie, Chap. 1, 2, 7, 8. Hermann, Paris (English translation: Springer-Verlag).
- Chevalley, C.: Théorie des groupes de Lie, tome III. Publ. Inst. Math. Nancago IV, Hermann, Paris, 1955.
- Humphreys, J.: Introduction to Lie Algebras and Representation Theory. GTM 9, Springer-Verlag, Heidelberg, 1972.
- Jacobson, N.: Lie Algebras. Intersc. Tracts, n°10, John Wiley and Sons, New York, 1962.
- Séminaire Sophus Lie. Théorie des algèbres de Lie – Topologie des groupes de Lie. Secr. Math., rue P. Curie, Paris, 1955.
- Serre, J.-P.: Algèbres de Lie semi-simples complexes. Benjamin, New York, 1966 (English translation: Springer-Verlag).

## *Formal Groups*

- Dieudonné, J.: Introduction to the theory of formal groups. Marcel Dekker, Inc., New York, 1973.
- Fröhlich, A.: Formal groups. Lect. Notes in Math., 74, Springer-Verlag, Berlin, 1968.
- Lazard, M.: Sur les groupes de Lie formels à un paramètre. Bull. Soc. Math. France, 83, 1955, p. 251–274.
- Lazard, M.: Lois de groupes et analyseurs. Ann. ENS, 72, 1955, p. 299–400.
- Manin, Yu.: The theory of commutative formal groups over fields of finite characteristic. Usp. Mat. Nauk, 18, 1963, p. 3–91 (Russ. Math. Surveys, 18, 1963, p. 1–84).

## *Differentiable Manifolds*

- Bourbaki, N.: Variétés différentielles et analytiques. Fasc. de Rés., §§1–7 and §§8–15, Hermann, Paris, 1971.
- Dieudonné, J.: Éléments d'Analyse (tome 3). Gauthier-Villars, Paris, 1970.
- Lang, S.: Differential Manifolds. Addison-Wesley, Reading, 1972.
- Warner, F.: Foundations of Differentiable Manifolds and Lie Groups. Scott, Foresman, Glenview, Illinois, 1971.

## *Topological Groups*

- Montgomery, D. and Zippin, L.: Topological transformation groups. Intersc., New York, 1955.
- Pontrjagin, L.: Topological Groups. Univ. Press, Princeton, 1939.

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- Bourbaki, N.: Groupes et Algèbres de Lie, Chap. 3. Hermann, Paris (English translation: Springer-Verlag).
- Chevalley, C.: Theory of Lie groups. Univ. Press, Princeton, 1946.
- Fulton, W. and Harris, J.: Representation Theory – A First Course, GTM 129, Springer-Verlag, 1991.

**Helgason, S.:** Differential Geometry and Symmetric Spaces. Acad. Press, New York, 1962.

**Hochschild, G.:** The structure of Lie groups. Holden-Day, San Francisco, 1965.

***p-adic groups***

**Dixon, J.D., Du Sautoy, M.P.F., Mann, A. and Segal, D.:** Analytic pro- $p$ -groups, Second Edition, Cambridge Univ. Press, Cambridge, 1999.

**Lazard, M.:** Groupes analytiques  $p$ -adiques. Publ. Math. IHES, 26, PUF, Paris, 1965.

***Algebraic Groups:***

**Borel, A.:** Linear Algebraic Groups, 2<sup>nd</sup> edit., Springer-Verlag, 1991.

**Chevalley, C.:** Sur certains groupes simples. Tôh. Math. J., 7, 1955, p. 14–66.

**Chevalley, C.:** Classification des groupes de Lie algébriques. Secr. Math., IHP, rue P. Curie, Paris, 1958; édition révisée par P. Cartier, Springer-Verlag, 2005.

**Demazure, M. et Gabriel, P.:** Groupes algébriques (tome I). Masson, Paris, 1970.

**Demazure, M. et Grothendieck, A.:** Schémas en groupes (SGA 3), Lect. Notes in Math., 151, 152, 153, Springer-Verlag, 1970.



# Problem

(Harvard Exam., Jan. 1965 – Time: 3 hours)

In what follows  $k$  denotes a field, and  $\mathfrak{g}$  a 3-dimensional Lie algebra over  $k$ , with basis  $\{x, y, z\}$  and relations:

$$[x, y] = z, \quad [x, z] = [y, z] = 0.$$

The universal algebra  $U\mathfrak{g}$  of  $\mathfrak{g}$  is denoted by  $U$ .

## I

1. Determine the center of  $\mathfrak{g}$ . Prove that  $\mathfrak{g}$  is nilpotent.
2. Let  $A$  be the center of  $U$ . Show that  $z \in A$ . If  $k$  is of characteristic  $p \neq 0$ , show that  $A$  also contains  $x^p$  and  $y^p$ , and that  $z, x^p, y^p$  are algebraically independent.
3. Give an example of an analytic group (over some complete field  $k$ ) having a Lie algebra isomorphic to  $\mathfrak{g}$ .

## II

In this section  $V$  is a vector space over  $k$ , and  $\varrho : \mathfrak{g} \rightarrow \text{End}(V)$  is a Lie algebra homomorphism (so that  $V$  is a  $\mathfrak{g}$ -module).

4. For any  $\lambda \in k$ , let  $V_\lambda$  be the set of  $v \in V$  such that  $\varrho(z)v = \lambda v$ . Show that  $V_\lambda$  is a  $\mathfrak{g}$ -submodule of  $V$ .
5. Assume  $k$  algebraically closed, and  $V$  irreducible<sup>(\*)</sup> of finite dimension. Show that there exists  $\lambda \in k$  such that  $\varrho(z) = \lambda$ , scalar multiplication by  $\lambda$ . Assume moreover that  $\text{char}(k) = 0$ ; show that  $\lambda = 0$  and classify all irreducible  $\mathfrak{g}$ -modules of finite dimension.
6. We now take for  $V$  the vector space  $k[T]$  of polynomials in one indeterminate  $T$ . Show that there exists a structure of  $\mathfrak{g}$ -module on  $V$  such that, if  $P \in k[T]$ :

$$\varrho(x) \cdot P = dP(T)/dT, \quad \varrho(y) \cdot P = T \cdot P(T), \quad \varrho(z) \cdot P = P.$$

Prove that  $V$  is irreducible if  $\text{char}(k) = 0$ .

---

(\*) A  $\mathfrak{g}$ -module  $V$  is said to be irreducible if  $V \neq 0$  and if the only  $\mathfrak{g}$ -submodules of  $V$  are  $0$  and  $V$ .

## III

In this section,  $k$  is algebraically closed of char.  $p \neq 0$ .

7. Let  $V$  be the  $\mathfrak{g}$ -module defined in question 6. Show that the  $\mathfrak{g}$ -submodules of  $V$  are of the form  $V_P = P(T^p) \cdot V$ , with  $P \in k[T]$ . Show that  $V/V_P$  is irreducible if and only if  $\deg(P) = 1$ .

8. Let  $W$  be an irreducible  $\mathfrak{g}$ -module, and let  $\varrho_W : \mathfrak{g} \rightarrow \text{End}(W)$  be the corresponding homomorphism. Show that  $W$  is isomorphic to one of the modules  $V/V_P$  defined above if and only if the following two conditions are satisfied:  $\varrho_W(z) = 1$ , and  $\varrho_W(x)$  is nilpotent.

9. Let again  $W$  be an irreducible  $\mathfrak{g}$ -module of finite dimension, and assume  $\dim(W) > 1$ . Show that  $\dim(W) = p$ , that  $\varrho_W(z)$  is equal to a scalar  $\lambda \neq 0$ , that  $\varrho_W(x)$  has only one eigenvalue  $\mu$ , and that  $\varrho_W(y)$  has only one eigenvalue  $\nu$ . Show that, for any  $(\lambda, \mu, \nu)$  with  $\lambda \neq 0$ , there exists a corresponding  $W$ , and that it is unique, up to isomorphism.

10. Prove that the center  $A$  of  $U$  is the polynomial algebra generated by  $z, x^p, y^p$ . If  $k'$  is an extension of  $k$ , and  $\varphi : A \rightarrow k'$  any homomorphism such that  $\varphi(z) \neq 0$ , show that  $U \otimes_A k'$  is a central simple algebra over  $k'$  of rank  $p^2$ . Prove that this remains true even if  $k$  is not algebraically closed.

11. Prove that every irreducible  $\mathfrak{g}$ -module is finite-dimensional.

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## Erratum to

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p.23, line 16. Replace  $H^2 = \{x, y\}$  by  $H^2 = \{xy\}$ .

p.120, exercise 2 b). In the denominator of the formula,  $(i + j - k)$  should be  $(i + j - k)!$ .