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BOOK REVIEW

Michael J. Crowe, ***Mechanics from Aristotle to Einstein***, Green Lion Press, Santa Fe, New Mexico, 2007.

Reviewed by: M.S. Sriram, Department of Theoretical Physics, University of Madras

According to the author, "the story of the development of mechanics from Galileo to Einstein's special theory of relativity is the most remarkable story in all secular history". He concedes that many may not find it so, as the ideas are complex and difficult to comprehend. However he believes that "the ideas are much more accessible than most persons assume". This is what he attempts to prove in this book which grew out of the courses taught by the author at the University of Notre Dame, USA. That is why we find very many illustrative examples and diagrams, worked-out problems, and problems to ponder in this book. "One special feature of this book is its inclusion of substantial selections from writings by a number of the most important contributors to the history of mechanics, especially Aristotle, Galileo, Descartes, Huygens, and Newton.... Commentaries supplying explications and contexts accompany these selections, enhancing their accessibility". The aim is to make the reader "understand not only what the scientist attained, but also how it was attained".

The book is divided into six chapters, namely, 1. Mechanics before Galileo, 2. Galileo and Terrestrial Mechanics, 3. From Galileo to Newton, 4. Newton and Mechanics, 5. Between Newton and Einstein, 6. Einstein and Relativity Theory.

There is a cursory treatment of Aristotle's approach to mechanics. Aristotle (384-322 BC) rejects the earlier Platonic view that mathematical forms are constituents of physical bodies, and assigns a role to experience. He divides all motion into two categories, namely, natural and violent. Though he had many false conceptions, he might have "provided later authors with an insightful analysis of motion of terrestrial bodies". Archimedes is dismissed in one sentence. One wishes that the author had given a little more space to the statics of Archimedes, which had a profound influence on Galileo. In later antiquity, Philoponus (*ca*. 500 AD) anticipated Galileo when he asserted that the time taken by a body to fall does not depend upon its weight.

In the medieval period before Galileo, scholars at Merton college of Oxford and at University of Paris led by Nicholas Oresme (1325-1382) arrived at the "Merton Mean Speed Theorem", which is a crucially important relation between acceleration, average speed, and distance travelled by a body. Hailed by the author as "the most important single medieval contribution to the history of physics", the geometrical derivation of the result by Oresme is reproduced in chapter 1. Relativity of motion is also discussed in this chapter. This problem was felt most intensely by astronomers who recognized that the motion of the starry vault could be explained either by having the earth rotate while the starry vault remains fixed, or vice versa. After giving a number of arguments in favour of earth's rotation, Oresme settles in favour of the traditional view that the earth does not move, citing scripture in support of this conclusion! However, "a number of the main advances that occurred in mechanics were directly linked to an enriched understanding of the relativity of motion".

Galileo's (1564-1642) "Discourses and Demonstrations Concerning Two New Sciences" is the beginning of modem mechanics. The author emphasizes the role of thought experiments in Galileo's formulations. For example, there is no direct documentation to support the widespread belief that he dropped weights from the leaning tower of Pisa to prove that the rate of fall of a falling body does not depend upon its weight. Similarly, it was through a thought experiment that Galileo concluded, that the final velocity of all bodies rolling down inclined planes of the same height but of different inclinations, are equal. As a matter of fact, this thought experiment is very appealing. Galileo's discovery of the isochronism of the pendulum and the relationship between the time period and the length of the pendulum are important. Far more important is his discussion of uniform acceleration, wherein the velocity is proportional to time and the distance traversed is proportional to the square of time. Galileo comes close to formulating the law of inertia when he states that "whatever degree of speed is found in the moveable, this is by its nature indelibly impressed on it when external causes of acceleration or retardation are removed". However, Galileo had adopted the idea of a naturally perpetual circular motion and his statement is not the same as the law of inertia of Newton (his first law). Galileo's treatment of projectile motion is very important. The motion of a projectile can be understood as being compounded of two motions: (1) the constant horizontal speed given to it, and (2) the vertical acceleration due to gravity. From this it is concluded that the path is a parabola. For all his greatness, Galileo's concern was primarily kinematic than dynamic.

Johannas Kepler (1571-1630), Rene Descartes (1596-1650) and Christiaan Huygens (1627-1695) were the “other late sixteenth and seventeenth century figures who were important in preparing the way for the great Newtonian system”. Kepler was perhaps the last great figure in the kinematical tradition of astronomy which extended over more than two millennia. Kepler’s first law is that planets move in ellipses with the Sun at one focus of the ellipse. Kepler’s second law is that a line from the Sun to the planet sweeps out equal areas in equal times. Kepler’s third law says that the square of the time period of a planet is proportional to the cube of the semi-major axis of ellipse in which it moves. Kepler’s three laws had a profound influence on Newton in his formulation of the universal law of gravitation.

In his works, “Descartes set out a more comprehensive system of physical science than any that had appeared in the centuries since Aristotle. Descartes’s system strongly influenced the system presented in 1687 by Isaac Newton... “. The most important contribution made to physics Descartes was his formulation of the law of inertia and his proposal that the quantity of motion in the universe is constant (amounting to the law of conservation of momentum). In his *Principia Philosophiae* he states:

“36. God is the primary cause of motion, and always conserves the same quantity of motion in the universe.

37. *The first law of nature:* that each thing (insofar as this depends on itself), persists in the same state, and thus what is once moved always carries on moving.

39. *The second law of nature:* that all motion is in itself straight, and therefore the things that move circularly always tend to recede from the center of the circle that they describe.”

Huygen’s single most important contribution to mechanics was his “law of centripetal acceleration”. The law is that for a particle moving on a circle of radius r with constant speed v, the acceleration, a of the particle towards the centre is given by $a = v^2/ r$. This law also plays an important role in Newton’s *Principia*. Huygens also wrote a book on the theory of collisions. A stationary ball hit by an identical ball starts moving with the latter’s velocity, whereas the latter loses all its motion and stops. A very elegant proof of this is given by Huygens in his book, using the principle of relativity of motion, which is reproduced in this chapter. In a brief paper, Huygens also provided statements of both the laws of conservation of momentum and of kinetic energy.

Chapter 4 on 'Newton and Mechanics' is really the centre-piece of this book. The chronology of the life of Isaac Newton (1642-1727) itself runs to six pages. The background to Newton's work is covered well. Contact with Robert Hooke helped Newton in conceptualizing the motion of bodies under the influence of a central force. Hooke had an idea of the inverse law of gravity, but no proof. Newton would prove it later using Kepler's laws.

Newton's masterwork, *Philosophiae Naturalis Principia Mathematica* (Mathematical principles of natural philosophy), was first published in 1687. This is divided into three books. The first book which is highly mathematical, contains relatively few direct applications to our world. In Book III, Newton shows that, when combined with other laws and propositions, inverse law of gravitation applies to our physical universe. Book II focusses on motions of bodies in resisting media and much of it is devoted to refuting the 'vortex cosmology' of Descartes, and not of much interest now. A number of passages from *Principia* are reproduced in this chapter, with comments by the author.

In Book I, various quantities like 'quantity of matter', 'quantity of motion' (essentially momentum), 'force of inertia', 'impressed force', 'centripetal force', 'accelerative quantity' etc. are defined first. In his own commentary to these, Newton explains 'absolute' and 'relative' time and space. He also distinguishes between absolute and relative motion and explains how absolute rotation can be detected using the famous 'water pail experiment'. Various important contemporaries of Newton like Leibniz, Berkeley and Huygens disagreed with his concept of absolute space and time. After the definitions, his famous three laws of motion are stated and explained. It is noteworthy that the famous equation, F = ma, never appears in *Principia*, but used effectively in Book III. One important corallory to the laws of motion is the 'parallelogram law for the composition of forces' analogous to Galileo's principle of superposition of velocities.

In a number of cases, ideas and methods of calculus appear in *Principia.* Actually, the methods of calculus appeared in the Kerala school of mathematics and astronomy nearly three centuries earlier. The author may not be aware of this. Be that as it may, Newton describes how the area under a curve can be calculated as a sum of infinitesimal strips just as in the modem procedure. However most of his proofs were actually geometrical. An example is the constancy of areal velocity under the action of a central force, which is simple and elegant. Newton also proved the expression for centripetal acceleration ($a = v^2/ r$). When combined with Kepler's third law, this leads to the inverse square law for gravity. In fact, this law follows from Kepler's first law also.

Whereas Book I is mathematical, Book III is on the system of the world formulated on the basis of results of Book 1. It is Newton's firm belief that nature is simple and does not indulge in superfluous causes. Newton discusses the astronomical observations pertaining to the motion of the planets around the Sun, Moon around the earth, and the satellites of Jupiter and Saturn around the respective planets, and notes that in each case the equal-area law and Kepler's third law hold. From these he concludes that "gravity is given to all planets without exception", and that "gravity which looks to each is inversely as the square of the distances of places from its center". There are many more proposals in Book III including ratio of masses of two planets, bulging of the earth at the equator, phenomena of tides, precession of equinoxes, and so on.

Many of Newton's predecessors and contemporaries had wondered about the reason for gravity. Newton firmly avoided the temptation of finding any such reason, as he did not want to 'contrive hypothesis', without any empirical basis. Newton emphasizes at several place that he does not know the cause of gravity.

Newton was a very religious person, an Anglican, but had anti-Trinitarian views, contrary to the dogma of the church in England at that time. He believed in an intelligent agent in the universe.

The author points out that there is widespread misconception that Newton's approach in *Principia* is inductivist, wherein each law or proposition is inductively justified when it is presented. He proposes a "hypothetico-deductive" reading of *Principia*. In the hypothetico-deductive (HD) method, a scientist begins with certain hypotheses. He or she draws conclusions from them, possibly using in this process other relevant information. These deductions typically take the form of predicting certain phenomena. If these do in fact occur, then one concludes that there is good evidence for the hypotheses. In the case of *Principia*, "the hypothetical part consists of Newton's laws and definitions; the phenomenal part consists of such empirical matters as Kepler's second law, Galileo's results, as well as precessonal, tidal and cometary phenomena". Newton himself did not want to give an impression that he was using the HD method, as his theory would be just another possible theory if he conceded the method! According to the author, Galileo and Newton also used the HD method.

In chapter 5, the author calls into question, the widespread belief that there were only two great modem revolutions in physics which were: (1) the one associated with Galileo and Newton, and (2) the second associated with Planck and Einstein (quantum theory and relativity respectively). Actually there were three more, namely, (i) the concept of electromagnetic fields developed by Faraday and Maxwell, (ii) discovery and development of the concept of energy that manifests itself in mechanical, electrical, chemical and other forms, and (iii) the gradual realization that physics itself is an unified field of study. The knowledge of developments in a variety of areas of physics, especially the heat theory, the kinetic theory of gases, the field theory of Faraday and the particle and wave theories of light, are recounted. Galilean relativity theory is explained in detail. As preparation for the next chapter, the famous Michelson-Morley experiment to determine the relative motion between the earth and ether is described, and the significance of the null result of the experiment is explained.

Special and general theories of relativity are the subject matter of the last chapter. The special theory of relativity was based on two postulates, namely: (1) the laws of nature must be the same in all inertial frames, and (2) the velocity of light in empty space is independent of the motion of the emitting body. The background to Einstein's postulates is presented well, especially the considerations which led Einstein to propose that a single relativity principle governs both mechanics and electrodynamics. The treatment of the special theory of relativity is almost the same as in any physics text book. The derivation of $E = mc^2$ is unsatisfactory as it assumes the formula for the variation of mass with velocity. The treatment of the general theory of relativity is necessarily cursory, as any more details would have involved mathematical concepts beyond the scope of the book. Even then, the principle of equivalence involving the equality of gravitational and inertial masses (an accident in Newtonian mechanics) is explained well, though not the relation between geometry and gravity. This chapter ends with a brief discussion of 'the philosophies of Mach ('positivist' and 'empiricist'), Planck and Einstein ('realist').

The pedagogical nature of the book is emphasized with the inclusion of an appendix on "Galileo laboratory" which "offers he reader the opportunity to carry out a set of experiments in pendular motion using easily accessible materials". There is a fairly detailed Bibliography at the end. It is surprising a comprehensive book like *'A History of Mechanics'* by Rene Dugas (Dover edition, 1988) is not included in the bibliography.

After Newton, classical mechanics was put on strong foundations by the Bernoullis, D' Alembert, Euler, Lagrange, Laplace, Hamilton, Jacobi and others in the eighteenth and nineteenth centuries. Especially important was *Mechanique Analytique* of Lagrange (1788). These developments don't find a place in this work. Part of the reason is that by way of concepts at the most fundamental level, there was no breakthrough in these works. Also any account of them would be very technical. In the present book, the emphasis is on the concepts, though the details of the works of the great masters are made available. Books in the area of history of science tend to be dry and overwhelming. This book is an exception, and is user-friendly. It would be a very useful book to students, researchers and also to intelligent laymen interested in the history of mechanics.

I. Venugopal D. Heroor, **The History of Mathematics and Mathematicians of India**, Vidya Bharati, Karnataka, Bangalore, 2006.

II. Venugopal D. Heroor, **Bhākarācārya's Jyotpatti —** An ancient tract on Indian Trigonometry with tr in English and Hindi, Exposition and Notes, Jagadguru Ramanandacharya Rajasthan Sanskrit University, Jaipur, 100 pages, 2007, Price: Rs. 195.00

III. Venugopal D. Heroor, **A Quiz Book on Mathematics and Mathematicians of India**, Aditi Prakashana, Bangalore, 135 pages, 2008, Price: Rs. 80.00

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All the three books were published by Venugopal D. Heroor one after another. Book I is a major work written by him on mathematics and mathematicians of India in historical perspective. It has been presented in ten sections maintaining a chronological order along with a short introduction. The sections are on: I. Indus Valley Mathematics (in 2 pages), II. Vedic mathetics (4 pages), III. Mathematics of the Vedāṅga phase, (16 pages), IV. Buddhist & Jaina Phase (10 pages), V. Pre-classical Age of Epics and Siddhāntas (9 pages), VI. Classical period (54 pages), VII. New Jaina writings to Bhāskara II (38 pages), VIII. Medieval mathematics in north India (18 pages), IX. Kerala mathematics (58 pages), and X. Mathematical glimpses of the three Presidency universities of Calcutta, Madras and Bombay (4 pages); the number of pages indicate relative importance given to each of these sections. The sections: VI, VIII and IX are quite elaborate, treated well and updated with latest knowledge in the field. The rests are just glimpses. Another beauty of the book is that the author has incorporated most of the important findings of K.S. Shukla and R.C. Gupta, Billard, Takao Hayashi and others in this book. Heroor has made a number of publications in Marathi to make Indian mathematics popular in Marathi language. He has proved himself equally competent in his write-up in English. He is an engineer, all his lines are measured, mostly correct and furnished with evidence from sources. An engineer interested in the field is a matter of great satisfaction. Of course, a little more flesh and blood like social situations congenial or detrimental to the development of a particular trend in mathematics, connections of one phase to the other, and the extent of its development would have been interesting. However, the book has been designed for students of mathematics. It is a useful production and I am sure the book will be popular among younger students.

Book II is another interesting tract of 24 verses, translated with exposition and notes by the same author, on *Jyotpatti* written by great Indian astronomer/ mathetician Bhāskara II of the 12th century AD. It was originally included as the 14th chapter of Golādhyāya section of *Siddhāntasîromaṇi* (1150 AD). The *jyotpatti* is derived from *jyā + utpatti*, and recognized as a special branch, i.e. trigonometry. It originates from ordinates *jyā* = r sinθ, and ko-*jyā* = r cosineθ for a point (x,y) in the first quadrant, which makes an angle θ at the centre, satisfying a relation $x^2 + y^2 = r^2$, for r as the radius of a circle. India had a great tradition in the field starting from Āryabhaṭa I (b. 496 AD) onwards, formally recognized and systematically compiled by Bhāskara II as an independent discipline to emphasize its importance among his followers. Heroor's plan is to popularize Bhāskara II's trigonometry among the modern generation of students and to throw light how methodical, systematic and in a way modern it was, since modern sine and co-sine could easily be obtained just dividing the Indian functions by r (radius), Indian trigonometry like Indian numerals, was recognized by the Arabs who developed it further and transmitted to Europe.

Book III has raised a large number of questions with answers in 'quiz format' based on Book I. There are 26 and 159 questions/answers in pre- and post- Āryabhaṭa stages of development, 51 and 34 questions/answers on the triumph of Indian astronomy and mathematics in China and West Asia, reference of 12 important Indian inventions credited to others, and a few tit bits on mathematical tradition, works and place of origin of scholars, and matching & filling up of gaps of different problems. It has five appendices also on miscellaneous items relating to mathematics in India and Abroad. The plan of the book is quite interesting and will benefit students who have interest in the field and are appearing for competitive examinations. A great effort has been made to make it updated. The information is more or less authentic and beneficial for scholars in general.

More such similar books are needed. All the books are very sincere in their approaches and deserve a place in all the libraries in India.

R. Balasubramanium, ***The Saga of Indian Cannons***, Aryan Books International, New Delhi, 2008, 350 pages, fully illustrated and entirely on art paper

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The first look on the book overwhelms the reader with a variety of colourful and attractive photographs, not only of cannons, but also of the related illustrations. The photographs are enchanting, the description engrossing. The author has done a very thorough and exhaustive search of the cannons from various parts of India and also of those used over a long span of time.

Use of cannons started in India with the Moghul invasion and the last use was in the 1857 uprisings against the British rule, after which it gave way to tank mounted artillery and long range and sophisticated howitzers. Naturally the compilation is for the period between fourteenth and nineteenth century AD. The author describes how the successes achieved through the use of cannons were essentially derived from the metallurgical skills of foundry and forge personnel of the time. Their application of the artistic and scientific skills resulted in the production of equipment of decisive strength at the battlefront.

One is intrigued by some of the very small and well decorated cannons illustrated and described in the book. The author convinces us that they were indeed functional cannons and because of their portability they were effective part of the war machine. It was a fact that militant kings guarded their forts with massive cannons all around its ramparts and also kept smaller and well decorated cannons for display purposes. Through the narration the author has also explained the different methods adopted in making the cannons. He has ,illustrated the all cast bronze cannon made by casting, forged cannons of wrought iron, the composite design with bronze cast over forged and welded wrought iron bore, etc. The last named was generally of a more complicated design where wrought iron inner pipe was made by bending wrought iron plate and welding, and was strengthened by covering it from outside by short overlapping wrought iron sleeves. The casting followed thereafter. He has also described and illustrated the multi-piece screwable cannon.

But historically the most important as well as destructive cannons are those used in the 1857 uprisings. The majestic although damaged 'Kaḍakbijli,' used by Ghaus Mohammad of Lakhmibai's army in Jhansi fort, has been covered from many angles as also the 'Bhawani Shanker' cannon operated by a woman cannoneer Moti Bai who was earlier a court dancer. The joint memorial nearby of Ghaus Mohammed, Moti Bai and Khuda Baksh (the chief of mounted forces) stands testimony to the valour and sacrifices of the Jhansi army. However, this monument has been mistakenly referred to as the grave of Moti Bai who was a Hindu by religion. The author has also pointed out the discrepancy between the inscription on the 'Bhawani Shanker' cannon and its English version nearby. But there are more discrepancies i.e. Jairam is not the Guru but the master craftsman and the characters alongside refer to the weight of shot and quantity of gunpowder required to be charged for firing.

A few important issues are missing though. The '*Anand Math*' uprising against the British substantially pre-dated both the war at Plassey of 1757 and the 1857 uprisings. The freedom fighters of *Anand Math* were known to have used cannons, even though in not very large numbers. This compilation has completely ignored this fact. Even though, remains of such cannons are unlikely to be found, it should have found a place in the description. Another omission is the mention of the cannon of the largest range in Jhansi Fort, the 'Ghangaraj' or the loud thunder. This cannon is probably missing and it was the original cannon in the hands of Ghaus Mohammad. The task is cut out for the author to try and locate the missing and historically important cannons - at least the documents and information on these - and prepare a supplementary volume.

Captions of some of the Figures are either hard to find or are missing. The photographs spreading over the front and back cover, as also that on the title pages, are of the cannons of Mehrangarh Fort in Jodhpur, but this fact can be ascertained only after a thorough examination of the illustration's inside the book.

On the whole the book presents a very exhaustive account which signifies the important role the Indian metallurgical heritage and tradition played in the imperial system of the period and also mentions the heavy price the Indian society paid when its rulers remained indifferent to the parallel developments elsewhere in the world.

Harkishan Singh, ***Views and Reviews***, Association of Pharmaceutical Teachers of India (APTI) Bangalore, 2008, p 628, Price not stated.

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Prof. Harikishan Singh has done an outstanding service to Pharmaceutical Sciences by regularly publishing books dealing with historical aspects of its growth and development in India as well as biographies of some of its stalwarts. The hall mark of these volumes has been references to large number of ordinarily inaccessible documents lying in academic institutions and repositories in and outside the country. The present volume is a compilation of 101 articles from among those published by him during the last 50 years at various places.

The articles cover a kaleidoscopic array of topics but almost all related to Pharmaceutical sciences. The subjects were of current interest when the papers were originally published but still have great historical value. Some of them have been published at rather inaccessible places like home journals of Institutions (e.g. Pharmacon of Sagar University, Pharmacos of Punjab University, Pharmstudent of Banaras Hindu University) or Proceedings of seminars, symposia etc.

The papers of Prof. Singh included in this volume can be broadly divided in 6 subheads besides a general group. The largest number of papers deals with teaching of Pharmacy to graduate and post-graduate students, development of syllabi and course contents etc. Prof. Singh has been intimately connected and has played a significant role in shaping the modern syllabi and courses in Pharmacy in the country. In addition, he has played important role in planning and developing major Pharmacy Institutions of the country like National Institute of Pharmacy Education and Research (NIPER) at Mohali. The volume contains 26 of the 80 papers written by him on this subject. Many of these have also been referred to in Volume 2 of the author's series on History of Pharmacy in India and Related Aspects (Pharmaceutical Education 1998). There are 16 papers on growth and development of Pharmacy and related disciplines in India. Contents of many of these have been included in Volume 3 of the above series titled Pharmacy Practice and published in 2002. There is an interesting paper about the first Pharma Journal of India starting publication in 1894 (it also refers to 2 possible Indo-Portuguese Journals started in 1864 and 1872 but not surviving for long).

Another important group of papers included in the volume concern the development of Indian Formularies and Pharmacopeias and drug regulatory procedures. Essential parts of many of these papers find place in Volume 1 of the above mentioned series published in 1994 and entitled *Pharmacopeias and Formularies*. Other smaller groups of papers in the present volume deal with development of Pharmaceutical Societies and Drug Industry in the country. There are some scientific reviews also (e.g. Stereochemistry didactics through workshop system, p 195; Reminiscences of work on natural products, p. 471).

A valuable inclusion in the book is the 14 papers published as tributes to doyens of Pharmaceutical Sciences in the country. Several of them are obituaries, centenary tributes etc. There are well known names likes ML Schroff, BV Patel, GP Srivastava, KSS Vardan etc. There are also a host of silent builders who had made tremendous contributions but shunned publicity. These stalwarts include persons like DE Anklelsaria, BM Mithal, KC Chatterji, HR Nanji, JC Ghosh etc. Prof Singh has recently (2005) published a full fledged biography of ML Schroff as volume 4 of his series and hopefully he would bring out similar tomes on a few other pioneers also. All the four volumes have been published by Vallabh Prakashan, Delhi Further details of some of these persons may be included in the fifth volume of his series, which is in press and entitled Modern Pharmacy Builders and Awareness (p 562). It will also be published by the same concern.

The compilation also includes 17 articles of a general nature, most of them published in the local daily newspaper, Tribune. They cover diverse subjects like Liberal arts versus professional education (p. 137), Ticketless bus commutation (p. 186) A noble man of railways (p. 391), Inter-community well (p. 421), Portrayal of conviction (p. 480). The articles make interesting reading and indicate the close observations Prof Singh makes of his surroundings at work or at leisure.

Some personal particulars of Prof. Singh have been provided as an Appendix. It lists his academic assignments, honors and awards, membership of committees etc. It would have been useful to have included a list of the 12 books published by him and a brief summary of his research contributions besides discovery of Chandonium which has been mentioned.

The book is nicely produced and contains some rare photographs. There is a comprehensive index also. The book is singularly free of Printers devils. The original place of publication of only one article is missing (p. 187) and it is unlikely to be intentional. It is one of those very few books which would be equally at home in the book shelf of a research worker or teacher or at the coffee table.