Review Article

Contributions of Physics to the Information and Communication Technology: Connecting Science, Technology, and Society- A Chronology of Technological Advancements

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Abstract

Science and technology have impacted all walks of society and therefore, all are interlinked. The development of cutting-edge technology is driven by the needs and demands of the rapidly changing modern society and science is the backbone of every technology. We interact with various communities of practices, technologies, and general peoples throughout our life in our highly technological and information-based society. A qualitative knowledge of science and roles played by it is, therefore, necessary from the viewpoint of technology, community, and society as a whole. This can be achieved by discussing qualitatively the scientific and technological contributions made by various scientific fields to society. One such combination is Physics, Information and Communication Technology (ICT), and society. Physics is one of the fundamental science subjects. Its concepts, principles, laws, and techniques contribute and strengthen the progress of all other branches of science including cross-, interdisciplinary-, and multidisciplinary-sciences, the innovation and development of various technologies, and the sustainable development of society. Here, we have briefly and systematically discussed the contribution of physics to the various components of Information and Communication Technology (ICT).

Keywords: Physics, ICT, Science, Technology, Society.

Introduction

Science and technology have been contributing immensely to our rapidly changing technology and information-based modern society (Gonzalez, 2005; Kumar et al, 2012; Standke et al, 1980; Bauchspies et al, 2005). Changes around ourselves can be observed when we compare today's (post) modernized world with earlier (medieval/dynasty) ages. There has been a continuous development of science & technology, owing to the demands of modern society such as communication, transportation, environment, entertainment, disaster management, health and welfare (medicine and diagnostic tools), (technology-enhanced) learning/ education and many more - the society that we live in today is largely shaped and influenced by science & technology (Gonzalez, 2005; Kumar et al, 2012; Standke et al, 1980; Bauchspies et al, 2005). For example, the invention and innovation of the radio, telephone, mobile/smartphones, & internet services have broadened communication and impacted almost all walks of life - we can communicate with anyone living in any part of the world in seconds through emails, faxes, mobile phones, texting services, video conferences, and social media channels and networks for various purposes (e.g., business, education, health, and social life) (Freeman, 1999; Haddon, 2004). Alternative and pollution-free modes of transport (e.g., electronic railway lines, cars, and buses) have significantly benefited society by reducing the carbon emission (Ercan et al, 2022). Effectively, every place is touched by humans – from the bed of the ocean to the interplanetary space, that is to say, human society has become very dependent on science and technology or vice-versa – a confluence of science, technology, and society (STS) (Gonzalez, 2005; Kumar et al, 2012; Standke et al, 1980; Bauchspies et al, 2005).

A qualitative discussion of various roles played by the sciences to the discovery and growth of technologies is necessary to generate and promote scientific literacy, awareness, and attitude among common peoples (public) as well as to integrate science, technology, and society (peoples) as common peoples of technology-based modern societies use technologies throughout their lives without knowing or understanding the science behind it (Scheufele, 2013; Turney, 1996; Stilgoe et al, 2014; Laugksch, 2000; Keith et al, 2017; Sarnoff, 1937). Physics, one of the fundamental subjects, has been playing a pivotal role in numerous areas of innovations and technological development vis-à-vis the progress of society (Gonzalez, 2005; Kumar et al, 2012; Standke et al, 1980; Bauchspies et al, 2005; Walker et al, 2016; Young et al, 2012; Gershenfeld, 2011; Wolf 2008; Deák, 2017; Fraden, 2004; Barlett, 2014; Davidovits, 2008; Colicchia et al, 2015; Tegmark, 2014; Hush, 2017; Biamonte et al, 2017; Dunjko et al, 2018; Kreupl, 2013; Shulaker et al, 2013). The various concepts and laws of physics have been used time and again to make the life of humans simple and comfortable - from walking, running, playing football to pushing and pulling of things; from the airplane that we see flying up high in the sky, satellites in space to the ships and submarines moving underwater; from everyday science and experience to the modern technology; and from individual to the society at large (Gonzalez, 2005; Kumar et al, 2012; Standke et al, 1980; Walker et al, 2016; Young et al, 2012; Rajaraman 2018). Physics also extends and enhances our understanding of other cross-, inter-, and multi-disciplinary scientific disciplines, which are directly or indirectly related to the society (e.g., biophysics, geophysics, astrophysics, nano-science & - technology, materials sciences, medical physics, engineering, technology, and environmental science) (Walker et al, 2016; Young et al, 2012; Mitchell et al, 2007; Hush, 2017; Neamen 2003; Mukhanov 2005; Ahrens, 2011). Even there are fields of study like econophysics and sociophysics (Chakrabarti et al, 2007).

Information and communication technology (ICT) is one such technology, which has impacted nearly all aspects of our modern society and has a close relation with physics (Haddon 2004; Gershenfeld 2011; Rajaraman 2018). In this article, we have presented a concise introduction of ICT and qualitatively discussed the contribution of physics to the historical development of various components of ICT from very beginning to the most recent one without mathematical nitty-gritty to link science, technology, and society.

What is ICT?

Information and Communication Technology (ICT) has become an integral part of our modern lives over the years with the advent and advancement of technologies (Haddon 2004; Gershenfeld 2011; Rajaraman 2018; Samuel et al, 2008). Our ways of communication have adopted different forms and formats with the evolution of mankind over thousands of years, for example, language-based communication over symbolic/art/painting, as we are social animals and communication is an important part of everyone's life (Christiansen et al, 2003). When we look around ourselves and compare the situation of today's world with the medieval period, there has been a drastic change in the field of information and communication. Briefly, ICT integrates or combines communications (audio, visual/audio-visual), necessary/required hardware (electronic components and modules) and software, data storage devices, and adheres some standard protocols to facilitate peoples (users) throughout the world to store, share, transmit, and retrieve (encrypted and sensitive) data (classified message), distant communication (presentation/conference, social interaction), and various online services (e.g., public outreach, reservation, shopping, sports and entertainment, educational broadcasting, and many more) (Haddon 2004; Rajaraman 2018; Samuel et al, 2008; Voogt et al, 2008; Anderson et al, 2002; Goodyear, 2010; Weert, 2004; Field, 2001; Tipton, 2008) Examples of some ICT components are radios, telephones (landline, cell, and smartphones), computers (desktop PCs, laptops and supercomputers), internet (cable and Wi-Fi), optical fibers, cloud computing, satellite communication, TVs, robots, teaching, social networking, etc., and the list is growing (Haddon, 2004; Rajaraman 2018; Charlton, 2009; Voogt et al, 2008; Anderson et al, 2002; Goodyear, 2010; Weert et al, 2004). ICT has revolutionized the teaching-learning process of the education system and as a result, a new field, technology-enhance-learning (TEL), has evolved and gained momentum over the years (Voogt et al, 2008; Goodyear 2010; Anderson, 2002). ICT is taking lifelong learning and lifelong education to a new dimension since peoples can take various online formal and non-formal degrees/courses to enhance their knowledge at their own pace for their careers and other purposes (Weert et al, 2004; Field, 2001). With every day that passes by, it is harder to imagine our work, business, transportation, education, pleasure/entertainment, security, communication, private/social life, and many more without ICT (Gershenfeld, 2000; Rajaraman 2018; Tipton 2008). ICT offers a wealth of information and knowledge to our society. Consequently, 'information society' and 'knowledge society' have evolved slowly but steadily over the years due to the tremendous advancement of ICT (Webster, 2006; Gritzalis et al, 2007; Phillips et al, 2017).

The contribution of physics to the development of ICT

Physics has been consistently contributing to the development of ICT. In this section, we briefly discuss the relation between physics and ICT.

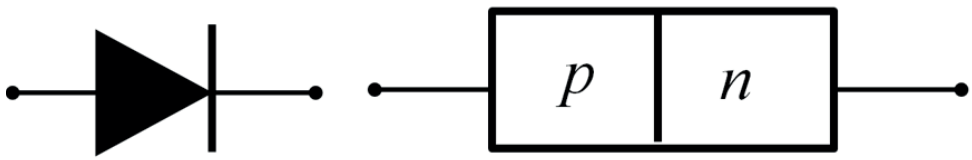
Telephone: The invention of the telephone (phone) has made communication more efficient and faster as it replaced the Telegraph (Freeman 1999; Haykin et al, 2009; Haykin, 2014; Haykin et al, 2007; Proakis, 2002). A telephone is a telecommunication device that permits two users to talk (communicate) directly when they are far apart (Freeman 1999). A telephone has two main parts - transmitter and receiver. When a person speaks (sound) in the telephone (here the transmitter), his voice is picked up by the microphone and is converted into electric signals; the signal is transmitted via cables and other communication channels to another telephone (here the receiver), which transforms the electronic signal into sound and the receiving person receives the voice (audio). Landlines, cell phone/mobile phones, and smartphones are typical examples (Freeman 1999; Haykin et al, 2009; Haykin, 2014; Haykin et al, 2007; Proakis, 2002).

Radio: Radio is the technology of using radio waves to carry information (in the form of sound energy) by systematically modulating and transmitting various properties (amplitude, frequency, phase, or pulse width) of electromagnetic waves through space from one place to another without a direct connection (Haykin et al, 2007; Proakis et al, 2002). The equipment that sends out a radio wave is known as the transmitter and equipment, which receives the signals, is known as the receiver (Haykin et al, 2007; Haykin et al, 2009; Proakis et al, 2002).

Television (TV): A TV plays a very important role in our society (Gulati, 2004; Kompare, 2006). It is a source of information or a medium of communication since through a TV we can see an event occurring in any part of the world - entertainment, local/ world news or information, opinion, debate, education, etc. A TV combines radio (audio) with video (moving pictures) - when radio transmits a sound signal through the air, television also sends a picture signal. These signals are carried by radio waves (electromagnetic waves) that propagate through the air and are received by the receiver. Paul Julius Gottlieb Nipkow, a German student, developed the first prototype of a TV in the year 1800 (Encyclopaedia Britannica, 2008): He sent images through wires with the help of a rotating metal disc. The invention was a three-step process: the camera that turned a picture and sound into a signal; a transmitter that sent the signal through the air; and a receiver that captured the signal and turned it back into picture and sound. Scientists and engineers used the concept light and developed color TV that could have a camera to capture red, green, and blue signals separately; transmission system to send color signals through the air; and a TV set that could turn them back into moving, multicolored images (Gulati, 2004).

Semiconductor and Nano Electronics and Technology: Unique properties (physical, chemical, etc.,) of semiconductors have revolutionized the electronics and technology (Kittel, 2004; Sze et al, 2012; Yu et al, 2010; Moutanabbir et al, 2010). Materials can be broadly classified into three categories - metals, semiconductors, and insulators (Sze et al, 2012). The physical principle which separates them is the ‘band gap’ (or band structure or energy band) (Kittel, 2004; Sze et al, 2012; Yu et al, 2010). For example, the electrical conductivity of semiconductor material is between a metal and an insulator. Semiconductors are used in detectors, diodes, transistors, light-emitting diodes (LED), high-power lasers, power electronics, high-gain amplifiers, integrated circuits (ICs), detectors, sensors, optical and magnetic storages, and many more high efficiency electronic and quantum devices for numerous applications including the secured storage and transmission/ communication of data (Fraden, 2004; Kittel, 2004; Sze et al, 20012; Yu et al, 2010; Moutanabbir et al, 2010). Properties (electrical, magnetic, thermal, chemical, etc.,) of a semiconductor can be tailored by doping one or more elements into it (Kittel, 2004; Sze et al, 2012; Yu et al, 2010; Moutanabbir et al, 2010). There are various types of semiconductors – intrinsic (Silicon, Si, and Germanium, Ge), extrinsic (*p*- and *n*-type), and compound (Kittel, 2004; Sze et al, 2012). If the charge carriers are holes (positive), it is *p*-type, and if the charge carriers are electrons (negative), it is an *n*-type (Sze et al, 2007). A pure (or intrinsic) semiconductor (Si or Ge) can be converted into a *p*-or *n*-type by doping suitable elements into it (Sze et al, 2012; Yu et al, 2010). A junction between two different semiconductors is known as *p-n* junction diode as shown in Fig. 1. A diode exhibits signal rectification and amplification property, generates voltage and optical signals under proper conditions (biasing and recombination of electron and hole) (Sze et al, 2007; Yu et al, 2010). A few examples of compound semiconductors are cadmium sulfide (CdS), lead sulfide (PbS), lead telluride (PbTe), indium antimonide (InSb), gallium arsenide (GaAs), and indium phosphide. In addition, there are several alloys such as gallium indium arsenide (GaInAs), mercury cadmium telluride (HgCdTe), and gallium arsenide phosphide (GaAsP) (Kittel, 2004; Sze et al, 2012; Yu et al, 2010; Moutanabbir et al, 2010).

Figure-1: Schematic diagram of a *p-n* junction diode

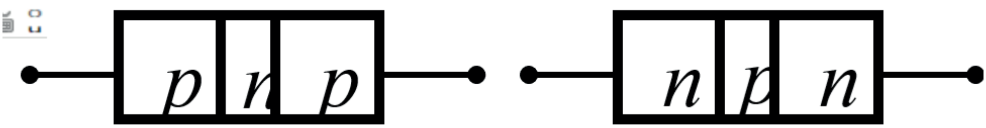


Various types of nanostructures (1 nm = 10^{-9} m), e.g., thin films, nanoparticles, quantum dots, nanorods, nanotubes, and nanoflowers have been used for numerous technological applications due to their unique physical and chemical properties (Wolf, 2006; Kreupl, 2013; Shulaker et al, 2013; Brink, 2007; Friedman et al, 2017; Morkoç 2009). Carbon nanotubes and nanorods, silver and gold nanoparticles, zinc oxide nanoparticles and nanorods are a few examples (Brink, 2007; Friedman et al, 2017; Morkoç et al, 2009). Numerous physical and chemical techniques (sol-gel, hydrothermal, molecular beam epitaxy, microwave, pulsed laser deposition, etc.,) have been used to fabricate them on various materials (substrates) in order to tailor their properties and to achieve the desired applications (such as solar cells, light-emitting diodes, high-power electronics, photonic and optoelectronic devices) (Wolf, 2006). Scientists are working on graphene for future ICT components and other technological applications (Kinaret et al, 2011; Choi et al, 2010; Khorasani et al, 2017; Rana et al, 2014). Graphene is a single hexagonal honeycomb plane of carbon atoms and the building block of full three-dimensional graphite (Choi et al, 2010). It exhibits unusual electronic properties (almost transparent, flexible, stronger than steel, and excellent conductor), which makes it one of the most promising materials for nano-technology over carbon nanotubes (Khorasani et al, 2017; Rana et al, 2014).

Computers: The first electronic digital computer was built by Prof. John Atanasoff, a theoretical physicist, and his physics graduate student Clifford Berry at the Department of Physics at Iowa State University (Henderson, 2009; Morley, 2009; Wang, 2020). The second electronic digital computer, called ENIAC (Electronic Numerical Integrator and Computer) and based on Atanasoff's pioneering work, was proposed, designed and completed in 1945 by physicists J.W. Mauchly and J.P. Eckert (Henderson, 2009; Rojas et al, 2000). This first generation of computers was slow, bulky, and unreliable as vacuum tubes were used to store & retrieve the information (Henderson, 2009; Morley, 2009; Rojas, 2000). They were later replaced by transistors - building blocks of all modern electronic devices (Wang, 2020).

Transistors, developed by J. Bardeen, W. Brattain, and W. Shockley, were the heart of the second generation of computers (Henderson, 2009; Boylestad, et al, 2013; Morley, 2008). They significantly reduced the size of computers and made them more efficient and reliable (Morley, 2008). Transistors form the foundation of digital logic gates and are crucial for memory storage and processing in microprocessors. Transistors can be broadly classified into two categories – bipolar junction transistors (BJTs) and field-effect transistors (FETs) (Boylestad et al, 2013). A BJT consists of three semiconductor layers: the emitter (E), the base (B), and the collector (C). These layers are either of P-type (positively charged carriers, also denoted as *p*-type) or N-type (negatively charged carriers, also denoted as *n*-type) semiconductor materials. There are two types of BJTs: NPN and PNP, depending on the arrangement of the layers as depicted in Fig. 2. The NPN (or, *npn*) transistor consists of a thin P-type base layer sandwiched between two N-type layers: the emitter and the collector (Boylestad, et al, 2013). The PNP (or *pnp*) transistor has the opposite arrangement, with a thin N-type base layer sandwiched between two P-type layers: the emitter and the collector (Boylestad, et al, 2013). It is to be noted that J. Bardeen was awarded twice the Nobel Prize in physics – transistor, and theory of superconductivity.

Figure-2: Schematic diagram of a *p-n-p* and *n-p-n* BJT. Emitter (E), base (B), and collector (C) are also shown



Integrated Circuits (ICs), developed by J. Kilby and R. Noyce, were used in the third generation of computers (Denning, 1971; Gray et al, 2009; Henderson, 2009; Wang, 2020). An IC is an assimilation of several transistors, resistors, and capacitors (Gray et al, 2009). ICs greatly enhanced efficiency, reliability, and storage capacity; lowered maintenance cost; and reduced the size of the computers in comparison to the earlier generations (Denning, 1971).

Microprocessors were used in the fourth generation of computers (Henderson, 2009; Sedra et al, 2015; Balch, 2003; Wang, 2020). They have made the fourth generation of computers more compact, powerful, reliable and affordable (Henderson, 2009). Artificial intelligence, discussed below, will become an integral part of the higher generation of computers (McCarthy, 2007; Narasimha, 1986; Wang, 2020).

Therefore, the generation of computers can be broadly divided into five categories over the years based on the type of hardware used in manufacturing these computers: First generation (~1940 ~ 1950) – vacuum tube (Fig. 3); Second generation (~1950 ~ 1960) – transistor; Third generation (~1960 ~ 1970) – integrated circuit (IC); Fourth generation (~1970 ~ present) – microprocessor; and Fifth generation (present ~ future) – artificial intelligence based (Henderson, 2009; Morley, 2009; Rojas et al, 2000; Denning, 1971; Narasimha, 1986; Wang, 2020;).

Figure-3: A first generation computer

World Wide Web (www) and Internet: World Wide Web (www) and internet work on some protocols and allow creating, organizing, transferring, publishing, sharing/communicating, uploading/downloading, purchasing, and browsing the information/documents for various purposes, and many more (The birth of the web; History of the world wide web; Soldatos, 2017; Lee et al, 1992). They have completely changed our daily lives – communication, education, research, entertainment, and business, just to name a few (Haddon, 2004; Rajaraman, 2018). Tim Berners-Lee, a graduate of Oxford University with an Honors degree in Physics, invented the World Wide Web (www) at CERN to fulfill the demands of scientists of Particle Physics Lab. for sharing the data and disseminating the results among various participating institutes/universities across the world (The birth of the web; history of the world wide web). He further developed URL (Uniform Resource Locator) and HTTP (Hyper Text Transfer Protocol, HTTP).

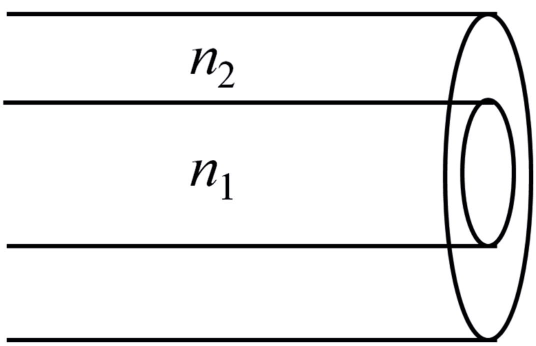
Satellites: Satellites are the astronomical (celestial) objects or bodies that revolve around the planets (Roddy, 2006). Their orbits are close as well as stable and are generally categorized as natural such as moon around the Earth and artificial (manmade). Artificial satellites are launched from the surface of the Earth through a complicated maneuver in order to put them in desired orbits to perform a specific task with a pre-defined life span under the gravitational attraction of the Earth (Roddy, 2006). Artificial satellites receive the signal (radio waves) from the Earth and send them back to the Earth via uplink and downlink processes. Geostationary satellites are placed in orbits in the plane of the equator, which move in the same sense as the Earth with the time period of revolution of 24 hours (i.e., Earth's rotation). This is why they always appear to be stationary with respect to an observer on the Earth (Roddy, 2006). These satellites are useful for weather forecasting (flood, tsunami, storm, etc.,), landscape, communication, and many more. Global Positioning System (GPS) is a navigational system that provides the precise location of an object as well as an accurate time (El-Rabbany, 2002). Concepts of the atomic clock and relativity are used in these navigation systems (El-Rabbany, 2002).

RADAR: It stands for Radio wave Detection And Ranging (Skolnik, 1980). It detects any nearby object (ship or plane) according to its range/efficiency. The radar sends out a signal (radio wave, i.e., electromagnetic wave) through its transmission antenna (transmitter), the radio wave is reflected by the coming object, which is recaptured by the receiving antenna and is processed by the detector of the radar system. Radar is a vital component of national security/interest (Skolnik, 1980). Another similar type of surveillance/remote sensing system is LiDAR, which is the acronym of Light Detection and Ranging that uses short laser pulses for the detection of nearby objects (Dong et al, 2017).

Smartphones: Smartphone has significantly impacted and changed our modern society – health, education, business, entertainment, communication, and personal/social lives (Woyke, 2014; Traxler et al, 2005; Colicchia et al, 2015). The touch screens of smartphones are either capacitive or resistive and physics has played an important role at every stage of the development of the phone (Nam et al, 2021; Ibrahim et al, 2019). Smartphones are equipped with camera, GPS, software, video calling facility (video conferencing), various applications, and many more necessary things (e.g., online booking/reservation, internet banking, file/photo sharing, and gaming) (Woyke, 2014). The touch screens phones that we carry in our pockets are called capacitive touch screens which respond to human skins since our skins conduct electricity and this is the reason that why we cannot operate these screens while wearing gloves (Nam et al, 2021; Ibrahim et al, 2019).

Optical Fiber Communication: Fiber optic, since its invention in the 1970s, has revolutionized the technology of communication – from electrical to optical (electromagnetic waves) due to the advancement of physics of optical materials (Ghatak et al, 1998; Senior, 2009). The advantages of optical fiber communication systems are low transmission (data, video, voice, internet, etc.,) loss, high bandwidth, lightweight, small diameter, and non-expensive. Optical fiber communication has made voice and video conferencing much easier (Firestone et al, 2007). In general, an optical fiber is made of core of refractive index n_1, which is surrounded (supported) by cladding of slightly lower refractive index n_2 (i.e., $n_2 < n_1$). Light travels through the fiber due to the phenomenon of total internal reflection (Ghatak et al, 1998; Senior, 2009). A simple diagram of an optical fiber is shown in Fig.4. There are various types of optic fibers such as glass/plastic, step-/grade-index, and single-/multi-mode for various applications in science, technology, and communication (Ghatak et al, 1998; Senior, 2009).

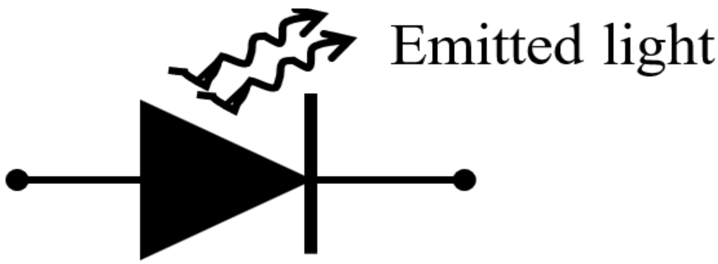
Figure-4: Schematic diagram of an optical fiber with core of refractive index n_1 and cladding of refractive index n_2.



Liquid-Crystal Display (LCD): Nowadays, we are very much familiar with thin and flat LCD monitors (TVs and PCs) (Boylestad et al, 2013; Chen 2011). As the name suggests, its underlying principle is the physics of liquid crystal. Liquid crystals move freely (i.e. flow like a liquid) under suitable electrical conditions but still maintain the structure of a crystal. LCD consumes less power than a light-emitting diode (LED). However, unlike LED, discussed below, it requires an external/internal light source to generate light (Boylestad et al, 2013).

Light Emitting Diode (LED): There are various types of LEDs (e.g., ordinary LED, organic LED, and quantum dot LED, which are widely used in various places (cell phone, street light, traffic signal, a display device, flash lamp, large advertising display boards, TVs, PCs, etc.) due to their small sizes and energy efficiencies (Boylestad et al, 2013; Planinšič et al, 2015; Chen et al, 2018; Qasim et al, 2013; Wood et al, 2010; Geffroy et al, 2006; Jang et al, 2023). The fundamental principle is the physics of semiconductor devices (Boylestad et al, 2013; Geffroy et al, 2006). A LED is a semiconductor (*p*–*n* junction diode) light source that gets activated and emits light (photons) by electron-hole recombination when a suitable excitation/voltage is applied to it as shown in Fig. 5 (Sze et al, 2007). An electron-hole pair is created when an electron moves from one energy level (band) to another one and leaves a hole in its initial energy level (Boylestad et al, 2013). Thus, a hole is a void of an electron and considered as positive. Light is emitted when the electron jumps back to the hole (known as electron-hole recombination) and the color of the emitted light (red, green, blue, etc.,) is determined by the energy band-gap of the semiconductor (i.e., the difference between the two energy levels) (Planinšič et al, 2015; Boylestad et al, 2013).

Figure-5: A sketch of a light emitting diode



Organic compounds are used as emissive (light-emitting) layers in Organic LEDs (OLEDs), which emit light under a suitable electric current (Chen et al, 2018; Geffroy et al, 2006). Though the working principle of an OLED is the same as LED, it uses organic layers (materials) to generate electrons and holes instead of *p*- or *n*-type materials (Geffroy et al, 2006; Boylestad et al, 2013). A simple OLED is made up of several layers – top (seal) and bottom (substrate) layers of protective glass or plastic, negative (cathode) and positive (anode) terminals between top and bottom layers, two emissive layers of organic molecules (where the light is produced), and the conductive layer sandwiched between the cathode and the anode (Geffroy et al, 2006). Various applications of OLEDs are television screens, computer monitors, mobile phones, handheld game consoles, Personal Digital Assistants (PDAs), etc. (Geffroy et al, 2006). Quantum dot LED (QD-LED or QLED), which uses the principle of quantum mechanics, will soon become a reality (Qasim et al, 2013; Wood et al, 2010).

Artificial Intelligence (AI), Machine Learning, Quantum Computer, and Quantum Cryptography: Scientists/ technologists are working vigorously to develop AI-based higher (future) generations of computers, software, robot, and other devices using the principle of quantum mechanics (McCarthy, 2007; Narasimha, 1986; Lemaignan et al, 2017; Eaton, 2007; Russel et al, 2010; Tegmark, 2014; Rajaraman, 2014;). According to Prof. John McCarthy, the founding figure of AI, it is "The science and engineering of making intelligent machines, especially intelligent computer programs" (McCarthy, 2007; Rajaraman, 2014). Machine learning, covering the domains of AI, computer science, and physics, has gained tremendous attention from the scientific community in recent years due to its capability of processing a large amount of data/information and make a future prediction/trend based on the fed data (Sarma et al, 2019). The main idea of AI and machine learning is to make a system to learn, think, behave, perform, analyze, recognize, and do many more in a fashion similar to human brains (Flasińki, 2016; Lemaignan et al, 2017; Tegmark, 2014; Sarma et al, 2019). Quantum computer and quantum cryptography rely on quantum mechanical phenomena (entanglement and superposition of quantum states) to store and analyze the input data/information (Spiller, 2002; Zeilinger, 1998; Menon et al, 2014; Tittel, 1998; Gisin, 2002; Ying, 2010; Keyl, 2002). Stephen J. Wiesner conceptualized the application of photons (a quantum mechanical particle, also known as quanta of light) in cryptography in 1970s to establish a secured connection/communication (transmission of data) between two persons at distant locations in such a way that if a third person tries to interfere the communication/steal the data (known as eavesdropping) it would alter the state of the particle and stop the communication (Montanaro, 2016; Gisin, 2002; Ying, 2010). Charles Bennett and Gilles Brassard proposed the well-known BB84 scheme for Quantum Key Distribution (QKD) in 1984 (Montanaro, 2016; Diamanti et al, 2016). Physics (quantum mechanics) also has been contributing significantly to the (quantum) neural network, quantum tensor flow, quantum machine learning, hybrid quantum-classical machine learning, and artificial neural network (Huang et al, 2021; Gebhart et al, 2023; Huggins et al, 2019; Ihunde, 2022; Gupta et al, 2001; Schuld, 2019; Sierra-Sosa et al, 2020). All these technologies are interconnected and have been extensively used in various domains and fields - basic and applied sciences, information and communication technology, manufacturing, business, finance, health care system, agriculture, mining, commerce, security/defense, robotics, computer games, and transportation, image processing, speech recognition, and many more – that is to say that they are getting deeply embedded in our modern lives/societies and are becoming more and more relevant as we move on (Erl, 2013; Han et al, 2012; Chaminade et al, 2009). It is pertinent to note that Physics plays a crucial role in the development and functioning of self-driving cars (also known as autonomous vehicles, AVs) (McCormick, 2019). Several fundamental principles of physics are applied to ensure the safety and efficiency of these vehicles. Self-driving cars rely on various sensors and algorithms, with physics principles governing the behavior of these sensors. For example, the reflection, refraction, and absorption of light and sound waves enable the vehicle to perceive its environment, detect obstacles, pedestrians, and other vehicles. The data are continuously feed to the car's computer, enabling it to make informed decisions.

Virtual Reality: Virtual reality (VR) is a technology that uses computer graphics, sensors, and displays to create an interactive and lifelike simulation of a three-dimensional (3D) environment (Radianti et al, 2020). With specialized VR headsets or devices, users are fully immersed in an artificial world, where their head and body movements are tracked to give them a sense of being present within the virtual environment. The ultimate goal of VR is to achieve a feeling of presence, making users believe they are physically part of the simulated world while still being in the real world. Virtual reality has numerous applications, including gaming, training and simulations, education, architectural and engineering visualizations, therapy and rehabilitation, entertainment, and media (Uriel et al, 2020; Cipresso et al, 2018). Over the years, VR technology has rapidly progressed and gained popularity, becoming more accessible to both consumers and industries (Cipresso et al, 2018; Hamad et al, 2022). As the technology continues to advance, it opens up exciting possibilities in various fields.

Physics plays a significant role in creating realistic and immersive VR experiences (Neroni et al, 2021; Harun et al, 2020). By accurately simulating the laws of physics within virtual environments, developers can enhance the sense of presence and interactivity for users. VR can be used to teach and learn physics concepts that are difficult to visualize or experience in the real world, such as electrostatics, quantum mechanics, relativity, etc. VR can also provide feedback and guidance to the learners through sounds, vibrations, or other instruments. Thus, by leveraging the power of physics simulations, VR experiences can provide users with a more immersive, interactive, and realistic world, expanding the potential of VR in entertainment, education, training, and various professional fields (Cipresso et al, 2018; Hamad et al, 2022).

ICT and education

ICT has revolutionized education, bringing a multitude of benefits to the learning process (Bansa et al, 2020; Fu, 2013; Weber et al, 2023; Martínez-Soto et al, 2023). One of the key advantages of ICT in education is enhanced access to information. With the internet, students can access a vast array of knowledge, resources, and educational materials from around the world, promoting independent and self-directed learning (Traxler et al, 2005). ICT also fosters interactive and engaging learning experiences through multimedia tools, simulations, and virtual reality, catering to different learning styles and making complex concepts easier to understand (Martínez-Soto et al, 2023; Uriel, 2020; Schindler et al, 2017). Additionally, ICT enables effective communication and collaboration among students and educators, breaking down geographical barriers and promoting global connections (Kumar et al, 2012). Furthermore, the integration of ICT in education has streamlined administrative tasks, improving efficiency and reducing paperwork. Overall, embracing ICT in education not only enriches the learning process but also equips students with essential digital literacy skills, preparing them for the challenges of the modern world (Schindler et al, 2017). However, it should be noted that other infrastructure are also required with ICT to improve the teaching-learning process (Lomos et al, 2023).

Conclusion

In summary, we have briefly introduced the concept of ICT and portrayed qualitatively contribution of physics to the various components of ICT. Our discussion has shown how science (physics), technology (ICT), and society are connected. ICT has drastically influenced how people work, communicate, learn, and live. We believe that with the advent of new components of ICT, the influence of physics will continue to grow.

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