in more usual parlance the rotation of the plane of polarization under the action of magnetic force. It would be hopeless to attempt to explain all the preliminaries of the experiment to those who had not given some attention to those subjects before, and he could only attempt it in general terms. It would be known to most of them that the vibrations which constituted light were executed in a direction perpendicular to that of the ray of light. By experiment he showed that the polarization which was suitable to pass the first obstacle was not suitable to pass the second, but if by means of any mechanism they were able, after the light had passed the first obstacle, to turn round the vibration, they would then give it an opportunity of passing the second obstacle. That was what was involved in Faraday's discovery. [Experiment.] As he had said, the full significance of the experiment was not yet realized. A large step towards realizing it, however, was contained in the observation of Sir William Thomson, that the rotation of the plane of polarization proved that something in the nature of rotation must be going on within the medium when subjected to the magnetizing force, but the precise nature of the rotation was a matter for further speculation, and perhaps might not be known for some time to come.

When first considering what to bring before them he thought, perhaps, he might include some of Faraday's acoustical experiments, which were of great interest, though they did not attract so much attention as his fundamental electrical discoveries. He would only allude to one point which, as far as he knew, had never been noticed, but which Faraday recorded in his acoustical papers. "If during a strong steady wind, a smooth flat sandy shore, with enough water on it, either from the receding tide or from the shingle above, to cover it thoroughly, but not to form waves, be observed in a place where the wind is not broken by pits or stones, stationary undulations will be seen over the whole of the wet surface. . . . . These are not waves of the ordinary kind, they are (and this is the remarkable point) accurately parallel to the course of the wind." When he first read that statement, many years ago, he was a little doubtful as to whether to accept the apparent meaning of Faraday's words. He knew of no suggestion of an explanation of the possibility of waves of that kind being generated under the action of the wind, and it was, therefore, with some curiosity that two or three years ago, at a French watering-place, he went out at low tide, on a suitable day when there was a good breeze blowing, to see if he could observe anything of the waves described by Faraday. For some time he failed absolutely to observe the phenomenon, but after a while he was perfectly well able to recognize it. He mentioned that as an example of Faraday's extraordinary powers of observation, and even now he doubted whether anybody but himself and Faraday had ever seen that phenomenon.

Many matters of minor theoretic interest were dealt with by Faraday, and reprinted by him in his collected works. He was reminded of one the other day by a lamentable accident which occurred owing to the breaking of a paraffin lamp. Faraday called attention to the fact, though he did not suppose he was the first to notice it, that, by a preliminary preparation of the lungs by a number of deep inspirations and expirations, it was possible so to aërate the blood as to allow of holding the breath for a much longer period than without such a preparation would be possible. He remembered some years ago trying the experiment, and running up from the drawing-room to the nursery of a large house without drawing any breath. That was obviously of great practical importance, as Faraday pointed out, in the case of danger from suffocation by fire, and he thought that possibly the accident to which he alluded might have been spared had the knowledge of the fact to which Faraday drew attention been more generally diffused.

The question had often been discussed as to what would have been the effect upon Faraday's career of discovery had he been subjected in early life to mathematical training. The first thing that occurred to him about that, after reading Faraday's works, was that one would not wish him to be anything different from what he was. If the question must be discussed, he supposed they would have to admit that he would have been saved much wasted labour, and would have been better *en rapport* with his scientific contemporaries if he had had elementary mathematical instruction. But mathematical training and mathematical capacity were two different things, and it did not at all follow that Faraday had not a mathematical mind. Indeed, some of the highest authorities (and there could be no higher authority on the subject than Maxwell) had held that his mind was essentially mathematical in its qualities, although they must admit it was not developed in a mathematical direction. With these words of Maxwell he would conclude: "The way in which Faraday made use of his idea of lines of force in co-ordinating the phenomena of electric induction shows him to have been a mathematician of high order, and one from whom the mathematicians of the future may derive valuable and fertile methods."

THE ROYAL NAVAL EXHIBITION.

THE Naval Exhibition, now being held at Chelsea, is distinctly a popular show. The management—recognizing that the first duty of an Exhibition is not to show a pecuniary deficit—has wisely decided to follow the lead given by Sir Philip Cunliffe Owen, and has devoted the chief of its energies to fireworks, waxworks, peep-shows, pictures, shooting-galleries, mimic sham fights, and musical entertainments of a kind known to sailors as "sing-songs." The end justifies the means. Not only does the Committee of distinguished Admirals labour to supply Londoners with a cheap and innocent means of enjoyment, but the final result will be the establishment of a substantial fund to endow a most deserving charity. Fortuitously there are features which possess a more serious interest; and though there may be nothing especially new in the Exhibition, the man of science who has not been brought much in contact with naval matters may find there a good deal that is worth consideration.

The Exhibition appears to be divided into about half-a-dozen sections, each under the direction of a committee. Of these the "Entertainments" and "Refreshments" Committees are of course the chief; but the Models Committee appears to be the one which has made the most serious effort to present a distinctly naval subject in logical sequence. In the Seppings Gallery there is a collection of models of warships illustrating the progress of naval architecture, from the *Great Harry* down to the very latest design of armour-clad battleship. The model of the *Great Harry* is of very doubtful authenticity, and is of modern construction, having been made by the aid of such pictures of the great sixteenth-century ship as exist. No historical collection of British warships would, however, be even approximately complete without a representation of this vessel. Charnock, our great authority on the subject, has styled her "the parent of the British Navy"; and if it be true, as supposed, that she was the first warship to sail on a wind, the claim is most amply justified. In fact, naval architecture as a science was not founded until it was discovered that ships could be, otherwise than by the aid of oars, taken to the quarter from which the wind was blowing. It must have seemed a great feat in those days—little less than necromancy. Fortunately for the timid intellects of our ancestors, the revelation broke upon them gently, for the rounded hulls, high topsides, and curiously rigged craft could not have sailed more than a point or two to windward. Still, it was the *Great Harry*, or one of her contemporaries, by means of which this new feature in seamanship was inaugurated; a feature by which the great middle period in the world's history of naval warfare was created, and which enabled the sailors of those times to make a distinct advance upon the lessons taught them by their instructors in the art of shipcraft, the Phœnicians, Romans, and Scandinavians. It would have been well if we had improved on our predecessors in other nautical matters as well; and we then should not have had, even in the present century, our shipwrights attaching lead sheathing to ships' bottoms with iron nails. The Romans used copper fastenings when they lead-covered the under-water part of their vessels.

There are but three models of seventeenth-century ships in the Exhibition, but one of these is a vessel that forcibly illustrates, by contrast, the mutability of the present age. The *Royal William* was designed by the first great naval architect, Phineas Pett—whose name might almost more appropriately have been given to the Models Gallery than that of Seppings—and was built at Chatham in 1670. She was originally a three-decker, carrying one hundred guns, but in 1757 she was cut down to a ship of 84 guns, and was finally broken up in 1813—a fact duly recorded by the present Director of Naval Construction, Mr. W. H. White, in his delightful lecture on "Modern War Ships," delivered a few years ago at the Mansion House. The *Royal William* must not, however, be taken as an example of the endurance of ancient materials so much as of the slow changes in design which characterized the proceedings of our ancestors. The original material part of the *Royal William* only lasted twenty-two years, for she was rebuilt, we are told, in 1692, and again in 1719; so that in this respect she compares unfavourably with so modern a vessel as our first ironclad, the *Warrior*, which has only recently been taken out of the Navy after a service career of not far from 30 years. Even now the *Warrior* has not been removed from the Navy list because she has become worn out, but simply because she has become obsolete. If we could reach finality in design—if the inventive brain would stagnate—there is no reason why the modern iron-built warship should not outlast its wooden predecessor by almost as great an extent as it exceeds it in power of destruction. It is true the natural life of the old ships was a long one. The *Victory* was forty years old when she was engaged in the battle of Trafalgar, and had seen much active service, having been launched at Chatham in 1765; but then she had been laid by as worn out in 1801, and it was only after extensive repairs that she was made fit for sea. A year or two ago, it will be remembered, she was found to be so rotten that she would have sunk at her moorings had she not been taken into dock and in part rebuilt. On the other hand, there is no reason why an iron ship should not last, provided she were properly painted and kept up, perhaps until the era when warships will have become relics of a barbarous past. The expression "properly painted" must be here taken in its literal sense; and with regard to steel ships due steps must be followed to remove mill-scale, a precaution which has not always been taken of late, as quite recent mishaps have testified.

Passing from hulls to motive power, we find the same governing principles as to durability of material and impermanence of design more strongly emphasized in the practice of to-day compared with that of the naval era which closed with the introduction of steam and iron hulls. With comparatively small variations in detail the rig of war ships has remained unchanged from the days of Pett down to those within the memory of men still living. The *Henri Grace à Dieu* shows a distinctly mediæval rig—although her fighting-tops are ridiculously like those of our very latest armour-clads—but it would take almost a sailor's eye to point out the differences in sail plan between Vandevelde's beautiful painting of the *Sovereign of the Seas*, "built in 1637," and the ships which appear on the canvases of Stanfield, Turner, and Cooke. So much for permanence of design with masts and sails; with the succeeding mode of propulsion, engines and boilers, we find as striking a result in the opposite direction. Steam machinery was first introduced into the Royal Navy in small gun-boats, and later in the paddle-wheel frigates, but it was not until the screw was proved to be the more effective instrument that even the most sanguine engineers could hope that engines and boilers would successfully rival masts and sails as a means of propulsion. We pass over, therefore, the unimportant era of paddle-wheels, but even taking screw engines alone we find that during the last forty years far greater changes have taken place in the design of steam machinery than characterized the arrangement of masts and sails during the two hundred years elapsing between the time the *Sovereign of the Seas* was built and the practical introduction of steam into the Navy; indeed we might, without any great fear of contradiction, go further and say that to the eye of the engineer there is no greater affinity between the screw engines of forty years ago and those of the present day, than existed between the rigging of the ships of the Norse sea-kings and those of almost our own day, putting on one side only the element of size. The collection of engine models in the Exhibition is far from complete, and is not to be compared with that of ship models. There is a good reason for this, as engineers work to drawings, and models are seldom made excepting as records; whilst their cost is so great as to render them available only for very rich firms. The collection of models shown by Messrs. Maudslay, Sons, and Field constitute the greater part of the historical collection in the Exhibition. Here may be seen representations of the first types of steam-engine introduced into the Navy; and we think a comparison of the early engines in this collection with, say, the magnificent model of the *Sardegna's* engines, shown by Messrs. Hawthorn, Leslie, and Co., will bear out the remarks we have made. What path the progress of marine engineering will follow in future it is difficult to forecast. The inventions of to-day always seem to have reached finality, but it is difficult to imagine that any fundamental change can be effected so long as we retain the use of steam as a vehicle for the conversion of heat into work. It may be that a little engine shown in the Exhibition—Priestman's oil engine—may contain the germ of a principle upon which marine engines may be designed in future, and that before we have got far into the twentieth century the marine boiler, with all its costliness and complication, may have become as much a relic of the past as the pole masts and uncouth sails of the *Great Harry*. Before that time arrives, however, the four-stroke cycle will have to be superseded.

It is, however, the steam boiler, rather than the engine, which has governed the design of ship machinery. Forty- to forty-five years ago, steam pressures were not generally higher than 5 to 8 pounds per square inch. With the introduction of tubes in place of flues, which took place between 1840 and 1850, the working pressure rose to 15 pounds per square inch. The square box boiler was in use, and with that type the working pressure was limited to about 30 pounds per square inch, or not much beyond, unless the staying of the flat surfaces was carried to an undesirable extent. With such a limit of pressure, the simple expansion engine was, properly, the usual type, but when the cylindrical marine boiler was introduced, the average steam pressure quickly rose to 60 pounds to the square inch, and the compound engine naturally followed. The surface condenser formed a necessary part of this step in advance, for, with the higher temperature due to the increased steam pressure, it was impossible to pass large quantities of salt water through the boilers without rapidly scaling them up. For some time the difficulty in generating higher pressure steam caused stagnation in marine engineering practice; until the substitution of steel for iron in boiler making, the advent of new types of furnaces, and improvements in the machinery used in boiler construction have enabled pressures as high as from 150 pounds to even 200 pounds to the square inch to be carried. The result has been that, for the two-cylinder compound engine, there have been substituted two types of engine, known respectively as the triple expansion engine and the quadruple expansion engine. The names are misleading, as even the ordinary compound engine expands its steam more than three or four times.

The growth of the science of marine engine design, which we have so briefly sketched out, may appear, to those who are not engineers, but little more than a record of increasing steam pressures. Undoubtedly a higher steam pressure has been the fundamental reason for these advances, but the carrying out of these successive changes in pressure has necessitated an entire reconstruction of marine engine practice; so that an engine working at 15 pounds pressure can hardly be said to belong to the same category as one working at 150 to 200 pounds pressure. Tooth-wheel gearing, which was first used with screw propellers, has long ago disappeared, side levers and trunks are no longer introduced, and the surface condenser has become a necessity. In the old days, with jet condensers, the boilers were fed entirely with salt water, now in the best marine practice the condensed steam is all returned to the boiler, excepting that which is unavoidably lost, and this quantity is made up by special distillers and condensers, the manufacture of which has introduced a new branch of marine engineering, as may be judged by several exhibits by different firms in the Exhibition. The practice of circulation of refrigerating water through the surface condenser by means of separate centrifugal pumping engines has also introduced a distinctive type of auxiliary marine engine, upon which several important firms have been chiefly employed. Indeed, the increase in auxiliary machinery has been as marked a feature in the recent progress of marine engineering as have been the changes in the main engines themselves. A battleship of the first class will carry between seventy and eighty separate engines, in addition to those used for driving the propellers. These include electric light engines, hydraulic machinery in connection with the working of heavy guns, steering engines, &c. As an instance of what is gained by the use of auxiliary machinery, an instance given by Mr. White may be quoted. On one occasion it took 78 men $1\frac{1}{2}$ minutes to put the helm of the *Minotaur* hard over. Steam gear was subsequently fitted, by the aid of which two men were able to do the same thing in 16 seconds.

We do not propose to give a list of the various objects exhibited, to which we have referred in penning these remarks. The official catalogue performs that function far more completely than we could hope to do. The collection at Chelsea is well selected and fairly complete, and there will be found there material for object-lessons in all we have advanced in this brief sketch. We may, however, with advantage, add a few figures as to money cost, which cannot fail to be of interest, and for which we are indebted to the Director of Naval Construction. The cost of a 100-gun line-of-battle ship at the beginning of the century was about £65,000 to £70,000, armament and stores being excluded. The corresponding outlay on the 110-gun sailing three-deckers of 1840 was about £110,000; and that of the 121-gun screw three-deckers of 1859 about £230,000, machinery included. The *Warrior*, completed in 1861, cost over £375,000; and the *Minotaur* class about £480,000. With the increase in size of the *Dreadnought*, and the introduction of hydraulic mechanism, came an increase of cost to £620,000; while the *Inflexible* cost no less than £810,000." The *Nile* and *Trafalgar*, complete with armament, would represent little less than a million sterling each. The cost of the armour-plating, propelling machinery, and hydraulic gun mountings alone, would have paid for five first-rates of Nelson's time. The sum paid for the armour alone on one of our latest battleships, such as the *Royal Sovereign*, would pay for the Natural History Museum at South Kensington; whilst even a first-class torpedo-boat costs as much to build and equip as a 40-gun frigate of Nelson's time.

A GEOLOGICAL EXCURSION IN AMERICA.

I BEG to call to your attention the following short account of a geological excursion planned for the benefit of foreign geologists who may attend the coming meeting of the International Geological Congress in this city in August next. It will afford an exceptionally favourable opportunity for European geologists to become personally familiar with the most important geological phenomena of the United States.

I venture, therefore, in their interest, to request that you publish some notice of it in your widely circulated periodical, with a request that those who desire to take part in it will kindly advise me as early as possible, in order that arrangements may be thoroughly perfected beforehand. A single train will carry 75 to 100 persons comfortably. If more join, the party will be arranged in two trains. Arrangements will have to be made beforehand at the various stopping places along the road for the reception of the party, and you can therefore readily understand the importance of knowing as early as possible how many are to be accommodated.

S. F. EMMONS, Secretary.

Washington, D.C., May 30.

For the close of the fifth session of the International Congress of Geologists, which is to be held at Washington, D.C., from August 26 to September 2, a grand geological excursion has been organized, which presents unusual attractions and facilities for the European geologists who attend the Congress, and who wish to see some of the geological wonders which have become familiar to them through the memoirs of American geologists. The excursionists will start from Washington, on September 3, on a special train of Pullman vestibuled cars, which will constitute a moving hotel, being provided with sleeping and toilet accommodations for both ladies and gentlemen, restaurant cars, smoking, reading, and bath rooms, and barber's shop, and so arranged that travellers can pass freely at all times from car to car through covered passages. It will accompany the party wherever the rails are laid in the regions visited, the hours being arranged so that all the most interesting portions of the route will be passed over in the daytime, and stops may be made wherever any object of special interest to the travellers presents itself. American geologists who have made special studies of the different regions visited will accompany the train, and explain their geological structure upon the ground. The main route laid out is over 6000 miles (nearly 10,000 kilometres) in length, and extends over 38° of longitude and 12° of latitude. It is planned to occupy 25 days, and the cost per person will be 265 dollars (1325 francs), which will cover all necessary expenses, of whatever kind, during the trip.

The following are the principal objects of geological interest which will be seen by those who make the excursion:—

Going westward, the Appalachian Mountains are first crossed, and an opportunity will be had to see the closely appressed Palæozoic rocks which constitute their typical structure. The prairie region of Indiana and Illinois, at the southern end of Lake Michigan, its ancient outlet