Understanding the IA Criterions and thoroughly understanding their ingredients.

Here following points should be kept scoring optimal in each criterion. The examples for each criterion have been mentioned for each criterion.

Presentation criterion A:

0 The exploration does not reach the standard described by the descriptors below.

1 The exploration has some coherence or some organization.

2 The exploration has some coherence and shows some organization.

3 The exploration is coherence and well organized.

4 The exploration is coherent, well organized, and concise.

Presentation is one of the most essential components of the IA as it overall develops an impression on the examiner. To score optimal in this criterion following things should be kept in mind as this what an examiner mainly looks for.

- ✓ Front page should have the title and number of pages. Here are the few examples.

Correlation

Research Question: *An investigation into the correlation between the grades of a student and the average number of hours he/ she studies in a year.*

No of pages: 17

Modelling And Predicting Grades

Can a model made from the previous years be used to determine the percentage or number of candidates that will achieve a certain grade?

No of pages: 16

- ✓ 12-20 pages with double line spacing
- ✓ Page numbering
- ✓ Introduction
- ✓ Specific Aim: In general, presentation means the overall organization and coherence of the IA. If your classmate can understand and follow your IA the way you understand it, it means, your IA is well presented. Being an examiner, we look for three things in the introduction, i.e., aim, rationale and plan. Given below are the two examples for the clear aim and an unclear aim in the IA.

Aim ✓

The aim of this exploration is to investigate whether the level of grades of a student (y-variable) is dependent upon the number of hours he studies in a year (x-variable): if studying more hours, a day can enhance a student's academic performance. I will be exploring this correlation because, being a student myself, it is my utmost priority to achieve the best possible grades I can.

Aim ✗

The aim of exploration is look at the patterns in the leaves. I would be formulizing it later in my exploration and do some interpolation and extrapolation.

✓ Focused Rationale

Rationale ✓

Recently when I heard about May 2020 exams being cancelled, I along with many others had one thing in mind. How can students be graded fairly when there are no exams? After learning about the grades based solely on IAs so I thought about ways in which I could answer this question conclusively. Then I got an idea! Why not model this phenomenon and see for me? This would not only make me appreciate math even more, but it would satisfy my curiosity of finding out if the kids from the May 2020 exams had a similar outcome to previous years.

Rationale ✗

I decided to pick this topic as it fascinated me to an extent that I thought to further explore it and to see if any appropriate math is applicable on it.

✓ Transparent Plan. There should be a clear approach and plan given in the introduction as mentioned below

Plan and Approach

To answer this question only secondary data could be used which was provided in the IB statistical bulletins that are present for anyone to view.

My first instinct was to take the data from the last 5 years and take the averages of the data after which I would plot it on a cumulative frequency curve but there were a few problems with that. Firstly, the May and November examinations had slightly different pass rates and mean grades which made it so that an average of both the sessions wouldn't be able to capture the most accurate picture of the last five years.
The second problem I found was that I needed to choose whether to plot the kids who didn't receive the diploma or the ones that did because in the statistical bulletins the percentages of each are different. Since all my seniors obtained the Diploma, I decided that the latter was a better option.
Listening to their grades the expected cumulative frequency curve would follow a logarithmic curve of $y = alnx + b$ with a vertical stretch factor of a and a y-intercept of b.

To test my hypothesis, I decided to take a larger data set and then use that to see if it would follow the proposed path as more people are near the middle leading to a steeper gradient at the start which slowly reduces to become an asymptote at 100% in an ideal case.

- ✓ The concepts should be elaborated clearly (avoid leaving the reader in the grey area)
- ✓ The transition between the topics and distinct concept should be linked (Fluidity of the document should be clear). Before starting a new paragraph, make your reader prepared what is going to come in the next paragraph and how it is related to the previous one by providing a rationale behind it.
- ✓ Avoid adding long table (Prefer appendices)
- ✓ Avoid repetition: This happens mostly in the IA and students do not take this into account and lose score in lacking conciseness of the IA.

✓ Conclusion in line with aim

Conclusion

It can be deduced that the data does follow a normal distribution however the scores of the students that have obtained the Diploma lie well in between three standard deviations of the mean and so the third empirical rule doesn't hold a lot of value in this case. Any how it came as a surprise that the point distribution does follow somewhat of a normal distribution and thus using the normal CDF function I will try and answer my question of: was the grade distribution for the May 2020 exams like previous years? And how closely does it resemble it.

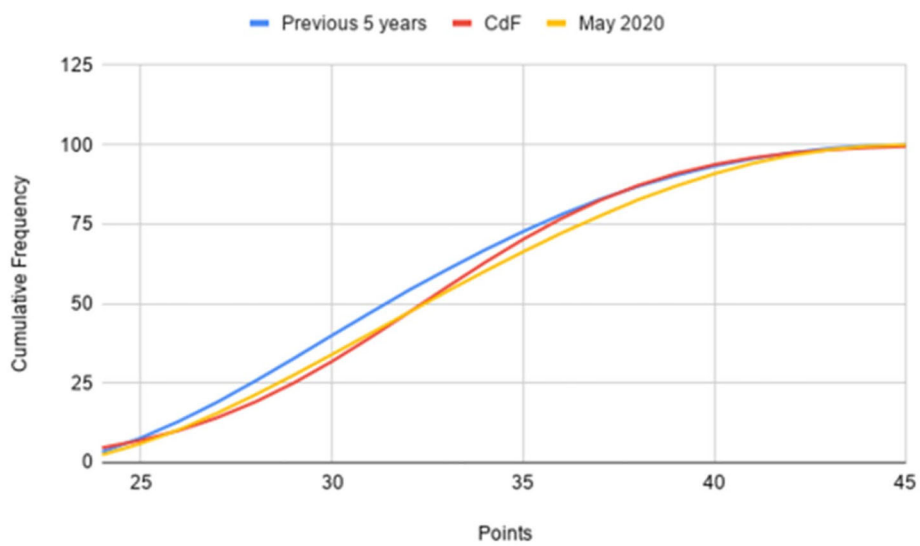


Fig. 10 CDF compared to the May 2020 and Previous 5 May examinations

This is a very interesting site to see. The CDF line follows the curve of the May 2020 examinations at the beginning and then merges with the line of the previous 5 May examinations. After seeing this I am confident that the grade distributions follow a normal distribution to a large extent and no specific points were awarded out of proportion to the May 2020 batch. Using excel I found the coefficient of determination r^2 of the Cdf with the previous 5 years to be 0.993465089 while for the May 2020 examinations it turned out to be 0.99616521. Although a minute difference it is safe to say that the CDF model is very precise at predicting the number of candidates receiving a particular grade.

Mathematical Communication B:

0 The exploration does not reach the standard described by the descriptors below.

1 The exploration contains some relevant mathematical communication which is partially appropriate.

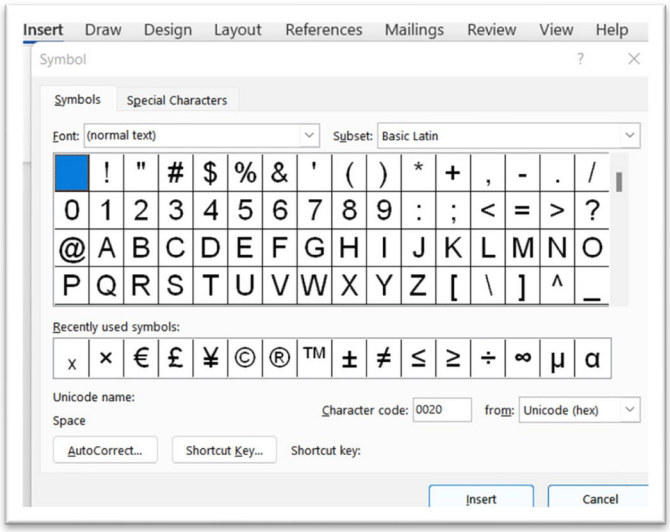
2 The exploration contains some relevant mathematical communication.

3 The mathematical communication is relevant, appropriate, and mostly consistent.

4 The mathematical communication is relevant, appropriate, and consistent throughout.

Mathematical communication is one of the most technical aspects of the IA as the examiner takes it quite seriously. By following the checklist below once can ensure maximum marks in this criterion.

- ✓ Define all key terms and variables
- ✓ Use real arithmetic sign (avoid generic signs such as * for multiplication or / for divisor)
- ✓ Write equations through an equation editor (Don't use alphabets such as use $2x + y$ instead of 2x+y)



- ✓ Center align the equations
- ✓ Along with equations the chart, table, graphs etc. should also be aligned in center
- ✓ Axes should be clearly labelled along with clear title of each chart

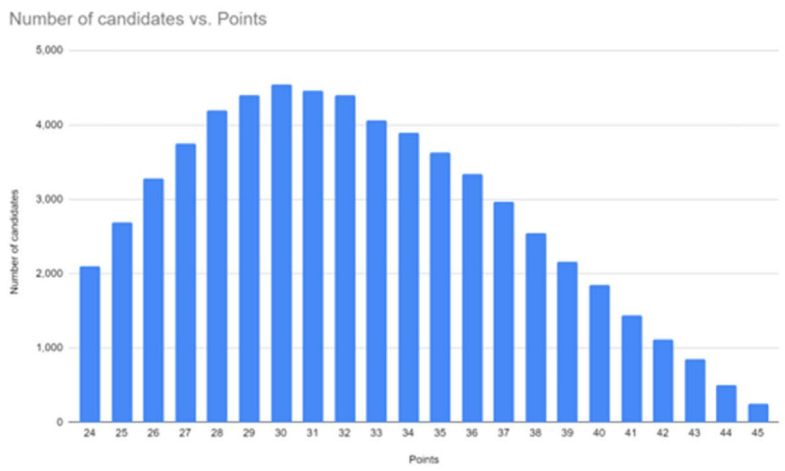


Fig 1. Histogram of the number of candidates achieving a certain number of points

- ✓ Keep in mind the significant figures as they should remain the same throughout the IA to maintain flow. The estimation should be quoted and done on the required spaces.

> Since I have collected the data from IB website which contains three significant figures, therefore, I will be keeping all my final answers to three significant figures. This would also allow me to keep with the practice for my final exams where I must leave my final answers to three significant figures.

> Since I have used Vernier Calipers to take my measurements, therefore I will keep all my findings and numbers to hundredth part of the mm as this is the least count of the device, I used to collect my data.

<u>Personal Engagement C:</u>

0 The exploration does not reach the standard described by the descriptors below.

1 There is evidence of some personal engagement.

2 There is evidence of significant personal engagement.

3 There is evidence of outstanding personal engagement.

Personal engagement is one of the trickiest criterions as most of the students struggle to execute this criterion on merit. These are some points that can help the student attain maximum score in criterion C.

- ✓ Affiliation with the topic and expectation of the results should be evident throughout the document
- ✓ Shouldn't be very generic
- ✓ An anecdote should complement the topic selection.

- ✓ Collection of data could be secondary or could be primary however collection method should be clear and straightforward.

> **Data Collection and Results**
>
> Using the statistical bulletins provided by the IB, I took the data from the last 5 May examination series from 2015-2019. The reason being that taking into account November series leads to data being skewed since the change in number of candidates is drastic which gives slightly different results. I have taken the averages of the number of candidates and then calculated the percentage and the cumulative frequency.
> The boundaries of each data point are the number of points the students have achieved while obtaining a diploma, i.e. 24 to 45.

- ✓ Opinion on the topic should be given at times as the flow of the document shouldn't seem mechanical. You do have the write to wonder or agree to disagree at times. (The document should seem realistic as in everything can't be perfect)
- ✓ Open-mindedness should surface the document (Perspective's should be welcomed)
- ✓ The topic shouldn't be very generic (Prefer something unique)
- ✓ Consistently reinforce why are you glad and excited to work on a certain topic.

Reflection D:

0 The exploration does not reach the standard described by the descriptors below.

1 There is evidence of limited reflection.

2 There is evidence of meaningful reflection.

3 There is substantial evidence of critical reflection.

Reflection is one of the most meticulous criterions where students are required to go deep and evaluate the process on merit. Keeping in mind the following points can bear maximum points in this criterion.

- ✓ Reflection must occur consistently at each point as it is one of the most common mistakes most student make, as they just restrict it to the evaluation part

- ✓ Comment on whatever the findings are
- ✓ Contextualize each result (as in what does r value imply, what does an intercept indicate etc.)
- ✓ Be honest and discuss the limitations of the process before examiner identifies it
- ✓ Evaluate the process in term of difficulty and how the experience was.
- ✓ Mention strengths and weaknesses
- ✓ Add various approaches and possible extensions.

Use of Mathematics E:

0 The exploration does not reach the standard described by the descriptors below.

1 Some relevant mathematics is used.

2 Some relevant mathematics is used. Limited understanding is demonstrated.

3 Relevant mathematics commensurate with the level of the course is used. Limited understanding is demonstrated

4 Relevant mathematics commensurate with the level of the course is used. The mathematics explored is partially correct. Some knowledge and understanding are demonstrated.

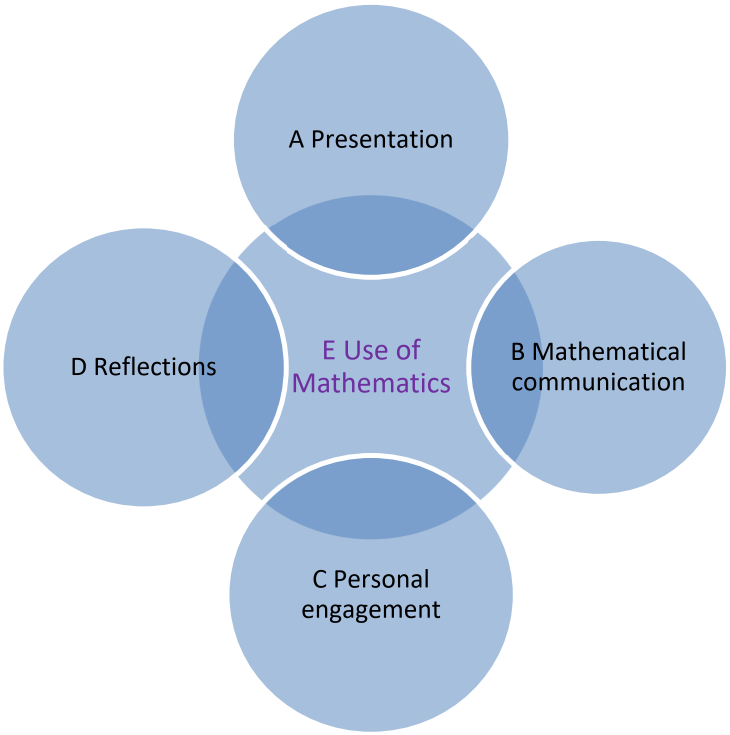
5 Relevant mathematics commensurate with the level of the course is used. The mathematics explored is mostly correct. Good knowledge and understanding are demonstrated.

6 Relevant mathematics commensurate with the level of the course is used. The mathematics explored is correct. Thorough knowledge and understanding are demonstrated.

Criterion E is a make or break for an IA as this determines the caliber and the rigor that has been depicted throughout the process. Following pint can prove to be a grade booster for the IA.

- ✓ Relevance is the key (Randomly discussing a certain concept is detrimental to the fluidity of the document)
- ✓ Clear knowledge and understanding of the applied concept should be demonstrated.
- ✓ The level should be kept on view as in an HL student cannot use a simple mathematical process such as 'finding correlation'. At least two to three concepts should be demonstrated
- ✓ Prefer showing working for each step
- ✓ Be precise and logical
- ✓ Avoid using simple math or just prior knowledge.
- ✓ Clear arguments should be made.

Radial Cycle for the Criterion



When I was new to IBDP, I used to think that one can get high score in the IA if one scores high in the first four criterions which are general and contain 14 scores out of 20 in total. And then getting 3 out of 6 in criterion A will allow them to score low high. However, later I discovered that criterion E is the core of all the other criterions. I mean how can one score high in presentation, communication, personal engagement, and reflections if the math applied in executing the exploration does not have rigor in it, or it may not be sufficient to meet the level of criterion D. If we do not use rigorous math, we won't get enough of the opportunities to make use of symbols, equations, and mathematical jargons. We can't go deeper into the exploration. We have not much to reflect on to get high scores in the first four criterions. So, while the process of selection of topic, make sure the topic has enough of the depth in it which would allow us to apply appropriate and rigorous math procedure in it to get nothing less than 5 in the use of math, only then we would be able to score good in the other four criterions.

Generally, math IAs can be done in the following areas but not limited to this.

3. INVESTIGATING THE RELATIONSHIP BETWEEN SCORING AVERAGE AND PUTTS PER ROUND AVERAGE ON THE PGA TOUR

Author: Aayush Vyas
Moderated Mark: 19/20
Level: Math AI SL

Introduction

A golf player myself, I want to investigate importance of putting for golf scores; an exploration into this topic would help me determine what to put emphasis on during my practise sessions. Thus, this exploration will investigate the relationship between scoring average (average total number of strokes per round) and putts per round average (average number of short shots made on the green around the hole) among players of the PGA Tour. The goal of this exploration is to determine the strength and nature of the relationship between scoring average and putts per round average and establish whether a player's putting abilities are independent of his golf scores.

It is expected there will be a weak positive relationship between the variables; the reason for that is that better players, so players with better scoring averages, perform better in a variety of statistics, and a putts per round average is only one of them.

In order to collect data, the list of players who were classified by the PGA Tour was gathered and organised according to their putts per round averages in the season 2019. Their scoring averages in the same season were also collected. A website with the official statistics of the PGA Tour was used as a source of the data.

Procedure of investigation

1. Collecting data: sampling and organising data into a table.
2. Performing the chi-squared test for independence.
3. Plotting a scatter plot, finding the line of the best fit and analysing the Pearson's correlation coefficient of the linear model.
4. Finding the line of quadratic regression and analysing the Pearson's correlation coefficient of the quadratic model.
5. Drawing conclusions.

6. Discussing areas for possible improvement and further research.

Data collection

To collect the data, ranks of players of the PGA Tour by putts per round average and by scoring average in the season 2019 were used. For sampling, the list of players by putts per round average was chosen instead of scoring average because there were 37 players more on the scoring average rank. Avoiding a situation in which a player would have to be replaced because his putts per round average would not be available was desirable, as that would have disrupted the sampling system and would have led to less reliable results. The sample for the investigation was chosen using systematic sampling (meaning that players were selected starting at a random position with a fixed periodic interval). Putts per round averages were available for 190 players and it was decided that a sample of 95 would be chosen, which meant that the interval was two. In numerous instances, there were a few players with the same putts per round average; when that was the case, a player from those with the same putts per round averages was chosen at random. Scoring averages were not taken into consideration when making this decision, because that could have made the sample biased. If, for example, the player with the highest scoring average was always chosen, the sample would underestimate the strength of the relationship if it were positive, and overestimate its strength if the relationship were negative.

When filling in data about scoring averages, two instances in which scoring average was unavailable for a player were encountered. In these cases, deterministic hot deck imputation was applied. Deterministic hot deck imputation is a method used for handling missing data in which a missing value is replaced with an observed value from the most similar unit (Andridge and Little 40). The unit for which data is inserted is called a recipient while that from which the data is being taken is called a donor. To perform deterministic hot deck

imputation, the player whose putts per round average was closest to that of the recipient was taken as donor (in both instances in this investigation that meant choosing another player with the same putts per round average).

Sample entries (top two and bottom two players, and one player for which deterministic hot imputation was performed) are available in table 1 for illustrative purposes. Full dataset used is available in Appendix A.

Table 1

Selected players of the PGA Tour, their scoring averages and putts per round averages in the 2019 season

Note: Blue colour indicates players for which deterministic hot deck imputation was performed. Names of donors are in parenthesis.

Name	Scoring average	Putts per round average
Jordan Spieth	71.46	27.71
Justin Rose	71.82	27.94
Trey Mullinax (J. J. Spaun)	72.24	29.29
John Chin	72.49	30.13
Corey Conners	70.78	30.17

Sources of data: "Putts per round." *PGA Tour Statistics.* PGA Tour, www.pgatour.com/content/pgatour/stats/stat.119.y2019.eoff.t060.html. Accessed 15 Apr. 2020 and

"Scoring average." *PGA Tour Statistics.* PGA Tour, www.pgatour.com/stats/stat.120.html. Accessed 15 Apr. 2020

Chi-squared test

Firstly, the chi-squared test was performed to establish whether the correlation between the variables is statistically significant, i.e. unlikely to be a result of chance. For the purposes of this test:

H_0: scoring average is independent of putts per round average.

H_1: scoring average is dependent on putts per round average.

Players were grouped based on means of the two data sets - one of scoring averages and one of putts per round averages (Table 2). This constitutes the observed frequencies – actual number of times each event occurred.

Table 2

Observed frequencies

	Below mean putts per round	Above mean putts per round	Total
Below mean scoring	29	22	51
Above mean scoring	15	29	44
Total	44	51	95

Expected frequencies (how many times each event is expected to occur if there were no relationship between the variables) were calculated by multiplying the observed value in the given scoring category and the given putting category, and then dividing the product by the total number of players. For example, the expected value (f_e) of the number of players with scoring average below mean and putts per round average below mean:

7. MODELING THE TIDE AND ITS CONNECTION WITH THE MOON PHASES

Author: Marilena Rentzou
Moderated Mark: 19/20
Level: Math AI SL

Introduction

In this project, I will try to create several mathematical models, using my knowledge of functions, their features and graphs, that will describe how water levels change over time during a day and also highlight the connection between tides and moon phases.

My reasons for doing so are twofold: Firstly, in order to attempt to construct a tide model that visitors to Phuket can consult before deciding to go for a swim or snorkeling and secondly to satisfy my curiosity and verify that "The disparity between high and low tide is at its highest during a full moon or a new moon."

More specifically, in this project, I will generate models describing how the water level rose and fell in Phuket, Thailand, on October 24th, 2020, from midnight to 23:00. I will then compare the model that provides the best fit (to the data of the 24th) against raw (observed) water level data for the same time period from October 25th in order to determine if the model provides as good a fit to this data set too and can, thus, be said to hold for a lengthier time period (to be determined) and not just a single day. I will also attempt to demonstrate the influence of the Moon on Earth's tides by looking at tide data on a new and full Moon.

The inspiration behind this internal assessment came from a trip I took to Phuket in Thailand two years ago. Here, for the first time in my life, I had to consider water levels before planning a beach activity. Due to the fact that the phenomenon of tides is not that noticeable in Greece where I live, except for the city of Chalkida, I was intrigued and decided to investigate how tides behave and to what extent do lunar cycles play a role in the process of their formation.

Tide is one of the most interesting natural phenomena in the world: it is the usual rise and fall of waters in the ocean. During high tide the water rises to a maximum level and reaches most of the shoreline. When water falls to its lowest level and recedes from the shore, that is low tide[1].

- [1]"Tide." *Dictionary.com*, Dictionary.com, www.dictionary.com/browse/tide. [Accessed 17 October 2020].

In general, within a twenty-four-hour cycle, most shorelines encounter two high and two low tides, while some places have only one each. The scale of the tides, high and low, varies during the month. The disparity between high and low tide is at its highest during a full moon or a new moon. That is because the gravitational pull is at its strongest when the Earth, the Sun and the Moon are in a line. The Sun's gravitational pull also plays a minor part in tide formation. Tides shift across the World as the ocean bulges.[2]

Fig.2: The phenomenon of tides in Phuket

But let us first look at what causes tides?

The tide phenomenon and what causes it

The gravitational field of the Moon is so strong it affects the Earth, particularly the ocean water. There is be a noticeable bulge on the Earth's side nearest to the Moon. The rise and

- [2]"Tide." *Wikipedia*, Wikimedia Foundation, 26 August. 2020, en.wikipedia.org/wiki/Tide. [Accessed 17 October 2020].

fall of the ocean level are a result of the pulling of the Moon's gravitational field as it moves around the Earth in orbit.

The tide is mainly created by the influence of the Moon's gravity, the sun's gravity, the rotation of the earth, the Moon's inclination, and meteorological conditions. The tide thus varies from place to place, due to the variance of the conditions mentioned above. The maximum value of the level rise is called high tide, and the minimum is called low tide.

While the Moon traverses its lunar orbit around the earth, at some point, it aligns with the Sun and the Earth twice, presenting the so-called conjugations and counterbalances.

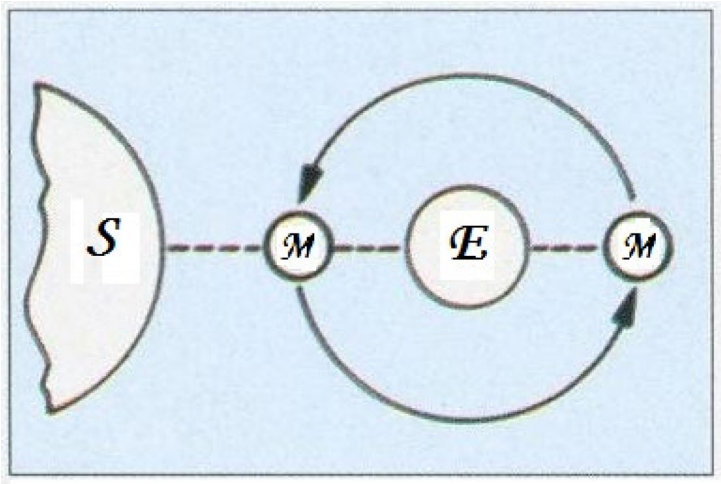


Fig.2 During its orbit around the Earth, the Moon aligns with the Earth and the Sun twice

When this happens, the gravitational forces of the sun and the moon are added, respectively increasing and decreasing the tidal effect. The high tides reach their maximum value and, respectively, the low tides to the minimum - Then we say that we have the spring tides (fig.1).

When the moon orbits the earth, it forms a right angle with the earth and the sun twice, that is, during its first and third quarters (fig. 2). When this happens, the gravitational forces of the sun and the moon are neutralized by each other, and therefore the intensity of the phenomenon is reduced. The high tides reach their minimum value and, respectively, the

low tides, the maximum. Then we can say that we have the square tides (neap tides). The tide range is the difference in tide height between high and low tide.

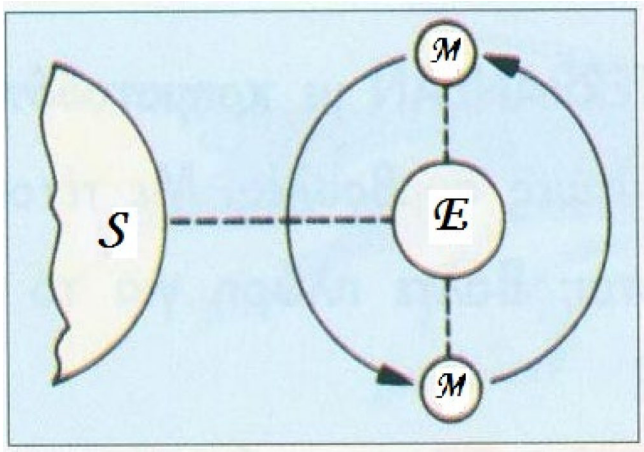


Fig. 3 During its orbit around the Earth, the Moon forms a right angle with the Earth and the Sun twice

The phases of the moon can be used to predict the tides of conjunction and those of squaring. When the Moon is situated between the Earth and the Sun either between the two (New Moon) or on the other side of the Earth (Full Moon) we know that we will have a tide of conjunction or opposition.

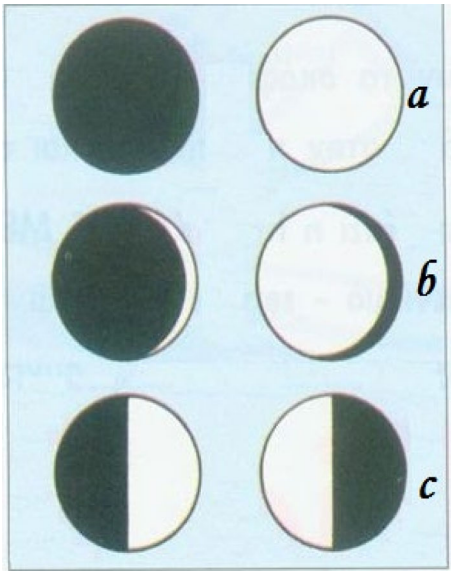


Fig. 4: The phases of the Moon