

TWO EXAMS TAKEN BY RAMANUJAN IN INDIA

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1. INTRODUCTION

On Thursday and Friday, December 3 and 4, of 1903, Srinivasa Ramanujan, who was to become the greatest Indian mathematician in his country's history, sat for the Matriculation Examination of Madras University. From documents recently found in the Tamil Nadu Archives, we have learned that Ramanujan obtained a Second Class place, permitting him to enter the Government College of Kumbakonam in the following year with a scholarship. As is now well known, by the time he entered college, Ramanujan was totally immersed in mathematics and would not study any other subject. He thus failed his exams, except for mathematics, at the end of his first college year and lost his scholarship.

In 1906 Ramanujan joined Pachaiyappa College in Madras on a partial scholarship awarded for his mathematical abilities, but after three months he fell ill and returned home to Kumbakonam. On Wednesday and Thursday, December 4 and 5, 1907, Ramanujan appeared for the FA Examination at Pachaiyappa College after private study. Every candidate for the First Arts (FA) Examination was required to provide evidence that he or she had studied for at least two years, with Ramanujan's year at Kumbakonam counting toward his requirement. Ramanujan failed English with a score of 38 out of 200; a minimum of 70 was needed to pass. In Sanskrit, he obtained a score of 34 out of 100, failing the exam by only one point. He passed mathematics with a score of 85 out of 150; only 45 points were required for passing. He failed to appear for the examinations in Physiology and History. If a candidate failed in any one of the prescribed subjects, she or he had to repeat the examinations in all subjects. Every candidate was required to choose a second language for study apart from English. It is curious that Ramanujan chose Sanskrit over his mother tongue, Tamil. For further details (but not the exam itself), see the book by Berndt and R. A. Rankin [5, p. 23].

One might speculate on why Ramanujan did so poorly on the FA exam; in particular, we might have expected Ramanujan to obtain a score of close to 150 in the mathematics exam. R. Kanigel [7, p. 52] remarks that up to 80% fail the FA exam. We offer three possible reasons for Ramanujan's failure.

First, as mentioned above, Ramanujan became ill after three months of study. Thus, he attended few lectures at Pachaiyappa College. Ramanujan's illness was likely dysentery. The English physician, D. A. B. Young, in reaching the diagnosis of hepatic

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amoebiasis for the cause of Ramanujan's early death, remarks [5, p. 68] "This [the illness which sent Ramanujan home] was probably amoebic dysentery, the most common form in India at the time, where the onset is usually gradual and the symptoms progressive but generally limited to abdominal discomfort and some diarrhoea, The dysentery may then continue for several weeks before subsiding in many cases only to reappear in one or more mild dysenteric episodes." Young further writes [5, p. 70] that, unless treated properly, amoebiasis is a permanent infection with the amoeba lodging themselves in the large intestinal area and becoming active if the patient's routines are somehow disturbed, as they obviously were with Ramanujan after his arrival in England. Although Ramanujan sat for the FA exam considerably after his first bout with dysentery, it is likely that this serious illness contributed adversely to Ramanujan's preparation for the FA exam.

Secondly, Ramanujan's single-minded devotion to mathematics most likely contributed to his failure on the FA examination, just as it was the primary reason for failing examinations at the completion of his only year at the College of Kumbakonam. Thus, even if well, Ramanujan undoubtedly would have found it difficult to turn his attention away from mathematics to such subjects as English and Physiology.

Thirdly, there were some mathematical subjects which Ramanujan evidently did not enjoy as much as he did others. Although Carr's *Synopsis* [6], Ramanujan's primary source for learning mathematics in India, has a large proportion of entries on geometry, Ramanujan devoted few of his efforts to this subject. Only two of the 58 problems which Ramanujan submitted to the *Journal of the Indian Mathematical Society* are in geometry. He wrote a one-page paper [8, p. 22] on "squaring the circle," and he devised some formulas for approximating the perimeter of an ellipse [8, p. 39], but otherwise his published papers do not touch on geometry. Of the 3200–3300 entries in his notebooks [9], only six (in Chapters 18 and 19 of his second notebook [9], [2]) have connections with geometry. Thus, we might surmise that the problems Ramanujan did not solve on the FA exam were from the exam on Geometry. Moreover, as readers will observe, some of the problems in the exam on Trigonometry are, really in fact, more properly placed in the exam on Geometry. On the other hand, Ramanujan proposed several interesting problems for the *Journal of the Indian Mathematical Society* on solving certain equations or systems of equations. His notebooks contain many further entries on solving equations; see, in particular, [3, Chap. 22]. Thus, we might assume that Ramanujan had little difficulty with the first portion of the exam, which was on algebra. (See [5, pp. 17–20] for how Carr's book [6] influenced Ramanujan, and see [8] or [5, pp. 215–258] for a discussion of the problems Ramanujan contributed to the *Journal of the Indian Mathematical Society*.)

To the best of our knowledge, the three exams described above were the only ones that Ramanujan took after leaving secondary school. In the fall of 2002, the second author searched the Tamil Nadu Archives in Chennai and found copies of the Matriculation Exam and the First Arts Examination taken by Ramanujan in 1903 and 1907, respectively. We have been unable to locate a copy of the exam for which Ramanujan sat at the completion of his first and only year at the Government College in

Kumbakonam. Since this examination was likely to have been administered locally in Kumbakonam, probably an extant copy cannot be found.

The purpose of this paper is to communicate these two examinations taken by Ramanujan in 1903 and 1907. For the matriculation exam, arithmetic, geometry, and algebra had maximum scores of 50, 35, and 35, respectively, providing a total of 120 marks from the grand total of 550 for the entire exam. On the FA exam, algebra, trigonometry, and geometry were each graded out of a total of 50 points; a maximum total of 600 points could be earned in all subjects. The questions give insight into the mathematical training of students in South India early in the twentieth century. Most readers will find some of the questions challenging.

(Although it is not our primary intention here to relate the other exams taken by Ramanujan, we offer a few sample questions from the FA English exam. From *Julius Caesar*, the examiners ask, for example, “Show how the character of Marcus Brutus and the action springing from it conduce to the catastrophe” and “Annotate: His coward lips did from their colour fly.” Several questions focus on Gray’s *Elegy*, such as “Give four instances from the *Elegy* of Gray’s “picturesque and pregnant epithets,” and show their appropriateness.” Further questions are directed toward *Ulysses*, the *Lotus-eaters*, *Kenilworth*, and Queen Elizabeth’s policies. The emphasis on English literature is, of course, a reflection of England’s colonial rule of India at that time.)

The second author also was able to locate information in the Tamil Nadu Archives about the examiners and the history of the College in Kumbakonam. There were ten examiners for the First Arts Examination administered by Madras University. At least three, B. Hanumanta Rau, R. Littlehailes, and P. V. Seshu Aiyar, either knew or would come to know Ramanujan. Seshu Aiyar was Ramanujan’s mathematics instructor during his one year at the Government College of Kumbakonam. Hanumanta Rau was Professor of Mathematics at Government Engineering College at Madras, and was strongly influential in obtaining a scholarship for Ramanujan to go to Cambridge [7, p. 178], [1, p. 295]. Littlehailes was Professor of Mathematics at Presidency College, Madras. Although somewhat reluctant at first to support Ramanujan, he helped secure a scholarship for Ramanujan’s stay at Cambridge. (See Kanigel’s biography [7, pp. 178, 182, 192–194] and Berndt and Rankin’s book [4] for more details.)

Kumbakonam College was established as a provincial school in 1854 and became a college in 1867. The first B.A. degrees were awarded in 1869. The College provided instruction prescribed by the University of Madras, with which it affiliated in 1877. The primary subjects were “Mathematics, Mental and Moral Science, and History.” The administrators and instructors at the College totalled 18 in 1907. It has often been called “The Cambridge of South India,” because of its high academic standards.

2. TERMINOLOGY

Readers of the exams which follow may find unfamiliar terms. The basic Indian unit of currency is a rupee (Re, sing.; Rs, pl.); there are 16 annas (a.) per rupee, and 12 paisas (p.) per anna. British lineal measures and weights were commonly used during the British rule of India. During Ramanujan’s school days, and later as well, problems on arithmetic examinations involving both Indian and British currencies, weights, and

measurements were common. Now India uses the metric system, but in rural areas the old measurements remain common. In former British currency, there were 20 shillings (s.) per pound (£) and 12 pence (d.) per shilling. One crore equals 10,000,000. A furlong (fur.) is one-eighth of a mile. One quarter (qr.) is equivalent to 25 pounds, and a hundredweight (cwt.) is 100 pounds.

The *incircle* of $\triangle ABC$ is now usually called the *inscribed circle*, whose radius, called the *inradius* of the triangle, is always denoted by r . The three *excircles* are the three circles that are tangent to the sidelines of the triangle. They are sometimes called the *escribed circles*, and their radii, called *exradii*, are commonly denoted by r_a, r_b , and r_c . The *circumcenter* is the center of the circumscribed circle, whose radius is always denoted by R . The *orthocenter* is the intersection of the altitudes. In a triangle, consider the nine points: the three midpoints of the sides, the three feet of the altitudes from the vertices to the opposite sides, and the three midpoints of the segments from the vertices to the orthocenter. These nine points all lie on a circle, and the center of the circle is called the *nine-point center*.

3. THE MATRICULATION EXAM, 1903

THURSDAY, 3RD DECEMBER, 10 A.M. TO 1 P.M.

ARITHMETIC

N.B.—(1) *Answers in money must be stated in Rs. a. p. and not as fractions of Re.*
 1. (2) *Except in the case of Question I, the process by which each result is obtained must be given in full.*

I. The following table shows the number of passengers carried on a certain railway and the amount of the fares paid by them in each of the months named:—

Month	Number of passengers carried	Amount of fares paid		
		Rs.	A.	P.
January	1,923,654	731,268	4	10
February	1,738,901	679,365	13	2
March	2,003,496	774,982	15	9
April	1,932,781	724,850	7	11
May	1,989,757	759,368	11	5
June	1,894,532	702,783	12	8

Find (a) the total number of passengers carried during the six months, (b) the total amount of fares paid, (c) the average amount (to the nearest pie) paid by each passenger in the month of May. [*The figures in the table need not be copied out for the purpose of finding the totals (a) and (b).*]

II. Reduce to its simplest form the expression:—

$$\frac{4\frac{4}{5} - 3\frac{3}{4} + 2\frac{2}{3} - 1\frac{1}{2}}{(6\frac{1}{5} - 5\frac{1}{4}) \div (4\frac{1}{3} - 3\frac{1}{2})} \div \frac{\frac{1}{2} - \frac{1}{3}}{\frac{1}{4} + \frac{1}{5}}$$

III. 1. Find the value of .09765625 of $Rs.26.10as.8p.$ — .0226851 of $Rs.101.4as.$

2. Taking exchange at $1s.3\frac{15}{16}d.$ per rupee, express a crore of rupees as the decimal of £1,000,000.

IV. Find by any method the value of 4165 tons 17 cwt. 3 qrs. 21 lbs. of wheat at $Rs.107.14as.8p.$ per ton.

V. The channel which conveys the water supply of a certain city is 10 ft. broad and 2 ft. deep, and the average rate of flow of the water is 1 mile per hour. Assuming that a gallon contains 277.274 cubic inches, and that the population of the city is 540,000, find to the nearest hundredth of a gallon the number of gallons supplied per day to each inhabitant.

VI. If the cost of metalling a road 10 miles 2 fur. 55yds. long and 9 ft. broad with metal costing $Rs.2.8as.1p.$ per cubic yard be $Rs.24,165.11as.5p.$, find what will be the cost of metalling a road 22 miles, 1 fur. 132 yds. long and 15 ft. broad with metal costing $Rs.2.3as.3p.$ per cubic yard, the depth of the metal in the latter case being half as great again as the depth in the former case.

VII. The banker's discount on $Rs.2,612.8as$ for a certain time at 5 per cent. per annum is equal to the true discount on $Rs.2,710.7as.6p.$ for the same time at the same rate. Find the time.

VIII. When exchange is at $1s.3\frac{15}{16}d.$ per rupee, a cycle agent in Madras remits £9. 11s. 3d., the cost of a machine which he has ordered from his agent in England. When the machine arrives at Madras he has to pay customs duty at the rate of 12 annas per £1 of the English price, and freight and landing charges amounting to $Rs.25.7as.11p.$ What price must he charge for the machine so as to gain 35 per cent. on his total outlay?

IX. A person holding 45 shares in a concern which paid a yearly dividend at the rate of $Rs.47.8as.$ per share, sold out when the shares were at $Rs.1,298.8as.$ each and invested two-thirds of the proceeds in 4 per cent. municipal debentures at $92\frac{3}{4}$ and the remainder in $3\frac{1}{2}$ per cent. Government paper. If by so doing he increased his annual income by $Rs.228.8as.$, find what price he paid for his Government paper.

X. In a certain year 4.5 per cent. of the passenger receipts of a railway were contributed by first class passengers, 12.3 per cent. by second class, and 83.2 per cent. by third class. In the following year the receipts from first class and third class passengers showed increases of 4 per cent. and $12\frac{1}{2}$ per cent. respectively, while the receipts from second class passengers showed a decrease of 10 per cent. Find to the first decimal place what percentage of the total passenger receipts was contributed by third class passengers in the latter year.

XI. The breadth of a rectangular park containing 77 acres $88\frac{3}{4}$ sq. yds. is three-fourths of its length. Find the length of either diagonal of the park.

THURSDAY, 3RD DECEMBER, 2 TO 4 P.M.

GEOMETRY

N.B.—*Figures must be carefully and neatly drawn.*

I. Prove that parallelograms on the same base and between the same parallels are equal to one another.

Parallelograms $AFGC, CBKH$ are described on AC, BC outside the triangle ABC . FG, KH meet in Z , ZC is joined, and through A, B lines AD, BE are drawn, both parallel to ZC and meeting FG, KH in D and E respectively. Prove that the figure $ADEB$ is a parallelogram equal in area to the sum of the parallelograms FC, CK .

II. From the right angle A of a right-angled triangle ABC , AD is drawn perpendicular to BC . Prove that the square on AB is equal to the rectangle $BC \cdot BD$.

Hence deduce a construction for describing a square equal to a given rectangle.

III. If C be any point in the straight line AB , prove that $AB^2 + BC^2 = 2AB \cdot BC + AC^2$.

Show that this proposition corresponds to the algebraical formula $(a - b)^2 = a^2 - 2ab + b^2$.

IV. Give, without proof, the construction for

(a) dividing a straight line into two parts such that the rectangle contained by the whole line and one of the parts may be equal to the square on the other part;

(b) drawing a common tangent to two given circles;

(c) describing a circle so as to touch a given straight line and a given circle at a given point.

V. Prove that the opposite angles of a quadrilateral inscribed in a circle are together equal to two right angles.

The straight lines BD, CE drawn perpendicular to the sides AC, AB of a triangle ABC intersect at O . Prove that AO , produced if necessary, cuts BC at right angles.

VI. Two straight lines AB, CD intersecting at O are such that the rectangle $AO \cdot OB$ is equal to the rectangle $CO \cdot OD$. Prove that the four points A, C, B, D lie on the circumference of a circle.

VII. The distance between the centres A, B of two equal circles is double the diameter of either circle. Two circles are described to touch both circles, and touching each other at the middle point of AB . Prove that a circle can be described touching all four circles.

FRIDAY, 4TH DECEMBER, 10 A.M. TO 12 NOON

ALGEBRA

I. 1. Multiply $2 \left(\frac{x}{y} + 1 + \frac{y}{x} \right)^2$ by $\frac{y}{2x} - 1 + \frac{x}{2y}$.

2. Divide $x^6 - a^3x^3 - 2a^6$ by $\frac{x^2}{a^2} - \frac{x}{a} + 1$.

3. Find the value of $\left(\frac{x}{x-a} \right)^2 + \left(\frac{x}{x+a} \right)^2$ in terms of n when $x^2 = a^2 \left(\frac{n+1}{n-1} \right)$.

II. Resolve into elementary factors:—

1. $(a^2b^2 - 1)(x^2 - y^2) + 4abxy$;
2. $216x^6 + 19x^3 - 1$.

III. Find the H. C. F. of

$$27a^5 - 45a^4 - 16, \quad \text{and} \quad 18a^5 - 45a^4 - 5a - 14.$$

IV. Reduce to their simplest forms the expressions:

1. $x(y + z - x)^2 + y(z + x - y)^2 + z(x + y - z)^2 + (x + y - z)(y + z - x)(z + x - y)$;
2. $\left(\frac{x + 4}{x^2 - x - 12} - \frac{x + 3}{x^2 + x - 12} \right) \div \left(1 + \frac{2(x^2 - 12)}{x^2 + 7x + 12} \right)$.

V. Extract the square root of the expression

$$(x^2 + y^2 - 2)^2 + 4(xy + 2)(x^2 + xy + y^2).$$

VI. Solve the equations:-

1. $\frac{2x^2 - x - 1}{2x - 1} + \frac{6x^2 - 4x + 1}{3x - 2} = \frac{2}{6x - 13} + \frac{6x^2 - 9x - 1}{2x - 3}$;
2. $2\frac{3}{5} + \frac{3x - 5y}{2} = \frac{2}{5}(x + 2), \quad 8 - \frac{x - 2y}{4} = \frac{x}{2} + \frac{y}{3}$;
3. $ab(x^2 + 1) = x(a^2 + b^2)$.

VII. B spends Rs.32 a month, and A, whose monthly income is to B's as 7:5, spends three times as much as B saves. If A's income were increased in the ratio of 7:10 and his expenditure in the ratio of 6:7, he would save Rs.21 a month more than before. Find B's income.

4. FIRST EXAMINATION IN ARTS, 1907
WEDNESDAY, 4TH DECEMBER-2 TO 4
ALGEBRA

I. Factorise

- (1) $12x^4 + 25x^3 - 25x - 12$.
- (2) $a^3 + b^3 + c^3 + 2abc - a^2b - a^2c - b^2c - b^2a - c^2a - c^2b$.

Arrange the product of the expressions included in $1 \pm x \pm y \pm z$ as a sum of symmetrical homogeneous functions.

II. Solve

- (a) $x^2 + y^2 = 25; 4x^2 - 5xy + y^2 = 13$;
- (b) $x + y + z = 5; x^3 + y^3 + z^3 - 6x = 35; x^2 + y^2 + z^2 - yz - zx - xy = 7$.

III. Show that a quadratic equation has two roots and no more.

Draw the graph of the expression $2x^2 - x - 15$ and find its minimum value.

IV. Define the arithmetic, geometric, and harmonic means between a and b ; show that they satisfy the relations

$$\frac{a-m}{m-b} = \frac{a}{a}, \quad \frac{a-m}{m-b} = \frac{a}{m}, \quad \frac{a-m}{m-b} = \frac{a}{b}$$

respectively.

The arithmetic mean between two numbers exceeds the geometric mean by 10 and the harmonic mean by 16. Find the numbers.

V. Find the number of permutations of n things taken r at a time.

A procession consists of nine cars. Two cars require six horses each, three four each, and four two each. The horses are supplied from a stable containing 36 horses. Find in the factorial notation the number of ways in which the horses can be assigned to the cars, the position of a horse in its team being regarded as indifferent.

VI. What is the coefficient of x^{20} in $(2x - 3x^2)^{12}$?

Find the value of

$$1 - C_1^2 + C_2^2 - C_3^2 + \dots,$$

where C_r^n is the number of combinations of n things r at a time.

VII. Sum to n terms the series whose r th term is $r(r-1)(2r-1)$.

Find the number of shot in a rectangular pile whose base is formed of 8 rows of 10 shot.

VIII. The price of a building block on a certain estate is composed of two parts; one part is proportional to the area, the other to the frontage, which is in each case the shorter side of the block. If a block 100 ft. by 80 ft. costs Rs. 8,000, and one 60 ft. by 30 ft. Rs. 3,900, what would a block 80 ft. by 45 ft. cost?

THURSDAY, 5TH DECEMBER—10 TO 12

TRIGONOMETRY

I. An angle at the centre of a circle is subtended by an arc whose length is equal to the diameter of the circle. Prove that the magnitude of this angle is independent of the length of the diameter.

The sides of two regular polygons subtend angles at their centres whose circular measures are the roots of the equation $105x^2 - 29\pi x + 2\pi^2 = 0$. Find the number of sides in each polygon.

II. Find by geometrical methods the expression for $\tan 2A$ in terms of $\tan A$. Similarly, prove that

$$\tan A = \frac{\sin 2A}{1 + \cos 2A}.$$

III. (1) Prove that

$$\cos 9^\circ - \sin 39^\circ - \cos 69^\circ + \sin 99^\circ = \sin \frac{9\pi}{20}.$$

(2) If $\sin \theta + \sin \phi = a$, and $\cos \theta + \cos \phi = b$, find the values of $\cos(\theta + \phi)$ and $\cos(\theta - \phi)$.

(3) Solve the equation

$$\cos 2\theta + \cos 4\theta - \cos 8\theta - \cos 10\theta = 2\sqrt{2} \cos \theta \sin 3\theta.$$

IV. Trace the changes in magnitude and sign of $\cot \theta$, while θ changes from 0 to 2π . Draw the graph of $\sec 2\theta$ from $\theta = 0$ to $\theta = \pi$.

V. State clearly and in detail the different cases which may arise in the solution of a triangle of which two sides and the angle opposite one of them is given.

In a triangle if $a = 352.25$, $b = 513.27$, $c = 482.68$, find A , having given

$$\log 6.741 = .82872$$

$$L \tan 20^\circ 38' = 9.57581$$

$$\log 3.2185 = .50765$$

$$L \tan 20^\circ 39' = 9.57619$$

$$\log 1.6083 = .20634$$

$$\log 1.9142 = .28199$$

[Here, $L(x) = \log_{10} x + 10$.]

VI. A man starts to walk along a straight road, and from his starting-point he sees a tower in the direction N.E. After walking a mile, the tower is exactly eastward, and at the end of another mile it is seen in the direction 30° South of due East. Find the distance of the man from his starting-point when he is nearest the tower.

VII. Find the radii of the excircles of a triangle, and prove that the distance between the circumcentre and orthocentre is

$$R\sqrt{1 - 8 \cos A \cos B \cos C}.$$

Prove that

$$(1) \cos(B - C) + \cos A = \frac{bc}{2R^2};$$

$$(2) \sum \frac{bc}{r} + 6R = 2R \sum \frac{b+c}{a}.$$

[There is some ambiguity in (2). The right side is an abbreviated notation for

$$2R \left(\frac{b+c}{a} + \frac{c+a}{b} + \frac{a+b}{c} \right).$$

However, the left side is more ambiguous. If r were meant to be the inradius, then it would have likely been factored out, and indeed the formula is incorrect with this interpretation. However, since r is not factored out, then the exradii r_a , r_b , and r_c are likely intended, i.e., the left side should be interpreted as

$$\frac{bc}{r_a} + \frac{ca}{r_b} + \frac{ab}{r_c} + 6R,$$

and indeed the formula is correct with this interpretation.]

THURSDAY, 5TH DECEMBER-1 TO 4

GEOMETRY

N.B.—Figures should be carefully and neatly drawn.

I. Prove that in a right-angled triangle the square on the hypotenuse is equal to the sum of the squares on the other two sides.

ABC is a triangle, right-angled at A. On AB and AC are described the squares of ACFG and ACKH outwards. If CF and BK intersect AB and AC in L and M respectively, prove that AL is equal to AM.

II. Show how to draw a pair of transverse common tangents to two given circles.

OA, OB are the direct common tangents of two circles, and AB a transverse common tangent touching them at P and Q. OP is joined, cutting the other circle in L and M. Show that LQ or MQ is a diameter of that circle.

III. Show how to inscribe a circle in a given triangle.

Through a given point draw a straight line which shall form with two given straight lines a triangle of given perimeter.

IV. Give constructions, without proof, in the following cases:—

(1) Describe a circle to touch a given circle and also a given straight line at a given point.

(2) Given the ortho-centre, the nine-point centre and a vertex, describe the triangle.

(3) Through a given point draw a straight line to pass through the intersection of two given straight lines whose point of intersection is inaccessible.

V. If a transversal is drawn to cut the sides or the sides produced of a triangle, prove that the product of three alternate segments is equal to the product of the other three segments.

Lines bisecting the angles B and C of the triangle ABC meet the opposite sides in D and E. If DE meet BC produced in F, prove that AF is the external bisector of the angle A.

VI. Show how to describe a rectilinear figure similar to a given rectilinear figure and equal in area to another given rectilinear figure.

VII. Prove that the rectangle contained by two sides of a triangle is equal to the rectangle contained by the diameter of the circum-circle of the triangle and the altitude perpendicular to the third side.

ABCD is a cyclic quadrilateral. Show that $AC : BD :: (AB \cdot AD + CB \cdot CD) : (BA \cdot BC + DA \cdot DC)$. [The now obsolete notation $a : b :: c : d$ is equivalent to $\frac{a}{b} = \frac{c}{d}$.]

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