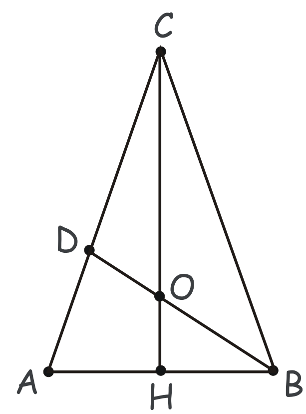
Homework for November 14, 2021.

Geometry.

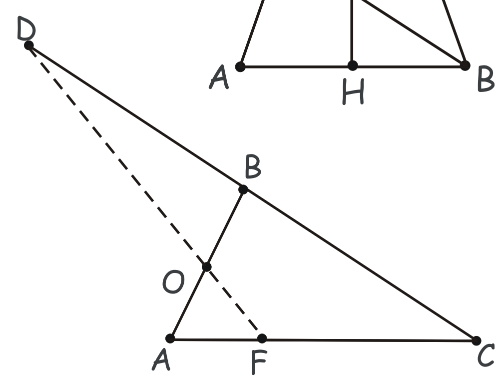
Review the classwork handout. Solve the unsolved problems from previous homeworks. Try solving the following problems, some of which we solved in the past using the similarity of triangles and Thales theorem, now using the method of point masses and the Law of Lever.

Problems.

1. Prove that if a polygon has several axes of symmetry, they are all concurrent (cross at the same point).
2. Prove that medians of a triangle divide one another in the ratio 2:1, in other words, the medians of a triangle "trisect" one another (Coxeter, Gretzer, p.8).
3. In isosceles triangle ABC point D divides the side AC into segments such that |AD|:|CD|=1:2. If CH is the altitude of the triangle and point O is the intersection of CH and BD, find the ratio |OH| to |CH|.



4. Point D belongs to the continuation of side CB of the triangle ABC such that |BD| = |BC|. Point F belongs to side AC, and |FC| = 3|AF|. Segment DF intercepts side AB at point O. Find the ratio |AO|:|OB|.



Algebra.

Review the classwork handout and complete the exercises. Solve the remaining problems from the previous homework (you may skip the ones considered in class). Solve the following problems.

Recap. In order to prove the equality $A(n) = B(n)$, for any n, using the method of mathematical induction you have to

- Prove that $A(1) = B(1)$
- Prove that $A(k+1) - A(k) = B(k+1) - B(k)$ (*)
- Then from assumption $A(k) = B(k)$ and from equality (*) follows $A(k+1) = B(k+1)$

1. Using mathematical induction, prove that $\forall n \in \mathbb{N}$,
   a. $\sum_{k=1}^{n}(2k-1)^2 = 1^2 + 3^2 + 5^2 + \cdots + (2n-1)^2 = \frac{4n^3-n}{3}$,
   b. $\sum_{k=1}^{n}(2k)^2 = 2^2 + 4^2 + 6^2 + \cdots + (2n)^2 = \frac{2n(2n+1)(n+1)}{3}$
   c. $\sum_{k=1}^{n} k^3 = 1^3 + 2^3 + 3^3 + \cdots + n^3 = (1+2+3+\cdots+n)^2$
   d. $\sum_{k=1}^{n} \frac{1}{(2k-1)(2k+1)} = \frac{1}{1\cdot 3} + \frac{1}{3\cdot 5} + \frac{1}{5\cdot 7} + \cdots + \frac{1}{(2n-1)(2n+1)} < \frac{1}{2}$
   e. $\sum_{k=1}^{n} \frac{1}{(7k-6)(7k+1)} = \frac{1}{1\cdot 8} + \frac{1}{8\cdot 15} + \frac{1}{15\cdot 22} + \cdots + \frac{1}{(7n-6)(7n+1)} < \frac{1}{7}$
   f. $\sum_{k=n+1}^{3n+1} \frac{1}{k} = \frac{1}{n+1} + \frac{1}{n+2} + \frac{1}{n+3} + \cdots + \frac{1}{3n+1} > 1$
2. **Recap**. Binomial coefficients are defined by
   $C_n^k = {}_nC_k = \binom{n}{k} = \frac{n!}{k!(n-k)!}$.
   a. Prove that $C_{n+k}^2 + C_{n+k+1}^2$ is a full square
   b. Find n satisfying the following equation,

   $$C_n^{n-1} + C_n^{n-2} + C_n^{n-3} + \cdots + C_n^{n-10} = 1023$$

   c. Prove that

   $$\frac{C_n^1 + 2C_n^2 + 3C_n^3 + \cdots + nC_n^n}{n} = 2^{n-1}$$