

200 ESTONIAN PHYSICS OLYMPIAD PROBLEMS FROM YEARS 2005 – 2011

With hints and solutions

Compiled by Taavet Kalda

Translated by ...

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Introduction

This book contains 200 high school physics problems from the regional rounds, national rounds, and the open competitions of the Estonian physics olympiads.

Each problem comes with a short hint for students who are stuck on problems but do not want to look at the solutions just yet. The topics have been sorted based on their topics and the level of difficulty. The difficulty is marked with up to five stars. To make the searching of problems easier, a prefix is attached before the problem numbers, “P” for problem statements, “H” for hints and “S” for solutions. For example, the statement of problem 133 is denoted with P133. Furthermore, the name of the author and the round are written next to the title of the problem alongside with a short abbreviation of the form P 1, G 1 etc, where the letters correspond to middle school and high school respectively. G 9 would for example stand for the ninth problem in the high school division.

Problems

Dynamics

- P1 Stone ★** Author: Aigar Vaigu, national round, 2005, G 1
A boy is in the basket of a balloon rising upwards at a constant speed of $v = 44 \text{ m/s}$. At a certain point, the boy lets a stone fall from the gondola, and then he throws a ball at the stone to try and hit it. What is the longest time the boy can wait between throwing the stone and throwing the ball? Standing on the ground, the boy could throw the ball vertically up to a height of $h = 20 \text{ m}$. It can be assumed that the balloon is high enough for the ball to hit the stone before it reaches the ground. Air resistance is negligible. Take the gravitational acceleration to be $g = 9.8 \text{ m/s}^2$.
- P2 ★** Author: Tundmatu autor, open competition, 2007, G 1
- P3 Horse ★** Author: Valter Kiisk, regional round, 2007, G 1
A boy who is sitting on a tree branch wants to drop onto a horse that happens to be galloping by right under the tree. The horse is moving at a speed of $v = 10 \text{ m/s}$ and the branch is $h = 3 \text{ m}$ higher than the saddle. What does the horizontal distance between the saddle and the branch have to be at the moment when the boy lets go of the branch?
- P4 ★** Author: Aigar Vaigu, regional round, 2010, G 1
- P5 ★** Author: Andreas Valdmann, regional round, 2011, G 1
- P6 ★** Author: Tundmatu autor, open competition, 2005, G 2
- P7 ★** Author: Tundmatu autor, open competition, 2006, G 3
- P8 ★** Author: Tundmatu autor, open competition, 2007, G 5
- P9 ★** Author: Tundmatu autor, open competition, 2008, G 2
- P10 ★** Author: Mihkel Kree, national round, 2008, G 1

P11	★	Author: Siim Ainsaar, national round, 2008, G 2
P12	★	Author: Mihkel Kree, regional round, 2009, G 2
P13	★	Author: Valter Kiisk, open competition, 2010, G 1
P14	★	Author: Valter Kiisk, national round, 2010, G 1
P15	★	Author: Stanislav Zavjalov, national round, 2011, G 2
P16	★★	Author: Tundmatu autor, open competition, 2007, G 6
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P33	★★★	Author: Andreas Valdmann, regional round, 2010, G 6
P34	★★★★	Author: Jaak Kikas, regional round, 2006, G 10
P35	★★★★	Author: Aigar Vaigu, regional round, 2008, G 6
P36	★★★★	Author: Mihkel Kree, regional round, 2008, G 9
P37	★★★★★	Author: Tundmatu autor, open competition, 2006, G 10
P38	★★★★★	Author: Jaan Kalda, open competition, 2011, G 9
P39	★★★★★	Author: Jaan Kalda, national round, 2006, G 10

Electric circuits

P40	★	Author: Koit Timpmann, national round, 2006, G 1
P41	★	Author: Valter Kiisk, regional round, 2009, G 4
P42	★	Author: Mihkel Pajusalu, national round, 2010, G 3
P43	★★	Author: Tundmatu autor, open competition, 2008, G 4
P44	★★	Author: Taavi Pungas, regional round, 2011, G 6
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P53	★★★	Author: Mihkel Rähn, regional round, 2006, G 7
P54	★★★	Author: Mihkel Kree, national round, 2009, G 3
P55	★★★★	Author: Valter Kiisk, regional round, 2008, G 8
P56	★★★★	Author: Valter Kiisk, national round, 2010, G 8
P57	★★★★★	Author: Andres Laan, national round, 2011, G 9

Electrostatics

P58	★★	Author: Tundmatu autor, open competition, 2005, G 5
P59	★★	Author: Tundmatu autor, open competition, 2005, G 4
P60	★★	Author: Aigar Vaigu, regional round, 2006, G 8
P61	★★	Author: Tundmatu autor, open competition, 2007, G 7
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Gases

P73	★	Author: Tundmatu autor, open competition, 2006, G 1
P74	★	Author: Tundmatu autor, open competition, 2007, G 3
P75	★	Author: Ott Krikmann, regional round, 2007, G 4
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Geometrical optics

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P89	★	Author: Koit Timpmann, regional round, 2010, G 3
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Kinematics

P113	★	Author: Oleg Košik, regional round, 2006, G 1
P114	★	Author: Jaan Kalda, regional round, 2007, G 2
P115	★	Author: Tundmatu autor, open competition, 2008, G 1
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P129	★★★★★	Author: Andreas Valdmann, national round, 2010, G 10

Wave optics

P130 ★★★★★

Author: Jaan Kalda, open competition, 2008, G 8

P131 ★★★★★★

Author: Jaan Kalda, national round, 2009, G 10

Magnetism

P132	★★	Author: Andres Laan, national round, 2011, G 5
P133	★★★	Author: Andres Laan, regional round, 2011, G 8
P134	★★★★	Author: Jaan Kalda, open competition, 2011, G 6
P135	★★★★★	Author: Jaan Kalda, national round, 2007, G 10
P136	★★★★★	Author: Siim Ainsaar, national round, 2008, G 10
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P138	★★★★★	Author: Jaan Kalda, regional round, 2010, G 9
P139	★★★★★	Author: Tundmatu autor, open competition, 2007, G 10

Statics

P140	★	Author: Mihkel Heidelberg, regional round, 2008, G 1
P141	★	Author: Tundmatu autor, open competition, 2007, G 2
P142	★	Author: Mihkel Kree, national round, 2009, G 1
P143	★★	Author: Tundmatu autor, open competition, 2005, G 3
P144	★★	Author: Ott Krikmann, regional round, 2005, G 2
P145	★★	Author: Oleg Košik, national round, 2009, G 2
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P151	★★★★	Author: Riho Taba, regional round, 2007, G 9
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P157	★★★★★	Author: Valter Kiisk, national round, 2011, G 10
P158	★★★★★	Author: Jaan Kalda, national round, 2005, G 10

Stellar mechanics

P159	★	Author: Mihkel Pajusalu, regional round, 2011, G 2
P160	★	Author: Urmo Visk, regional round, 2009, G 1
P161	★★	Author: Tundmatu autor, open competition, 2009, G 5
P162	★★★	Author: Oleg Košik, national round, 2005, G 9
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P164	★★★★★	Author: Mihkel Kree, national round, 2010, G 7

Thermodynamics

P165	★	Author: Jaan Susi, national round, 2005, G 3
P166	★	Author: Jaak Kikas, national round, 2007, G 1
P167	★	Author: Urmo Visk, regional round, 2008, G 4
P168	★	Author: Tundmatu autor, regional round, 2011, G 3
P169	★	Author: Riho Taba, regional round, 2006, G 2
P170	★	Author: Aleksei Vlassov, regional round, 2007, G 3
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P172	★	Author: Urmo Visk, regional round, 2009, G 3
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P186	★★★★	Author: Valter Kiisk, national round, 2006, G 8
P187	★★★★★	Author: Tundmatu autor, open competition, 2008, G 10

Miscellaneous

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|-------------|-------------|---|
| P188 | ★ | Author: Jaan Kalda, open competition, 2008, G 3 |
| P189 | ★★ | Author: Urmo Visk, national round, 2006, G 5 |
| P190 | ★★★ | Author: Jaan Kalda, national round, 2008, G 4 |
| P191 | ★★★★ | Author: Jaan Kalda, open competition, 2008, G 9 |

Liquid mechanics

P192	★	Author: Tundmatu autor, open competition, 2005, G 1
P193	★★	Author: Taavi Pungas, national round, 2011, G 4
P194	★★★	Author: Oleg Košik, regional round, 2005, G 7
P195	★★★	Author: Mihkel Kree, national round, 2005, G 5
P196	★★★	Author: Siim Ainsaar, regional round, 2006, G 9
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P198	★★★	Author: Tundmatu autor, open competition, 2009, G 6
P199	★★★★	Author: Tundmatu autor, open competition, 2005, G 8
P200	★★★★	Author: Mihkel Kree, national round, 2008, G 8

Hints

H1

H2

H3 One can express the free fall time via the equation $s = \frac{at^2}{2}$.

H4

H5

H6

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H17

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H200

Solutions

S1 Stone ★

Author: Aigar Vaigu, national round, 2005, G 1

S2 ★

Author: Tundmatu autor, open competition, 2007, G 1

S3 Horse ★

Author: Valter Kiisk, regional round, 2007, G 1

The free fall time is

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \cdot 3}{9.81}} \approx 0.78 \text{ s}$$

The desired distance is thus $s = vt = 10 \text{ m/s} \cdot 0.78 \text{ s} = 7.8 \text{ m}$.

S4 ★

Author: Aigar Vaigu, regional round, 2010, G 1

S5 ★

Author: Andreas Valdmann, regional round, 2011, G 1

S6 ★

Author: Tundmatu autor, open competition, 2005, G 2

S7 ★

Author: Tundmatu autor, open competition, 2006, G 3

S8 ★

Author: Tundmatu autor, open competition, 2007, G 5

S9 ★

Author: Tundmatu autor, open competition, 2008, G 2

S10 ★

Author: Mihkel Kree, national round, 2008, G 1

S11 ★

Author: Siim Ainsaar, national round, 2008, G 2

S12 ★

Author: Mihkel Kree, regional round, 2009, G 2

S13 ★

Author: Valter Kiisk, open competition, 2010, G 1

S14 ★

Author: Valter Kiisk, national round, 2010, G 1

S15 ★

Author: Stanislav Zavjalov, national round, 2011, G 2

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S76	★	Author: Mihkel Rähn, national round, 2008, G 3
S77	★★	Author: Valter Kiisk, regional round, 2006, G 5
S78	★★	Author: Valter Kiisk, regional round, 2007, G 5
S79	★★	Author: Eero Uustalu, national round, 2009, G 4
S80	★★★	Author: Tundmatu autor, open competition, 2008, G 6
S81	★★★	Author: Tundmatu autor, open competition, 2009, G 7
S82	★★★	Author: Mihkel Heidelberg, national round, 2010, G 6
S83	★★★★★	Author: Tundmatu autor, open competition, 2006, G 8
S84	★★★★★	Author: Oleg Košik, national round, 2007, G 6
S85	★★★★★	Author: Jaan Kalda, regional round, 2009, G 9
S86	★★★★★	Author: Jaan Kalda, open competition, 2010, G 10
S87	★	Author: Valter Kiisk, national round, 2007, G 3

S88	★	Author: Tundmatu autor, open competition, 2009, G 2
S89	★	Author: Koit Timpmann, regional round, 2010, G 3
S90	★★	Author: EFO žürii, national round, 2006, G 2
S91	★★	Author: Tundmatu autor, open competition, 2007, G 4
S92	★★	Author: Mihkel Kree, regional round, 2005, G 5
S93	★★	Author: Mihkel Kree, regional round, 2006, G 6
S94	★★	Author: Jaak Kikas, regional round, 2007, G 6
S95	★★	Author: Jaak Kikas, national round, 2008, G 5
S96	★★	Author: Mihkel Rähn, national round, 2009, G 7
S97	★★	Author: Jaan Kalda, open competition, 2010, G 4
S98	★★★	Author: Tundmatu autor, open competition, 2006, G 6
S99	★★★	Author: Tundmatu autor, regional round, 2009, G 7
S100	★★★	Author: Jaan Kalda, regional round, 2009, G 8
S101	★★★	Author: Tundmatu autor, open competition, 2009, G 8
S102	★★★★	Author: Tundmatu autor, open competition, 2007, G 9
S103	★★★★	Author: Andreas Valdmann, regional round, 2010, G 8
S104	★★★★	Author: Siim Ainsaar, regional round, 2011, G 10
S105	★★★★	Author: Mihkel Kree, regional round, 2007, G 10

S106	★★★★★	Author: Tundmatu autor, open competition, 2005, G 10
S107	★★★★★	Author: Jaan Kalda, national round, 2007, G 8
S108	★★★★★	Author: Mihkel Kree, national round, 2007, G 9
S109	★★★★★	Author: Aigar Vaigu, regional round, 2008, G 10
S110	★★★★★	Author: Jaan Kalda, national round, 2010, G 9
S111	★★★★★	Author: Andreas Valdmann, national round, 2011, G 8
S112	★★★★★	Author: Mihkel Kree, national round, 2006, G 9
S113	★	Author: Oleg Košik, regional round, 2006, G 1
S114	★	Author: Jaan Kalda, regional round, 2007, G 2
S115	★	Author: Tundmatu autor, open competition, 2008, G 1
S116	★	Author: Tundmatu autor, open competition, 2009, G 1
S117	★	Author: Valter Kiisk, regional round, 2005, G 1
S118	★	Author: Oleg Košik, regional round, 2011, G 4
S119	★★	Author: Oleg Košik, regional round, 2006, G 3
S120	★★	Author: Jaan Kalda, regional round, 2008, G 2
S121	★★	Author: Jaan Kalda, national round, 2009, G 5
S122	★★★	Author: Jaan Kalda, national round, 2005, G 6
S123	★★★	Author: Tundmatu autor, open competition, 2011, G 7

S124	★★★★	Author: Jaan Kalda, national round, 2011, G 6
S125	★★★★	Author: Tundmatu autor, national round, 2007, G 5
S126	★★★★	Author: Siim Ainsaar, open competition, 2009, G 10
S127	★★★★	Author: Jaan Kalda, national round, 2009, G 8
S128	★★★★★	Author: Tundmatu autor, open competition, 2011, G 10
S129	★★★★★	Author: Andreas Valdmann, national round, 2010, G 10
S130	★★★★	Author: Jaan Kalda, open competition, 2008, G 8
S131	★★★★★	Author: Jaan Kalda, national round, 2009, G 10
S132	★★	Author: Andres Laan, national round, 2011, G 5
S133	★★★	Author: Andres Laan, regional round, 2011, G 8
S134	★★★★	Author: Jaan Kalda, open competition, 2011, G 6
S135	★★★★★	Author: Jaan Kalda, national round, 2007, G 10
S136	★★★★★	Author: Siim Ainsaar, national round, 2008, G 10
S137	★★★★★	Author: Oleg Košik, open competition, 2010, G 8
S138	★★★★★	Author: Jaan Kalda, regional round, 2010, G 9
S139	★★★★★	Author: Tundmatu autor, open competition, 2007, G 10
S140	★	Author: Mihkel Heidelberg, regional round, 2008, G 1
S141	★	Author: Tundmatu autor, open competition, 2007, G 2

S142	★	Author: Mihkel Kree, national round, 2009, G 1
S143	★★	Author: Tundmatu autor, open competition, 2005, G 3
S144	★★	Author: Ott Krikmann, regional round, 2005, G 2
S145	★★	Author: Oleg Košik, national round, 2009, G 2
S146	★★	Author: Roland Matt, regional round, 2011, G 5
S147	★★	Author: Mihkel Kree, national round, 2011, G 3
S148	★★★	Author: Siim Ainsaar, national round, 2010, G 4
S149	★★★	Author: Tundmatu autor, open competition, 2006, G 7
S150	★★★	Author: Aigar Vaigu, national round, 2010, G 5
S151	★★★★	Author: Riho Taba, regional round, 2007, G 9
S152	★★★★	Author: Jaan Kalda, open competition, 2009, G 9
S153	★★★★	Author: Jaan Kalda, national round, 2011, G 7
S154	★★★★★	Author: Siim Ainsaar, national round, 2008, G 9
S155	★★★★★	Author: Taavi Pungas, open competition, 2010, G 9
S156	★★★★★	Author: Jaan Kalda, regional round, 2010, G 10
S157	★★★★★	Author: Valter Kiisk, national round, 2011, G 10
S158	★★★★★	Author: Jaan Kalda, national round, 2005, G 10
S159	★	Author: Mihkel Pajusalu, regional round, 2011, G 2

S160	★	Author: Urmo Visk, regional round, 2009, G 1
S161	★★	Author: Tundmatu autor, open competition, 2009, G 5
S162	★★★	Author: Oleg Košik, national round, 2005, G 9
S163	★★★★	Author: Siim Ainsaar, regional round, 2009, G 10
S164	★★★★★	Author: Mihkel Kree, national round, 2010, G 7
S165	★	Author: Jaan Susi, national round, 2005, G 3
S166	★	Author: Jaak Kikas, national round, 2007, G 1
S167	★	Author: Urmo Visk, regional round, 2008, G 4
S168	★	Author: Tundmatu autor, regional round, 2011, G 3
S169	★	Author: Riho Taba, regional round, 2006, G 2
S170	★	Author: Aleksei Vlasov, regional round, 2007, G 3
S171	★	Author: Jaak Kikas, regional round, 2008, G 3
S172	★	Author: Urmo Visk, regional round, 2009, G 3
S173	★	Author: Oleg Košik, open competition, 2010, G 2
S174	★	Author: Urmo Visk, regional round, 2010, G 2
S175	★	Author: Taavi Pungas, national round, 2011, G 1
S176	★★	Author: Urmo Visk, regional round, 2008, G 5
S177	★★	Author: Ott Krikmann, regional round, 2005, G 3

S178	★★	Author: Mihkel Kree, national round, 2008, G 6
S179	★★	Author: Andres Laan, regional round, 2010, G 5
S180	★★	Author: Koit Timpmann, national round, 2010, G 2
S181	★★★★	Author: Tundmatu autor, regional round, 2005, G 8
S182	★★★★	Author: Tundmatu autor, open competition, 2007, G 8
S183	★★★★	Author: Jaan Kalda, national round, 2009, G 6
S184	★★★★	Author: Oleg Košik, national round, 2006, G 7
S185	★★★★	Author: Mihkel Heidelberg, national round, 2007, G 7
S186	★★★★★	Author: Valter Kiisk, national round, 2006, G 8
S187	★★★★★★	Author: Tundmatu autor, open competition, 2008, G 10
S188	★	Author: Jaan Kalda, open competition, 2008, G 3
S189	★★	Author: Urmo Visk, national round, 2006, G 5
S190	★★★★	Author: Jaan Kalda, national round, 2008, G 4
S191	★★★★★	Author: Jaan Kalda, open competition, 2008, G 9
S192	★	Author: Tundmatu autor, open competition, 2005, G 1
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S198	★★★	Author: Tundmatu autor, open competition, 2009, G 6
S199	★★★★	Author: Tundmatu autor, open competition, 2005, G 8
S200	★★★★	Author: Mihkel Kree, national round, 2008, G 8