# Modelling real-world problems in introductory physics

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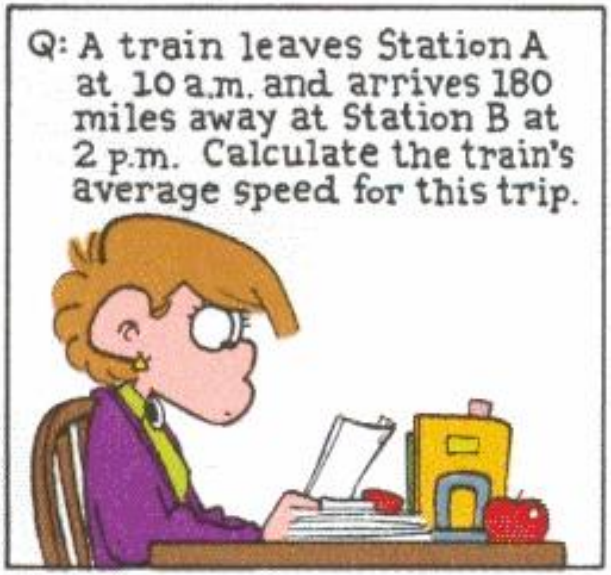
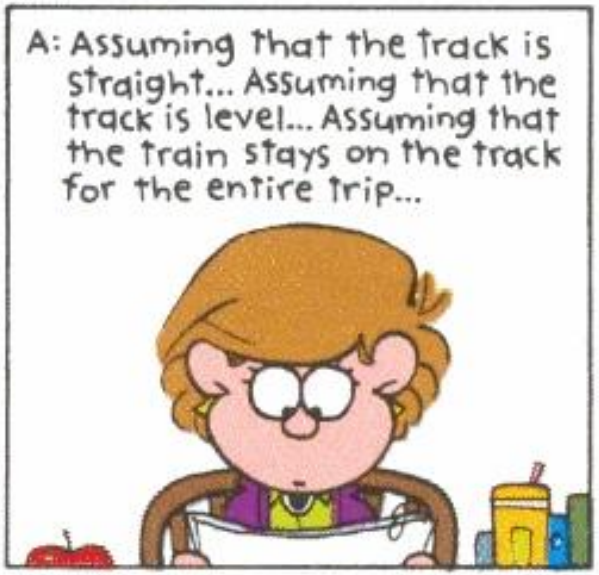
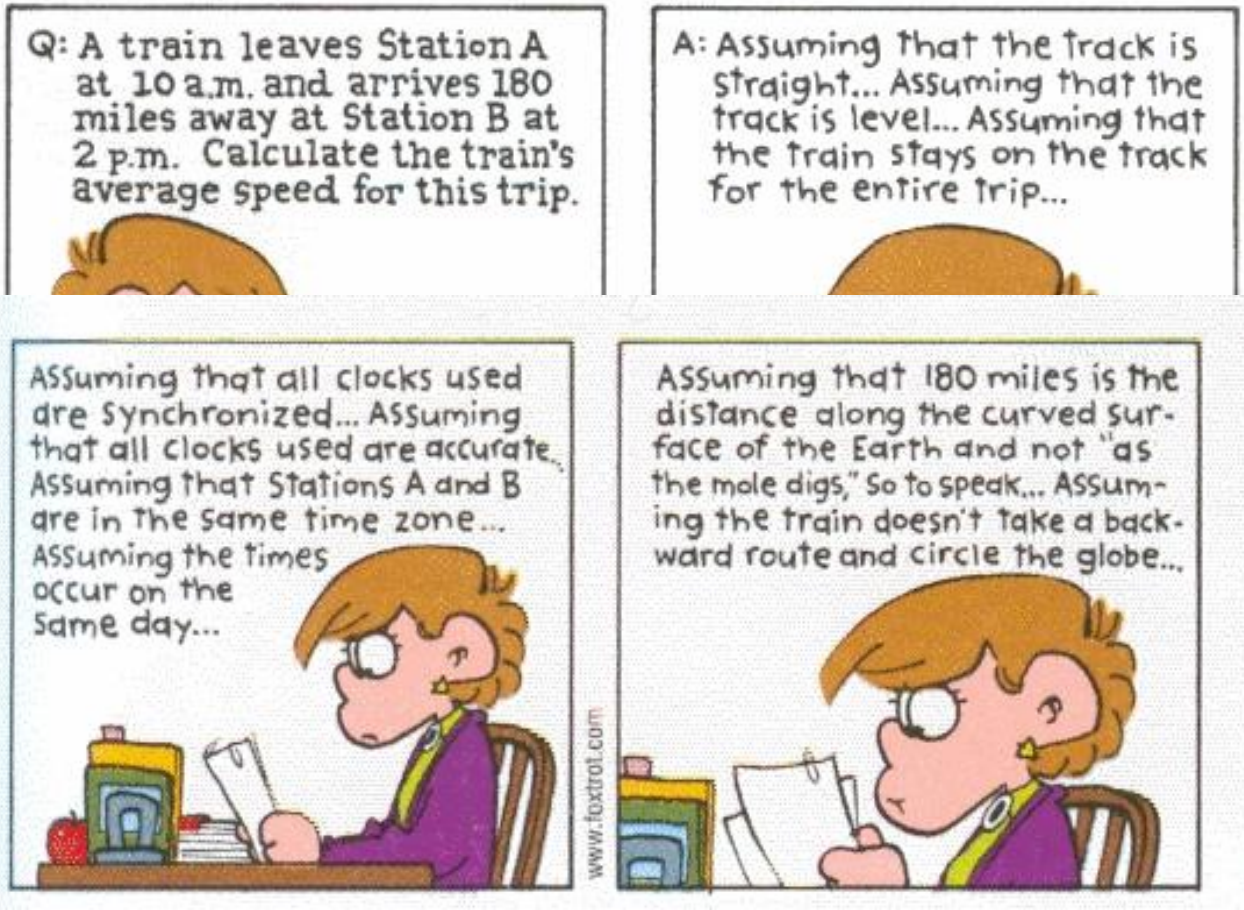



by Bill Amend "Understanding Physics", Cummings et al., p.3

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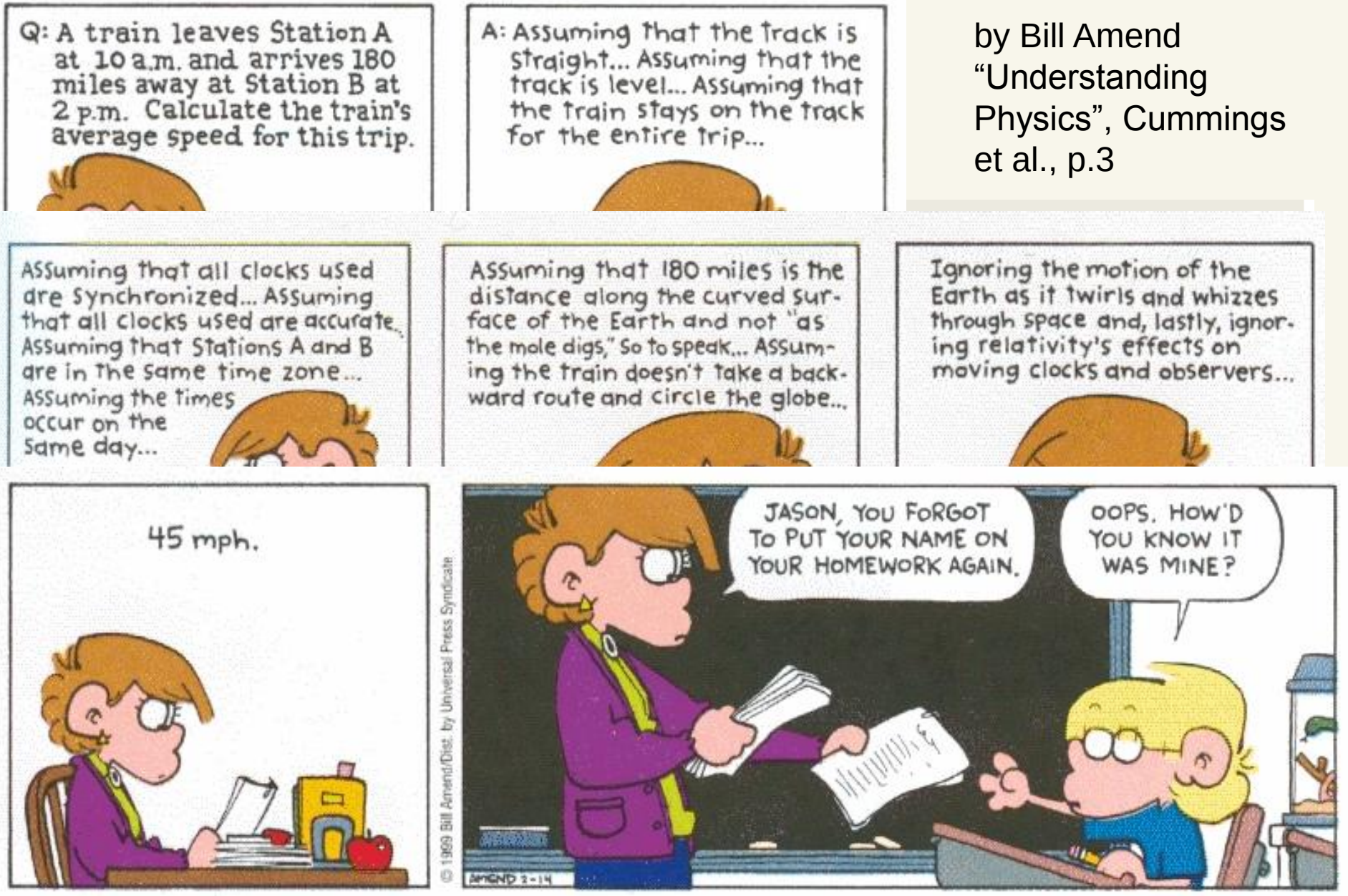


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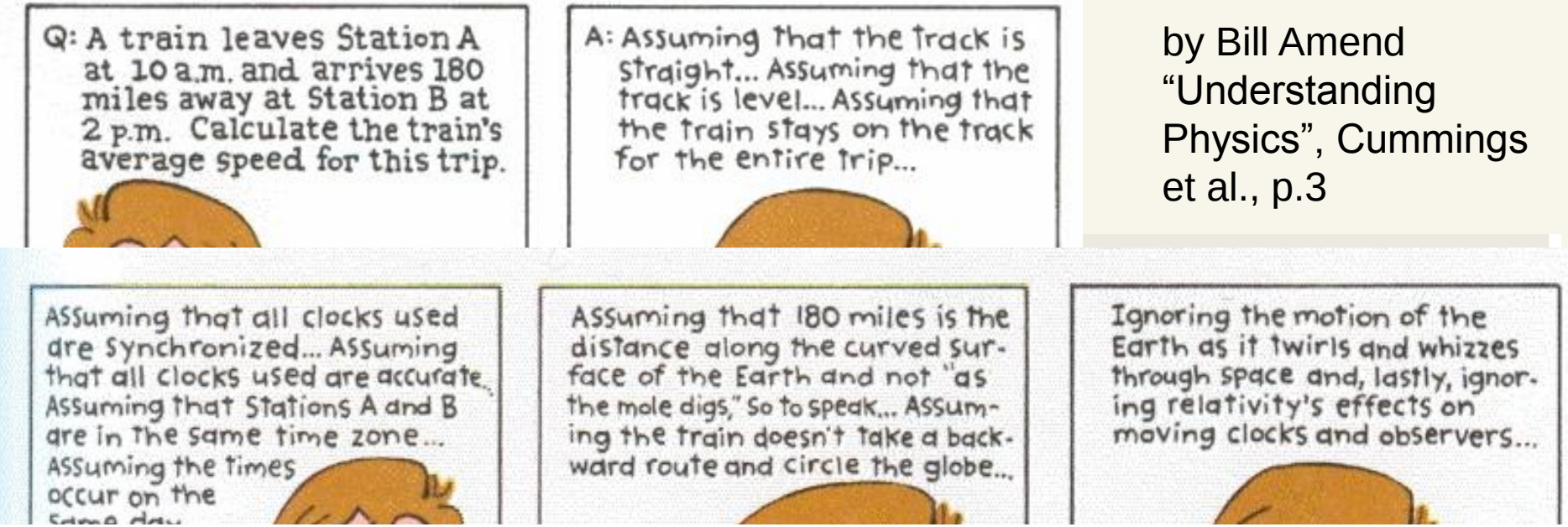


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"Understanding Physics", Cummings et al., p.3

" A typical physicist's initial strategy is to understand simple systems as completely as possible by constructing physical laws that describe them. Once this is accomplished, the next step is to add more and more real-world complexity to the system one step at a time."

# Group Discovery Project

- Three-week long Problem Based Learning (PBL) project, equivalent to 7-lecture course
  - context-rich, real world, ill-defined problem, missing data
  - open-ended or multiple paths
  - group work
  - modified role of tutors as facilitators

# Timing

- End of first year
- consolidation and synthesis of knowledge and skills learnt during the year
- requires learning new physics and numerical techniques + transferable skills

# Project Aims

- Give students the chance to experience working like a real physicist (working in “research mode”) and the freedom to come up with their own solution
- Enhance problem-solving skills as well as communication and team-working skills
- Enhanced student ownership, motivation, independent learning, empowerment
- Deeper learning

# Topics

- 50 to 90 students, groups of 3 to 5 students (balance of skills and abilities in each group)

- 2008/09: Advising the Scottish Golf Union on the optimum angle for the loft of a driver for three golf courses around the world.
- 2009/10: Advising an international panel on the future trajectory of a potentially hazardous asteroid and possible mitigation strategies.

# Group Discovery Project - Schedule

- Information retrieval session (given by library staff)
- Introductory session: project aims, introductory exercises, students brainstorm the problem and plan next steps
- Workshop session
- Two facilitator sessions, students submit a group action plan prior to each session.
- Group report and oral presentation + questions.

# Facilitators

- Facilitator role is decisive
- Facilitator resources:  facilitator guide, example solution, literature
- Pre-meeting with facilitators
- Facilitator meeting after the first facilitator session with students

# Introductory Session

- Brief presentation explaining project aims
- Students brainstorm the problem before being given the problem text

# Introductory Session – Warm-up questions

- **Working in your groups, write down as many factors as you can that might affect the distance a golf ball travels when struck by a golf club.**

- **Now think like physicists and write down what you think are the top 5 factors in order of importance in influencing the distance**

# Group Discovery Project - Assessment

- Process and Content assessment
- Individual
  Facilitator sessions (10%)
- Group
  Group action plans (10%)
  Group report (40%)
  Group presentation with demonstration of their simulation and panel question session (40%)
- Group mark moderated by peer assessment using WebPA (http://webpaproject.lboro.ac.uk/)

# Outcomes in 2008/09

- Students modelled the golf ball trajectory using the Euler method of numerical integration.
- Factors considered in model:
  - All: Drag, lift, effect of height above sea level
  - Many: temperature, humidity, spin and velocity dependence of lift
  - Some: swing, bounce, wind, gravity

- Excel (VBA Macros), Python, Java

# Outcomes 2008/09 - Project Reports

Group Discovery

Group M
"WOW Technol

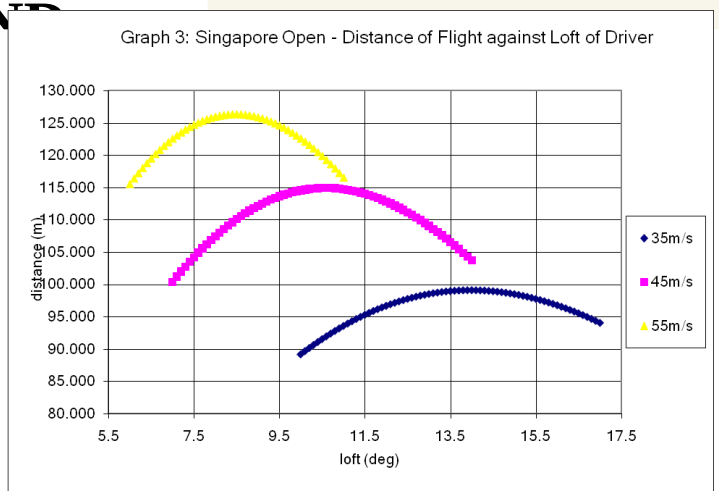
Words 1,186

**TEAM LEGF**

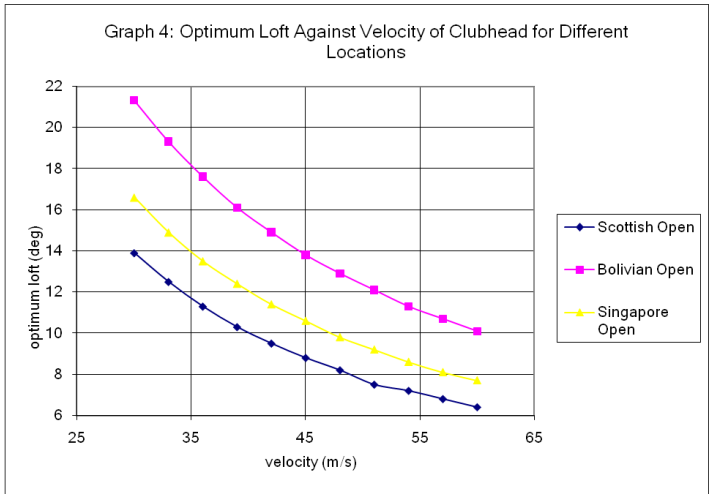
**TEN YEARS ON; HEL
SCOTTISH GOLF ORG
FIND THEIR NEXT C**

**Team Legend (also known as**

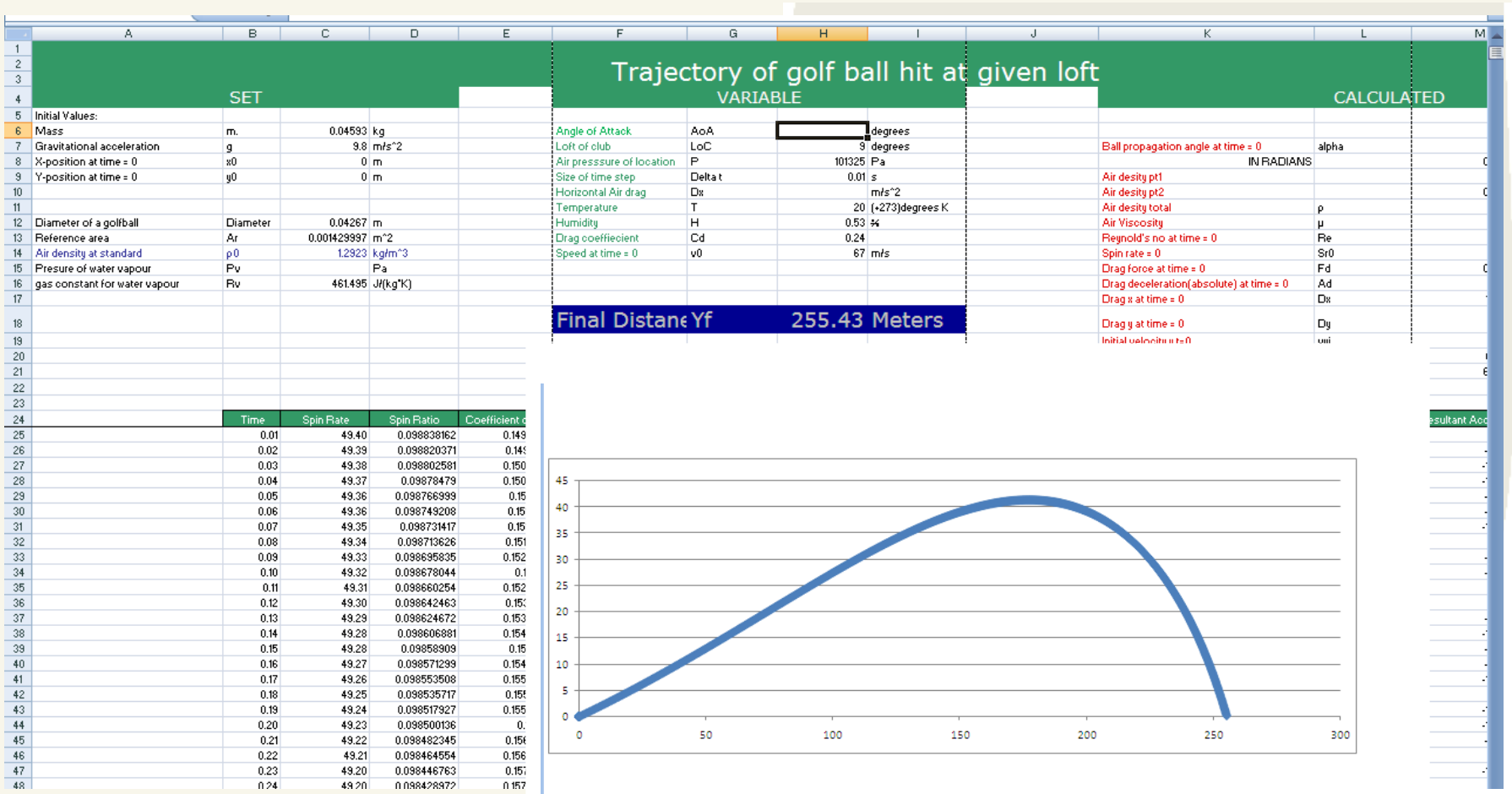
**Word Count:**
1, 152 words




All of these graphs demonstrate that the higher the velocity of the club head, the lower the optimum loft of the driver.



# Outcomes 2008/09 - Models



Trajectory of golf ball hit at given loft

| SET | | | |
|---|---|---|---|
| Initial Values: | | | |
| Mass | m. | 0.04593 | kg |
| Gravitational acceleration | g | 9.8 | m/s^2 |
| X-position at time = 0 | x0 | 0 | m |
| Y-position at time = 0 | y0 | 0 | m |
| Diameter of a golfball | Diameter | 0.04267 | m |
| Reference area | Ar | 0.001429997 | m^2 |
| Air density at standard | ρ0 | 1.2923 | kg/m^3 |
| Presure of water vapour | Pv | | Pa |
| gas constant for water vapour | Rv | 461.495 | J/(kg*K) |

| VARIABLE | | | |
|---|---|---|---|
| Angle of Attack | AoA | | degrees |
| Loft of club | LoC | 9 | degrees |
| Air presssure of location | P | 101325 | Pa |
| Size of time step | Delta t | 0.01 | s |
| Horizontal Air drag | Dx | | m/s^2 |
| Temperature | T | 20 | (+273)degrees K |
| Humidity | H | 0.53 | % |
| Drag coeffiecient | Cd | 0.24 | |
| Speed at time = 0 | v0 | 67 | m/s |
| Final Distane | Yf | 255.43 | Meters |

| CALCULATED | | |
|---|---|---|
| Ball propagation angle at time = 0 | alpha | |
| IN RADIANS | | 0 |
| Air desity pt1 | | |
| Air desity pt2 | | 0 |
| Air desity total | ρ | |
| Air Viscosity | μ | |
| Reynold's no at time = 0 | Re | |
| Spin rate = 0 | Sr0 | |
| Drag force at time = 0 | Fd | 0 |
| Drag deceleration(absolute) at time = 0 | Ad | |
| Drag x at time = 0 | Dx | |
| Drag y at time = 0 | Dy | |
| Initial velocity u t=0 | uni | |

| Time | Spin Rate | Spin Ratio | Coefficient |
|---|---|---|---|
| 0.01 | 49.40 | 0.098838162 | 0.149 |
| 0.02 | 49.39 | 0.098820371 | 0.149 |
| 0.03 | 49.38 | 0.098802581 | 0.150 |
| 0.04 | 49.37 | 0.09878479 | 0.150 |
| 0.05 | 49.36 | 0.098766999 | 0.15 |
| 0.06 | 49.36 | 0.098749208 | 0.15 |
| 0.07 | 49.35 | 0.098731417 | 0.15 |
| 0.08 | 49.34 | 0.098713626 | 0.151 |
| 0.09 | 49.33 | 0.098695835 | 0.152 |
| 0.10 | 49.32 | 0.098678044 | 0.1 |
| 0.11 | 49.31 | 0.098660254 | 0.152 |
| 0.12 | 49.30 | 0.098642463 | 0.153 |
| 0.13 | 49.29 | 0.098624672 | 0.153 |
| 0.14 | 49.28 | 0.098606881 | 0.154 |
| 0.15 | 49.28 | 0.09858909 | 0.15 |
| 0.16 | 49.27 | 0.098571299 | 0.154 |
| 0.17 | 49.26 | 0.098553508 | 0.155 |
| 0.18 | 49.25 | 0.098535717 | 0.155 |
| 0.19 | 49.24 | 0.098517927 | 0.155 |
| 0.20 | 49.23 | 0.098500136 | 0. |
| 0.21 | 49.22 | 0.098482345 | 0.156 |
| 0.22 | 49.21 | 0.098464554 | 0.156 |
| 0.23 | 49.20 | 0.098446763 | 0.157 |
| 0.24 | 49.20 | 0.098428972 | 0.157 |

# Outcomes in 2009/10

- Students numerically modelled the trajectory of a potentially hazardous asteroid and considered impact mitigation strategies.
- Factors considered in model:
  - All: gravitational attraction by the Sun
  - Many: gravitational attraction to the Earth, position of the Moon, the other planets, precision of model, sanity checks of model.
- Mitigation strategies: fragmentation, deflection of trajectory (nuclear detonation, impact collision, etc.), Torino scale considerations

# “Sanity checks” of models

- Effect of time step on results
- Sensitivity of model to input parameters
- 2008/09: Expected shape of trajectory and expected distances for golf ball trajectory
- 2009/10: Period of Earth’s orbit and asteroid’s orbit as expected from Kepler’s Third Law. Deviation from circular orbit for eccentricity=0.

# Outcomes 2009/10 - Project Reports

**PHYSICS 1B**

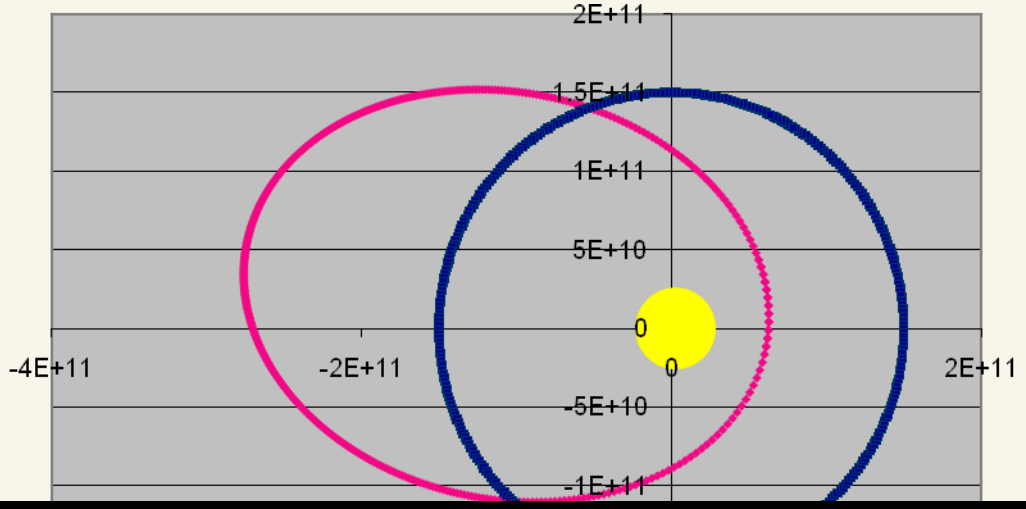
**Project Report**

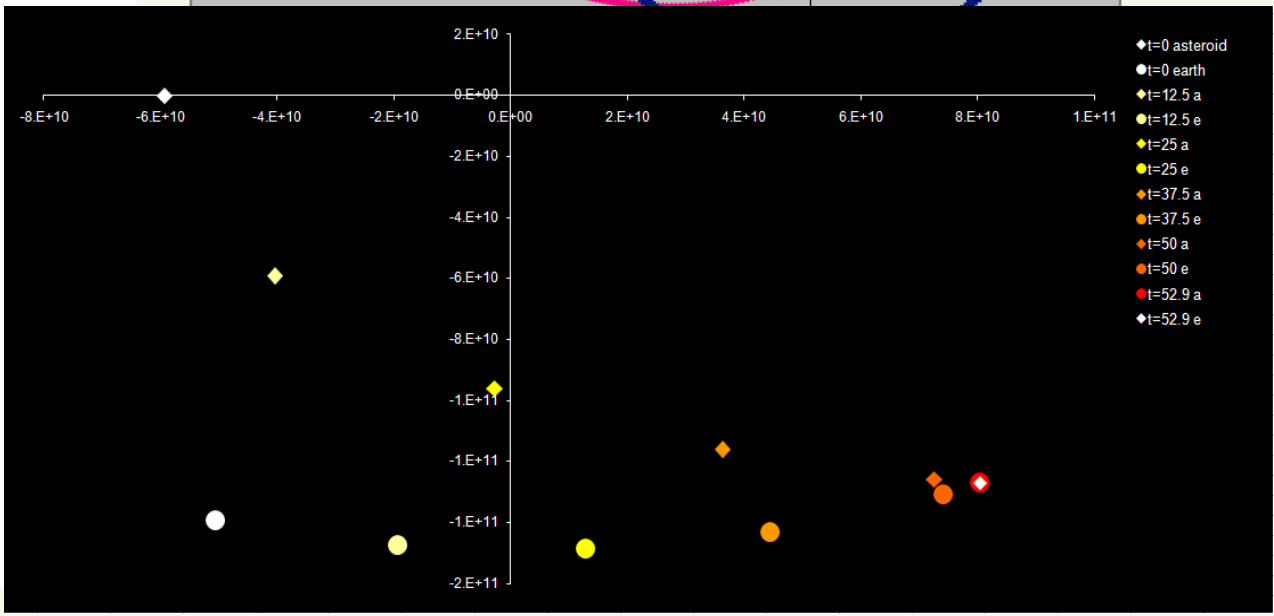
**Group G**

**Mission Statement:**

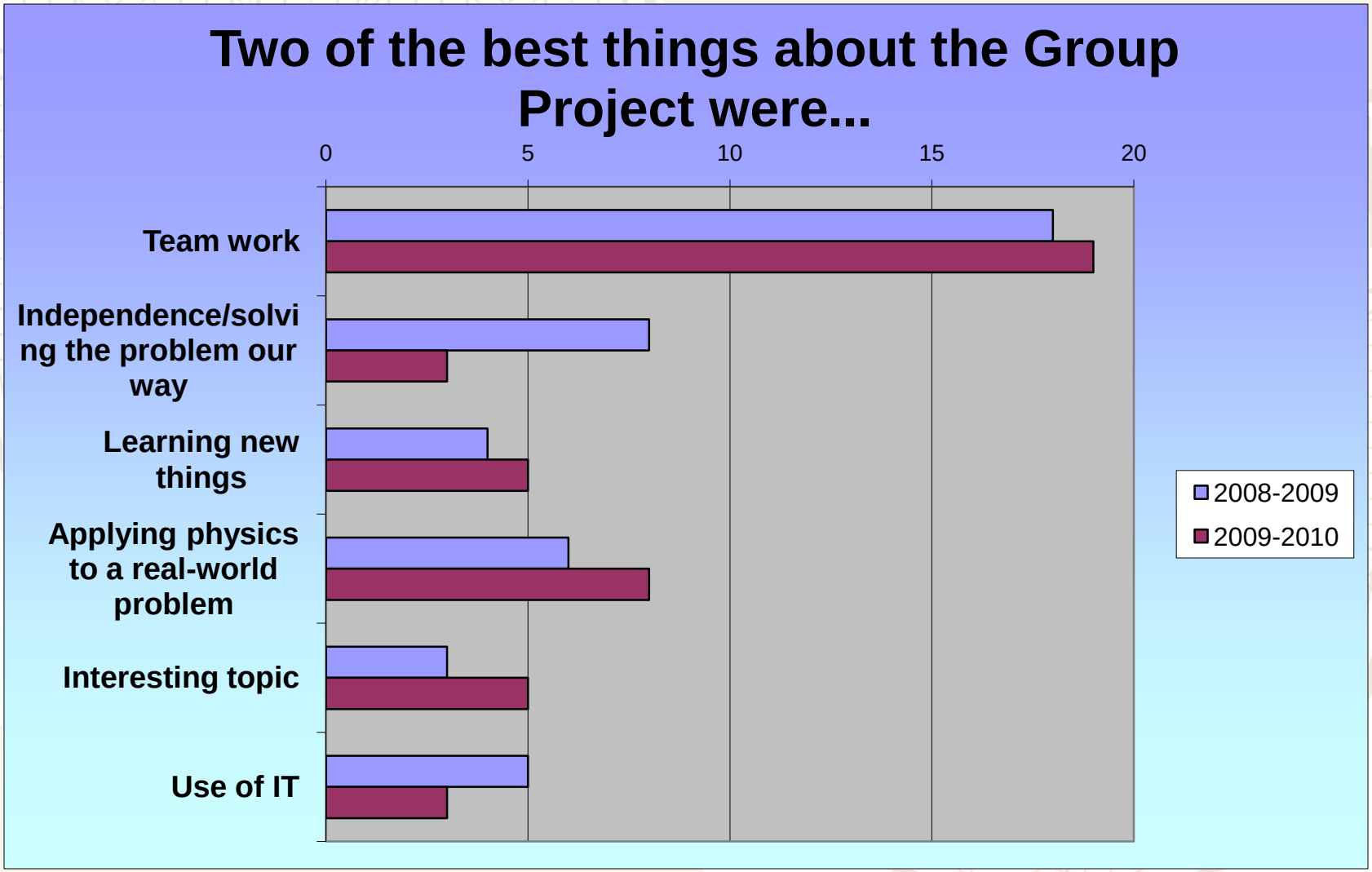
To model the future trajectory as precisely as possible and devise a physically realistic plan for altering the trajectory and/or minimizing impact damage of Potentially Hazardous Asteroid (PHA) 2344.

**Compiled by:**



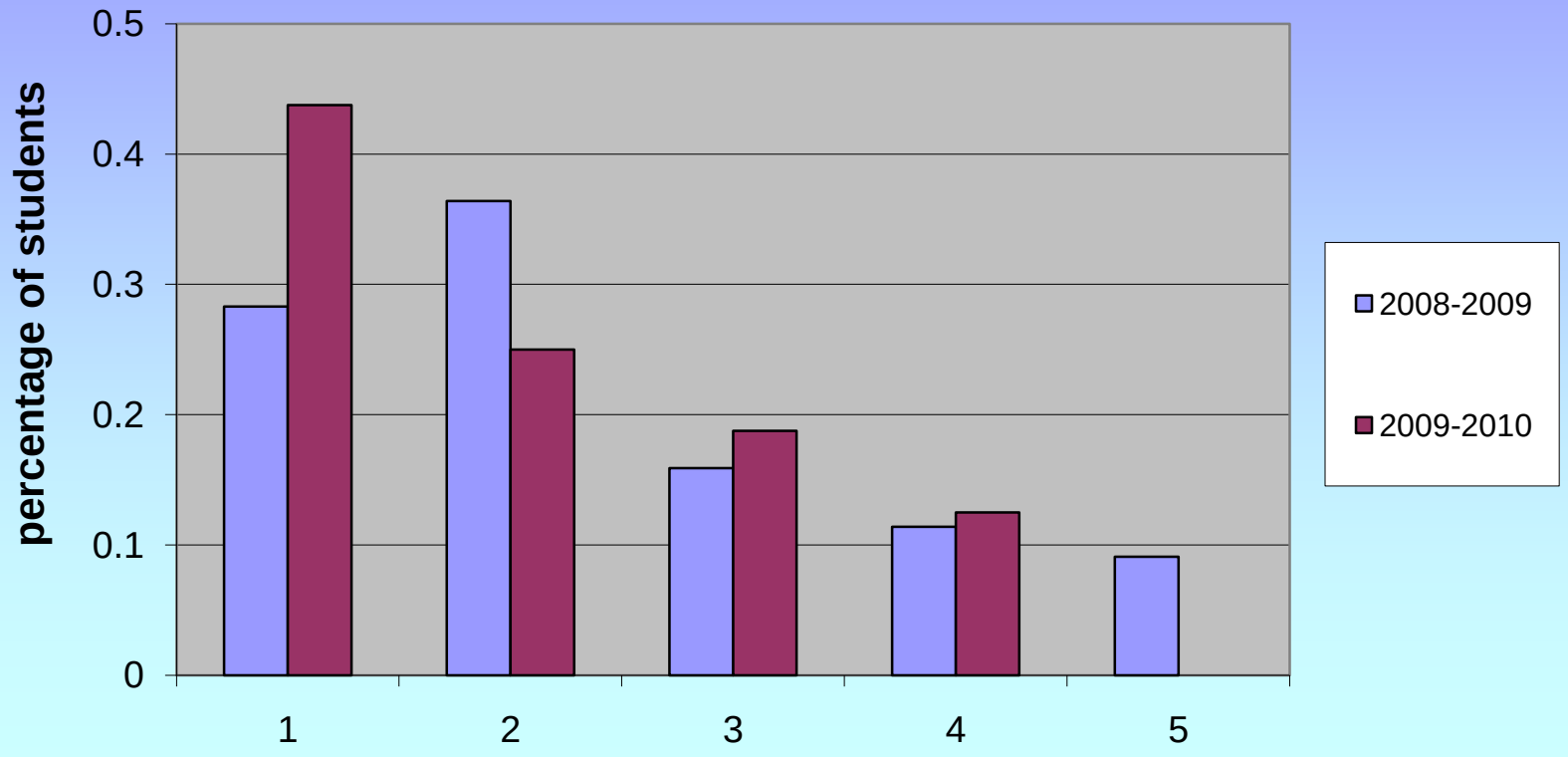
# Student survey results




08/09: 45 returns
09/10: 32 returns

# Student survey results

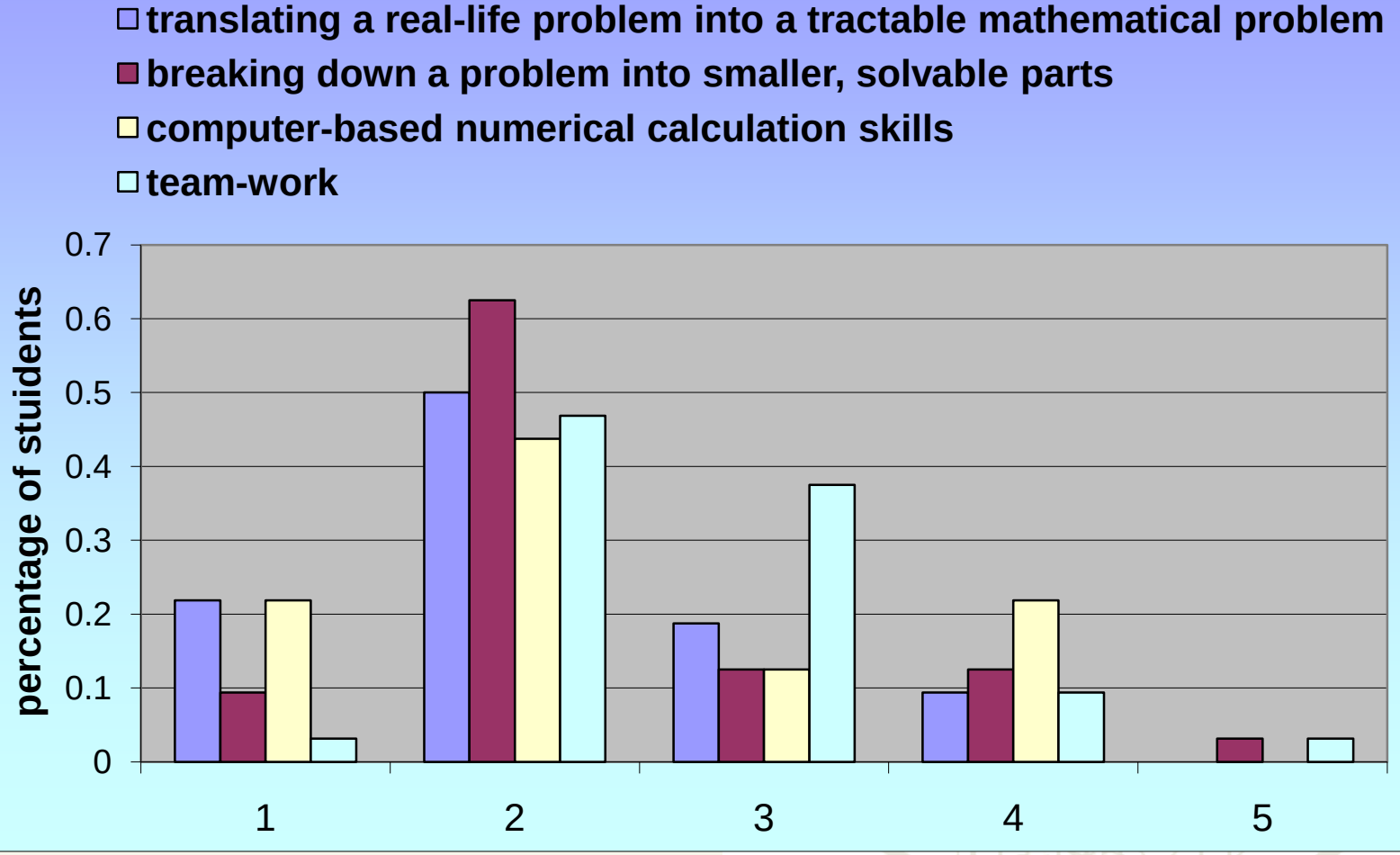
# Did you find the Group Project more or less interesting than working on standard tutorial problems?



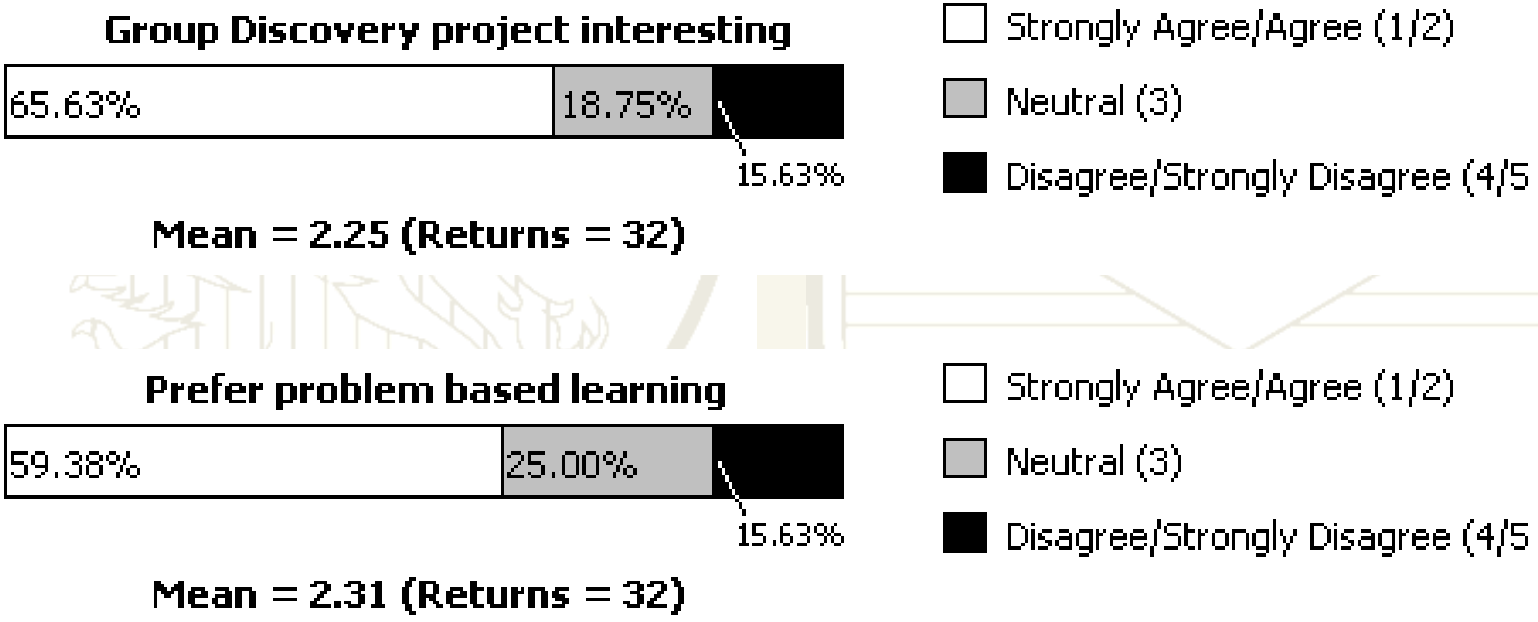

much more interesting

much less interesting

## Which of the following skills do you think you improved through the Group Project (2009/10)



# 2009/10 PH1012 Module evaluation returns



# Conclusions

- Using PBL in first year can give students insight into the research process in terms of creating a simple model, layering of complexity and sanity checks. It can enhance problem-solving and transferable skills
- We have found the following factors important:

  -explaining the reasons for doing this type of project

  -structuring the process (group action plans, timetabling)

  -level and topic of problem, availability of books/articles

  -staff facilitators. Pre-meetings and facilitator guide

  -clear grade descriptors for project report and orals

# Outlook

- The Group Discovery Project will run with different topics in 2010 and 2011 – further evaluation is planned.
- Future work: investigation of the effect of the project on students' understanding of the scientific research process and problem-solving strategies.

# PBL resources

- **PossiBiLities: a practice guide to problem-based learning in physics and astronomy**
  http://www.le.ac.uk/leap/pblguide.pdf
- **Web resources for problem-based learning**
  http://www.heacademy.ac.uk/assets/ps/documents/primers/primers/ps0090_web_resources_for_problem_based_learning_mar_2005.pdf
- **LEAP project problem bank**
  http://www.le.ac.uk/leap/
- **HEA database of practicals**
  www.heacademy.ac.uk/physsci/resources/practicals
- **University of Delaware PBL problem bank**
  https://primus.nss.udel.edu/Pbl/