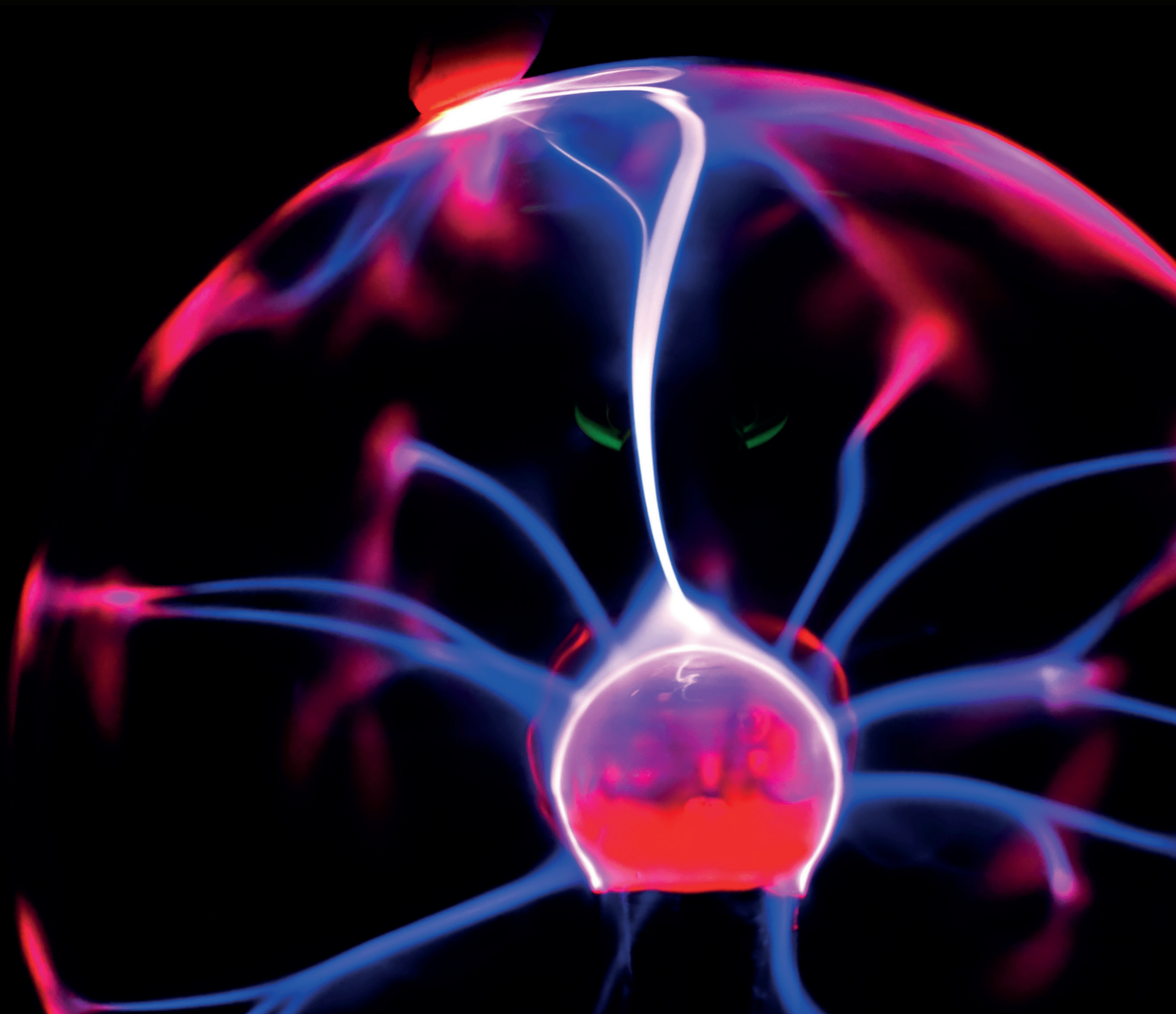


# PHYSICAL SCIENCES

## FOR NGSS



# Contents

## CLASSROOM GUIDE

The Contents: A Planning Tool.....	CG3
Identifying Learning Intentions and Goals .....	CG4
Scaffolded Learning with the 5 Es .....	CG5
Practical Investigations .....	CG8
Teaching Strategies for Classroom Use .....	CG9
Differentiated Learning.....	CG12
The Concept Maps.....	CG13
Engineering Design Solutions.....	CG14
The Nature of Science .....	CG15
Evaluating Student Performance .....	CG16
CCCs and SEPs Summary by Number .....	CG18
Summary of BIOZONE's 3D Approach By Chapter .....	CG19
Identifying CCSS Connections .....	CG22
Teacher's Notes .....	CG25
BIOZONE's Pedagogy .....	CG26

Copyright © 2020 Richard Allan  
Published by BIOZONE International Ltd

**Purchases of this book may be  
made direct from the publisher:**



### BIOZONE Corporation

USA and Canada

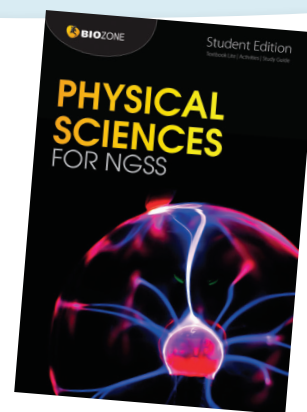
FREE phone: 1-855-246-4555

FREE fax: 1-855-935-3555

Email: [sales@thebiozone.com](mailto:sales@thebiozone.com)

Web: [www.thebiozone.com](http://www.thebiozone.com)

## FAQs ABOUT PHYSICAL SCIENCES FOR NGSS



What is its pedagogical approach?	CG5- CG7 CG26
How do I allocate time through the course?	CG3
Does it cater for all three dimensions of the NGSS?	CG19- CG21
Are the CCSS Math and Literacy Connections addressed?	CG23- CG24
Are the ELD Standards addressed?	CG23- CG24
Is it phenomenon based?	CG5, CG8
How are the 5Es incorporated?	CG5-CG8
Are there practical investigations?	CG8
How is engineering design addressed?	CG14
How does it address the Nature of Science?	CG15
How do I use the workbook in the classroom?	CG9
Are there tools for differentiated instruction (including gifted and talented students)?	CG11- CG12
How can I support English language learners?	CG12
How can I evaluate student performance? Are there test banks?	CG16- CG17
Are there teacher's notes?	CG25

Next Generation Science Standards (NGSS) is a registered trademark of Achieve. Neither Achieve nor the lead states and partners that developed the Next Generation Science Standards were involved in the production of this product and do not endorse it.

# The Contents: A Planning Tool

The contents pages are not merely a list of the activities in the student edition. Encourage your students to use them as a planning tool for their program of work. Students can identify the activities they are to complete and then tick them off when completed. The teacher can also see at a glance how quickly the student is progressing through the assigned material.

**Contents**

Using This Book .....v  
Using BIOZONE'S Resource Hub .....viii  
Physical Sciences: A Flow of Ideas .....x

**Skills for Physical Sciences**

**Key Skills and Knowledge** ..... 1

1. The Scientific Method ..... 1  
2. Safety ..... 2  
3. Observation and Measurement ..... 3  
4. Materials ..... 4  
5. Units ..... 5  
6. Accuracy and Precision ..... 6  
7. Working with Data ..... 7  
8. Graphing ..... 8  
9. Data Analysis ..... 9  
10. Inference ..... 10  
11. Reasoning ..... 11  
12. Summing Up ..... 12

13. Standard Equipment in Chemistry ..... 26  
14. Investigations in Chemistry ..... 27  
15. Materials ..... 28  
16. Periodic Table ..... 29

17. Safety ..... 30  
18. Working with Data ..... 31  
19. Inference ..... 32  
20. Atomic Theory and Rutherford's Experiment ..... 36  
21. Atomic Structure ..... 39  
22. Atomic Models and Valence Electrons ..... 42  
23. Exploring the Periodic Table ..... 44  
24. Trends in the Periodic Table ..... 47  
25. Valence Electrons and Reactivity ..... 51  
26. Bonding ..... 52  
27. Ionic Bonding ..... 53  
28. Covalent Bonding ..... 56  
29. Molecular Shape ..... 58  
30. Intra- and Intermolecular Forces ..... 61  
31. Comparing Substances ..... 64  
32. Review Your Understanding ..... 67  
33. Summing Up ..... 68

**PS1.B Chemical Reactions**

**Key Skills and Knowledge** ..... 34

34. Antacid Chemistry ..... 34  
35. Using Mass to Determine ..... 35  
36. The Mole ..... 36

37. Molar Mass ..... 37  
38. Molar vs Empirical Formula ..... 38  
39. Percentage Composition ..... 39  
40. Balancing Equations ..... 40  
41. Stoichiometry ..... 41  
42. Limiting Reagents and Concentration ..... 42  
43. Calculating Standard Solution ..... 43  
44. Making a Claim ..... 44  
45. Reaction Rates ..... 45  
46. Reaction in Chemical Reaction ..... 46  
47. Energy and Chemical Reaction ..... 47  
48. Reversible Reactions ..... 48  
49. Equilibrium Reactions ..... 49  
50. Le Chatelier's Principle ..... 50  
51. Chemical Equilibria ..... 51  
52. Acids and Bases ..... 52  
53. Review Your Understanding ..... 53  
54. Summing Up ..... 54

**PS1.C Nuclear Processes**

**Key Skills and Knowledge** ..... 56

56. Nuclear Power ..... 56  
57. Inside the Nucleus ..... 57  
58. Isotopes ..... 58  
59. Radioactive Decay ..... 59  
60. Fission and Chain Reactions ..... 60  
61. Fission vs Fusion ..... 61  
62. Review Your Understanding ..... 62  
63. Summing Up ..... 63

**MOTION AND STABILITY: FORCES**

**Key Skills and Knowledge** ..... 64

64. Forces and Motion ..... 64  
65. Breaking Bricks ..... 65  
66. Distance and Displacement ..... 66  
67. Speed and Velocity ..... 67  
68. Acceleration ..... 68  
69. Introduction to Forces ..... 69  
70. Newton's Second Law ..... 70  
71. Newton's Third Law ..... 71  
72. Introduction to Momentum ..... 72

**PS2.A Forces and Motion**

**Key Skills and Knowledge** ..... 134

134. Breaking Bricks ..... 135  
135. Distance and Displacement ..... 136  
136. Speed and Velocity ..... 139  
137. Acceleration ..... 147  
138. Introduction to Forces ..... 151  
139. Newton's Second Law ..... 154  
140. Newton's Third Law ..... 164  
141. Introduction to Momentum ..... 166

**PS2.B Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 167

167. Forces and Motion ..... 167  
168. Breaking Bricks ..... 168  
169. Distance and Displacement ..... 169  
170. Speed and Velocity ..... 170  
171. Acceleration ..... 171  
172. Introduction to Forces ..... 172  
173. Newton's Second Law ..... 173  
174. Newton's Third Law ..... 174  
175. Introduction to Momentum ..... 175

**PS2.C Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 176

176. Forces and Motion ..... 176  
177. Breaking Bricks ..... 177  
178. Distance and Displacement ..... 178  
179. Speed and Velocity ..... 179  
180. Acceleration ..... 180  
181. Introduction to Forces ..... 181  
182. Newton's Second Law ..... 182  
183. Newton's Third Law ..... 183  
184. Introduction to Momentum ..... 184

**PS2.D Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 185

185. Forces and Motion ..... 185  
186. Breaking Bricks ..... 186  
187. Distance and Displacement ..... 187  
188. Speed and Velocity ..... 188  
189. Acceleration ..... 189  
190. Introduction to Forces ..... 190  
191. Newton's Second Law ..... 191  
192. Newton's Third Law ..... 192  
193. Introduction to Momentum ..... 193

**PS2.E Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 194

194. Forces and Motion ..... 194  
195. Breaking Bricks ..... 195  
196. Distance and Displacement ..... 196  
197. Speed and Velocity ..... 197  
198. Acceleration ..... 198  
199. Introduction to Forces ..... 199  
200. Newton's Second Law ..... 200  
201. Newton's Third Law ..... 201  
202. Introduction to Momentum ..... 202

**PS2.F Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 203

203. Forces and Motion ..... 203  
204. Breaking Bricks ..... 204  
205. Distance and Displacement ..... 205  
206. Speed and Velocity ..... 206  
207. Acceleration ..... 207  
208. Introduction to Forces ..... 208  
209. Newton's Second Law ..... 209  
210. Newton's Third Law ..... 210  
211. Introduction to Momentum ..... 211

**PS2.G Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 212

212. Forces and Motion ..... 212  
213. Breaking Bricks ..... 213  
214. Distance and Displacement ..... 214  
215. Speed and Velocity ..... 215  
216. Acceleration ..... 216  
217. Introduction to Forces ..... 217  
218. Newton's Second Law ..... 218  
219. Newton's Third Law ..... 219  
220. Introduction to Momentum ..... 220

**PS2.H Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 221

221. Forces and Motion ..... 221  
222. Breaking Bricks ..... 222  
223. Distance and Displacement ..... 223  
224. Speed and Velocity ..... 224  
225. Acceleration ..... 225  
226. Introduction to Forces ..... 226  
227. Newton's Second Law ..... 227  
228. Newton's Third Law ..... 228  
229. Introduction to Momentum ..... 229

**PS2.I Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 230

230. Forces and Motion ..... 230  
231. Breaking Bricks ..... 231  
232. Distance and Displacement ..... 232  
233. Speed and Velocity ..... 233  
234. Acceleration ..... 234  
235. Introduction to Forces ..... 235  
236. Newton's Second Law ..... 236  
237. Newton's Third Law ..... 237  
238. Introduction to Momentum ..... 238

**PS2.J Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 239

239. Forces and Motion ..... 239  
240. Breaking Bricks ..... 240  
241. Distance and Displacement ..... 241  
242. Speed and Velocity ..... 242  
243. Acceleration ..... 243  
244. Introduction to Forces ..... 244  
245. Newton's Second Law ..... 245  
246. Newton's Third Law ..... 246  
247. Introduction to Momentum ..... 247

**PS2.K Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 240

240. Forces and Motion ..... 240  
241. Breaking Bricks ..... 241  
242. Distance and Displacement ..... 242  
243. Speed and Velocity ..... 243  
244. Acceleration ..... 244  
245. Introduction to Forces ..... 245  
246. Newton's Second Law ..... 246  
247. Newton's Third Law ..... 247  
248. Introduction to Momentum ..... 248

**PS2.L Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 241

241. Forces and Motion ..... 241  
242. Breaking Bricks ..... 242  
243. Distance and Displacement ..... 243  
244. Speed and Velocity ..... 244  
245. Acceleration ..... 245  
246. Introduction to Forces ..... 246  
247. Newton's Second Law ..... 247  
248. Newton's Third Law ..... 248  
249. Introduction to Momentum ..... 249

**PS2.M Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 242

242. Forces and Motion ..... 242  
243. Breaking Bricks ..... 243  
244. Distance and Displacement ..... 244  
245. Speed and Velocity ..... 245  
246. Acceleration ..... 246  
247. Introduction to Forces ..... 247  
248. Newton's Second Law ..... 248  
249. Newton's Third Law ..... 249  
250. Introduction to Momentum ..... 250

**PS2.N Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 243

243. Forces and Motion ..... 243  
244. Breaking Bricks ..... 244  
245. Distance and Displacement ..... 245  
246. Speed and Velocity ..... 246  
247. Acceleration ..... 247  
248. Introduction to Forces ..... 248  
249. Newton's Second Law ..... 249  
250. Newton's Third Law ..... 250  
251. Introduction to Momentum ..... 251

**PS2.O Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 244

244. Forces and Motion ..... 244  
245. Breaking Bricks ..... 245  
246. Distance and Displacement ..... 246  
247. Speed and Velocity ..... 247  
248. Acceleration ..... 248  
249. Introduction to Forces ..... 249  
250. Newton's Second Law ..... 250  
251. Newton's Third Law ..... 251  
252. Introduction to Momentum ..... 252

**PS2.P Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 245

245. Forces and Motion ..... 245  
246. Breaking Bricks ..... 246  
247. Distance and Displacement ..... 247  
248. Speed and Velocity ..... 248  
249. Acceleration ..... 249  
250. Introduction to Forces ..... 250  
251. Newton's Second Law ..... 251  
252. Newton's Third Law ..... 252  
253. Introduction to Momentum ..... 253

**PS2.Q Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 246

246. Forces and Motion ..... 246  
247. Breaking Bricks ..... 247  
248. Distance and Displacement ..... 248  
249. Speed and Velocity ..... 249  
250. Acceleration ..... 250  
251. Introduction to Forces ..... 251  
252. Newton's Second Law ..... 252  
253. Newton's Third Law ..... 253  
254. Introduction to Momentum ..... 254

**PS2.R Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 247

247. Forces and Motion ..... 247  
248. Breaking Bricks ..... 248  
249. Distance and Displacement ..... 249  
250. Speed and Velocity ..... 250  
251. Acceleration ..... 251  
252. Introduction to Forces ..... 252  
253. Newton's Second Law ..... 253  
254. Newton's Third Law ..... 254  
255. Introduction to Momentum ..... 255

**PS2.S Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 248

248. Forces and Motion ..... 248  
249. Breaking Bricks ..... 249  
250. Distance and Displacement ..... 250  
251. Speed and Velocity ..... 251  
252. Acceleration ..... 252  
253. Introduction to Forces ..... 253  
254. Newton's Second Law ..... 254  
255. Newton's Third Law ..... 255  
256. Introduction to Momentum ..... 256

**PS2.T Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 249

249. Forces and Motion ..... 249  
250. Breaking Bricks ..... 250  
251. Distance and Displacement ..... 251  
252. Speed and Velocity ..... 252  
253. Acceleration ..... 253  
254. Introduction to Forces ..... 254  
255. Newton's Second Law ..... 255  
256. Newton's Third Law ..... 256  
257. Introduction to Momentum ..... 257

**PS2.U Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 250

250. Forces and Motion ..... 250  
251. Breaking Bricks ..... 251  
252. Distance and Displacement ..... 252  
253. Speed and Velocity ..... 253  
254. Acceleration ..... 254  
255. Introduction to Forces ..... 255  
256. Newton's Second Law ..... 256  
257. Newton's Third Law ..... 257  
258. Introduction to Momentum ..... 258

**PS2.V Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 251

251. Forces and Motion ..... 251  
252. Breaking Bricks ..... 252  
253. Distance and Displacement ..... 253  
254. Speed and Velocity ..... 254  
255. Acceleration ..... 255  
256. Introduction to Forces ..... 256  
257. Newton's Second Law ..... 257  
258. Newton's Third Law ..... 258  
259. Introduction to Momentum ..... 259

**PS2.W Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 252

252. Forces and Motion ..... 252  
253. Breaking Bricks ..... 253  
254. Distance and Displacement ..... 254  
255. Speed and Velocity ..... 255  
256. Acceleration ..... 256  
257. Introduction to Forces ..... 257  
258. Newton's Second Law ..... 258  
259. Newton's Third Law ..... 259  
260. Introduction to Momentum ..... 260

**PS2.X Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 253

253. Forces and Motion ..... 253  
254. Breaking Bricks ..... 254  
255. Distance and Displacement ..... 255  
256. Speed and Velocity ..... 256  
257. Acceleration ..... 257  
258. Introduction to Forces ..... 258  
259. Newton's Second Law ..... 259  
260. Newton's Third Law ..... 260  
261. Introduction to Momentum ..... 261

**PS2.Y Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 254

254. Forces and Motion ..... 254  
255. Breaking Bricks ..... 255  
256. Distance and Displacement ..... 256  
257. Speed and Velocity ..... 257  
258. Acceleration ..... 258  
259. Introduction to Forces ..... 259  
260. Newton's Second Law ..... 260  
261. Newton's Third Law ..... 261  
262. Introduction to Momentum ..... 262

**PS2.Z Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 255

255. Forces and Motion ..... 255  
256. Breaking Bricks ..... 256  
257. Distance and Displacement ..... 257  
258. Speed and Velocity ..... 258  
259. Acceleration ..... 259  
260. Introduction to Forces ..... 260  
261. Newton's Second Law ..... 261  
262. Newton's Third Law ..... 262  
263. Introduction to Momentum ..... 263

**PS2.AA Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 256

256. Forces and Motion ..... 256  
257. Breaking Bricks ..... 257  
258. Distance and Displacement ..... 258  
259. Speed and Velocity ..... 259  
260. Acceleration ..... 260  
261. Introduction to Forces ..... 261  
262. Newton's Second Law ..... 262  
263. Newton's Third Law ..... 263  
264. Introduction to Momentum ..... 264

**PS2.AB Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 257

257. Forces and Motion ..... 257  
258. Breaking Bricks ..... 258  
259. Distance and Displacement ..... 259  
260. Speed and Velocity ..... 260  
261. Acceleration ..... 261  
262. Introduction to Forces ..... 262  
263. Newton's Second Law ..... 263  
264. Newton's Third Law ..... 264  
265. Introduction to Momentum ..... 265

**PS2.AC Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 258

258. Forces and Motion ..... 258  
259. Breaking Bricks ..... 259  
260. Distance and Displacement ..... 260  
261. Speed and Velocity ..... 261  
262. Acceleration ..... 262  
263. Introduction to Forces ..... 263  
264. Newton's Second Law ..... 264  
265. Newton's Third Law ..... 265  
266. Introduction to Momentum ..... 266

**PS2.AD Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 259

259. Forces and Motion ..... 259  
260. Breaking Bricks ..... 260  
261. Distance and Displacement ..... 261  
262. Speed and Velocity ..... 262  
263. Acceleration ..... 263  
264. Introduction to Forces ..... 264  
265. Newton's Second Law ..... 265  
266. Newton's Third Law ..... 266  
267. Introduction to Momentum ..... 267

**PS2.AE Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 260

260. Forces and Motion ..... 260  
261. Breaking Bricks ..... 261  
262. Distance and Displacement ..... 262  
263. Speed and Velocity ..... 263  
264. Acceleration ..... 264  
265. Introduction to Forces ..... 265  
266. Newton's Second Law ..... 266  
267. Newton's Third Law ..... 267  
268. Introduction to Momentum ..... 268

**PS2.AF Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 261

261. Forces and Motion ..... 261  
262. Breaking Bricks ..... 262  
263. Distance and Displacement ..... 263  
264. Speed and Velocity ..... 264  
265. Acceleration ..... 265  
266. Introduction to Forces ..... 266  
267. Newton's Second Law ..... 267  
268. Newton's Third Law ..... 268  
269. Introduction to Momentum ..... 269

**PS2.AG Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 262

262. Forces and Motion ..... 262  
263. Breaking Bricks ..... 263  
264. Distance and Displacement ..... 264  
265. Speed and Velocity ..... 265  
266. Acceleration ..... 266  
267. Introduction to Forces ..... 267  
268. Newton's Second Law ..... 268  
269. Newton's Third Law ..... 269  
270. Introduction to Momentum ..... 270

**PS2.AH Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 263

263. Forces and Motion ..... 263  
264. Breaking Bricks ..... 264  
265. Distance and Displacement ..... 265  
266. Speed and Velocity ..... 266  
267. Acceleration ..... 267  
268. Introduction to Forces ..... 268  
269. Newton's Second Law ..... 269  
270. Newton's Third Law ..... 270  
271. Introduction to Momentum ..... 271

**PS2.AI Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 264

264. Forces and Motion ..... 264  
265. Breaking Bricks ..... 265  
266. Distance and Displacement ..... 266  
267. Speed and Velocity ..... 267  
268. Acceleration ..... 268  
269. Introduction to Forces ..... 269  
270. Newton's Second Law ..... 270  
271. Newton's Third Law ..... 271  
272. Introduction to Momentum ..... 272

**PS2.AJ Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 265

265. Forces and Motion ..... 265  
266. Breaking Bricks ..... 266  
267. Distance and Displacement ..... 267  
268. Speed and Velocity ..... 268  
269. Acceleration ..... 269  
270. Introduction to Forces ..... 270  
271. Newton's Second Law ..... 271  
272. Newton's Third Law ..... 272  
273. Introduction to Momentum ..... 273

**PS2.AK Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 266

266. Forces and Motion ..... 266  
267. Breaking Bricks ..... 267  
268. Distance and Displacement ..... 268  
269. Speed and Velocity ..... 269  
270. Acceleration ..... 270  
271. Introduction to Forces ..... 271  
272. Newton's Second Law ..... 272  
273. Newton's Third Law ..... 273  
274. Introduction to Momentum ..... 274

**PS2.AL Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 267

267. Forces and Motion ..... 267  
268. Breaking Bricks ..... 268  
269. Distance and Displacement ..... 269  
270. Speed and Velocity ..... 270  
271. Acceleration ..... 271  
272. Introduction to Forces ..... 272  
273. Newton's Second Law ..... 273  
274. Newton's Third Law ..... 274  
275. Introduction to Momentum ..... 275

**PS2.AM Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 268

268. Forces and Motion ..... 268  
269. Breaking Bricks ..... 269  
270. Distance and Displacement ..... 270  
271. Speed and Velocity ..... 271  
272. Acceleration ..... 272  
273. Introduction to Forces ..... 273  
274. Newton's Second Law ..... 274  
275. Newton's Third Law ..... 275  
276. Introduction to Momentum ..... 276

**PS2.AN Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 269

269. Forces and Motion ..... 269  
270. Breaking Bricks ..... 270  
271. Distance and Displacement ..... 271  
272. Speed and Velocity ..... 272  
273. Acceleration ..... 273  
274. Introduction to Forces ..... 274  
275. Newton's Second Law ..... 275  
276. Newton's Third Law ..... 276  
277. Introduction to Momentum ..... 277

**PS2.AO Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 270

270. Forces and Motion ..... 270  
271. Breaking Bricks ..... 271  
272. Distance and Displacement ..... 272  
273. Speed and Velocity ..... 273  
274. Acceleration ..... 274  
275. Introduction to Forces ..... 275  
276. Newton's Second Law ..... 276  
277. Newton's Third Law ..... 277  
278. Introduction to Momentum ..... 278

**PS2.AP Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 271

271. Forces and Motion ..... 271  
272. Breaking Bricks ..... 272  
273. Distance and Displacement ..... 273  
274. Speed and Velocity ..... 274  
275. Acceleration ..... 275  
276. Introduction to Forces ..... 276  
277. Newton's Second Law ..... 277  
278. Newton's Third Law ..... 278  
279. Introduction to Momentum ..... 279

**PS2.AQ Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 272

272. Forces and Motion ..... 272  
273. Breaking Bricks ..... 273  
274. Distance and Displacement ..... 274  
275. Speed and Velocity ..... 275  
276. Acceleration ..... 276  
277. Introduction to Forces ..... 277  
278. Newton's Second Law ..... 278  
279. Newton's Third Law ..... 279  
280. Introduction to Momentum ..... 280

**PS2.AR Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 273

273. Forces and Motion ..... 273  
274. Breaking Bricks ..... 274  
275. Distance and Displacement ..... 275  
276. Speed and Velocity ..... 276  
277. Acceleration ..... 277  
278. Introduction to Forces ..... 278  
279. Newton's Second Law ..... 279  
280. Newton's Third Law ..... 280  
281. Introduction to Momentum ..... 281

**PS2.AT Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 274

274. Forces and Motion ..... 274  
275. Breaking Bricks ..... 275  
276. Distance and Displacement ..... 276  
277. Speed and Velocity ..... 277  
278. Acceleration ..... 278  
279. Introduction to Forces ..... 279  
280. Newton's Second Law ..... 280  
281. Newton's Third Law ..... 281  
282. Introduction to Momentum ..... 282

**PS2.AU Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 275

275. Forces and Motion ..... 275  
276. Breaking Bricks ..... 276  
277. Distance and Displacement ..... 277  
278. Speed and Velocity ..... 278  
279. Acceleration ..... 279  
280. Introduction to Forces ..... 280  
281. Newton's Second Law ..... 281  
282. Newton's Third Law ..... 282  
283. Introduction to Momentum ..... 283

**PS2.AV Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 276

276. Forces and Motion ..... 276  
277. Breaking Bricks ..... 277  
278. Distance and Displacement ..... 278  
279. Speed and Velocity ..... 279  
280. Acceleration ..... 280  
281. Introduction to Forces ..... 281  
282. Newton's Second Law ..... 282  
283. Newton's Third Law ..... 283  
284. Introduction to Momentum ..... 284

**PS2.AW Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 277

277. Forces and Motion ..... 277  
278. Breaking Bricks ..... 278  
279. Distance and Displacement ..... 279  
280. Speed and Velocity ..... 280  
281. Acceleration ..... 281  
282. Introduction to Forces ..... 282  
283. Newton's Second Law ..... 283  
284. Newton's Third Law ..... 284  
285. Introduction to Momentum ..... 285

**PS2.AX Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 278

278. Forces and Motion ..... 278  
279. Breaking Bricks ..... 279  
280. Distance and Displacement ..... 280  
281. Speed and Velocity ..... 281  
282. Acceleration ..... 282  
283. Introduction to Forces ..... 283  
284. Newton's Second Law ..... 284  
285. Newton's Third Law ..... 285  
286. Introduction to Momentum ..... 286

**PS2.AY Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 279

279. Forces and Motion ..... 279  
280. Breaking Bricks ..... 280  
281. Distance and Displacement ..... 281  
282. Speed and Velocity ..... 282  
283. Acceleration ..... 283  
284. Introduction to Forces ..... 284  
285. Newton's Second Law ..... 285  
286. Newton's Third Law ..... 286  
287. Introduction to Momentum ..... 287

**PS2.AZ Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 280

280. Forces and Motion ..... 280  
281. Breaking Bricks ..... 281  
282. Distance and Displacement ..... 282  
283. Speed and Velocity ..... 283  
284. Acceleration ..... 284  
285. Introduction to Forces ..... 285  
286. Newton's Second Law ..... 286  
287. Newton's Third Law ..... 287  
288. Introduction to Momentum ..... 288

**PS2.BA Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 281

281. Forces and Motion ..... 281  
282. Breaking Bricks ..... 282  
283. Distance and Displacement ..... 283  
284. Speed and Velocity ..... 284  
285. Acceleration ..... 285  
286. Introduction to Forces ..... 286  
287. Newton's Second Law ..... 287  
288. Newton's Third Law ..... 288  
289. Introduction to Momentum ..... 289

**PS2.BB Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 282

282. Forces and Motion ..... 282  
283. Breaking Bricks ..... 283  
284. Distance and Displacement ..... 284  
285. Speed and Velocity ..... 285  
286. Acceleration ..... 286  
287. Introduction to Forces ..... 287  
288. Newton's Second Law ..... 288  
289. Newton's Third Law ..... 289  
290. Introduction to Momentum ..... 290

**PS2.BC Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 283

283. Forces and Motion ..... 283  
284. Breaking Bricks ..... 284  
285. Distance and Displacement ..... 285  
286. Speed and Velocity ..... 286  
287. Acceleration ..... 287  
288. Introduction to Forces ..... 288  
289. Newton's Second Law ..... 289  
290. Newton's Third Law ..... 290  
291. Introduction to Momentum ..... 291

**PS2.BD Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 284

284. Forces and Motion ..... 284  
285. Breaking Bricks ..... 285  
286. Distance and Displacement ..... 286  
287. Speed and Velocity ..... 287  
288. Acceleration ..... 288  
289. Introduction to Forces ..... 289  
290. Newton's Second Law ..... 290  
291. Newton's Third Law ..... 291  
292. Introduction to Momentum ..... 292

**PS2.BE Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 285

285. Forces and Motion ..... 285  
286. Breaking Bricks ..... 286  
287. Distance and Displacement ..... 287  
288. Speed and Velocity ..... 288  
289. Acceleration ..... 289  
290. Introduction to Forces ..... 290  
291. Newton's Second Law ..... 291  
292. Newton's Third Law ..... 292  
293. Introduction to Momentum ..... 293

**PS2.BF Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 286

286. Forces and Motion ..... 286  
287. Breaking Bricks ..... 287  
288. Distance and Displacement ..... 288  
289. Speed and Velocity ..... 289  
290. Acceleration ..... 290  
291. Introduction to Forces ..... 291  
292. Newton's Second Law ..... 292  
293. Newton's Third Law ..... 293  
294. Introduction to Momentum ..... 294

**PS2.BG Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 287

287. Forces and Motion ..... 287  
288. Breaking Bricks ..... 288  
289. Distance and Displacement ..... 289  
290. Speed and Velocity ..... 290  
291. Acceleration ..... 291  
292. Introduction to Forces ..... 292  
293. Newton's Second Law ..... 293  
294. Newton's Third Law ..... 294  
295. Introduction to Momentum ..... 295

**PS2.BH Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 288

288. Forces and Motion ..... 288  
289. Breaking Bricks ..... 289  
290. Distance and Displacement ..... 290  
291. Speed and Velocity ..... 291  
292. Acceleration ..... 292  
293. Introduction to Forces ..... 293  
294. Newton's Second Law ..... 294  
295. Newton's Third Law ..... 295  
296. Introduction to Momentum ..... 296

**PS2.BI Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 289

289. Forces and Motion ..... 289  
290. Breaking Bricks ..... 290  
291. Distance and Displacement ..... 291  
292. Speed and Velocity ..... 292  
293. Acceleration ..... 293  
294. Introduction to Forces ..... 294  
295. Newton's Second Law ..... 295  
296. Newton's Third Law ..... 296  
297. Introduction to Momentum ..... 297

**PS2.BJ Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 290

290. Forces and Motion ..... 290  
291. Breaking Bricks ..... 291  
292. Distance and Displacement ..... 292  
293. Speed and Velocity ..... 293  
294. Acceleration ..... 294  
295. Introduction to Forces ..... 295  
296. Newton's Second Law ..... 296  
297. Newton's Third Law ..... 297  
298. Introduction to Momentum ..... 298

**PS2.BK Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 291

291. Forces and Motion ..... 291  
292. Breaking Bricks ..... 292  
293. Distance and Displacement ..... 293  
294. Speed and Velocity ..... 294  
295. Acceleration ..... 295  
296. Introduction to Forces ..... 296  
297. Newton's Second Law ..... 297  
298. Newton's Third Law ..... 298  
299. Introduction to Momentum ..... 299

**PS2.BL Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 292

292. Forces and Motion ..... 292  
293. Breaking Bricks ..... 293  
294. Distance and Displacement ..... 294  
295. Speed and Velocity ..... 295  
296. Acceleration ..... 296  
297. Introduction to Forces ..... 297  
298. Newton's Second Law ..... 298  
299. Newton's Third Law ..... 299  
300. Introduction to Momentum ..... 300

**PS2.BM Motion and Stability: Forces and Interactions**

**Key Skills and Knowledge** ..... 293

293. Forces and Motion ..... 293  
29



# Identifying Learning Intentions and Goals

In developing *Physical Sciences for NGSS*, we have embraced the three dimensions of the NGSS framework, emphasizing the application of ideas and skills to new scenarios. The activities in *Physical Sciences for NGSS* have been specifically designed to address the **disciplinary core ideas (DCIs)**, **science and engineering practices**, and **crosscutting concepts** in a way that helps students to meet specific performance expectations.

In the Teacher's Edition, all three dimensions are embedded in the text and color coded for easy identification (below). The performance expectations are also identified. It is important to note that *this coding is a tool for the teacher and is not present in the Student Edition*.

This identifies the DCI(s) to which this chapter applies.

PS2.A

## 5: Forces and Motion

129

Activity number

### Anchoring Phenomenon

**Breaking bricks** How is it possible to break many bricks, blocks of ice, or boards of wood stacked on top of one another? What physical principles explain these feats of strength?

64 76

### How can Newton's laws explain how and why things move?

- ☐ 1 The study of motion is an important part of physics. How do you describe the motion of objects around you? Identify the three main aspects of motion and use **SEP-2** to describe these different aspects of movement. Understand the relationship between speed and velocity. Use and interpret mathematical representations to describe the relationship between distance and time to determine velocity **SEP-4**. Investigate this relationship for yourselves and plot your results **SEP-3**.
- ☐ 2 What do we mean when we say something is accelerating? Use a mathematical expression (equation) to calculate the acceleration for an object traveling in a particular direction. Given a known acceleration, time, and final velocity, how would you calculate distance traveled? **SEP-5** Draw and interpret graphs of displacement versus time and velocity versus time **SEP-4** **PS2.A** **CCC-2** **HS-PS2-1**.
- ☐ 3 What do you understand by the term force? What happens when unbalanced forces are applied to an object? Interpret data on the effect of friction on motion **SEP-4**. Explain why friction is an important consideration in the design and operation of moving objects. Weight is a specific kind of force due to gravity but forces can act on objects from any direction. Draw a simple model **SEP-2** to illustrate the effect of a constant force being applied to objects of increasing mass **PS2.A** **CCC-2** **HS-PS2-1**.
- ☐ 4 You now understand the difference between mass and weight and can analyze the motion of objects subjected to a constant force (gravity). Interpret data **SEP-4** **PS2.A** of the effect **CCC-2** of increasing mass on acceleration and explain the relationship between the force on an object, its mass, and its acceleration. Examples of a falling object, and object rolling down a ramp, or a moving object being pushed by a constant force **HS-PS2-1**.
- ☐ 5 Understand that forces come in action-reaction pairs which are always equal in magnitude and opposite in direction. Why don't these action-reaction pairs cancel each other out? Draw and analyze free body diagrams **SEP-2** **SEP-4** to calculate **SEP-5** the net force on objects of known masses and thus determine their acceleration.
- ☐ 6 Extend your study of forces and motion to include an exploration of collisions and momentum. Investigate **SEP-3** the momentum of objects of different masses rolling down a ramp. Use your results **SEP-5** to explain how momentum is conserved **CCC-2** the distance the marbles roll **PS2.A**.
- ☐ 7 Analyze the results **SEP-5** of investigations of the effect of collisions on the momentum of colliding objects in an isolated system **PS2.A** **CCC-4**. Explain the results in terms of conservation of momentum **HS-PS2-2**.
- ☐ 8 Extend your analysis to explain the effects of collisions between real objects, such as motor vehicles. Investigate **SEP-3** what happens when the force of a colliding object is spread out over a longer (or shorter) period of time. Use math **SEP-5** to demonstrate this and explain its significance to how much damage occurs during a collision **PS2.A** **HS-PS2-2**.

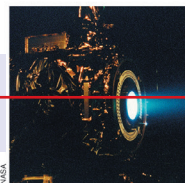
### Guiding questions

These are guiding questions to help students ask important question in the chapter.

The activity in the book related to these questions or statements. Some activities contribute to meeting the NGSS performance expectations.

A red number indicates the summative assessment for this chapter, where an NGSS performance expectation is addressed.

The relevant science and engineering practices are indicated in **blue**.



### How can mathematical models of Newton's laws be used to test and improve engineering designs?

- ☐ 9 Use your understanding of changes in momentum and impulse to analyze the design of modern safety equipment, e.g. crash helmets for different sports and crumple zones in cars. Use math **SEP-5** to explain how these safety devices reduce the force delivered during a collision **PS2.A** **CCC-2** **HS-PS2-2**.
- ☐ 10 Demonstrate your understanding of forces and momentum by carrying out an investigation **SEP-3** to design a landing device to protect a raw egg from a fall of at least 4 m. Working in groups, discuss how you will make the lander and the different designs **SEP-6** you could use to cushion the egg at impact and/or slow its descent **CCC-2**. Justify your design choice in terms of Newton's laws of motion **PS2.A** **HS-PS2-2** **HS-PS2-3** **HS-ETS1-2** **HS-ETS1-3**.

72 73 77

74 76 77

75

The relevant crosscutting concepts are indicated in **green**.

The relevant disciplinary core are indicated in **orange**.

The relevant performance expectation is indicated in **red**.



# Scaffolded Learning with the 5 Es

In developing *Physical Sciences for NGSS* we have utilized the 5Es instructional model as a basis for developing materials to address all three dimensions of the NGSS framework: **disciplinary core ideas (DCIs)**, **science and engineering practices**, and **crosscutting concepts**. By successfully completing the activities, students can demonstrate competence in all three dimensions. This is central to meeting the performance expectations for *Physical Sciences for NGSS* with confidence.

## The Five Es

- Engage:** make connections between past and present learning experiences.
- Explore:** become actively involved in the activity.
- Explain:** communicate the learning experience.
- Elaborate:** expand on the concepts learned.
- Evaluate:** assess understanding of the concepts.



**BIOZONE encourages the development of the NGSS learner profile using the 5Es model**

BIOZONE's series for NGSS is **phenomenon-based**. Students engage with phenomena through their own investigations and observations, through modeling and data analysis, and through collaborative work and discussion.

Using phenomena to drive inquiry promotes discussion and the sharing of ideas. The iterative approach presents opportunities to look at phenomena from several different perspectives. This allows students of all abilities to expand their thinking and understanding, increasing understanding each time the phenomenon is revisited.

Each chapter begins with an **anchoring phenomenon** (right). In each instance, we have chosen a phenomenon that the student is probably familiar with, but which they cannot explain (or cannot explain fully). Teachers can use this activity to find out what the students already know (or think they know) before delving into the content more fully.


The subsequent activities in a chapter take the students, step by step, through phenomena that explore the ideas inherent in the anchoring phenomenon. By the time students revisit the anchoring phenomenon, they should be able to fully explain it.

130

## 64 Breaking Bricks

**Key Question:** How is it possible to break many bricks, blocks of ice, or boards of wood stacked on top of one other? What physical principles explain these feats of strength?

- ▶ Have you ever seen a martial arts demonstration where the demonstrators break boards with their hands? These demonstrations usually start with the novices breaking one board and move on to veterans showing off their strength and skill by breaking multiple boards in one strike. Some demonstrations even include brick breaking.
- ▶ The karate chop is a well-known technique used to break boards with the hand. However, when dealing with large stacks of hard objects like wood or bricks, the karate chop is not the best technique. So the karate chop is not the best technique.




172

## 76 Review Your Understanding

**Key Question:** How is it possible to break many bricks, blocks of ice, or boards of wood stacked on top of each other? What physical principles explain these feats of strength?

- ▶ Recall the beginning of the chapter when you were asked questions involving breaking bricks. With what you have learned, think about how the concepts of forces, momentum, and impulse are involved in breaking bricks.
- ▶ One very important principle involved in brick-breaking is momentum. The more momentum an object has, the more force it can generate when it comes into contact with another object. This is why the velocity of the strike to the brick is important. The faster the strike, the greater the momentum. When breaking bricks, the downward punch increases the momentum available by involving some of the mass of the individual to the strike. Increased velocity and increased mass both contribute to increased momentum.



Each chapter begins with an **anchoring phenomenon** (e.g. *Breaking Bricks*). By the time the students have worked through the activities in the chapter they should be able to fully explain it when it is revisited at the end of the chapter

©2020 BIOZONE International  
ISBN: 978-1-927309-79-7  
Photocopying Prohibited

©2020 BIOZONE International

The content of the *Physical Sciences for NGSS* is organized into 11 chapters based on the DCIs of the High School Physical Sciences framework. Chapter 1 addresses basic skills for students in physical sciences. Chapters 2 - 11 each begin with an introduction outlining learning goals, which is immediately followed by the anchoring phenomenon. Activities make up the bulk of each chapter, with each one focusing on the student investigating and developing understanding of a phenomenon, applying that understanding to new scenarios, and developing (or practicing) a skill or essential science practice, such as graphing, data analysis, modeling, or evidence-based explanation.

Annotated diagrams and photographs are a major part of most activities and the student's understanding of the information is evaluated through questions and/or tasks involving data handling and interpretation. Tabs at the bottom of the page identify crosscutting concepts, science and engineering practices, and disciplinary core ideas as appropriate. Tabs in the margin also indicate if the activity is supported via **BIOZONE's Resource Hub**, which provides online teacher and student support for specific aspects of the activity.

Concepts are presented as a logical sequence, which may be divided among several consecutive activities. Understanding of phenomena is developed progressively through exploration and explanation.

### ENGAGE with phenomena

Activities normally begin with a brief task, observation, or example to engage student thinking, allowing them to review their current understanding of a phenomenon, or providing an interesting (if not yet fully explained) piece of information that relates to the concept about to be studied. This is a chance for teachers to assess prior knowledge or engage students by posing challenging questions about seemingly simple phenomena.

71

Introduction to Momentum

161

**Key Question:** How do we describe the quantity of motion in an object and how do we use it to explain why some objects are more difficult to stop than others?

**Momentum**

Ever played pool or gone bowling? These games operate on the same principle: using the movement of one ball to move or knock over other objects.

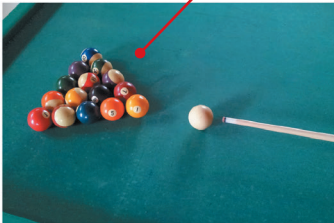
- In the game of pool (right) the white ball is used to maneuver the others around the table. Sometimes when it hits a target ball, the target will move away while the white ball stops moving. Other times, the white ball continues to move but more slowly after hitting the target ball, which also moves but more slowly.
- An important part of pool or bowling, is the concept of **momentum**. In pool, momentum for the white ball is transferred to the target ball to make it move. How this is done will determine the way the target ball and the white ball move after colliding.
- Momentum is a physics term referring to the quantity of motion an object has.
- Momentum can be defined as "mass in motion". All objects have mass, so if an object is moving, it has momentum.
- Momentum is dependent on two variables: mass and velocity.
- Momentum ( $p$ ) is equal to the mass of an object ( $m$ ) multiplied by the velocity of the object ( $v$ ):

$p = mv$

$$\begin{array}{c} p \\ m \quad v \end{array}$$

- Momentum has units of kilogram meters per second (kg m/s).
- Because momentum has a velocity component, it is a vector with the same direction as the velocity.


- Determine the momentum of:
  - a 60 kg running back running east at 10 m/s: \_\_\_\_\_
  - a 36,000 kg semi traveling north on interstate 95 at 30 m/s: \_\_\_\_\_
  - a 5.0 gram snail moving south at 2.0 meters per hour: \_\_\_\_\_
- A car has 30,000 units of momentum. What would the car's new momentum be if:
  - its velocity was halved: \_\_\_\_\_
  - its velocity was doubled: \_\_\_\_\_
  - its mass was doubled: \_\_\_\_\_
  - its velocity was doubled and its mass halved: \_\_\_\_\_
- Which has the greater momentum: a 25,000 kg truck moving at 5 m/s, or a 1200 kg car moving at 21 m/s? \_\_\_\_\_
- A 990 kg car reduces its velocity from 22 m/s to 13 m/s. Calculate the change in the car's momentum: \_\_\_\_\_




©2020 BIOZONE International  
ISBN: 978-1-927309-79-7  
Photocopying Prohibited

SSM

PS2.A





Important formulae that students should be able to understand and use are given in a dark blue box. Fact family triangles make use of these formulae simpler.

Students are given enough information to complete the activity's tasks. To progress through the activity they may need to apply knowledge and information developed earlier in the activity. Answers to questions are not always directly available on the page. Students may need to analyze data or information and draw conclusions to answer the questions and progress to the next part of the activity. Students are sometimes asked to do further research or carry out their own research or investigation.

This part of the activity also has supporting resources on **BIOZONE's Resource Hub** assigned to it.

Relevant SEPs, DCIs, and CCCs are identified through the tab system.

Students can **EXPLORE** the phenomenon via practical activities, creating their own models, analyzing or using second hand data, or interpreting diagrams. In this example, students use marbles of different mass and size to explore the concept of momentum. They also explore momentum using second-hand data of carts on an air track.

## 72 Investigating Collisions

**Key Question:** How do collisions influence the momentum of objects and how do we account for their relative influences mathematically?

**Collisions**  
Moving objects have momentum. But what happens when two objects moving in opposite directions crash into each other? Where does the momentum go?

Some students wanted to investigate this problem. They set up two carts on an air track to minimize friction. The mass of each cart was measured. Cart 1 had a mass of 0.75 kg, cart 2 had a mass of 0.75 kg.

The students noted that sometimes objects stick together when they collide (**completely inelastic collision**), and other times they rebound (**elastic collision**). To simplify their investigation, they filled magnets to the carts so that they would stick together when they collided. A radar speed gun was available to measure velocity before and after the collisions.

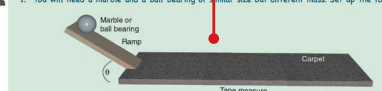
For the first investigation, cart 2 was made stationary in the center of the air track. Cart 1 was given a push in the direction of cart 2. The results of four trials that they carried out are shown in table 1.

**Marble momentum**  
Marbles (or ball bearings) are great for exploring motion. Because they are made of glass or steel, they are smooth and hard. This means they roll with very little friction on smooth, hard surfaces and convert very little kinetic energy to heat and sound during collisions. When collisions are like this, they are said to be **elastic collisions**.

**INVESTIGATION 5.2: Investigating momentum**  
See appendix for equipment list.

You can work in pairs or small groups for this investigation.

- You will need a marble and a ball bearing of similar size but different mass. Set up the following:



- Measure the mass of marble.
- Measure the length of the ramp and place the marble at the top.
- Roll the marble down the ramp four times and record the distance that it runs along the carpet each time on the table below.
- Calculate the average distance and record it in the appropriate table below.
- Measure the mass of the ball bearing.
- Replace the marble with the ball bearing and repeat steps 6 and 7.
- Calculate the velocity of the marble and ball bearing as they leave the ramp and add to the table.

where  $g = 9.8 \text{ m/s}^2$ ,  $\theta$  is the angle of incline of the ramp and  $\Delta x$  is the length of the ramp in meters.

Roll the marble down the ramp four times and record the distance that it runs along the carpet each time on the table below.

Calculate the average distance and record it in the appropriate table below.

Measure the mass of the ball bearing.

Replace the marble with the ball bearing and repeat steps 6 and 7.

Calculate the velocity of the marble and ball bearing as they leave the ramp and add to the table.

**Table 1**

Velocity cart 1 (m/s)	Momentum cart 1 (kg m/s)	Velocity cart 2 (m/s)	Momentum cart 2 (kg m/s)	Velocity cart 1&2 after collision (m/s)	Total momentum of carts (kg m/s)
0.52		0.00		0.26	
0.64		0.00		0.33	
0.32		0.00		0.16	
0.13		0.00		0.07	

**Table 2**

Velocity cart 1 (m/s)	Momentum cart 1 (kg m/s)	Velocity cart 2 (m/s)	Momentum cart 2 (kg m/s)	Velocity cart 1&2 after collision (m/s)	Total momentum of carts (kg m/s)
0.41		-0.11		0.16	
0.12		-0.35		-0.11	
0.37		-0.35		0.01	
0.29		-0.30		0.00	

1. (a) Complete tables 1 and 2 (above) by calculating the momentum of each cart.  
(b) Explain the students' results:

©2020 BIOZONE International ISBN 978-1-927389-79-7 Photocopying Prohibited

Students **EXPLAIN** phenomena by building on what they discovered through exploration. They are encouraged to use scientific principles and logical reasoning to construct explanations and devise solutions to the problems presented to them. Here students analyze data of initial and final velocities to find and explain the underlying relationship between initial and final momentum.

## 72 Investigating Collisions

**Key Question:** How do collisions influence the momentum of objects and how do we account for their relative influences mathematically?

**Collisions**  
Moving objects have momentum. But what happens when two objects moving in opposite directions crash into each other? Where does the momentum go?

Some students wanted to investigate this problem. They set up two carts on an air track to minimize friction. The mass of each cart was measured. Cart 1 had a mass of 0.75 kg, cart 2 had a mass of 0.75 kg.

The students noted that sometimes objects stick together when they collide (**completely inelastic collision**), and other times they rebound (**elastic collision**). To simplify their investigation, they filled magnets to the carts so that they would stick together when they collided. A radar speed gun was available to measure velocity before and after the collisions.

For the first investigation, cart 2 was made stationary in the center of the air track. Cart 1 was given a push in the direction of cart 2. The results of four trials that they carried out are shown in table 1.

**Table 1**

Velocity cart 1 (m/s)	Momentum cart 1 (kg m/s)	Velocity cart 2 (m/s)	Momentum cart 2 (kg m/s)	Velocity cart 1&2 after collision (m/s)	Total momentum of carts (kg m/s)
0.52		0.00		0.26	
0.64		0.00		0.33	
0.32		0.00		0.16	
0.13		0.00		0.07	

**Table 2**

Velocity cart 1 (m/s)	Momentum cart 1 (kg m/s)	Velocity cart 2 (m/s)	Momentum cart 2 (kg m/s)	Velocity cart 1&2 after collision (m/s)	Total momentum of carts (kg m/s)
0.41		-0.11		0.16	
0.12		-0.35		-0.11	
0.37		-0.35		0.01	
0.29		-0.30		0.00	

1. (a) Complete tables 1 and 2 (above) by calculating the momentum of each cart.  
(b) Explain the students' results:

©2020 BIOZONE International ISBN 978-1-927389-79-7 Photocopying Prohibited

After sound explanations of phenomena are developed, students have opportunity to **ELABORATE**, applying their understanding to new phenomena or using their experience to develop or refine engineering solutions to relevant problems. Here students apply the concepts of momentum and impulse to design a landing device that will protect an egg from a fall.

Students **EVALUATE** their investigations. This can provide opportunities for **formative assessment** (if you wish). In this example, students evaluate their lander design and decide if there are any improvements that could be made. There is opportunity here for peer assessment.

## 75 Crumple Zones and Crash Helmets

**Key Question:** How are the principles of momentum and impulse applied to limit damage to sensitive objects and save lives?

**Landing on Mars**  
NASA is by far the most active space agency in the world. They have sent many probes to Mars, and they have successfully landed on Mars. The Mars Pathfinder lander used a slightly different technique to land on Mars. It used a parachute to slow its descent, and then it used a small retrorocket to slow its descent further. The retrorocket was fired at a height of about 100 meters, and the lander was then out of the sky and on the ground. When it hit the ground, it was not too hard. The retrorocket was fired at a height of about 100 meters, and the lander was then out of the sky and on the ground. When it hit the ground, it was not too hard.

**INVESTIGATION 5.4: Building a lander**  
See appendix for equipment list.

- You will now have the opportunity to put your knowledge of forces and momentum to the test. The objective of this investigation is to build a device that will protect a raw egg from a fall of at least four meters.
- The conditions: You will build a landing device that will protect a raw egg from a fall of at least four meters. You are free to use the equipment (shown) in any way but there may be no platform for the lander to fall onto (landers don't have convenient foam landing pads to fall onto when they reach their destination).
- The equipment: 1 egg, 60 cm of tape, 5 rubber bands, 1 small garbage or plastic bag, 10 paper clips, 1 m string, 20 plastic or paper straws, 1 plastic egg or similar sized object for testing. Your teacher may modify this equipment as they wish.
- Building time will be determined by your teacher.
- Before you begin, discuss with your group how you will construct the lander and in what ways you could cushion the egg at impact or slow its descent to reduce the shock of landing. You could research lander design online to gather ideas before you begin construction.

**Lander design**  
Now that you have built and tested your egg lander you must evaluate its structure and performance.

- Describe the structure of your lander:
- On a scale of 1-5, how did your egg survive the fall? (1 = completely scrambled, 5 = safe and sound):
- If your egg cracked, what could have been done to keep it from cracking if you repeated the test?
- Recall the landing devices designed used by other groups in your class. Which of these were the most effective? Can you explain why?
- Given enough material, it would be easy possible to design a lander that would protect the egg from a much higher fall than 5 m. The same applies to planetary landers. However, there are numerous constraints on the development of these devices, one of which is cost. Discuss with your group what other constraints there might be on the design on a lander for Mars:

©2020 BIOZONE International ISBN 978-1-927389-79-7 Photocopying Prohibited

## INVESTIGATION 5.4: Building a lander

See appendix for equipment list.

- You will now have the opportunity to put your knowledge of forces and momentum to the test. The objective of this investigation is to build a device that will protect a raw egg from a fall of at least four meters.
- The conditions: You will build a landing device that will protect a raw egg from a fall of at least four meters. You are free to use the equipment (shown) in any way but there may be no platform for the lander to fall onto (landers don't have convenient foam landing pads to fall onto when they reach their destination).
- The equipment: 1 egg, 60 cm of tape, 5 rubber bands, 1 small garbage or plastic bag, 10 paper clips, 1 m string, 20 plastic or paper straws, 1 plastic egg or similar sized object for testing. Your teacher may modify this equipment as they wish.
- Building time will be determined by your teacher.
- Before you begin, discuss with your group how you will construct the lander and in what ways you could cushion the egg at impact or slow its descent to reduce the shock of landing. You could research lander design online to gather ideas before you begin construction.

**Lander design**  
Now that you have built and tested your egg lander you must evaluate its structure and performance.

- Describe the structure of your lander:
- On a scale of 1-5, how did your egg survive the fall? (1 = completely scrambled, 5 = safe and sound):
- If your egg cracked, what could have been done to keep it from cracking if you repeated the test?
- Recall the landing devices designed used by other groups in your class. Which of these were the most effective? Can you explain why?
- Given enough material, it would be easy possible to design a lander that would protect the egg from a much higher fall than 5 m. The same applies to planetary landers. However, there are numerous constraints on the development of these devices, one of which is cost. Discuss with your group what other constraints there might be on the design on a lander for Mars:

©2020 BIOZONE International ISBN 978-1-927389-79-7 Photocopying Prohibited



# Practical Investigations

Throughout *Physical Sciences for NGSS*, students are given opportunities to explore phenomena through experimentation. These **investigative phenomena** are opportunities for students to develop competency in laboratory procedures, to practice and refine skills in observation and analysis, and to manipulate data. Some investigations act as stimulus material while others require students to take what they have already learned and apply their knowledge to a more complex scenario.

The investigations provide an excellent opportunity for collaborative work and will stimulate discussion and the sharing of ideas. You may wish to pair students of different abilities together. Confident students can guide and encourage less able students and, in this relaxed environment, striving students will be encouraged to share their own observations and thoughts. Collaboration through paired practical work provides an excellent opportunity for English language learners to interact in meaningful ways to extend their English language and scientific vocabulary.

Each investigation is clearly numbered (sequentially through the chapter). A list of the equipment and chemicals required for each investigation is provided in the appendix. Only standard equipment is used (no special kits are required).

The investigations provide students with health and safety information at the start of the investigation.

- Ensure your students read through the procedure fully *before beginning* the investigation.
- Highlight any hazardous or important steps, and make sure the students follow your directions.
- Chapter 1 (Science Practices) contains basic safety guidelines for working in a laboratory. Students should complete these activities as appropriate before they begin their own investigations.

**INVESTIGATION 5.1: Distance, displacement, and velocity** See appendix for equipment list.

1. Set out a straight line (one-dimensional) course with 9 markers at 10 m intervals as shown below. The starter and the runner are at the middle of the course.

2. On the right side of the course, each marker has 2 timers, one for the outward journey and one for the return journey.

3. On the starter's signal (they should use a large visual signal):  
(a) The runner runs from the middle of the course to one end and then back to the opposite end.  
(b) All the timers start timing at the starter's signal and stop when the runner reaches their marker.

4. Complete the tables below:

d = distance traveled (m)	t = time elapsed (s)
0	0
10	
20	
30	
40	
50	
60	
70	
80	
90	

d = displacement (m)	t = time elapsed (s)
0	0
10	
20	
30	
40	
50	
60	
70	
80	
90	

d <sub>final</sub> - d <sub>initial</sub> (m)	t <sub>final</sub> - t <sub>initial</sub> (s)	v = Δd/Δt (m/s)	t = mid interval time (s)
10 - 0 = 10			
20 - 10 = 10			
30 - 20 = 10			
40 - 30 = 10			
50 - 40 = 10			
60 - 50 = 10			
70 - 60 = 10			
80 - 70 = 10			
90 - 80 = 10			
0 - 10 = -10			
-10 - 0 = -10			
-20 - -10 = -10			
-30 - -20 = -10			
-40 - -30 = -10			

NOTE:  $t_{\text{mid interval}} = (t_{\text{final}} + t_{\text{initial}}) \div 2$

**37 Using Molar Mass**

**Key Question:** How can the mole and molar mass be used to find chemical formula?

**Finding the formula**  
A working knowledge of molar mass and moles can help us determine the molecular formula of new compounds. In the investigation below you will determine the formula for magnesium oxide.

**INVESTIGATION 3.2 Finding the formula:** See appendix for equipment list.

**⚠️ Magnesium is a flammable metal. If ignited it produces a bright and extremely hot flame that can cause severe burns. Do not look directly at the flame. Wear protective eyewear and use tongs to handle the crucible.**

M(O) = 16.0 g/mol, M(Mg) = 24.3 g/mol

1. Weigh a crucible and lid on a balance. Record the mass:
2. Coil a 10 cm length of magnesium ribbon and place it in the crucible. Replace the lid and reweigh. Record the mass of the crucible, lid, and magnesium ribbon here:
3. Place a clay triangle onto a tripod and put the crucible in it. Heat the crucible with a Bunsen burner. Using tongs, open the lid to allow air into the crucible.
4. Watch for the magnesium to ignite (this may take a few minutes). When it does, immediately place the lid back on the crucible.
5. Continue heating the crucible for several minutes, lifting the crucible lid slightly once or twice to allow air into the crucible.
6. After several minutes, check to see if the reaction is complete. You will be able to tell as a white powder (magnesium oxide) will form and no flame or "smoke" will be seen.
7. Leaving the crucible lid on, turn the Bunsen off and allow the crucible to cool. Check to make sure all the magnesium has reacted. If there is still some metal in the crucible, you will need to continue heating.
8. When the crucible is cool, reweigh the crucible, magnesium oxide, and lid. Record the mass here:

1. (a) Calculate the mass of magnesium at the start of the reaction: \_\_\_\_\_  
(b) Calculate the mass of magnesium oxide formed: \_\_\_\_\_  
(c) Calculate the mass of oxygen that has reacted with the magnesium: \_\_\_\_\_  
(d) Calculate the moles (n(Mg)) of magnesium used in the reaction: \_\_\_\_\_  
(e) Calculate the moles (n(O)) of oxygen in the reaction: \_\_\_\_\_  
(f) What is the ratio of n(Mg) to n(O) (in whole numbers)? \_\_\_\_\_  
(g) What is the formula for magnesium oxide? \_\_\_\_\_  
(h) Write a balanced equation for the reaction of magnesium metal (Mg) with oxygen gas (O<sub>2</sub>). \_\_\_\_\_

©2020 BIOZONE International  
ISBN 978-1-927399-79-7  
Photocopying Prohibited

Chemical hazards and required PPE (where applicable) are clearly identified on the investigation.

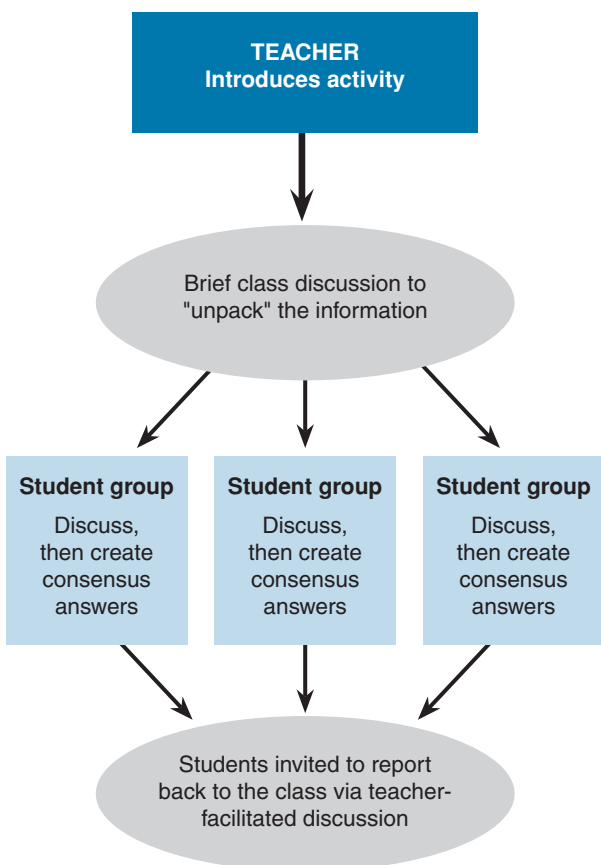
The investigations have been designed using everyday materials and equipment easily found in most high school laboratories. No special kits are required.

# Teaching Strategies for Classroom Use

Achieving effective differential instruction in classes is a teaching challenge. Students naturally have mixed abilities, varying backgrounds in the subject, and different language skills. Used effectively, BIOZONE's student books and supporting resources can make teaching a mixed ability class easier. Here, we suggest some approaches for differential instruction.

## MAKING A START

Regardless of which activity you might be attempting in class, a short introduction to the task by the teacher is a useful orientation for all students. For collaborative work, the teacher can then divide the class into appropriate groups, each with a balance of able and less able students. Depending on the activity, the class may regroup at the end of the lesson for discussion.



## Using collaboration to maximize learning outcomes

- The structure of *Physical Sciences for NGSS* allows for a flexible approach to unpacking the content with your students.
- The content can be delivered in a way to support collaboration, where students work in small groups to share ideas and information to answer and gain a better understanding of a topic, or design a solution to a problem.
- By working together to ask questions and evaluate each other's ideas, students maximize their own and each other's learning opportunities. They are exposed to ideas and perspectives they may not have come up with on their own.
- Collaboration, listening to others, and voicing their own ideas is valuable for supporting English language learners and developing their English and scientific vocabularies.
- Use a short, informal collaborative learning session to get students to exchange ideas about the answer to a question. Alternatively, collaboration may take a more formal role that lasts for a longer period of time (e.g. assign groups to work together for a practical activity, to research an extension question, or design a solution to a problem).



The teacher introduces the topic. They provide structure to the session by providing background information and setting up discussion points and clear objectives. Collaboration is emphasized to encourage participation from the entire group. If necessary, students in a group can be assigned specific tasks.



Students work in small groups so that everyone's contribution is heard. They collaborate, share ideas, and engage in discourse. The emphasis is on sharing ideas, discussing questions, formulating answers. Students may even come up with additional questions and discussion points.



Students report back on their findings. Each student should have enough knowledge to report back on the group's findings. Reporting consists primarily of providing answers to questions, but may involve presenting a report, model, or slide show, or contributing to a debate. Students can revise their original answers providing a powerful second learning moment.





## Peer to peer support

- **Peer-to-peer learning** is emphasized throughout the book, and is particularly valuable for more challenging activities in which the content is more complex or the questions require students to draw on several areas of their knowledge to solve a problem.
- Stronger students can assist their peers and both groups benefit from verbalizing their ideas. Students for whom English is a second language can ask their classmates to explain unfamiliar terms and this benefits the understanding of both parties.
- **Practical investigations** are an ideal vehicle for peer-to-peer learning. Students can work together to review their results, ask and answer questions, and describe phenomena. There are also opportunities for students to collaborate using online simulations (e.g. **Energy2D** shown below).

162 **Marble momentum**

▶ Marbles (or ball bearings) are great for exploring motion. Because they are made of glass or steel, they are smooth and hard. This means they roll with very little friction on smooth, hard surfaces and convert very little kinetic energy to heat and sound during collisions. When collisions are like this, they are said to be **elastic collisions**.

**INVESTIGATION 5.2: Investigating momentum** See appendix for equipment list.

You can work in pairs or small groups for this investigation.

1. You will need a marble and a ball bearing of similar size but different mass. Set up the following:

2. Measure the mass of marble.
3. Measure the length of the ramp and place the marble at the top.
4. The velocity of the marble at the bottom of the ramp can be calculated by combining the equation you derived in question 7 of page 141 and using right angle trigonometry to find the acceleration:  

$$v = \sqrt{2g\sin\theta\Delta x}$$
 where  $g = 9.8 \text{ m/s}^2$ ,  $\theta$  is the angle of incline of the ramp and  $\Delta x$  is the length of the ramp in meters.
5. Roll the marble down the ramp four times and record the distance that it runs along the carpet each time on the table below.
6. Calculate the average distance and record it in the appropriate table below.
7. Measure the mass of the ball bearing.
8. Repeat the investigation with the ball bearing.
9. Calculate the average distance and record it in the appropriate table below.

Test	1	2	3	4	Average
Distance					

Test	1	2	3	4	Average
Distance					

5. Describe the motion of the marble and ball bearing.

Students work in pairs or small groups to determine the effect of mass on momentum, using marbles rolling down a ramp. They can use their results to formulate a relationship between mass and the distance rolled by the marble.

Sharing ideas and observations promotes scientific dialogue.

©2020 BIOZONE International  
ISBN: 978-1-927209-79-7  
Photocopying Prohibited

105 **Modeling Energy Flow** 249

**Key Question:** How does modelling help us understand thermodynamics and energy flow?

**Energy2D**

▶ Computer simulations reproduce the behavior of a system using a computer. They provide a way to predict and model changes in a system by altering specific conditions within that system. Computer simulations allow us to examine complex systems and run many simulations in a short space of time without having to experiment with a physical system. The results of simulations are more accurate when the simulation closely models the real system.

▶ In this activity you will explore heat transfer using a simulation program called Energy2D. This is free, downloadable simulation software developed by Dr Charles Xie at the Concord Consortium. The software has many simulations (right) and a workspace where you can build your own thermal experiments.

▶ In this activity, you will use the program to model heat transfer by conduction.

**Energy2D tools**

▶ Download Energy2D via the link on **BIOZONE's Resource Hub** or from <http://energy.concord.org/energy2d/index.html>

▶ When you open the program you will see the screen on the right. Become familiar with the tools (below).

Drawing tools let you draw the object you want to investigate. You can add thermometers and anemometers to measure temperature and wind speed.

You can zoom in and out of the simulation. You can also draw simple shapes like rectangles and circles.

**Getting started**

Follow the steps below to get started with the simulation.

- i. Click on the 'New' button to create a new simulation.
- ii. Run the simulation. You can stop the simulation at any time by clicking the 'Stop' button.
- iii. You can view the simulation as a graph. After you have run your simulation click the graph icon to view the graph. If you would like to see the data graphed as the simulation runs, simply click on the graph icon before you click Run.

Now you are familiar with the simulation you will carry out some simple investigations on energy transfer.

Students carry out computer simulations to study heat transfer. They can compare simulated results to the results they obtained in their own investigations. This provides an opportunity for peer discussion to account for any differences.

Any new ideas or questions arising from the discussion can easily be tested on the simulation.

©2020 BIOZONE International  
ISBN: 978-1-927209-79-7  
Photocopying Prohibited

## Interactive revision of tasks in class

Review answers in class via BIOZONE WORLD

The teacher view in BIOZONE WORLD has model answers which can be toggled on and off using the show/hide buttons on an activity page.

View activities in BIOZONE WORLD on a shared screen and reveal the answers as required. This is ideal for:

- Providing a concise model answer after a group or class discussion.
- Self marking by students. Students can amend their answer if necessary, providing a powerful secondary learning moment.
- Providing a quick review of answers if time is short.

Students benefit from the feedback in class, where questions can be addressed, and teachers benefit by having students self-mark their work and receive helpful feedback on their responses.

This approach is particularly suited to activities with questions requiring a discussion, as students will be able to clarify some aspects of their responses. Stronger students can benefit by contributing to the explanatory feedback and class discussion.



## NGSS as collaboration and discovery

- BIOZONE's *Physical Sciences for NGSS* provides multiple chances for collaboration and discovery. By working together and sharing ideas, students are exposed to different perspectives and levels of knowledge about phenomena.
- NGSS requires deeper student engagement with less emphasis on facts and more on understanding. By exploring principles and concepts within a context students are more easily able to apply these principles to new phenomena.
- BIOZONE's *Physical Sciences for NGSS* uses the NGSS framework to develop student understanding by providing a range of activities. These include getting students to think about and share what they already know and then build on this knowledge by exploring and explaining phenomena.



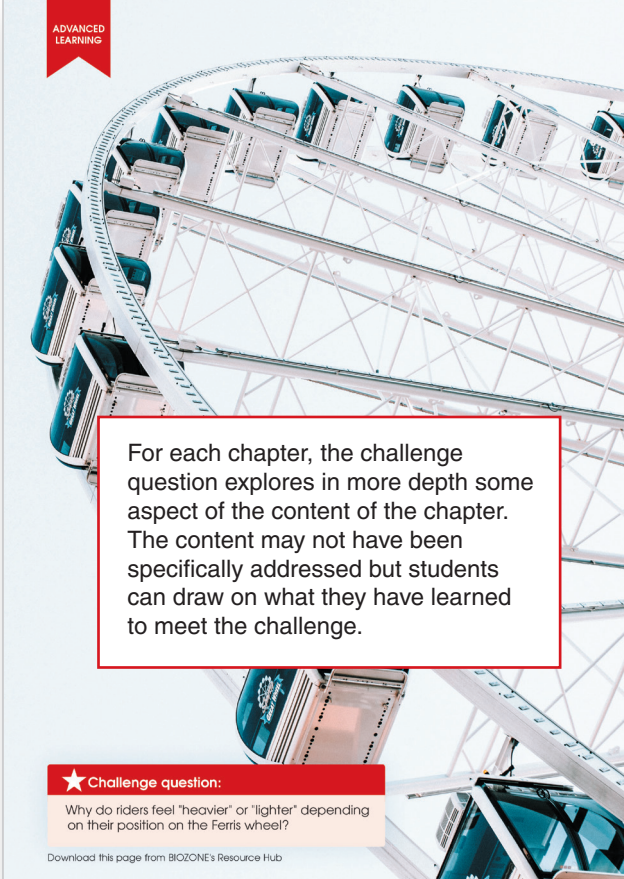
**Student A** is capable. He helps to lead the discussion and records the discussion in a structured way.

**Students B and C** are also capable but less willing to lead discussion they will add ideas to the discussion but need a little direction from A to do so.

**Student D** is less able but gains ideas and understanding from the discussion of students A, B, and C. She may add to the discussion as she gains confidence in the material being studied.

## Student challenges

Do you ever need that little extra fun challenge for your more able students? The **Teacher's Edition** includes an extra page immediately preceding or following the **Teacher's Notes** at the beginning of each chapter (placement depends on pagination constraints). This page provides a challenge question for gifted and talented students in particular (or any students keen to have go!). It can be downloaded from **BIOZONE's Resource Hub**, where it is the first link for each chapter.



ADVANCED LEARNING

★ **Challenge question:**

Why do riders feel "heavier" or "lighter" depending on their position on the Ferris wheel?

Download this page from BIOZONE's Resource Hub



ADVANCED LEARNING

★ **Challenge question:**

How do the properties of waves explain the appearance of optical phenomena such as glories (top) and fog bows (bottom)?

Download this page from BIOZONE's Resource Hub

# Differentiated Learning

The structure of *Physical Sciences for NGSS* promotes differentiated instruction, and has been designed to cater for students of all abilities. BIOZONE's collaborative approach to science inquiry encourages students of all abilities to share their ideas and knowledge with their peers while at the same time broadening their own understanding of phenomena. There are several ways you can use *Physical Sciences for NGSS* to implement differential instruction in your classroom:

**37 Using Molar Mass**

**Key Question:** How can the mole and molar mass be used to find chemical formula?

**Finding the formula**

A working knowledge of molar mass and moles can help us determine the molecular formula of new compounds. In the investigation below you will determine the formula for magnesium oxide.

**INVESTIGATION 3.2 Finding the formula:**

Magnesium is a flammable metal. If ignited it produces a bright and extremely hot flame that can cause severe burns. Do not look directly at the flame. Wear protective eyewear and use tongs to handle the crucible.

1. Weigh a crucible and lid on a balance. Record the mass: \_\_\_\_\_

2. Cut a 10 cm length of magnesium ribbon and place it in the crucible. Replace the lid and reweigh. Record the mass of the crucible, lid, and magnesium ribbon here: \_\_\_\_\_

3. Place a clay triangle onto a tripod and put the crucible in it. Using tongs, open the lid to allow air into the crucible.

4. Watch for the magnesium to ignite (this may take a few minutes). When it does, immediately place the lid back on the crucible.

5. Continue heating the crucible for several minutes. The crucible lid slightly once or twice to allow air to enter.

6. After several minutes, check to see if the magnesium has completely reacted. If it has, the lid will be able to lift as a white powder (magnesium oxide) and no flame or "smoke" will be seen.

7. Leaving the crucible lid on, turn the Bunsen burner off. Allow the crucible to cool. Check to make sure all the magnesium has reacted. If there is still some metal in the crucible, you will need to continue heating.

8. When the crucible is cool, reweigh the crucible, magnesium oxide, and lid. Record the mass here: \_\_\_\_\_

1. (a) Calculate the mass of magnesium at the start of the reaction: \_\_\_\_\_

(b) Calculate the mass of magnesium oxide formed: \_\_\_\_\_

(c) Calculate the mass of oxygen that has reacted with the magnesium: \_\_\_\_\_

(d) Calculate the moles (n(Mg)) of magnesium used in the reaction: \_\_\_\_\_

(e) Calculate the moles (n(O)) of oxygen in the reaction: \_\_\_\_\_

(f) What is the ratio of n(Mg) to n(O) (in whole numbers)? \_\_\_\_\_

(g) What is the formula for magnesium oxide? \_\_\_\_\_

(h) Write a balanced equation for the reaction of magnesium metal (Mg) with oxygen gas (O<sub>2</sub>): \_\_\_\_\_

**Animations and videos:** Use the videos and animations on BIOZONE's Resource Hub to help striving learners with their English language skills and understanding of content. The Resource Hub also provides material tagged for gifted and talented students (also see p. CG11).

**48 Bond Energies**

**Key Question:** How can we use the energy stored in bonds to predict or calculate the energy in a reaction?

It takes energy to break a chemical bond. Energy is released when a bond is formed. The difference between the amount of energy used to break a bond and the energy released when new bonds form will determine the  $\Delta H$  of the reaction.

**Average bond enthalpy** is the energy required to break one mole of a specified bond type in a gaseous state. By knowing the bond enthalpies of the reactants and products in a reaction we can calculate the overall enthalpy of the reaction without having to carry out any experiments.

Consider the following reaction:

Bond	Enthalpy (kJ/mol)
C-H	+413
O=O	+498
C=O	-805
O-H	-464

For any reaction:  $\Delta H = \text{sum of the bond enthalpies in reactants} - \text{sum of the bond enthalpies in products}$

For the reaction above there are (4 x C-H bonds + 2 x O=O bonds) - (2 x C=O bonds + 4 x O-H bonds).

Thus:  $(4 \times 413 + 2 \times 498) - (2 \times 805 + 4 \times 464) = 2648 - 3456 = -808 \text{ kJ/mol}$  for the combustion of CH<sub>4</sub>.

The measured enthalpy of combustion for methane is -882 kJ/mol. If we take account for the fact that water returns to the liquid state and add in the enthalpy of vaporization for water (41 kJ/mol) then we get a more accurate answer:  $2648 - (3456 + 2 \times 41) = -900 \text{ kJ/mol}$ .

The final discrepancy is due to the use of average bond enthalpies (for example the enthalpies of C-H vary from 439 kJ/mol to 411 kJ/mol depending on the molecule and its state).

1. Estimate the enthalpy change for the reaction between ethane and oxygen:  $\text{CH}_3\text{CH}_3 + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$

2. Estimate the enthalpy change for the reaction between ethane and bromine:  $\text{CH}_3\text{CH}_3 + \text{Br}_2 \rightarrow \text{CH}_3\text{CH}_2\text{Br} + \text{HBr}$

**Red flag codes** beside a section or question (on the Teacher's Edition) indicate that students may need extra guidance from the teacher. These questions are also suitable as challenges for more able students to tackle on their own. For able students, also see our **challenge question** pages (see p. CG11)

**37 Using Molar Mass**

**Key Question:** How can the mole and molar mass be used to find chemical formula?

**Finding the formula**

A working knowledge of molar mass and moles can help us determine the molecular formula of new compounds. In the investigation below you will determine the formula for magnesium oxide.

**INVESTIGATION 3.2 Finding the formula:**

Magnesium is a flammable metal. If ignited it produces a bright and extremely hot flame that can cause severe burns. Do not look directly at the flame. Wear protective eyewear and use tongs to handle the crucible.

1. Weigh a crucible and lid on a balance. Record the mass: \_\_\_\_\_

2. Cut a 10 cm length of magnesium ribbon and place it in the crucible. Replace the lid and reweigh. Record the mass of the crucible, lid, and magnesium ribbon here: \_\_\_\_\_

3. Place a clay triangle onto a tripod and put the crucible in it. Using tongs, open the lid to allow air into the crucible.

4. Watch for the magnesium to ignite (this may take a few minutes). When it does, immediately place the lid back on the crucible.

5. Continue heating the crucible for several minutes. The crucible lid slightly once or twice to allow air to enter.

6. After several minutes, check to see if the magnesium has completely reacted. If it has, the lid will be able to lift as a white powder (magnesium oxide) and no flame or "smoke" will be seen.

7. Leaving the crucible lid on, turn the Bunsen burner off. Allow the crucible to cool. Check to make sure all the magnesium has reacted. If there is still some metal in the crucible, you will need to continue heating.

8. When the crucible is cool, reweigh the crucible, magnesium oxide, and lid. Record the mass here: \_\_\_\_\_

1. (a) Calculate the mass of magnesium at the start of the reaction: \_\_\_\_\_

(b) Calculate the mass of magnesium oxide formed: \_\_\_\_\_

(c) Calculate the mass of oxygen that has reacted with the magnesium: \_\_\_\_\_

(d) Calculate the moles (n(Mg)) of magnesium used in the reaction: \_\_\_\_\_

(e) Calculate the moles (n(O)) of oxygen in the reaction: \_\_\_\_\_

(f) What is the ratio of n(Mg) to n(O) (in whole numbers)? \_\_\_\_\_

(g) What is the formula for magnesium oxide? \_\_\_\_\_

(h) Write a balanced equation for the reaction of magnesium metal (Mg) with oxygen gas (O<sub>2</sub>): \_\_\_\_\_

A group symbol indicates where students can work together. Group work provides opportunities for student collaboration and peer-to-peer support to explore phenomena. Working in groups, students can experience the benefits of collaboration in the scientific process of discovery. By speaking and listening to each other, English language skills and scientific vocabulary are extended.

**108 pH of acids and bases**

The pH scale is based on the concentration of H<sup>+</sup> ions in a solution (H<sup>+</sup> ions actually exist as H<sub>3</sub>O<sup>+</sup> in solution). It is a logarithmic scale so that the concentration of H<sup>+</sup> changes by ten times from one pH unit to the next.

pH actually means the hydrogen (H) potential (p) of the solution (p) is also related to power, or potential (capacity).

Water exists in an equilibrium with the hydronium ion (H<sub>3</sub>O<sup>+</sup>) and the hydroxide ion (OH<sup>-</sup>):

$$\text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^-$$

For simplicity H<sub>3</sub>O<sup>+</sup> is usually just written as H<sup>+</sup> so:

$$\text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{OH}^-$$

The equilibrium lies far to the left, so the concentrations of both H<sup>+</sup> and OH<sup>-</sup> are extremely small (1 x 10<sup>-7</sup> mol/L).

We can use these concentrations to work out the pH of water. If we take the negative log<sub>10</sub> value of the H<sup>+</sup> ion then:

$$-\log_{10} 1 \times 10^{-7} = 7$$

The equation can be written as:  $\text{pH} = -\log_{10}[\text{H}^+]$  (the square brackets [ ] mean concentration).

If we know the pH of a solution we can also work out the H<sup>+</sup> concentration of that solution using the negative inverse log<sub>10</sub> (10<sup>-pH</sup>). So if the pH is 5.3 then:  $10^{-5.3} = 5.0 \times 10^{-6} \text{ mol/L}$  of H<sup>+</sup> ions.

The equation can be written as  $[\text{H}^+] = 10^{-\text{pH}}$ .

It is useful to note at this stage that as [H<sup>+</sup>] increases [OH<sup>-</sup>] decreases at the same rate. This can be seen in the equation:  $[\text{H}^+][\text{OH}^-] = 1 \times 10^{-14}$ . This value is related to as  $K_w$  and is constant.

Thus if [H<sup>+</sup>] =  $1.0 \times 10^{-1}$  then  $[\text{OH}^-] = 1 \times 10^{-14} / 1.0 \times 10^{-1} = 1.0 \times 10^{-13}$ .

2. Calculate the pH of the following solutions:

(a) 2.5 x 10<sup>-2</sup> mol/L \_\_\_\_\_

(b) 6.0 x 10<sup>-11</sup> mol/L \_\_\_\_\_

with the following pH:

(c) pH 14.0 \_\_\_\_\_

(d) pH 11.4 \_\_\_\_\_

is a pH 3 solution than a pH 4 solution? \_\_\_\_\_

calculate its pH: \_\_\_\_\_

The ions they form in solution are shown:

Acid/base	Acid	Base	Ions in solution
HNO <sub>3</sub>	Acid		H <sup>+</sup> NO <sub>3</sub> <sup>-</sup>
CH <sub>3</sub> COOH	Acid		H <sup>+</sup> CH <sub>3</sub> COO <sup>-</sup>
NaOH		Base	Na <sup>+</sup> OH <sup>-</sup>
KOH		Base	K <sup>+</sup> OH <sup>-</sup>
NH <sub>3</sub>		Base	NH <sub>4</sub> <sup>+</sup> OH <sup>-</sup>

(a) What ions do the acids have in common? \_\_\_\_\_

(b) What ions do the bases have in common? \_\_\_\_\_

(c) Complete the reaction:  $\text{NH}_3 + \text{H}^+ \rightleftharpoons \text{NH}_4^+$

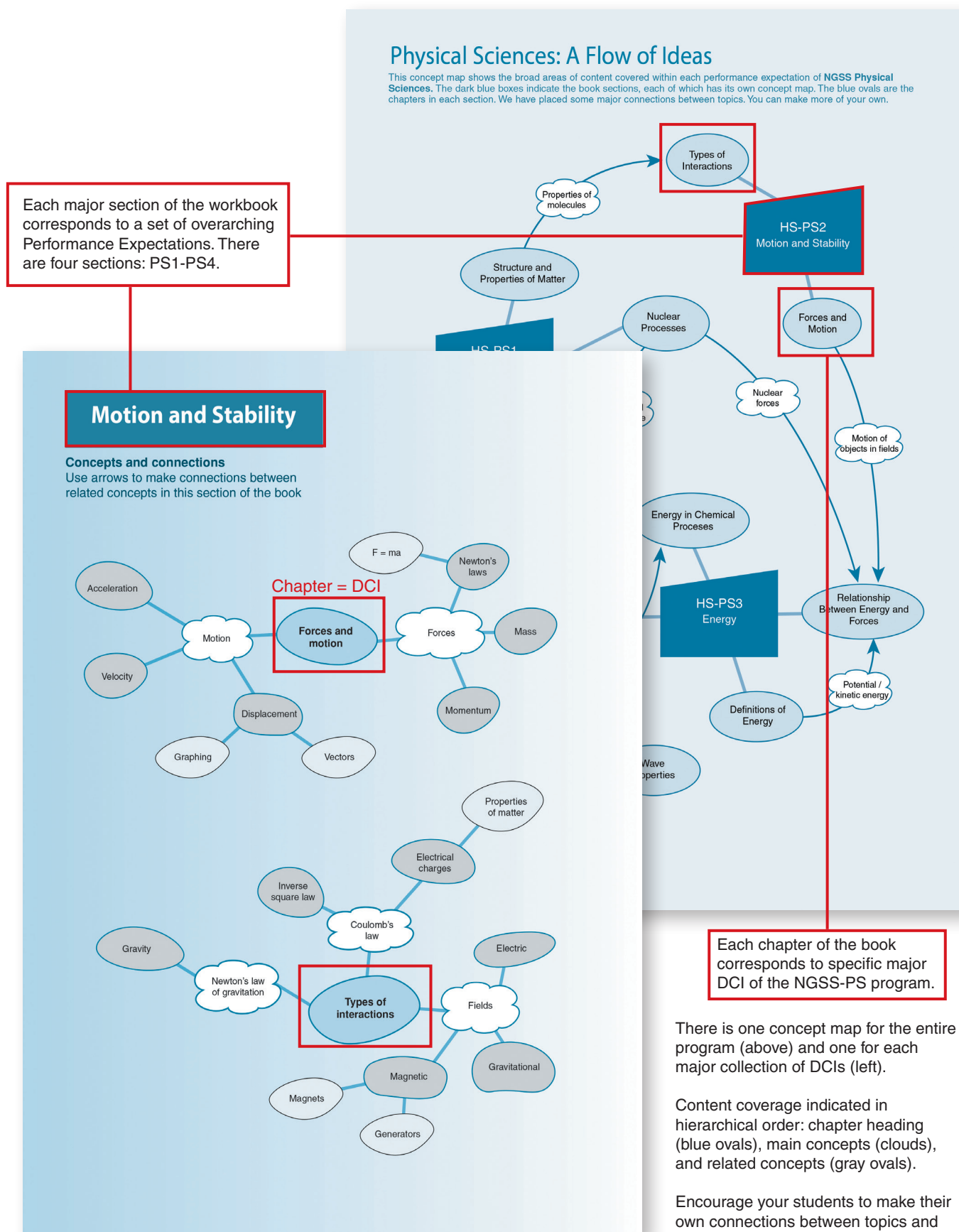
(d) The reaction in (c) above is an equilibrium. How might this affect the expected pH of an NH<sub>3</sub>/OH<sup>-</sup> solution? \_\_\_\_\_

A red figure with a **NEED HELP?** icon helps students identify where they can go to get help with a specific skill. Skills and tips for computation, data analysis, plotting, statistical analysis, and aspects of experimental design are provided in the Basic Skills chapter at the start of the book. Students can visit this chapter regularly, or you can assign activities as homework before they attempt a specific task in class.



# The Concept Maps

The concept maps in Physical Sciences for NGSS have two broad purposes: to provide a map of ideas covered in the program and to provide a vehicle for students to make their own connections between those ideas. They are particularly useful as graphic organizers for striving students and visual learners. The introductory map provides an overview of the structure of the *NGSS Physical Sciences* program. Section concept maps divide the book into four parts, each providing a visual summary of one of four broad areas within the program, corresponding to PS1-PS4. Students can make their own connections between ideas on the concept maps as they work through the topics.





# Engineering Design Solutions


ETS SEPs, DCIs, and PEs as indicated in the NGSS framework are met through appropriately integrated engineering and design challenges. Typically tasks include analyzing problems, developing solutions using engineering, evaluating a design solution based on costs and benefits, or modeling a design solution.

The three dimensions of the NGSS framework appropriate to each design challenge are indicated in the chapter introduction of the Teacher's Edition and indicated through the tab system on the activity itself. Such tasks are usually examples of 'ELABORATE' as they involve the students applying what they have learned to solve a problem. As such, they also make good tasks for formative or summative assessment.

171

**INVESTIGATION 5.4: Building a lander** See appendix for equipment list.

- You will now have the opportunity to put your knowledge of forces and momentum to the test. The objective of this investigation is to build a device that will protect a lander from descent of at least four meters.
- The conditions: You will build a landing device that will protect a raw egg from a fall of at least four meters. You are free to use the equipment (below) in any way but there may be no platform for the lander to fall onto (landers don't have convenient foam landing pads to fall onto when they reach their destination).
- The equipment: 1 egg, 60 cm of tape, 5 rubber bands, 1 small garbage or plastic bag, 10 paper clips, 1 m string, 20 plastic or paper straws, 1 plastic egg or similar sized object for testing. Your teacher may modify this equipment as they wish.
- Building time will be determined by your teacher.
- Before you begin, discuss with your group how you will construct the lander and in what ways you could cushion the egg at impact or slow its descent to reduce the shock of landing. You could research lander design online to gather ideas before you begin construction.



**Lander design**

7. Now that you have built and tested your egg lander you must evaluate its structure and performance.

- Describe the structure of your lander: \_\_\_\_\_
- On a scale of 1-5, how did your egg survive the fall? (1 = completely scrambled, 5 = safe and sound): \_\_\_\_\_
- If your egg cracked, what could have been done to keep it from cracking if you repeated the test? \_\_\_\_\_
- Recall the landing devices designed used by other groups in your class. Which of these can you explain why? \_\_\_\_\_
- Given enough material, it would be easily possible to design a lander than would protect fall than 5 m. The same applies to planetary landers. However, there are numerous constraints these devices, one of which is cost. Discuss with your group what other constraints there a lander for Mars: \_\_\_\_\_

©2020 BIOZONE International  
ISBN: 978-1-927309-79-7  
Photocopying Prohibited

In this ETS example, students are asked to design and build a device to protect an egg from a fall of 4 meters using specified equipment. They test, evaluate, and refine their design to find a successful solution.

252

- On the **BioZone resource hub** watch the video in which an elaborate Rube Goldberg machine is used:
  - How many times was energy transferred from one object or system to another? \_\_\_\_\_
  - The energy in the original starting collision appears to run the whole device, with numerous reactions, often with greater energy. Explain why this isn't actually the case: \_\_\_\_\_
  - Why can this machine be used only once? \_\_\_\_\_

**Engineering energy conversion devices**

Unlike Rube Goldberg machines, most devices are designed to be as efficient as possible - to get the most work out of the input energy. As we learned, the energy in the universe is limited. And most of that energy is in forms inaccessible to us. What's more, when we harvest energy we lose much of it in the form of unusable heat energy. This further limits the energy available for our use. When we consider the energy demands for society and the energy we have available, efficiency becomes very important.

You will now have the opportunity to design your own energy conversion device by applying the basic principles of energy conversion. This design challenge can be done outside the classroom in groups or individually as your teacher decides. Your teacher will determine the amount of time you can take.

The goal of this design challenge is simple: **you must build a device that will produce the greatest temperature change in 4 liters of water in fifteen minutes.** Water must be able to flow through or around your device based on the conditions below.

Your device will be attached to a heating station set up by your teacher so that the testing conditions will be uniform for all the devices. A basic heating station will consist of two heat lamps on chemistry lab stands with clamps which can be easily adjusted, a submersible fountain pump with adjustable flow control, a container that will hold the 4 liters of water that will be heated and is able to submerge the fountain pump, a thermometer, and a stopwatch or timer. The actual layout of the heating station will depend on your teacher and available materials.

Make sure to note that your device will need to connect to the water pump - you will need appropriate hose connections to attach your device to the pump hoses.

You will need to: - research and submit a design to your teacher  
- build and test the design  
- refine the design and make any changes necessary  
- submit a plan showing any revisions of the design to your teacher  
- present a report that describes how your device works, its power output and efficiency, and situations where it will be best used.  
- provide a demonstration of the device so that it can be compared to other devices designed by your classmates.

Available materials may be limiting. Be sure you are aware of the materials you have available when designing your device. Keep note of any portion of your device where an unavailable material may have made a difference.

Note: **Efficiency = energy in / energy out.**

**Energy out** can be calculated from the temperature change in the water. 1 mL (1 g) of water requires 4.2 joules to raise its temperature by 1°C or  $E = m \times 4.2 \times \Delta T$  (where  $m$  = mass in grams of water and  $\Delta T$  = the change in temperature).

**Energy in** can be calculated using the power ratings of the heat lamps. Heat lamps are approximately 96% efficient, so the energy in will be the wattage of the heat lamps  $\times 0.96 \times$  time in seconds.

- (a) In the space below, summarize your research notes on a possible device to build. You may use extra paper if needed:

©2020 BIOZONE International  
ISBN: 978-1-927309-79-7  
Photocopying Prohibited

Students have previously studied energy transfer. They use their knowledge to design a way to heat a flow of water given various constraints. In designing their solution, students must take into consideration the materials used and the efficiency of their design in achieving the outcome.

# The Nature of Science

The Nature of Science combines established information with new knowledge to constantly refine what we know about the natural world. Eight Nature of Science understandings are presented in the NGSS document. Four are associated most closely with Science and Engineering Practices, and four with the Crosscutting Concepts. The Nature of Science understandings have been incorporated into most activities in *Physical Sciences for NGSS*, so we have not identified them specifically on the activity pages. Some examples of activities relating to the eight Nature of Science understandings are illustrated below. The subheading to which they relate is also given.

## Nature of science understandings most closely associated with science and engineering practices

**37 Finding the nucleus**

**Key Question:** How do Ernest Rutherford, Hans Geiger and Ernest Marsden conduct a series of experiments to find the nucleus, and how do they use the results to determine the structure of the atom?

1. Describe the experimental setup and the results of the experiment.

2. Explain how the results of the experiment led to the discovery of the nucleus.

3. Calculate the mass of the nucleus.

4. Calculate the radius of the nucleus.

5. Calculate the density of the nucleus.

6. Calculate the mass of the nucleus.

7. Calculate the radius of the nucleus.

8. Calculate the density of the nucleus.

9. Calculate the mass of the nucleus.

10. Calculate the radius of the nucleus.

11. Calculate the density of the nucleus.

12. Calculate the mass of the nucleus.

13. Calculate the radius of the nucleus.

14. Calculate the density of the nucleus.

15. Calculate the mass of the nucleus.

16. Calculate the radius of the nucleus.

17. Calculate the density of the nucleus.

18. Calculate the mass of the nucleus.

19. Calculate the radius of the nucleus.

20. Calculate the density of the nucleus.

Scientific investigations use a variety of methods.

- Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge

**37 Using Molar Mass**

**Key Question:** How do you use the mole and molar mass to calculate the mass of a chemical formula?

1. Calculate the mass of the molecule.

2. Calculate the mass of the molecule.

3. Calculate the mass of the molecule.

4. Calculate the mass of the molecule.

5. Calculate the mass of the molecule.

6. Calculate the mass of the molecule.

7. Calculate the mass of the molecule.

8. Calculate the mass of the molecule.

9. Calculate the mass of the molecule.

10. Calculate the mass of the molecule.

11. Calculate the mass of the molecule.

12. Calculate the mass of the molecule.

13. Calculate the mass of the molecule.

14. Calculate the mass of the molecule.

15. Calculate the mass of the molecule.

16. Calculate the mass of the molecule.

17. Calculate the mass of the molecule.

18. Calculate the mass of the molecule.

19. Calculate the mass of the molecule.

20. Calculate the mass of the molecule.

Scientific knowledge is based on empirical evidence.

- Scientific knowledge is based on empirical evidence.

**57 Inside the Nucleus**

**Key Question:** What is the internal structure of the atomic nucleus?

1. Calculate the mass of the nucleus.

2. Calculate the mass of the nucleus.

3. Calculate the mass of the nucleus.

4. Calculate the mass of the nucleus.

5. Calculate the mass of the nucleus.

6. Calculate the mass of the nucleus.

7. Calculate the mass of the nucleus.

8. Calculate the mass of the nucleus.

9. Calculate the mass of the nucleus.

10. Calculate the mass of the nucleus.

11. Calculate the mass of the nucleus.

12. Calculate the mass of the nucleus.

13. Calculate the mass of the nucleus.

14. Calculate the mass of the nucleus.

15. Calculate the mass of the nucleus.

16. Calculate the mass of the nucleus.

17. Calculate the mass of the nucleus.

18. Calculate the mass of the nucleus.

19. Calculate the mass of the nucleus.

20. Calculate the mass of the nucleus.

Scientific knowledge is open to revision in light of new evidence.

- Most scientific knowledge is quite durable but is subject to change based on new evidence and/or reinterpretations of existing evidence.

**22 Atomic Models and Valence Electrons**

**Key Question:** How do the electrons bond with a nucleus?

1. Calculate the mass of the nucleus.

2. Calculate the mass of the nucleus.

3. Calculate the mass of the nucleus.

4. Calculate the mass of the nucleus.

5. Calculate the mass of the nucleus.

6. Calculate the mass of the nucleus.

7. Calculate the mass of the nucleus.

8. Calculate the mass of the nucleus.

9. Calculate the mass of the nucleus.

10. Calculate the mass of the nucleus.

11. Calculate the mass of the nucleus.

12. Calculate the mass of the nucleus.

13. Calculate the mass of the nucleus.

14. Calculate the mass of the nucleus.

15. Calculate the mass of the nucleus.

16. Calculate the mass of the nucleus.

17. Calculate the mass of the nucleus.

18. Calculate the mass of the nucleus.

19. Calculate the mass of the nucleus.

20. Calculate the mass of the nucleus.

Science models, laws, mechanisms, and theories explain natural phenomena.

- Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory.

## Nature of science understandings most closely associated with crosscutting concepts

**The nature of science: a brief overview of atomic theory**

**Key Question:** What is the nature of science?

1. Calculate the mass of the nucleus.

2. Calculate the mass of the nucleus.

3. Calculate the mass of the nucleus.

4. Calculate the mass of the nucleus.

5. Calculate the mass of the nucleus.

6. Calculate the mass of the nucleus.

7. Calculate the mass of the nucleus.

8. Calculate the mass of the nucleus.

9. Calculate the mass of the nucleus.

10. Calculate the mass of the nucleus.

11. Calculate the mass of the nucleus.

12. Calculate the mass of the nucleus.

13. Calculate the mass of the nucleus.

14. Calculate the mass of the nucleus.

15. Calculate the mass of the nucleus.

16. Calculate the mass of the nucleus.

17. Calculate the mass of the nucleus.

18. Calculate the mass of the nucleus.

19. Calculate the mass of the nucleus.

20. Calculate the mass of the nucleus.

Science is a way of knowing.

- Scientific knowledge has a history that includes refinement of, and changes to, theories, ideas, and beliefs over time.

**37 Using Molar Mass**

**Key Question:** How do you use the mole and molar mass to calculate the mass of a chemical formula?

1. Calculate the mass of the molecule.

2. Calculate the mass of the molecule.

3. Calculate the mass of the molecule.

4. Calculate the mass of the molecule.

5. Calculate the mass of the molecule.

6. Calculate the mass of the molecule.

7. Calculate the mass of the molecule.

8. Calculate the mass of the molecule.

9. Calculate the mass of the molecule.

10. Calculate the mass of the molecule.

11. Calculate the mass of the molecule.

12. Calculate the mass of the molecule.

13. Calculate the mass of the molecule.

14. Calculate the mass of the molecule.

15. Calculate the mass of the molecule.

16. Calculate the mass of the molecule.

17. Calculate the mass of the molecule.

18. Calculate the mass of the molecule.

19. Calculate the mass of the molecule.

20. Calculate the mass of the molecule.

Scientific knowledge assumes an order and consistency in natural systems.

- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and will continue to do so in the future.

**57 Inside the Nucleus**

**Key Question:** What is the internal structure of the atomic nucleus?

1. Calculate the mass of the nucleus.

2. Calculate the mass of the nucleus.

3. Calculate the mass of the nucleus.

4. Calculate the mass of the nucleus.

5. Calculate the mass of the nucleus.

6. Calculate the mass of the nucleus.

7. Calculate the mass of the nucleus.

8. Calculate the mass of the nucleus.

9. Calculate the mass of the nucleus.

10. Calculate the mass of the nucleus.

11. Calculate the mass of the nucleus.

12. Calculate the mass of the nucleus.

13. Calculate the mass of the nucleus.

14. Calculate the mass of the nucleus.

15. Calculate the mass of the nucleus.

16. Calculate the mass of the nucleus.

17. Calculate the mass of the nucleus.

18. Calculate the mass of the nucleus.

19. Calculate the mass of the nucleus.

20. Calculate the mass of the nucleus.

Science is a human endeavor.

- Technological advances have influenced the progress of science and science has influenced advances in technology.

**36 The Mole**

**Key Question:** What is the mole and how is it used in chemistry?

1. Calculate the mass of the molecule.

2. Calculate the mass of the molecule.

3. Calculate the mass of the molecule.

4. Calculate the mass of the molecule.

5. Calculate the mass of the molecule.

6. Calculate the mass of the molecule.

7. Calculate the mass of the molecule.

8. Calculate the mass of the molecule.

9. Calculate the mass of the molecule.

10. Calculate the mass of the molecule.

11. Calculate the mass of the molecule.

12. Calculate the mass of the molecule.

13. Calculate the mass of the molecule.

14. Calculate the mass of the molecule.

15. Calculate the mass of the molecule.

16. Calculate the mass of the molecule.

17. Calculate the mass of the molecule.

18. Calculate the mass of the molecule.

19. Calculate the mass of the molecule.

20. Calculate the mass of the molecule.

Science addresses questions about the natural and material world.

- Scientific knowledge indicates what can happen in natural systems - not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.

# Evaluating Student Performance

*Physical Sciences for NGSS* provides ample opportunity for students to demonstrate their understanding and proficiency in all three dimensions of the standards. Opportunities for both formative and summative assessment are provided.


All activities (including assessments) have been designed to be three-dimensional in their approach, with the goal to enabling achievement of specific performance expectations. Performance expectations (PE) are not always met through completion of one activity or assessment, but through completion of a connected suite of tasks (as intended by the framework).

Assessments involve a variety of tasks as appropriate to a 3D approach, e.g., constructing models, analyzing and interpreting data, explaining, and communicating understanding through short and long answers, drawings, calculations, group work, design, and problem solving. The structure of the tasks is such that students use specific science and engineering practices and apply relevant crosscutting concepts to demonstrate their understanding of disciplinary core ideas.

**Formative assessments** can be chosen by the teacher to determine how a student's knowledge is progressing within a selected topic. We suggest that 'ELABORATE' and 'EVALUATE' sections of activities be used for formative assessment. These may incorporate some aspect of a performance expectation with the goal being to build confidence. Teachers can revise their instruction, revisit material, or set further tasks if a student is having difficulty with the material. Revisiting the Anchoring Phenomenon near the end of each instructional segment also provides a way to evaluate student understanding.

**INVESTIGATION 5.4: Building a lander** See appendix for equipment list.

- You will now have the opportunity to put your knowledge of forces and momentum to the test. The objective of this investigation is to build a device that will protect a lander from descent of at least four meters.
- The conditions: You will build a landing device that will protect a raw egg from a fall of at least four meters. You are free to use the equipment (below) in any way but there may be no platform for the lander to fall onto (landers don't have convenient foam landing pads to fall onto when they reach their destination).
- The equipment: 1 egg, 60 cm of tape, 5 rubber bands, 1 small garbage or plastic bag, 10 paper clips, 1 m string, 20 plastic or paper straws, 1 plastic egg or similar sized object for testing. Your teacher may modify this equipment as they wish.
- Building time will be determined by your teacher.
- Before you begin, discuss with your group how you will construct the lander and in what ways you could cushion the egg at impact or slow its descent to reduce the shock of landing. You could research lander design online to gather ideas before you begin construction.



**Lander design**

7. Now that you have built and tested your egg lander you must evaluate its structure and performance.

- Describe the structure of your lander: \_\_\_\_\_
- On a scale of 1-5, how did your egg survive the fall? (1 = completely scrambled, 5 = safe and sound): \_\_\_\_\_
- If your egg cracked, what could have been done to keep it from cracking if you repeated the test? \_\_\_\_\_
- Recall the landing devices designed used by other groups in your class. Which of these were the most effective? Can you explain why? \_\_\_\_\_
- Given enough material, it would be easily possible to design a lander that would protect the egg from a much higher fall than 5 m. The same applies to planetary landers. However, there are numerous constraints on the development of these devices, one of which is cost. Discuss with your group what other constraints there might be on the design on a lander for Mars: \_\_\_\_\_

©2020 BIOZONE International  
ISBN: 978-1-927389-79-7  
Photocopying Prohibited

171

## 44 Verifying a Claim

87

**Key Question:** How can we verify the claims made by manufacturers of products, using standardized solutions?

### Finding the concentration of ethanoic acid in vinegar

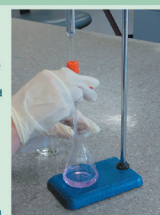
- A standard sodium hydroxide solution is useful for testing the acid concentration of various solutions. It must be standardized whenever it is used as it tends to absorb carbon dioxide from the air, which can change the concentration.
- In the following investigations, you will standardize a solution of NaOH from the lab supply then immediately use it to calculate the concentration of ethanoic (acetic) acid in a store bought white vinegar.
- For the following set of investigations use the following molar masses:  $M(H) = 1.0 \text{ g/mol}$ ,  $M(C) = 12.0 \text{ g/mol}$ ,  $M(O) = 16.0 \text{ g/mol}$ ,  $M(Na) = 23.0 \text{ g/mol}$ ,  $M(Cl) = 35.5 \text{ g/mol}$ .



### INVESTIGATION 3.6 Standardizing NaOH:

See appendix for equipment list.

- Add 50 mL of 1 mol/L NaOH solution to a clean, dry 100 mL beaker. Transfer 25 mL to a 250 mL volumetric flask using a 25 mL pipette.
- Alternatively weigh 1 gram of solid NaOH in a 100 mL beaker and dissolve with distilled water before transferring to a volumetric flask.
- Following the same procedure as to produce the HCl earlier, dilute the NaOH by filling the volumetric flask up to the mark with distilled water.
- Rinse a burette with the dilute NaOH solution. Then fill the burette with the solution.
- Rinse a pipette with your standardized HCl solution then pipette four 20 mL samples into four clean, dry 100 mL conical flasks.
- Add two drops of phenolphthalein indicator to the conical flasks. This will turn pink when the HCl/NaOH reaction is complete.
- Again, you will need to carry out at least three titrations plus a trial run. Use the table at the bottom of the page to record your results.
- Record the initial burette volume. Add the NaOH solution from the burette to the HCl while swirling the flask until the indicator just changes color. Record the final volume and calculate the difference (the titre).
- Carry out the titration at least three more times and record the volume added for each.



The titration is complete when the phenolphthalein turns a slight pink.

Burette reading	Trial titration	First titration	Second titration	Third titration
Initial reading				
Final reading				
Difference (titre)				

1. Write a balanced equation for sodium hydroxide (NaOH) reacting with hydrochloric acid (HCl):

2. (a) Calculate  $n(HCl)$  in the conical flasks: \_\_\_\_\_

(b) Calculate the average (mean) volume of NaOH solution used: \_\_\_\_\_

(c) Calculate  $n(NaOH)$  used: \_\_\_\_\_

(d) Calculate the concentration of NaOH in volumetric flask: \_\_\_\_\_

©2020 BIOZONE International  
ISBN: 978-1-927389-79-7  
Photocopying Prohibited





**Summing up** tasks at the close of each instructional segment can be used as a formal summative testing moment to evaluate student skills, understanding, and application of knowledge. These tasks are designed to meet part or all of one or more performance expectations. Material to address specific performance expectations is identified with a red tab in the margin throughout the Teacher's Edition. Performance expectations are also identified in the chapter introduction for the instructional segment, and in the tables summarizing BIOZONE's 3D approach by chapter earlier in this guide.

**Note: All coding associated with assessment is hidden from the student and is available only in teacher's materials.**

The specific performance expectation addressed is identified with a red tab in the margin of the Teacher's Edition. Students do not see this coding.

**55 Summing Up**

**Chemical reactions**

1. Balance the following equations:

(a)  $\text{Ca} + \text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2$

(b)  $\text{Li} + \text{H}_2\text{O} \rightarrow \text{LiOH} + \text{H}_2$

(c)  $\text{C}_2\text{H}_6 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$

(d)  $\text{C}_2\text{H}_5\text{OH} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$

2. A chemist accidentally mislabeled a container and carried out a series of tests. The results are as follows:

The density of the metal lay between gold and silver.

When reacted with acid, the reaction was vigorous.

When reacted with water the reaction was vigorous.

When burned in oxygen, a one gram piece of metal produced 3.66 grams of oxide.

What do you think this metal was? Explain.

**PS1-7** 3. Fertilizers show the different percentage of nitrogen – phosphorus – potassium. A fertilizer company made a fertilizer claim (NPK<sub>10-10-10</sub>).

A student tested the percentage of N in it. The equation for the reaction is  $\text{BaCl}_2(\text{aq}) + \text{Na}_2\text{SO}_4(\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2\text{NaCl}(\text{aq})$ . The solid barium sulfate was then filtered.

(a) Calculate the mass of  $(\text{NH}_4)_2\text{SO}_4$  in 100 g of fertilizer.

(b) Calculate the concentration of the  $(\text{NH}_4)_2\text{SO}_4$  solution.

(c) How many moles of  $\text{SO}_4^{2-}$  are in 50 mL of the solution?

(d) What mass of  $\text{BaSO}_4$  would be expected to form from 50 mL of the solution?

(e) Was the fertilizer company correct in its claim?

**PS1-4** 4. A student builds a cart powered by a fan. When the fan is turned on, the sail will catch the air moved by the fan.

Explain why the cart will not move when the fan is turned on:

**PS2-2** 5. An astronaut floating in space holds a ball. The astronaut-ball system has a velocity of 0 m/s. The 70 kg astronaut pushes the 1.3 kg ball directly away from her so that the ball attains a velocity of 1.5 m/s. Calculate the velocity of the astronaut after she releases the ball.

6. Two astronauts (each with mass 70 kg) push off each other in space. One carries 46.7 kg of equipment and moves away with a speed 0.3 m/s.

(a) Calculate the velocity of the 'unloaded' astronaut.

(b) Determine how far apart the astronauts are after 5 s. Show your working.

7. A truck with a mass of 15,000 kg moving at 25 m/s crashes into the back of a small 1100 kg car moving at 15 m/s. They stick together after the collision.

(a) Calculate the momentum of the system before the collision and after the collision.

(b) Calculate the velocity of the truck-car system after the collision.

8. A golf club swings and hits a golf ball from a tee. The golf club makes contact with the golf ball for 0.5 milliseconds ( $5.00 \times 10^{-4}$  seconds). The mass of the golf ball is 0.045 kilograms. The velocity of the ball off the tee is 78 m/s.

(a) What is the impulse experienced by the golf ball?

(b) What is the force applied to the golf ball?

(c) Use two different methods to show the acceleration of the golf ball off the tee is  $156,000 \text{ m/s}^2$ .

**Thermochemistry**

5. (a) Define the term endothermic:

(b) Sketch a graph showing the enthalpy change for the reaction:

6. Sketch a graph showing the enthalpy change for the reaction:

7. The reaction of carbon with oxygen is  $\text{C}_{(s)} + \text{O}_{2(g)} \rightarrow \text{CO}_{2(g)}$ .

(a) Explain what the notation for the reaction means.

(b) How much energy is released is 2.6 moles of  $\text{CO}_2$  are produced?

8. Two skydivers jump out of a plane. They both are the same body orientation while falling (horizontal position). Skydiver A has a mass of 75 kg. Skydiver B has a mass of 85 kg.

(a) What is the magnitude of the force on skydiver A?

(b) What is the magnitude of the force on skydiver B?

(c) Both skydivers reach terminal velocity (acceleration equals zero). Explain why the terminal velocity is reached.

(d) They open their parachutes. Explain why the parachutes open.

Summative assessments are three dimensional assessments of student understanding, including but not restricted to:

- Short answer questions
- Long answer questions
- Graphing
- Data analysis and interpretation
- Modeling

## Does BIOZONE provide test banks?

- ▶ We are currently developing test banks to test the DCI content within each chapter.
- ▶ These will test content knowledge, and take the form of:
  - Multiple choice
  - True/False
  - Modified True/False
  - Multiple response
  - Matching
  - Short answer
  - Yes/No
  - Numeric response
- ▶ Test bank questions will be formatted for ingestion into test generator software such as ExamView.
- ▶ Standard and credit recovery options will be available.

## Credit recovery questions

### Science Practices

#### True/False

1. Investigations require you to make assumptions about the system you are working with.

ANS: T

2. You should always record and report the units of measurement during investigations.

ANS: T

#### Modified True/False

3. Base units are independently expressed and cannot be used on their own.

ANS: F

Modified answer: Base units are independently expressed and can be used on their own.

4. The color of a Bunsen flame has no relationship to its temperature.

ANS: F

Modified answer: The color of a Bunsen flame gives an indication of its temperature.

5. The density of a substance is the relationship between the mass of a substance and its volume.

ANS: T

#### Multiple choice

6. The inverse square law applies to:

- a. Gravity
- b. Electric fields
- c. Light intensity
- d. Sound intensity
- e. All of the above

ANS: e

7. Light intensity at 3x the distance from the source is equal to:

- a. 1/4 the brightness of the source
- b. 1/8 the brightness of the source
- c. 1/9 the brightness of the source
- d. 1/2 the brightness of the source

ANS: c

# Identifying CCCs and SEPs by Number

## CROSSCUTTING CONCEPTS (CCCs)

CCCs are unifying ideas that apply across all disciplines of science. A CCC connects topics where the same unifying concept underpins the content. A statement for each numbered CCC is provided below. CCCs are identified by number in the tables following and in the embedded coding in the chapter introductions (Teacher's Edition). Statements are paraphrased.

### 1: Patterns

In grades 9-12, students observe patterns in systems at different scales and cite patterns as evidence for causality in supporting explanations of phenomena. They recognize that classifications or explanations at one scale may need revision using a different scale, thus requiring improved investigations and experiments. They identify and analyze patterns, and use analysis to re engineer and improve designed systems.

### 2: Cause and effect

In grades 9-12, students understand that empirical evidence is required to differentiate between cause and correlations and to make claims about cause and effect. They suggest cause and effect relationships to explain and predict behaviors in natural and designed systems. They also propose causal relationships by examining what is known about smaller-scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects.

### 3: Scale, proportion, and quantity

In grades 9-12, students understand that the significance of a phenomenon depends on the scale, proportion, and quantity at which it occurs. They recognize that patterns observable at one scale may not be observable or exist at other scales and that some systems can only be studied indirectly. Students use orders of magnitude to understand how a model at one scale relates to a model at another scale. They use algebraic thinking to examine scientific data and predict the effect of a change in one variable on another.

### 4: Systems and system models

In grades 9-12, students investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They use models to simulate the flow of energy, matter, and interactions within and between systems at different scales. They also use models and simulations to predict the behavior of a system and recognize why these predictions have limited precision and reliability. They also design systems to do specific tasks.

### 5: Energy and matter

In grades 9-12, students learn that the total amount of energy and matter in closed systems is conserved. They can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. They also learn that energy cannot be created or destroyed, only transferred and transformed. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

### 6: Structure and function

In grades 9-12, students investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal a system's function and/or solve a problem. They infer the functions and properties of natural and designed objects and systems from their structure, the way their components are shaped and used, and the molecular substructures of their various materials.

## 7: Stability and change

In grades 9-12, students understand that much of science deals with constructing explanations of how things change and how they remain stable. They quantify and model changes in systems over short or very periods of time. They see that some changes are irreversible and that negative feedback can stabilize a system, while positive feedback can destabilize it. They recognize that systems can be designed for more or less stability.

## SCIENCE & ENGINEERING PRACTICES (SEPs)

SEPs for NGSS are overlapping and interconnected practices that students should know and understand. A statement for each numbered SEP is provided below. SEPs are identified by number in the tables following and in the embedded coding in the chapter introductions (Teacher's Edition).

### 1: Asking questions and defining problems

"Asking questions and defining problems in 9-12 builds on K-8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations."

### 2: Developing and using models

"Modeling in 9-12 builds on K-8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s)."

### 3: Planning and carrying out investigations

"Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual mathematical, physical, and empirical models".

### 4: Analyzing and interpreting data

"Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data."

### 5: Using mathematics and computational thinking

"Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and non-linear functions, including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simulations are created and used based on mathematical models of basic assumptions."

### 6: Constructing explanations and designing solutions

"Constructing explanations and designing solutions in 9-12 builds on K-8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories".

### 7: Engaging in argument from evidence

"Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science."

### 8: Obtaining, evaluating, and communicating information

"Obtaining, evaluating, and communicating information in 9-12 builds on K-8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs."

# Summary of BIOZONE's 3D Approach By Chapter

Science and Engineering Practices (SEPs), Crosscutting Concepts (CCCs), Disciplinary Core Ideas (DCIs), and Performance Expectations (PEs) for each chapter of *Physical Sciences for NGSS* are listed in the tables following. An introductory "Science Practices" chapter is also included. Performance Expectations are met within the chapter and/or the *Summing Up* activity.

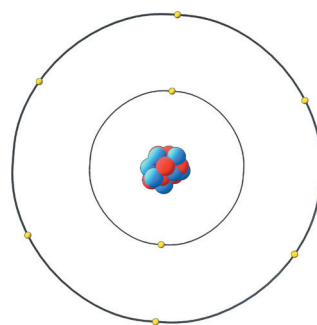
## 1: SCIENCE PRACTICES

Activity	SEP	DCI	CCC	PE
1	1, 6, 7, 8	NA	4	NA
2	2	NA	4	NA
3	1	NA		NA
4	3,5	NA		NA
5	5,8	NA		NA
6	3, 4, 5	NA		NA
7	4, 5	NA		NA
8	3,4,5,8	NA	1, 2	NA
9	3,4,5	NA	1	NA
10	3	NA		NA
11	5	NA		NA
12	3	NA		NA
13	2, 3, 6	NA		NA
14	3	NA		NA
15	2, 3, 6	NA		NA
16		NA	3	NA



## 2: STRUCTURE AND PROPERTIES OF MATTER

Activity	SEP	DCI	CCC	PE
18-21	2	PS1.A	1	
22	2	PS1.A	1	HS-PS1-1
23	2, 4	PS1.A	1	
24-25	2	PS1.A	1	HS-PS1-1
26-28	2	PS1.A	1	
29, 30	3, 6	PS1.A	1	
31	2, 3	PS1.A	1	HS-PS1-3
33	2	PS1.A		HS-PS1-1



## 3: CHEMICAL REACTIONS

Activity	SEP	DCI	CCC	PE
35-36	5, 6	PS1.B	5	HS-PS1-7
37	3, 5, 6	PS1.B	1, 5	HS-PS1-7
38-40	5, 6	PS1.B	1, 5	HS-PS1-7
41	5, 6	PS1.B	1, 3, 5	HS-PS1-2, HS-PS1-7
42	5, 6	PS1.B	1, 5	HS-PS1-2, HS-PS1-7
43	2, 3, 5, 6	PS1.B	1, 5	HS-PS1-2, HS-PS1-7
44	3, 5, 6	PS1.B	1, 5	HS-PS1-2, HS-PS1-7
45	3, 6	PS1.B	1	HS-PS1-5
46	2, 3	PS1.B, PS3.D	5	HS-PS1-4
47	2, 3, 5	PS1.B, PS3.D	5	HS-PS1-4
48	2	PS1.B, PS3.D	5	HS-PS1-4
49	3, 6	PS1.B	4, 7	HS-PS1-5
50-51	6	PS1.B	4, 7	HS-PS1-5
52	6	PS1.B	7	HS-PS1-6
53	3, 5, 6	PS1.B	7	
55	2, 5, 6	PS1.A, PS1.B	1, 5	HS-PS1-2, HS-PS1-4, HS-PS1-5, HS-PS1-6 HS-PS1-7





## 4: NUCLEAR PROCESSES

Activity	SEP	DCI	CCC	PE
57	2, 3	PS1.C	5	HS-PS1-8
58	2	PS1.C	5	HS-PS1-8
59	2, 3, 8	PS1.C	5	HS-PS1-8
60	2	PS1.C	5, 7	HS-PS1-8
61	2	PS1.C	5, 7	
63	2	PS1.C	5	HS-PS1-8



## 5: FORCES AND MOTION

Activity	SEP	DCI	CCC	PE
65-66	3, 4	PS2.A	2	
67-68	4	PS2.A	2	HS-PS2-1
69-70	2, 5, 4	PS2.A	2	
71	3, 5	PS2.A	4	
72-73	5	PS2.A	4	HS-PS2-2
74	3, 5	PS2.A	4	HS-PS2-2
75	3, 5, 6	PS2.A, ETS1.A, ETS1.C	2	HS-PS2-2, HS-PS2-3, HS-EST-1-2, HS-EST1-3
77	4, 5	PS2.A	2, 4	HS-PS2-1, HS-PS2-2



## 6: TYPES OF INTERACTIONS

Activity	SEP	DCI	CCC	PE
79	5	PS2.B	1	
80	2, 5, 6	PS2.B	1	HS-PS2-4
81	3, 5	PS2.B	1	
82	2, 5	PS2.B	1, 4	HS-PS2-4
83	2	PS3.C	2	HS-PS3-5
84	2, 3	PS2.B, PS3.C	1, 2	
85	2, 3	PS2.B, PS3.C	2	
86	3	PS2.B	2	HS-PS3-5
87	2	PS3.C	2	HS-PS3-5
88	3, 6	PS2.B, PS3.A	2, 5	HS-PS2-5, HS-PS3-5
89	3, 6, 8	PS2.B	6	HS-PS2-6
91	2, 5, 8	PS2.B, PS3.C	1, 2, 6	HS-PS2-4, HS-PS2-6, HS-PS3-5



## 7: DEFINITIONS OF ENERGY

Activity	SEP	DCI	CCC	PE
93	2, 6	PS3.A	4, 5	
94	2, 5	PS3.A	4, 5	
95	2, 5	PS3.A	4, 5	HS-PS3-1
96	2, 5	PS3.A	4, 5	HS-PS3-2
97	2, 3, 5	PS3.A	4, 5	HS-PS3-2
98	2, 5	PS3.A	2, 4, 5	HS-PS3-2
99	2, 5	PS3.A	4, 5	
101	2	PS3.A	4	HS-PS3-1



## 8: CONSERVATION OF ENERGY AND ENERGY TRANSFER

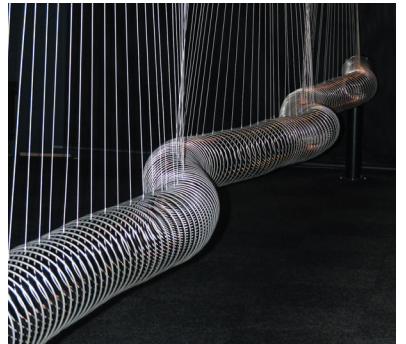
Activity	SEP	DCI	CCC	PE
103	2, 5, 6	PS3.B, PS3.D	4, 5	HS-PS3-1, HS-PS3-2 HS-PS3-3, HS-PS3-4
104	3, 6	PS3.B, PS3.D	4, 5	HS-PS3-1, HS-PS3-3, HS-PS3-4
105	2, 3, 5	PS3.A, PS3.B	4, 5	HS-PS3-1
106	3, 5	PS3.B	4	
107	5	PS3.B	4	
108	2, 3, 6	PS3.B, PS3.D, ETS1.1	4, 5	HS-PS3-1, HS-PS3-3, HS-PS3-4, HS-ETS1-1
110	2	PS3.A, PS3.B	4, 5	HS-PS3-1, HS-PS3-2



Chocolateak CC 3.0

## 9: WAVE PROPERTIES

Activity	SEP	DCI	CCC	PE
112-113	3, 5	PS4.A	2	HS-PS4-1
114	5	PS4.A	2	HS-PS4-1
115	5	PS4.A	2	
116	3, 5	PS4.A	2	HS-PS4-1
117	3, 7	PS4.A	2, 4	
118	1, 4, 8	PS4.A	2, 7	HS-PS4-2, HS-PS4-5
120	5	PS4.A	2	HS-PS4-1



## 10: ELECTROMAGNETIC RADIATION

Activity	SEP	DCI	CCC	PE
122	7	PS4.B	4, 5	
123	3, 7	PS4.B	4, 5	HS-PS4-3
124	8	PS4.B	2	HS-PS4-4
125	8	PS4.B	2	HS-PS4-4
127		PS4		HS-PS4-3



## 11: INFORMATION TECHNOLOGY AND INSTRUMENTATION

Activity	SEP	DCI	CCC	PE
128	8	PS4.C	2	
129-130	8	PS4.C	2	
132	8	PS4.C	2	HS-PS4-5



# Identifying CCSS Connections

The activities in *Physical Sciences for NGSS* provide many opportunities to address the Common Core State Standards (CCSS) for numeracy, and literacy, and English language development (ELD). The incorporation of these standards allows students to practice and develop these key skills while exploring science.

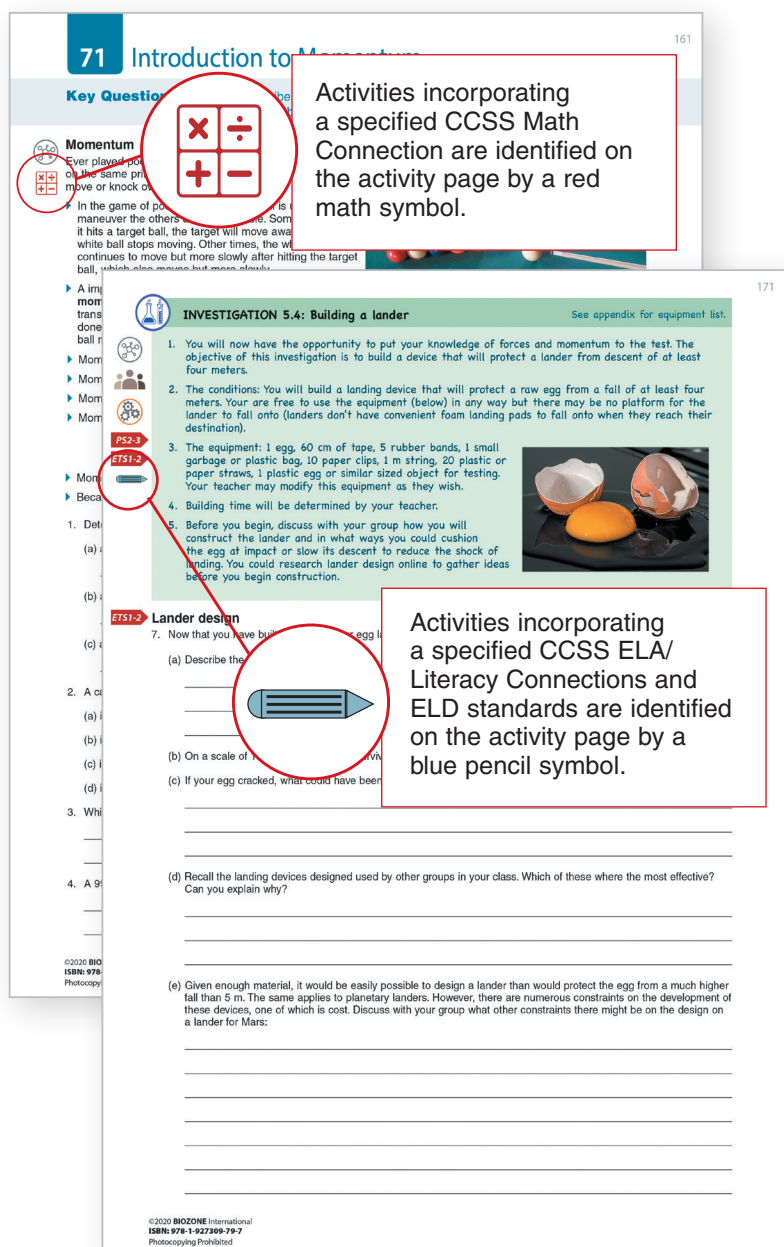
Activities incorporating the CCSS Math Connections, ELA/ literacy, and ELD Connections specified in the NGSS Science Framework are identified by codes (right) in the **Teacher's Edition**.

Note that this coding is a tool for the teacher and is not present in the Student Edition.

- ▶ A red calculator indicates a math connection.
- ▶ A blue pencil indicates an ELA/literacy or ELD connection.

A list of the specific Math Connections, ELA/ Literacy Connections and ELD Standards addressed in the NGSS framework can be found in the tables at the bottom of this page and on the following pages.

BIOZONE recognizes that ELD Standards are not to be used in isolation, and are intended to be implemented in conjunction with ELA/Literacy and other academic content standards. This is why you will see them appearing along with the relevant ELA/literacy connection in the following tables.



## 1: SCIENCE PRACTICES

Activity number	Activity	CCSS Math connection	CCSS ELA/Literacy & ELD connection
1	The Nature of Science		WHST.9-12.2, SL.9-12.1, ELD.P.11-12.1, 5
6	Accuracy and Precision	MP.6, HSN-Q.A., HSS-ID.A.2	
7	Working With Numbers	MP.4, HSA-CED.A.4	
8	Graphical Analysis	MP.4, HSS-ID.A.1, HSS.ID.C.7	
9	Describing the Data	MP.4, HSS.ID.A.2, HSS.ID.A.2	
10	Investigations in Physics	MP.4, HSS-ID.A.1	
15	Measurement and Quantitative Analysis		SL.9-12.1, ELD.P.11-12.1, 5

## 2: STRUCTURE AND PROPERTIES OF MATTER

Activity number	Activity	CCSS Math connection	CCSS ELA/Literacy & ELD connection
20	Atomic Theory and Rutherford's Experiment		WHST.9-12.8
24	Trends in the Periodic Table	MP4	



**3: CHEMICAL REACTIONS**

Activity number	Activity	CCSS Math connection	CCSS ELA/Literacy & ELD connection
36	The Mole	MP.2, HSN-Q.A.1	
37	Using Molar Mass	MP.2, HSN-Q.A.2	
38	Empirical Formulae	MP.2, HSN-Q.A.2	
39	Percentage Composition	MP.2, HSN-Q.A.2	
40	Balancing Equations	MP.1, MP.2, HSN-Q.A.1	
41	Stoichiometry	MP.2, HSN-Q.A.1, HSN-Q.A.3	
43	Creating Standard Solutions	MP.2, HSN-Q.A.1 , HSN-Q.A.3	
44	Verifying a Claim	MP.2, HSN-Q.A.1 , HSN-Q.A.3	
47	Enthalpy and Chemical Reactions	MP.2, HSN-Q.A.1, HSN-Q.A.3	
48	Bond Energies	MP.4	
49	Reversible Reactions	MP.4, HSN-Q.A.1	
52	Industrial Equilibria	MP.4, HSN-Q.A.1	
53	Acids and Bases	MP.4, HSN-Q.A.1	
55	Summing Up	MP.4, HSN-Q.A.1	

**4: NUCLEAR PROCESSES**

Activity number	Activity	CCSS Math connection	CCSS ELA/Literacy & ELD connection
59	Radioactive Decay	MP.4	
61	Fission vs Fusion	MP.4	

**5: FORCES AND MOTION**

Activity number	Activity	CCSS Math connection	CCSS ELA/Literacy & ELD connection
65	Distance and Displacement	MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2	RST.11-12.7
66	Speed and Velocity	MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, HSA-SSE.A.1, HSA-CED.A.4, HSS-ID.A.1	
67	Acceleration	MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, HSA-SSE.A.1, HSA-CED.A.1, HSA-CED.A.2 HSA-CED.A.4, HSA-SSE.B.3	
69	Newton's Second Law	MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, HSA-SSE.A.1, HSA-CED.A.1, HSA-CED.A.2 HSA-CED.A.4	
71	Introduction to Momentum	MP.2, MP.4, HSN-Q.A.1	
72	Investigating Collisions	MP.2, MP.4,	
73	Law of Conservation of Momentum	MP.2, MP.4, HSA-CED.A.1	
74	Impulse	MP.2, MP.4, HSN-Q.A.1	
75	Crumple Zones and Crash Helmets	MP.2, MP.4, HSN-Q.A.1	
76	Review Your Understanding	MP.2, MP.4, HSN-Q.A.1	
77	Summing Up	MP.2, MP.4, HSN-Q.A.1	

**6: TYPES OF INTERACTIONS**

Activity number	Activity	CCSS Math connection	CCSS ELA/Literacy & ELD connection
79	Gravity	MP.4	
80	Newton's Law of Gravitation	MP.2, MP.4, HSN-Q.A.1, HSA-SSE.A.1, HSA-CED.A.1, HSA-CED.A.2 HSA-CED.A.4, HSA-SSE.B.3	
82	Coulomb's Law	MP.2, MP.4, HSN-Q.A.1, HSA-CED.A.1, HSA-CED.A.2 HSA-CED.A.4,	
83	Electric Fields	MP.2, MP.4, HSA-SSE.B.3, HSA-CED.A.4	
87	Magnetic Fields	MP.2, MP.4, HSA-SSE.B.3, HSA-CED.A.1	
89	Forces in Materials		RST.11-12.7, WHST.11-12.2, 7
91	Summing Up	MP.2, MP.4, HSA-SSE.A.1, HSA-SSE.B.3	

**7: DEFINITIONS OF ENERGY**

Activity number	Activity	CCSS Math connection	CCSS ELA/Literacy & ELD connection
94	The Physics of Work	MP.2, MP.4, HSN-Q.A.1	
95	The Work-Kinetic Energy Theorem	MP.2, MP.4, HSN-Q.A.1	
96	Stored Energy	MP.2, MP.4, HSN-Q.A.1	
97	Conservation of Energy	MP.2, MP.4, HSN-Q.A.1	
98	Pendulums	MP.2, MP.4	
99	Efficiency	MP.2, MP.4	
100	Review Your Understanding	MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2	
101	Summing Up	MP.2, MP.4, HSN-Q.A.1, HSN-Q.A.2, HSN-Q.A.3	

**8: CONSERVATION OF ENERGY AND ENERGY TRANSFER**

Activity number	Activity	CCSS Math connection	CCSS ELA/Literacy & ELD connection
104	The Second Law of Thermodynamics	MP.2, MP.4, HSS-IS.A.1	
105	Modeling Energy Flow	MP.2, MP.4	
106	Work and Power	MP.2, MP.4	
107	Energy and Power Plants	MP.2, MP.4	
108	Energy Conversion Devices		WHST.11-12.2
110	Summing Up	MP.2, MP.4, HSN-Q.A.1	

**9: WAVE PROPERTIES**

Activity number	Activity	CCSS Math connection	CCSS ELA/Literacy & ELD connection
112	Properties of Waves	MP.4	
113	The Speed of Sound	MP.2, MP.4, HAS-SSE.A.1, HAS-SSE.B.E, HSA.CED.A.4	
118	Digitizing Waves	MP.2, MP.4	

**10: ELECTROMAGNETIC RADIATION**

Activity number	Activity	CCSS Math connection	CCSS ELA/Literacy & ELD connection
123	Evaluate Claim		RST.9-10.8, RST.11-12.7

**11: INFORMATION TECHNOLOGY AND INSTRUMENTATION**

Activity number	Activity	CCSS Math connection	CCSS ELA/Literacy & ELD connection
132	Summing Up		RST.11-12.7, WHST.9-12.2

# Teacher's Notes

Extended teacher's notes are found at the front of each chapter in the Teacher's Edition of *Physical Sciences for NGSS*. These notes appear immediately after the chapter introduction and provide context for the material and additional detail for the learning points (matched point for point). Where appropriate, opportunities to incorporate group work, practical activities, or design challenges are explained. Suggestions for differentiated instruction are also provided, including ways to support striving learners, e.g. through peer-to-peer support. For gifted and talented students we have included a "challenge question" and an associated image on the page immediately preceding or following the teacher's notes (see page CG11).

Most activities are supported by material on **BIOZONE's Resource Hub**. The hub provides access to a large collection of free resources to supplement your teaching. Where they are provided, they are identified with a hub icon in the margin of both the Student Edition and Teacher's Edition. Where the resource is integral to the delivery of the activity (e.g. online data sets, computer simulations, or spreadsheets) we have indicated this in the teacher's notes.

The anchoring phenomenon provides a context for the chapter. We have included some questions you may wish to ask your students to engage them in the topic and ideas for student engagement.

The guiding questions and numbering of learning aims is the same as in each chapter introduction of the Student Edition and Teacher's Edition (learning aims are matched point for point).

Opportunities for group work are identified. They provide opportunities for collaboration and can be used to develop ELA skills such as speaking and listening, developing language, and research and presentation skills.

Important learning aims, including when students need to understand and use significant equations, are specified.

Practical investigations or design challenges are identified. These can be used to deepen a student's understanding of a concept or idea. Practical activities are essential for developing competency over a range of science skills and help students to become comfortable working in a STEM environment.



## 5. Forces and Motion

Chapter number and name



### Anchoring phenomenon

The anchoring phenomenon "Breaking Bricks" introduces students to the concept of forces and their applications. Students can discuss forces involved and how it is possible to break a brick without breaking your hand (or head). Students could look for some of the more improbable feats of brick breaking on the internet (e.g. breaking 30 or more bricks at once) and discuss if they believe them or not and what forces are involved.

### How can Newton's laws explain how and why things move?

1. Studying motion helps review important ideas that underlie many concepts in physics. Terms such as distance and displacement, speed and velocity are covered and used to introduce the concept of scalar and vector quantities. Students use and construct diagrams to illustrate these concepts. **Students are introduced to the use of mathematical formulas to describe motion. There is opportunity to work in groups to carry out practical tasks that demonstrate some of the concepts covered.**
2. Acceleration is an important part of motion as it is part of the link between the motion of an object and any forces involved ( $F = ma$ ). It is therefore important that students understand the concept of acceleration and are able to use mathematical formulas and diagrams to describe it and relate it to distance and velocity. In many cases, students are shown how a formula can be derived from known information by simple substitution and rearrangement of equations. Understanding how to use these formulas is important when calculating forces involved in collisions (see #10). **An important task here is for students to derive an equation for displacement given acceleration and velocity, but not time. Using the equations they already know, students should be able to derive the final equation  $Dx = (v_f^2 - v_i^2) \div 2a$ .**
3. Students are introduced to the concept of forces via Newton's first law. Simple tasks, such as thinking about the motion of a tennis ball, help students build the concept that a change in motion requires a force. Students are introduced to the concept of balanced and unbalanced forces by using and constructing diagrams. Students analyze data on friction and learn that friction is a force that resists motion. The concept of the coefficient of friction is introduced and returned to when studying forces on an incline.
4. It is important that students understand the difference between weight and mass and use these terms correctly. Students can analyze experimental data to show the relationship between force, mass, and acceleration, and thus develop an understanding of Newton's second law. **A method for this experiment is given, so students should be able to carry out their own investigation if time permits.** Graphing the results helps students visualize the relationships being investigated and how to find an unknown variable in a relationship. Students should be able to use free body diagrams to analyze and describe the effect of forces on objects. Students are then able to apply these ideas to more complex problems, such as free fall and objects on an incline. The Dawn spacecraft is a good example of the long term effect of even a small unbalanced force being constantly applied to an object.
5. Students complete their study of forces with a review of Newton's third law and force pairs. Students compare a diagram showing all the force pairs involved and a free body diagram, showing a summary of the net forces. They use this to explain how a plane increases its altitude.

6. Momentum is introduced using a description of a pool game and balls on a pool table. Students can work in groups to carry out a simple investigation of the effect of mass on momentum using marbles or ball bearings rolling down a ramp.
7. The law of conservation of momentum is an important concept as it explains the way objects behave in
8. include impulse. Students can work in groups to investigate impulse by investigating the forces experienced by a bungee jumper using elastic and non-elastic materials. In this case, the elastic material spreads out the time of the collision (between the bungee jumper's feet and the cord wrapped around them). **Students should be able to use equations from earlier in the chapter to show the effect of extending collision time on the force experienced and explain the significance of this.**

### How can mathematical models of Newton's laws be used to test and improve engineering designs?

9. Students are given real world collision data and situations. Here they can clearly see the effect of increasing the time over which the force is felt by studying how NASA lands Mars probes and the differences in G forces (multiples of gravity) felt in crashes in cars built four decades apart. **This crash data is available on-line at the NHTSA Vehicle Crash Test Database (see BIOZONE's Resource Hub) along with photos and reports of test crashes for many different models of car.**
10. Students have the opportunity to break into groups and apply their understanding of Newton's laws and collisions and impulse to build a device that will protect an egg from a 4 m fall. This is a good opportunity to review the concepts covered in the chapter and discuss how they might apply to landing on the surface of a rocky surface or

Your attention is drawn to materials on the Resource Hub when the resource is integral to the delivery of the activity. In this instance it is crash data obtained from the NHTSA Vehicle Crash Test Database.



# BIOZONE's Pedagogy

## A worktext approach

BIOZONE's delivery method is a departure from a traditional textbook. We combine the very best features of a textbook with the utility of a workbook, producing a worktext resource. Importantly, the worktext is owned by the student: it is their own resource to utilize. Whether they are using the print or digital version, students customize their worktext with notes and annotations, checking off their progress in the contents and chapter introductions, and input their answers on the pages as they work through the activities.

Using a highly graphical approach and short blocks of text, we deliver textbook quality information in an accessible and engaging way, ensuring students are not overwhelmed by large amounts of information. As students interact with the stimulus material and work through activities, they are encouraged to input their answers directly onto the page. This simple act reinforces the learning moment and forms a record of work as they progress through the material. Students find revision a breeze because the stimulus material, questions, and their answers are in one place.

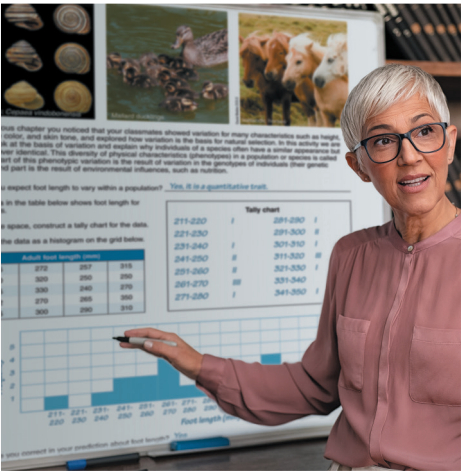
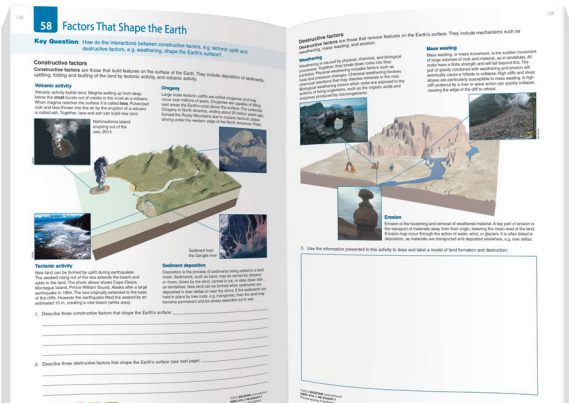
We have included a wide range of activity types in this title. These include practical activities (experimental investigations, modelling, and simulations), research activities, and assessment tasks. The variety of activity types provides flexibility in the way teachers can assign them. For example, work can be assigned to be carried out as homework, completed in class, or set for revision. Teachers can assign students to work on activities individually or set work as a group. The activity based approach simplifies assigning work, and teachers can utilize this approach to set work for substitute teachers in their absence

## Not all answers need to be graded!

Within the activities, there are plenty of opportunities for students to record answers to the questions. This approach reinforces the learning moment, provides space for students to record their work, and acts as a revision tool when students are preparing for assessments. This approach does not mean that teachers are expected to review or grade all student responses. We suggest that only key activities or questions are graded. This might be assessment tasks at the end of each chapter or at the conclusion of a unit. You may also choose to grade activities with content that students have traditionally found challenging, or where there is often a misunderstanding of the topic. Teachers can also choose to share answers with students. Sharing the model answers allows students to self report grades: an exercise known to be a powerful pedagogical learning tool (Hattie(2009)). Having access to model answers also allows students to refine their initial response if needed. This provides a powerful second learning moment to consolidate and extend understanding. Teachers can utilize the show/hide model answer feature in the digital platform to share answers.

## Features to accelerate student learning

Student learning can be influenced by many factors. A synthesis of more than 1,400 meta studies by Hattie (2009) involving over 80,000 individual studies and 300 million students has revealed some of the major influences to student learning. Some factors negatively influence student learning (red, right) while others have positive effects (yellow, green, and blue, right). BIOZONE's approach incorporates many of the factors shown to positively influence student learning, these are underlined in red on the diagram (right). By utilizing *Physical Sciences for NGSS*, these factors are organically incorporated into content delivery and enhance the teacher and learner experience.



Hattie, J. (2009). Visible Learning. Routledge